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Geothermal Direct Use Program Opportunity Notice Projects Lessons Learned

***Final Report
1978-1986***

B. C. Lunis

Idaho National Engineering Laboratory

U.S. Department of Energy • Idaho Operations Office

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Opportunity Notice Projects
Lessons Learned***

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GEOHERMAL DIRECT USE
PROGRAM OPPORTUNITY NOTICE PROJECTS
LESSONS LEARNED

Final Report

1978-1986

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Idaho Falls, Idaho 83415

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ABSTRACT

The use of geothermal energy for direct-use applications was aided through the development of a number of successful field experiment projects funded on a cost-shared basis by the U.S. Department of Energy, Division of Geothermal Technology. This document provides a summary of the projects administered by the U.S. Department of Energy's Idaho Operations Office and technically monitored through the Idaho National Engineering Laboratory (EG&G Idaho, Inc.). An overview of significant findings and conclusions is provided, as are project descriptions and activities, resource development, design, construction, and operational features. Legal and institutional considerations are also discussed.

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1. BACKGROUND

The use of geothermal energy in direct-use applications was primarily limited to health spa applications prior to 1977. State-of-the-art engineering, construction and economic and institutional data were lacking in a period when greater use of alternate energy forms was needed. The U.S. Department of Energy, Division of Geothermal Technology, as part of the national geothermal program plan, which had the goal of encouraging the private and municipal development of geothermal resources for direct-use of these resources, issued two Program Opportunity Notice (PON) solicitations requesting proposals to cost-share field experiment projects. The notices, issued in 1977 and 1978, enabled the government to cost-share a significant portion of the high front-end financial risk with private and municipal developers in a variety of applications. Twenty-three projects resulted and were started in 1978 and 1979. Thirteen of these projects were administered by U.S. Department of Energy's Idaho Operations Office (IDO), eight by the San Francisco Operations Office (SAN), and the Nevada Operations Office (NVOO) was responsible for two. This document is limited to a discussion of the projects administered by IDO.

SAN and NVOO administered the PON projects shown in Table 1, a listing of the projects which are not discussed in this report; however, information may be obtained by contacting the following:

DOE-SAN

Department of Energy, San Francisco Operations Office
Chief, Fossil Geothermal Energy Branch
1333 Broadway
Oakland, CA 94612
Telephone 415/273-6365, FTS 536-6365

DOE-NVOO

Department of Energy, Nevada Operations Office
Engineering and Energy Management Division
P.O. Box 14100
Las Vegas, NV 89114
Telephone 702/295-3424, FTS 575-3424

TABLE 1. PON PROJECTS ADMINISTERED BY DOE-SAN AND NV00

<u>Project</u>	<u>Location</u>	<u>DOE Contract Number</u>	<u>DOE Office</u>	<u>Status</u>
Institutional Heating				
El Centro	El Centro, CA	DE-AC03-79ET27054	SAN	Inadequate resource
Klamath County YMCA	Klamath Falls, OR	DE-FG03-79ET27046	SAN	Operating
Navarro College	Corsicana, TX	DE-FC08-78ET27058	NV	Operating
T-H-S Hospital	Marlin, TX	DE-AC08-78ET27059	NV	Operating
District Heating				
Klamath Falls	Klamath Falls, OR	DE-AC03-78ET27154	SAN	Operating
Moana	Reno, NV	DE-AC03-79ET27029	SAN	Not finalized to date
Susanville	Susanville, CA	DE-AC03-79ET27040	SAN	Operating
Agribusiness				
Aqua Farms Int.	Dos Palms area, CA	DE-AC03-79ET27047	SAN	Operating; Raising Prawns
Kelley Hot Springs	Kelley Hot Springs, CA	--	SAN	Discontinued-archaeological site interference
Agricultural Center				
Industrial				
Holly Sugar	Brawley, CA	DE-AC03-79ET27039	SAN	Inadequate resource

IDO, with technical monitoring support provided by the Idaho National Engineering Laboratory (EG&G Idaho, Inc, a prime Laboratory contractor), produced nine successful projects, with only four not becoming operational. Five of the thirteen IDO projects are district heating and another five are institutional heating. Two are agribusiness, and one is an industrial project.

The development of the PON projects produced many benefits, perhaps the most important being the lessons that were learned in the initiation of a relatively new technology. This report is directed towards those lessons learned so that greater effort can be expended in advancing the state-of-the-art in geothermal direct use developments rather than in "reinventing the wheel."

2. SUMMARY

2.1 Program Benefits

The PON program has made significant contributions toward the development of the geothermal industry at a time when greater use of renewable energy forms was needed. The development of each PON project, whether or not the project actually operated, has resulted in numerous qualified consultants, engineers and builders who had limited knowledge about geothermal development prior to this program. The PON projects gave the impetus and background to encourage additional applications of geothermal energy. The many lessons learned through the development of each project have contributed to the geothermal industry's growth, and this report is centered about these lessons learned.

2.2 Projects Synopsis

The thirteen PON projects administered through DOE-ID are located throughout the Western United States as shown in Figure 1. The projects can be categorized into four groups; (1) institutional heating, (2) district heating, (3) agribusiness, and (4) industrial (Table 2). Following is a brief synopsis of these projects.

Institutional Heating: These projects produced four operating facilities and one that experienced a drilling failure. The Haakon School project provides space heating for school buildings before the geothermal fluid is cascaded in use to a community district heating area in Philip, South Dakota. The St. Mary's Hospital project demonstrates the feasibility of using 108°F fluid to provide for space and domestic hot water heating. The Utah State Prison project system provides for space and domestic hot water heating in the minimum security facility, but problems related to the existing system that was retrofitted for geothermal use, and lack of system acceptance by prison personnel, are resulting in the transfer of the use of the geothermal fluid to a new facility being designed specifically to use geothermal energy. Montana's Warm Springs State Hospital project has a good operating system, but it is inactive because the State has not

Fig. 1 PON Projects Location Map

TABLE 2. PON PROJECTS ADMINISTERED BY DOE-IDO

Project	Location	DOE Contract Number	Principal Investigator	Contract Period	Status
Institutional Heating					
Haakon School	Philip, SD	DE-FC07-78ET27080	Haakon School District 27-1	06/30/78--09/30/82	Operating
St. Mary's Hospital	Pierre, SD	DE-FC07-78ET28441	St. Mary's Hospital	06/30/78--06/30/83	Operating
Utah State Prison	Draper, UT	DE-FC07-79ET27027	Utah Div. of Facilities/Const. Management	03/14/79--01/31/86	Operating
Warm Springs Hosp.	Near Butte, MT	DE-AC07-79ET27055	Multitech, Inc.	01/30/79--08/31/83	Operated until pump failure
Douglas High School	Box Elder, SD	ET-78-F-07-1727	Douglas School System	02/14/78--04/27/79	Drilling failure
District Heating					
Boise	Boise, ID	DE-FC07-79ET27053	City of Boise	03/23/79--09/30/85	Operating
Elko	Elko, NV	DE-AC07-79ET27033	Elko Heat Co.	03/10/79--10/09/83	Operating
Pagosa Springs	Pagosa Springs, CO	DE-FC07-79ET27030	Town of Pagosa Springs	03/23/79--04/30/86	Operating
Madison County	Rexburg, ID	DE-FC07-79ET27028	Madison County Energy Commission	02/16/79--04/30/82	Inadequate resource
Monroe City	Monroe, UT	DE-FC07-78ET27054	Monroe City	07/14/78--07/31/81	Poor economics
Agribusiness					
Utah Roses	Sandy, UT	DE-AC07-79ET27056	Utah Roses, Inc.	01/24/79--02/28/83	Operating
Diamond Ring Ranch	Haakon County, SD	DE-FC07-78ET28419	SD School of Mines and Technology	06/30/78--09/30/82	Operated until loop anti-freeze was lost
Industrial					
ORE-IDA Foods, Inc.	Ontario, OR	DE-AC07-78ET28424	ORE-IDA Foods, Inc.	05/17/78--05/31/82	Inadequate resource

provided funding to replace the failed production well submersible pump. Douglas High School, Box Elder, South Dakota was unable to have its well completed into the Madison aquifer and the project was abandoned.

District Heating: The district heating system in Elko, Nevada satisfactorily provides heating service to three customers and geothermal fluid for direct use in a laundry. This successful system is being expanded. Pagosa Springs, Colorado has a fine closed loop system, but final resolution of water rights is limiting expansion of the customer base. The Boise City, Idaho system is a technically excellent system that is plagued with an inadequate customer base that could have significant consequences. If the well had produced adequate flow, Madison County, Idaho would have cascaded the fluid from a potato processing plant to a district heating system in the City of Rexburg. Monroe City, Utah produced a reasonably good well, but the project economics precluded further development of the 164°F resource with 600 gpm flow.

Agribusiness: Utah Roses demonstrates the feasibility of using a 123°F resource to supply heat in a six-acre greenhouse located at Sandy, Utah. This project precipitated another Utah Roses greenhouse geothermal project adjacent to the Utah State Prison PON project. The Diamond Ring Ranch in Central South Dakota did use the artesian flowing fluid to heat numerous ranch structures, operate a grain drying facility, and provide domestic and stock watering, and irrigation. Antifreeze, used in the closed loop system, leaked out and was never replaced, returning the use of the fluid from the existing well to its original purpose-watering and irrigating.

Industrial: The one industrial project at the ORE-IDA food processing facility in Ontario, Oregon has a 10,054 ft deep well with a bottom hole temperature of 380°F. Inadequate fluid flow halted the project, but accommodations were provided for possible rework of the well at a later date.

3. SUMMARY PROJECT DATA

Key resource, production and use systems, and cost data are provided in Tables 3, 4, and 5 in order to provide a brief overview of the comparative characteristics of the PON projects. Additional information is provided in the sections of this report covering each project, and greater detail is available from the PON final and other reports listed for each project.

TABLE 3. PON PROJECTS RESOURCE CHARACTERISTICS

Project	Well Depth (ft)	Maximum Flow Rate (gpm)	Static Water Level (ft)	Pump Setting (ft)	Distance to First Use (ft)	Resource Temperature (°F)
Institutional Heating						
Douglas High School	--	--	--	--	--	--
Haakon School	4,226	340	+333	Artesian	200	157
St. Mary's Hospital	2,176	375	+1411	Artesian	400	108
Utah State Prison	1,000	--	+95	Artesian	1,600	181
Warm Springs State Hospital	1,498	60	+36	987	80	156
District Heating						
Boise Idaho						
Well No. 1	2,010	No test	--	--	1,750	155
Well No. 2	800	1,500	+24	-100	--	172
Well No. 3	1,893	2,000	-8	--	--	172
Well No. 4	1,103	2,000	+24	-100	--	172
Elko, NV	868	>600	+128	-60	3,820	178
Madison County, ID	--	--	--	--	--	--
Monroe City, UT	--	--	--	--	--	--
Pagosa Springs, CO						
Well No. 3	300	200	+112	--	500	131
Well No. 4	299	Abandoned	--	--	--	--
Well No. 5	275	700	+112	--	--	148
Agribusiness						
Diamond Ring Ranch, SD	--	--	--	--	--	--
Utah Roses, UT	--	--	--	--	--	--
Industrial						
ORE-IDA Foods, Inc., OR	--	--	--	--	--	--

TABLE 4. PON PROJECTS TECHNICAL DATA SUMMARY

Project	Well Depth (ft)	Temperature (°F)	Flow Rate (gpm)	Flow Method	Distance to First Use Point (ft)	Peak Heat Load (Million Btu/hr)
Institutional						
Haakon School	4,266	153	300	artesian	200	8.4
St Mary's Hospital	2,176	108	385	artesian	400	5.5
Warm Springs State Hospital	1,498	154	60	pumped	80	1.8
Douglas High School	3,639	--	--	--	--	--
Utah State Prison	1,000	180	100	artesian/pumped	1,600	5.0
District Heating						
Boise	800-2010 ^a	170	500-2000	pumped	1,750 ^b	100
Elko	852	177	400	artesian	3,820	11.4
Pagosa Springs	274-300	131-149	600-1200	artesian	500	9.1
Madison County	3,932	72	--	--	--	85
Monroe City	1,500	164	600	pumped	--	20.2
Agribusiness						
Utah Roses	4994	123	180	pumped	50	2.9
Diamond Ring Ranch	4112	152	170	artesian	4,000	2.3
Industrial						
ORE-IDA Foods	10,054	380	--	--	--	63

a. Four wells, one not productive.

b. 10,600 ft to far end of system.

TABLE 5. PON PROJECTS COST SUMMARY DATA

Project	Resource and Production Well (\$)	Distribution System (\$)	Other ^a (\$)	Total (\$)	Participant Share (%)	Due Share (%)	Simple Payback (yr)
Institutional							
Haakon School	312,280	784,330	113,990	1,210,600	22.0	78.0	12.0
St. Mary's Hospital	309,300	345,800	83,050	738,150	25.4	74.6	9.5
Utah State Prison	199,100	517,200	111,300	827,600	40.4	59.6	15.5
Warm Springs State Hospital	456,650	122,750	177,350	756,750	4.7	95.3	9.7
Douglas High School	449,400	--	13,500	462,900	84.2	15.8	--
District Heating							
Boise	2,216,450	4,011,400	529,150	6,757,000	46.3 ^b	53.7	6.1
Elko	336,050	835,900 ^c	226,300	1,398,300	20.7	59.2	11.0
Pagosa Springs	300,800	1,033,000	153,800	1,487,620	18.0	82.0	20.0
Madison County	769,100	--	120,100	889,200	10.0	90.0	--
Monroe City	237,000	--	898,000	1,135,000	57.0	43.0	--
Agribusiness							
Utah Roses	416,000	205,000	77,500	698,500	34.0	66.0	8
Diamond Ring Ranch	90,000 ^d	271,000	42,100	403,100	38.0	62.0	8
Industrial							
ORE-IDA Foods	1,912,300	--	617,600	2,529,900	9.5	90.5	--

a. Includes technical support, management, legal, technology transfer and other support costs.

b. Includes funds from BPA, DOE Public Buildings Program, BWSWD, a limited partnership, Economic Development Administration and Boise City.

c. Includes \$281,000 building retrofits by others.

d. Existing well value.

4. SIGNIFICANT FINDINGS AND RECOMMENDATIONS

4.1 General

Significant findings and recommendations are provided for each of the PON projects in their approximate sections of this report. A summary review of these general findings and recommendations follows.

Every Project is Unique

If there is a geothermal law, it is that every project is unique. The development of the PON projects stressed the uniqueness of each direct use project. Legal and institutional considerations vary state to state and location to location. Each resource and each well drilled in a given resource varied in many characteristics. The fluids produced from the geothermal wells required the use of different types of piping and equipment materials. The physical location of each project impacted the availability and quality of goods and services. The PON activities showed there is no potential to rubber-stamp development activities, and amplified the need for qualified task performers.

Simplicity is Key to Operational Success

Most of the PON projects are located in smaller communities or even in isolated locations (such as the Diamond Ring Ranch in central South Dakota). Lack of highly trained personnel to build and operate the systems, and suppliers with limited inventories stressed the need for simple systems. Systems components that are "different" than those normally operated by plant operators can contribute to rejection of the new "complicated" geothermal system, as was observed at the Utah State Prison. Conversely, the simplicity of the Pagosa Springs closed loop system has led to acceptance and pride on the part of the town's operators.

A Strong Promoter is Needed to Develop Each Project

Most of the PON projects had one or more individuals who caused each project to become successful. The uniqueness of each project, and sometimes the tasks that appeared to be insurmountable required the guiding efforts of very dedicated project "champions." The Pagosa Springs project, faced with potential water rights battles, was carried through to successful operation due to the ongoing efforts patiently and continuously provided by the town's mayors and water systems supervisor. Frequent visits with the system's customers, other well owners, and appropriate local and state officials contributed to the project's success. At the Utah State Prison, the lack of "selling" maintenance personnel on the project resulted in their rejection of the system installed.

Strong technical expertise was not normally available in the smaller communities where systems were developed, and those skills had to be developed. This was one of the many positive results of the PON program.

Customers Are Needed for District Heating Systems

Although this appears to be so obvious a need that it is not worthy of mention, the opposite is true. Perhaps the most successful project from a technical and operational standpoint, the Boise City system, is faced with the potential of failing because of the lack of customers. Organizations and individuals committed to becoming customers, but many would not expend funds to change their systems to accommodate a geothermal system. This situation emphasizes the need to totally sell potential users on a geothermal district heating system, and obtaining written retrofit commitments very early in the project development period. Obligation of funds to perform retrofits could be incorporated into the basic package to help ensure having customers. Numerous expressions of interest were given from potential users in Pagosa Springs, but the lack of final resolution of the water rights issues has delayed adding new customers that would in turn improve the project's revenue stream. The Elko project initiated their work with only three customers on the basis that they could later expand the number of users. However, without the federal funding provided through

the PON program, the now successful project would not have been feasible initially. The Haakon School, recognizing the potential to utilize the spent geothermal fluid after it exited the community heating district, was unable to add customers because of the legal arrangements they had entered into with the heating district. The near-term small customer base contributed to the decision to cancel the Monroe City project.

Funding and Costing Methods Can Affect Development

Initial assumptions regarding unrealized resource capabilities, coupled with the detailed project cost estimate almost doubling the preliminary cost estimate, resulted in discontinuing the Monroe City, Utah district heating project. Realistic near-term system loading would not be sufficient to generate enough revenue to cover system operating costs. This stresses the need to develop as much detail as possible early in the project development stage. The lack of funding for retrofits has contributed to the tenuous financial position of the Boise district heating system. The inability to obtain funds to replace the Warm Springs State Hospital submersible pump caused a proven system to become inoperative. Even though the payback period for the pump is very short, state funding methodologies and the legislature's nonprovision of funding have halted the replacement. Funding limits precluded drilling a planned second well that may have been productive for the ORE-IDA project. Without the tax benefits received during the first year of operation of the Utah Roses project, at a time of extremely high interest rates, it is likely that the first year's savings would not have been economically satisfactory.

Legal and Institutional Considerations Play a Major Role

Environmental assessments prepared for the different PON projects generally indicated minimal impact, and this was borne out during project performance. The Haakon School project experienced additional expenditures of funds and time to add a treatment facility to remove sulfates containing Radium 226 found in the Madison Aquifer geothermal fluids. Discharge of spent fluids into the Missouri River by St. Mary's Hospital, and into the

Boise River by the City of Boise, created extensive permitting actions and special activities before authorization was granted by state and federal agencies. Similar approval actions were required for the Utah State Prison project. Utah Roses spent considerable effort to obtain their surface discharge permit. The Warm Springs State Hospital, through a comprehensive review of Montana's statutes, found that many shortcomings existed in the areas of clear definition of terms, regulatory requirements, and state agency jurisdiction over geothermal development. This situation also applied to most, if not all, of the PON projects in varying degrees. Frequent interface between the PON developers and regulatory and other involved persons was generally beneficial and necessary in working through the maze of approvals. The efforts spent by these "novel" pioneering projects have greatly increased the understanding and functioning of the legal and institutional needs, making the way easier and smoother for later developers.

The Boise City project entailed establishing a completely new utility for which few of the attendant circumstances were clearly defined or definable. This translated to a major amount of work and cost. They also were faced with having two governments involved, and City and the Boise Warm Springs Water District, adding to their institutional problems.

Established water rights proved to be a concern, particularly with Pagosa Springs. The issue has not been resolved to date, and grey areas in the relatively new state's legislation regarding adjudication procedures for rights of new wells could possibly result in litigation.

State of Idaho bond requirements gave no recognition to the county's special relationship with the state, causing Madison County to seek bonding that was not available from ordinary bonding companies. They resolved the situation by placing funds in an escrow savings account.

Qualified Personnel are Needed

The development of the PON projects has generally resulted in a source of qualified designers, engineers, constructors, and developers. The

varied expertises needed to successfully complete a geothermal project places great responsibility on those initiating a project to seek out competent help. Remote, scattered geothermal sites generally do not have local expertise, and until that is developed, help is needed from outside areas.

Each project requires its "champion(s)" to successfully carry a project through to completion. Those PON projects that had dedicated persons were basically more successful than those that had lesser support, for whatever reason.

If qualified local contractors are available in the project area, they should be utilized because they have to "live" with their work.

Direct Use Projects Can Be Economical

Projects utilizing geothermal fluids directly to provide space conditioning, domestic hot water, heat for agriculture, processing, and other uses can be built economically. The payback periods for the PON project would be considered too long by many, but expertise developed through this effort is available to develop projects with shorter payback periods. Each direct use project has to be evaluated to determine its competitive position with the other energy sources that may (or may not) be available at the specific project site.

Cascaded Uses Can Improve Economics

The Haakon School District receives an annual income from a small heating district in Philip, which utilizes the geothermal fluid after it leaves the school complex. However, restrictions in the agreement between the school and the district limits future expansion. The Diamond Ring Ranch first used their fluids for heating, then grain drying, watering and irrigating. ORE-IDA would have cascaded their food processing operation to provide space and water heating. Other PON developers indicated that cascaded uses, when added, could materially improve project economics.

4.2 Technical

Well Siting Affects Resource Development

Adjustment of a well siting by any distance within several thousand feet did not appear to be a factor for those projects (Haakon School and St. Mary's Hospital) that selected the Madison Aquifer as their resource. However, this was not verified for the Douglas High School project because drilling failed before the Madison Aquifer was reached. (An excellent overview of the geological features of the Madison formation is covered in the Diamond Ring Ranch section of this report.)

The Utah State Prison resource test program indicated the well production capacity would be stressed when both the prison's and the adjacent Utah Roses wells were operated at higher use rates. This was later verified when the prison well lost its artesian flow, which did not return until the reservoir was allowed some time to restore itself. The prison is adding a production pump to their system to maintain flow, but limited pumping of the reservoir will be required.

St Mary's Hospital well could have located anywhere within the immediate vicinity of the existing travertine mound. Since this was within 100 ft of the existing steam heating plant, the distribution costs were minimal.

Acid treatment to improve well production had little benefit for the Warm Springs Hospital, but the 70 to 90 gpm flow achieved is adequate to meet the project's needs.

The location of other geothermal wells in a given area is no guarantee of results. Four production wells for the Boise City district heating system were drilled, and even though other wells existed in the area, one of the four drilled proved to be nonproductive. Pagosa Springs had three wells drilled in the vicinity of numerous existing wells, and one of these was unsuccessful.

The Elko "wildcat" well (one where no advance knowledge of artesian pressure being encountered was known), produced 800 gpm artesian flow, but not without its problems. A leaking at a casing lap, and open hole bridging resulted in a well rework program that cost more than the original well. Insufficient information for the design of the well completion program is considered to be the causative factor.

The Utah Roses well site, situated among thermal wells and springs, was selected because of convenience and because no scientific case could be established for a more geologically desirable drill site within two miles. The well is less productive than minimum expectations, but a significant portion of the heating needs are being met.

The 3942 ft deep Madison County well had outstanding permeability and productivity, but only 72°F temperatures were encountered. Casing would have been required to drill deeper, perhaps 2000 ft more to achieve the minimum desired temperature of 120°F. Neither air drilling or heavy mud usage to control lost circulation was feasible for the deeper drilling effort.

Due to economic considerations, the ORE-IDA well was not drilled at the primary site, the location selected because of its position over a predicted fault. It is believed that had the primary site been drilled, adequate flow could have been obtained. The 10054 ft deep well, with a bottom hole temperature of 380°F, was pressurized at 1400 psi at the wellhead and 350 gpm of water was pumped into the well to produce a mini-hydrofac in the lower zones. However, the effort was unsuccessful.

The Douglas School System drilling effort failed for a number of reasons. The inability to have the drilling contractor revise his drilling procedures, an improperly maintained mud program and possible drilling rig limitations contributed towards not being able to drill past the 3639 ft level into the Madison aquifer.

Spent Geothermal Fluid Disposal Can be a Significant Consideration

The Haakon School project geothermal fluid contained Radium 226, necessitating the addition of a treatment plant using barium chloride as the treating agent. The treatment was needed to permit ultimate discharge into a nearby river. Modification of the system was also required to prevent sulfates from precipitating in piping between the treatment plant and a two-cell settling pond.

Direct discharge of spent geothermal fluids into nearby rivers, such as at Boise, St. Mary's Hospital and the Utah State Prison necessitated considerable activity to obtain necessary permits and approvals.

The Elko Heat Co. had to repeat the entire water rights permitting process because the fluid would be surface discharged rather than the original plan to use an injection well. This proved to be time consuming and costly.

Considerable delay occurred for the Utah Roses project because of confusion and delay in interfacing between state and federal agencies, primarily because it was a "first." The pioneering efforts of the PON projects should result in less effort being expended by developers because the learning curve has increased.

Piping and Production Systems Needs are Unique to Each Project

The Utah State Prison geothermal system remained clean, primarily by maintaining a carbon dioxide blanket in the surge tank to prevent aeration of the fluid. However, considerable operational problems were experienced because the existing system that was modified to accommodate geothermal heating had leakage, deterioration and technical problems.

Pressure surges brought about in the Boise City district heating multi-pump system caused significant problems that required system modification to permit gradual flow changes.

Insulated vs. uninsulated piping has to be determined for each application. Elko Heat Company utilized an insulated system, but subsequent evaluation indicated that uninsulated piping could be used in many localities, depending on local conditions. A section of 4 in. PVC piping was not insulated, but later temperature drop measurements showed that insulation could have been cost effective.

Considerable evaluation work on long range performance of heat exchangers for the Utah Roses project was performed. Finned copper tube heat exchangers were selected because of lower installed costs, even if they would have to be replaced in five years.

The Diamond Ring Ranch project stressed the need to passively protect the geothermal system from freezing in cold, remote locations. They also learned that isolation valving should be installed external to an installation to prevent building interior flooding damage.

The use of corrosion coupon tests or monitoring samples with newly available corrosion detection equipment can avoid costly material failures and loss of reliability in the operational system.

Direct-Use Projects Can Operate Satisfactorily

The Haakon School, St. Mary's Hospital, Warm Springs State Hospital, Boise, Elko, and Pagosa Springs projects have all operated through one or more heating seasons in good to excellent fashion. Operator acceptance was good for most projects, except that experienced at the Utah State Prison project. Minor problems were observed with fitting leakage. Scaling problems were minimal; in fact, the geothermal fluid side of the Utah State Prison project's heat exchanger was much cleaner than the secondary side that served an existing system. The Warm Springs State Hospital project operated very well until a pump failed; it has not been replaced due to state funding methodologies. System operation and capacities were generally as expected, but a limited customer base has impacted the Boise City project's revenue stream.

5. INSTITUTIONAL PON PROJECTS--INTRODUCTION

Five institutional projects were developed, four of which became operational. The Haakon School project in Philip, South Dakota is satisfactorily providing heating to their school complex, then selling the spent geothermal fluid to a small district heating network in the downtown area of Philip. Heat is provided to new and existing facilities of St. Mary's Hospital in Pierre, South Dakota. Geothermal fluid provides heat in a closed-loop system for both space heating and culinary water in the Utah State Prison Minimum Security facility. Although the system is operational, work is proceeding to build a new facility at the prison, which will use the geothermal fluid now used for the minimum security facility. Warm Springs State Hospital, Warm Springs, Montana has its space and water heating needs met with 154°F geothermal fluids, expect that the deep well pump failed and has not been replaced because of state funding methodologies. The Douglas High School Board in Box Elder, South Dakota planned to drill their own well, then utilize the PON program to develop the remainder of the project. The project was not completed because the well was not drilled to completion.

This section of the report provides summary data, project history and development, resource and drilling information, how the geothermal fluid was used, alternate considerations, legal and institutional factors, and cost, schedule, and operational data. Significant observations and conclusions relative to each project are also given.

HAAKON SCHOOL PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: Haakon School District Heating

Project Data:

Project Description: The project demonstrates the feasibility of utilizing a moderate temperature (~153°F) geothermal resource to provide service water and space heating of school, business, and commercial buildings in the City of Philip, South Dakota.

Location: Philip, South Dakota

Peak Heat Load: 8.4 million Btu/h

Annual Heat Load: 17.8 Billion Btu/yr (89% load factor)

Simple Payback: 12 yr

Status: The system continues to provide space heating for the Haakon School District and the city district heating network.

Cooperative Agreement Data:

Number: DE-FC07-78ET-27080

Period: May 10, 1978 to August 1, 1985

DOE Share: \$944,100 (78%)

Participant Share: \$266,500 (22%)

Total Cost: \$1,210,600

Principal Investigator:

Charles A. Maxon, Supt. of Schools,
Haakon School District 27-1, Box 117,
Philip, SD 57567
605/859-2437

Other Participants:

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Dan Bjerke
Brady Engineering
550 Colorado Blvd.
Spearfish, SD 57783
605/642-2656

Well Design

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Francis, Meador & Gellhaus
1823 West Main
Rapid City, SD 57702
605/342-4105

Drill Supervision

C. Lee Mueller
Energy Drilling Specialists, Inc.
821 17th St., Suite 806
Denver, CO 80202
303/573-7011

Production Well Drilling

Joe D. Banks
Northern Wyoming Drilling Co.
P.O. Box 487
Gillette, WY 82716
307/682-9354

Transmission and Distribution Pipelines and Disposal System
Construction

O. R. Ramstad
Ramstad, Inc.
2040 West Main Street
Rapid City, SD 57702
605/343-7280

Geothermal Conversion and Boiler Replacement
Julian Wolff
Wolff's Heating & Plumbing
P.O. Box 71
Spearfish, SD 57783
605/642-5755

2. PROJECT HISTORY

The Haakon School project located at Philip, South Dakota (Figures 6.1 and 6.2) was initiated to demonstrate the feasibility of using the known geothermal resource of the water in the Madison formation for service water and space heating of existing buildings; retrofitting existing oil fired steam and electric heating systems to utilize lower temperature water; and developing methods of and systems for treating water of unacceptable quality to a state complying with water quality standards.

The City of Philip drilled a well into the Madison Limestone formation in 1962 and obtained a flow of 153°F water originally reported at 1,040 gpm. The water was used to supplement the municipal water supply when necessary, but because of its temperature, dissolved solids and general poor quality, was discharged into the Grindstone Creek drainage when not required as a supplemental source. The School District Board of Education authorized and funded a feasibility study to determine if this source of energy could be used to heat their buildings and service water. Hengel, Berg and Associates, Architects-Engineers of Rapid City, were retained to determine if the armory-high school, elementary school, vocational school, and the music buildings at Philip could be heated with this water. The project appeared feasible, and a PON cost shared agreement was entered into in January 1978. A new well was drilled (the existing well proved not to be feasible) to a depth of 4266 ft, producing an initial artesian flow of 300 gpm of geothermal fluid at a temperature of 155°F.

The existing heating systems of the school buildings and the business buildings were converted to utilize the geothermal energy. An ion exchange system to treat the geothermal effluents was not effective, and a treatment plant using barium chloride was constructed to remove the sulfates containing Radium 226 that are in the geothermal fluid. The treated water leaving the settling ponds is discharged into the North Fork of the Bad River. A district heating system was developed to heat nine business facilities in the central business district of the City of Philip, using the 130°F water discharged from the school buildings. The barium chloride

Fig. 6.1 Location map

Fig. 6.2 Geothermal system location plan

treatment system required some modification after use to prevent sulfates from precipitating in pipes between the treatment plant and the two-cell settling ponds.

The geothermal fluid was introduced into the school heating systems in November 1980 and provided all of the heat required by the buildings for the remainder of the heating season. Only one business building in the heating district obtained heat from the system during the 1980-1981 heating season. During the 1981-1982 heating season, the school buildings were heated entirely by the geothermal system except for one 2-h period when the boiler in the elementary building was operated to counteract excessive heat loss adjacent to leaky windows when the chill factor exceeded -55°F . Six of the eight business district systems received more than 90% of the required heat from the geothermal system. Two of the business systems, which were not designed to provide 100% of the heat, obtained more than 75% of the required heat from the geothermal system.

3. GENERAL DESCRIPTION

A new well was sited at an open area on school property near the high school-armory building and drilled into the Madison aquifer. Total well depth is 4266 ft. Geothermal fluid at 153°F is flowed artesian from the well at about 300 gpm through a transmission pipeline to the school buildings to plate type heat exchangers. Fresh water is circulated to the armory-high school, an elementary and middle school, and a vocational building. The geothermal fluid is then piped to a small cluster of downtown business buildings that were retrofitted to accommodate the geothermal fluid. The spent fluid then flows through a small barium chloride treatment plant that removes Radium 226 before the treated fluid is discharged into two settling ponds. After settling, the fluid is ultimately discharged into the nearby Bad River.

The secondary piping circuits in each of the school buildings includes circulating pumps, new or modified existing standby or backup heating equipment, new or modified existing terminal heating units and the necessary controls to operate the equipment.

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

The project demonstrates the feasibility of utilizing a moderate temperature geothermal fluid from the Madison aquifer to provide space and water heating for school and business buildings.

A qualified and experienced water well engineer needs to be retained to plan and monitor the well drilling for any geothermal project. As an example of this need, a drill stem, which was too small for the drilling loads, twisted off and was never recovered. Fortunately, the tools lost were bypassed and the drilling continued to a successful conclusion.

Any water treatment system required should be thoroughly tested. After several weeks of operation, the flow through the barium chloride treatment system gradually decreased and could not be reestablished at the original rate by any control adjustments. Disassembly of the piping in the barium chloride treatment plant for removal of Radium 226 revealed extensive deposits of sulfates on the vanes of the static mixer, on the interior of the pipe and on every downstream item from the point at which the barium chloride solution was introduced into the system. The deposits could be removed, with some difficulty, by chipping and scraping, but the underground valves were not readily accessible, and the deposits on them either prevented or reduced their operation. A static mixer with removable vanes was designed and installed in the place of the original static mixer. This was intended to delay the precipitation of sulfates until the solution reached the settling pond. The deposits on the vanes were not as dense and hard as those which occurred on the original static mixer. However, the pipe downstream from the mixer continued to accumulate deposits until maximum flow could not be obtained. An external, trough-type baffle mixer was designed, constructed and installed between the treatment plant and the ponds. The barium chloride slurry was piped along and in contact with the 6-in. pipeline to ensure that the slurry would not freeze. Photographs of the mixer in operation indicate extensive turbulence and mixing. First tests of the amount of sulfates in the

discharge from the settling ponds indicate that the mixer is effective and that the sulfates in the discharge water are being reduced and retained in the pond.

Regulations should be included in the district heating system contracts with building owners that include a clause requiring the building system to operate at the working pressure in the pipeline, or the building owner should provide a pressure reducing valve at his own expense. This would allow all users to operate at the most efficient pressure.

All contact areas of filament wound epoxy pipe must be dry before making joints or leakage can occur, based on testing performed at the project.

All requirements for record keeping, including format, should be developed as early in the project as possible.

Cooperation among the Department of Energy, The Idaho National Engineering Laboratory, the Haakon School District Board of Education, the Heating District Directors and the design professionals was excellent.

5. THE RESOURCE

5.1 General

The project site overlays the Madison formation, an extensive source of geothermal fluids. The Madison formation is made up of porous or fractured limestone and dolomite, and is recharged naturally from rain and surface water at higher elevations. Existing wells into the Madison formation in the project vicinity are artesian.

The reliability of flow and temperature of water from the Madison formation had been adequately established by records of wells in the vicinity. The City of Philip well, drilled in 1962, is located approximately three miles north of the school buildings and 154°F water had been flowing continuously since it was drilled.

5.2 Drilling

The first phase of the project was to drill a new well into the Madison formation on land owned by the Haakon School District adjacent to their school buildings. Plans and specifications for the new well were prepared by Francis-Meador-Gellhaus, Inc., consulting engineers of Rapid City, South Dakota.

A contract was awarded to Northern Wyoming Drilling Company, the only bidder. The contractor proceeded drilling at his own risk. He was unable to provide a performance bond and labor and material payment bond until the well was completed. Without the bond, a formal contract could not be entered into between the Haakon School District and Northern Wyoming Drilling Company. This placed the contractor in a zero cash flow position, and exposed the Haakon School District to a potential legal or financial problem.

The well was completed to a total depth of 4266 ft (see Figure 6.3). The original plans required a 10-3/4-in. casing for the first 1000 ft, a 7-5/8-in. casing from the 1000 ft to the 3800 ft depth, and an open hole

Fig. 6.3 Haakon School Well Diagram

bore from the 3800 to the 4100 ft depth. To prevent future problems of sluffing encountered below the 3800 ft depth, it was necessary to install a 5-in. O.D. flush joint casing inside the 7-5/8-in. casing. The bottom of this 5-in. O.D. casing extends to a depth of approximately 3900 ft.

5.3 Testing

The initial attempt to measure the flow with a weir box was unsuccessful because the box had been designed for larger flows than were obtained. Preliminary testing using a stop watch and a 55 gal drum indicated a maximum flow rate of approximately 320 gpm of water at a temperature of 156°F. Flow tests using a free flow orifice indicates that the well is capable of sustaining a long-term artesian flow rate of 300 gpm.

From the water quality samples obtained and tested, the water quality of the well appeared to be similar to the water quality of the City of Philip well which is located 2-1/2 mi northeast of this well.

The flow tests also showed that the geothermal fluid contains about 99 ± 2 pico curies per liter (pCi/L) of Radium 226. The allowable effluent daily average limitation (for 30 consecutive days) is 3 pCi/L. In practice, the allowable measured value for a sample is 10 pCi/L. This required the installation of a system to add barium chloride that chemically coprecipitates out the sulfates containing Radium 226. The sulfates are held in two ponds sized to retain 45 years of precipitates.

6. THE ENERGY EXTRACTION AND USE SYSTEM

6.1 General

The energy extraction system includes the well (Figure 6.3) and wellhead equipment (Figures 6.4 and 6.5), and transmission piping to plate type heat exchangers that provide, on the secondary side, heated water for domestic use and space heating. After passing through the heat exchangers, the geothermal fluid is gravity flowed to the business district heating system, then through a barium chloride facility to two settling ponds that discharge into the nearby Bad River (Figure 6.6). Necessary valving and controls are provided.

The artesian flow of the well delivers 300 gpm at 15 psi with a shut-in pressure of 125 psi. (Based on experience with other wells in the Madison formation, the well should be able to sustain a long term flow of 300 gpm.) The pressure, and a drop in elevation of 100 ft from the wellhead to the business district heating system, eliminated the need for primary system pumps.

The geothermal fluid is flowed through glass fiber filament wound epoxy pipe to plate type exchangers in the school buildings. A single pipe transmits the fluid to the first school buildings; a two pipe reverse return is used between the first and second building where the return and supply are combined into a single pipe that carries the fluid to the first building in the business district heating system. A two-pipe reverse return system is used in the heating district. The fluid is again combined and transmitted to the treatment plant. The length of the transmission system is 5277 ft.

The existing space heating equipment was used wherever possible to operate at the temperature of the geothermal fluid rather than the original steam or hot water system. The elementary school heating schematic is shown in Figures 6.7 as a representative sample of the schools' systems. Geothermal fluid flows through the heat exchangers when the outdoor air temperature falls to 65°F. Water for space heating is pumped through

Fig. 6.4 Final Wellhead Configuration

Fig. 6.5 Final Wellhead Configuration - Cont'd

Fig. 6.6 Haakon School System Schematic

Fig. 6.7 Haakon Elementary School Heating Schematic (Armory Building Similar)

the heating system side of the heat exchanger and the space heating circuits. A separate pump moves water through the domestic water circuit and its heat exchanger. A new eight unit modular hot water boiler provides augmenting and/or backup capacity in the armory-high school building. The existing steam boiler in the elementary building was converted to hot water to provide augmenting and/or backup capacity for the elementary and auxiliary buildings.

The business district heating system users were responsible for the design and installation of their own systems. Untreated geothermal fluid is used directly by the heating district with one exception where a shell and tube heat exchanger is used.

The treatment plant that is used to remove Radium 226 includes a small building that houses the barium chloride treatment equipment. This equipment consists of tanks for mixing barium chloride slurry, pumps for injecting the slurry into the pipeline, a static mixer to mix the slurry with the pipeline water, two settling ponds and the piping and valves to control the discharge into the river.

7. INSTRUMENTATION AND CONTROLS

An outdoor reset thermostat control opens the main valve when the outdoor temperature falls to 65°F allowing geothermal water to flow through the transmission pipe line. Each building has its own system controls.

The energy monitoring system operates only when manually activated by loading the recorders with paper and pen. The flow meter records flow of geothermal water and the temperature gage records the temperature of the water.

Environmental controls consist of an electric space heater to heat the wellhead building in the event of a well shutdown during low temperatures.

Thermometers at the end of the district heating system and at the treatment plant show the change of temperature between these two points. A remote temperature sensor is installed 6 ft downstream from the point where the supply and return lines were joined downstream from the elementary school.

Control components, in addition to the manual valves on the supply and return pipes at each user's service entrance, are located in the well house and at the fire station, which is the last user on the transmission system. A motor operated, modulating volume control valve located in the well house is controlled by an outdoor reset thermostat which increases the volume of water as the outdoor temperature decreases. At the fire station, which is approximately 100 ft lower than the well house, a second motor operated modulating volume control valve is located in the hot water return line from the heating district, and a combination pressure relief-pressure sustaining valve is located in the hot water supply line from the heating district. The volume control valves maintain the proper quantity of water to the systems. The pressure sustaining valve at the lowest point in the distribution system maintains pressure to force the water through the various distribution and users' heating systems.

Pump controls at the treatment plant allow precise but variable quantities of barium chloride slurry into the pipe line. Manually operated valves control water entering the settling ponds and the discharge into the Bad River. There is no continuous monitoring at the plant, but a thermometer in the pipe measures the temperature of water entering the plant. This enables the operator to determine if the energy remaining in the water is usable and available for future development.

Samples of the discharge water are taken periodically and analyzed for Radium 226 content. Adjustments in the barium chloride slurry are made if necessary to obtain changes in the precipitation rate.

8. ALTERNATE CONSIDERATIONS

Reinjection was eliminated as a possible means of geothermal fluid disposal because of cost and the unacceptability of discharging untreated fluids containing Radium 226 into the subsurface.

The School District decided to retrofit their buildings, using the existing equipment wherever possible, augmenting the capacity with additional equipment or replacing equipment as a last resort. The old boiler in the armory-high school was to be replaced with a new modular boiler to serve as backup to the geothermal system. The corrosive nature of the geothermal water and the greater efficiency of plate type heat exchangers led to their selection in preference to the shell and tube type. Exchanger plates were available in a variety of corrosion resistant materials and alloys. Forty-five days of testing polished metal coupons exposed to flowing geothermal water showed that 316 stainless steel was the most suitable material for use wherever geothermal water contacts metal.

Analysis was made comparing one central plate heat exchanger for the entire school complex with separate smaller exchangers for space heating and domestic water for the armory-high school, space heating and domestic water for the elementary, vo-ag, and music buildings, and future expansion. Separate heat exchangers were selected to avoid shutdown of the school system in the event of failure of the large heat exchanger.

An experiment was performed with an ion exchange system to remove the sulfates without the problem of deposits in the pipe. This system worked during the initial flow, but quickly lost its effectiveness. It was not pursued because of the excessive cost of barium sulfate due to the short effective life of the medium.

9. SYSTEM OPERATION

The system operates successfully, providing all the heat for space and water normally required by the school district, and at least 75% of the heat required for the business heating district. The artesian flow is adequate to force water through the school systems' heat exchangers and the pipe line to the district heating system. The difference in elevation between the wellhead and the district heating system has provided adequate head for each of the heating district members. The 154°F temperature of the water has been adequate for heating the school buildings and their service water, and the temperature of the water leaving the school site is approximately 130°F. The heating district users have been able to obtain more heat than anticipated from the geothermal water. However, treatment of the geothermal water to remove the sulfates which contain Radium 226 without causing other problems, such as deposits in the pipe, has been more difficult than anticipated.

The plate heat exchangers have operated satisfactorily. Each heat exchanger was disassembled in June 1982, after about one and one-half years of service, for inspection and cleaning. The geothermal sides of the plates appeared absolutely clean, but a very thin film of particulate deposit could be wiped from the plates. The building heating system sides of the plates contained minor deposits from the existing piping. The service water heat exchangers geothermal sides were clean; the service water side of the high school-armory heat exchanger had heavy deposits of iron oxide. The plates were easily washed with water before any of the deposits were allowed to dry.

The barium chloride treatment process effectively removed the sulfates which contained the Radium 226. However, the sulfates precipitated immediately after the introduction of the barium chloride and coated the static mixer vanes, the interior of the pipe and the downstream valves. Attempts to delay the precipitation were only partially successful. The substitute ion exchange method was not successful. The open trough static mixer, located outside the building, works satisfactorily. Tests of the discharge water, since installation of the open trough mixer, indicate that the amount of sulfates in the water was reduced.

Radium 226 is an alpha emitter for which very little shielding is required. The pond cannot be drained or the sludge allowed to dry, because dust from this sludge would carry the Radium 226. Sludge removal and disposition will have to be done every thirty years.

Vertical discharge unit heaters furnished for the gymnasium did not have sound ratings in the manufacturer's literature submitted for approval. The units have an unacceptably high sound level, and attempts to reduce fan speed by changing motor controls have not yet proven successful. The supply water temperature is lower than that normally used in space heating operations, and the equipment is operated at nearly maximum capacity. The lesson taught here is that equipment test data should be required before purchase.

10. SYSTEM COSTS, SCHEDULE, AND ORGANIZATION

10.1 System Costs

The total cost of the project was \$1,210,600, excluding the cost of conversion and retrofitting of the business district heating system buildings. The DOE share was \$944,100, and Philip Geothermal, Inc., the developers of the business district heating system, contributed \$52,000. Haakon School District 27-1 provided \$214,500. The major project costs are shown in Table 6.1.

TABLE 6.1. PROJECT COST SUMMARY

<u>Item</u>	<u>Cost (\$)</u>
Well Drilling	311,515
Standard Water Tests	765
Heat Exchangers	13,600
Piping and Treatment Plant	438,130
School Retrofit	329,000
Testing	3,600
Technical Support	74,910
Management and Other Costs	28,350
Information Dissemination	<u>10,730</u>
Total	1,210,600

With a total annual heating load of 9535×10^6 Btu, the estimated payback is about 12 years for the system. (The fuel savings for 1983 were about \$112,000.)

The barium chloride treatment system is and will be a continuing expense because of the need for barium chloride. However, it appears that the static mixer problem has been solved by the installation of the exterior, open trough type of mixer. A contingency fund for such items should have been included in the original budget.

The business district heating system pays the school district \$2500 annually for the first five years of the contract, and the amount increases \$500 each year for the next five years. The estimated annual operating cost, mostly for barium chloride treatment is about \$9200. Deducting this income, the net annual operating cost is \$6700.

10.2 Schedule

The project was planned in phases, the first being planning the project and drilling a new well. Design and construction of heating system modifications were next. The third phase involved the design and construction of the discharge pipeline and the treatment plant. Fourth, service was provided to the heating district, and the last phase involves system operation and maintenance. The project schedule is shown in Figure 6.8.

10.3 Organization

The School District Board of Education was the project sponsor. Hengel, Berg and Associates were the project engineers. Other participants are identified in Figure 6.9.

TASK	1977	1978	1979	1980	1981	1982
FEASIBILITY STUDY FOR DIRECT UTILIZATION OR GEO- THERMAL WATER	JFHAMJJASONH	JFHAMJJASONH	JFHAMJJASONH	JFHAMJJASONH	JFHAMJJASONH	JFHAMJJASONH

ENVIRONMENTAL IMPACT ASSES- SMENT OF GEOTHERMAL SYSTEM	*****	*****				
GEOTHERMAL DISTRIBUTION PIPELINE & BARIUM CHORIDE PLANT (DESIGN)	*****	*****	*****	*****		
NEW WELL (DESIGN)		*****				
GEOTHERMAL CONVERSION & BOILER REPLACEMENT (DESIGN)		*****	*****	*****		
PHILIP BUISNESS HEATING DISTRICT GEOTHERMAL (DESIGN)		*****	*****	*****	*****	
SUBMISSION OF FON		*				
WELL DRILLING & TESTING			-----+++++	+++++	+++++	+++++
HEAT EXCHANGERS (DESIGN)			*****			
GEOTHERMAL DISTRIBUTION PIPELINE & BARIUM CHORIDE PLANT				-----	+++++	+++++
GEOTHERMAL CONVERSION & BOILER REPLACEMENT				-----	+++++	+++++
PHILIP BUISNESS HEATING DISTRICT GEOTHERMAL					-----+	+++++
LEGEND: PRE-CONSTRUCTION: ***, CONSTRUCTION: ---, OPERATION: +++						

Fig. 6.8 Project schedule

Fig. 6.9 Project Organization

11. LEGAL AND INSTITUTIONAL CONSIDERATIONS

An environmental impact assessment was completed August 25, 1978 and approved January 2, 1979. An addendum to the report was completed January 3, 1980. It included the method of treating the geothermal water to remove the Radium 226 contained in the sulfates present in the water.

Geothermal water from well flow tests was discharged into the nearby storm sewer which discharges into the Bad River. This river has intermittent flow, with highest volume in the spring. No long term adverse effects on stream life were anticipated and none occurred.

The State, through the South Dakota Department of Water and Natural Resources, Office of Water Quality, required a permit to drill the well, and through the Department of Environmental Protection, required a National Pollutant Discharge Elimination System (NPDES) permit to discharge the geothermal water into a waterway.

The School District, a political subdivision of the state, owns the land on which the well was drilled and through which the upper part of the pipeline passes. The pipeline is located in streets and alleys wherever possible. Initially, the line was located to cross railroad property, but necessity to provide a treatment plant and two settling ponds required additional property on which to locate the plant. The location selected avoided railroad property, but did require construction and maintenance easements from property owners. The School District obtained all easements.

The City of Philip did not require construction or building permits for either the pipeline or modifications to the heating plants of the school buildings. They did provide easements for the pipeline along alleys and streets.

The distribution pipeline location passes through three parcels of private property. Ten foot wide construction and maintenance easements were obtained by the School District from the property owners.

12. REFERENCES

Much of the information and figures contained in this report are excerpted from the project final report prepared by Hengel Associates, and appreciation and thanks are extended to them for their contribution. Their final report, identified below, provides additional details of the project for interested individuals.

- *1. Hengel Associates, Direct Utilization of Geothermal Energy for Haakon School District, South Dakota, Final Report, January 1977-March 1985, Report No. DOE/ET/27080, Cooperative Agreement No. DE-FC07-78ET27080.
- *2. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984
- *3. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

* Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

ST. MARY'S HOSPITAL PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: St. Mary's Hospital Geothermal Heating

Project Data:

Project Description: The project demonstrates the feasibility of utilizing a moderate temperature (108°F) geothermal resource to provide heat for domestic hot water and space heating at St. Mary's Hospital.

Location: Pierre, South Dakota

Peak Heat Load: 5.55 million Btu/h

Annual Heat Load: 11.44 billion Btu/yr with 24% load factor.

Simple Payback: 9.5 yr

Status: Operational and monitoring. Provides 50% of the heat for existing structures with 83,000 sq ft and 95% to the new 65,000 sq ft facility with an estimated annual savings of about \$80,000.

Cooperative Agreement Data:

Number: DE-FC07-78ET28441

Period: June 30, 1978 to June 30, 1983

DOE Share: \$550,381 (74.6%)

Participant Share: \$187,770 (25.4%)

Total Cost: \$738,151

Principal Investigator:

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2. PROJECT HISTORY

The St. Mary's Hospital geothermal heating project originated with an energy use analysis, which was conducted in 1976 by the firm of Kirkham, Michael and Associates (KMA). A study prepared in 1977 by J. P. Gries, Ph.D., retired dean of the graduate school of the South Dakota School of Mines, provided support for the potential of a geothermal resource in the project area. A proposal was submitted in response to the 1977 PON solicitation. St. Mary's Hospital was one of two hospitals selected and a cooperative agreement was entered into on June 30, 1978. The original schedule period was 24 mo, but was later extended to obtain representative operating data.

The project well was drilled in the spring of 1979, yielding 108°F fluid with an artesian flow of 275 gpm that was later increased to 385 gpm through stimulation and casing perforation. Final EPA and Corp of Engineers' approval delayed until 1980 the second phase of the work, including building retrofitting, extending piping to the new building, constructing a wellhouse, and providing discharge piping to the Missouri River. The existing building began using geothermal fluid in early fall and the new addition by late fall 1980.

Excessive backup boiler use, caused by faulty insulation in the new building, occurred during the first year of operation resulting in understated savings. During the second year, problems of varying degrees of seriousness developed in the system. The system performed well during the third season, yielding the anticipated fuel savings and performance.

3. GENERAL DESCRIPTION

A well drilled to a depth of 2176 ft in the Madison aquifer provides 108°F geothermal fluid with an artesian flow of 385 gpm. The fluid passes through three flat plate heat exchangers, located in a wellhouse at the wellhead, before it is discharged directly into the Missouri River. Heat used from heat exchanger No. 1 is extracted by a closed loop system with a circulating centrifugal pump, which delivers 100°F water to the new and existing buildings heating systems (Figure 7.1).

The domestic water, which is preheated by heat exchangers No. 2 and No. 3, is stored in an insulated 4000-gal tank located within the heat exchanger building and is made available for use upon demand.

The system provides preheating of hot domestic water, heating of makeup air for ventilation and space heating with existing room fan coil units for the existing hospital (Figure 7.2). The new building addition receives domestic hot water from the heat exchangers and space heating by using the geothermally heated water directly in the hot deck coil of the building air handling units (Figure 7.3).

S2 2472

Fig. 7.1 St. Mary's Hospital Well House and Exchanger Building

S2 2432

Fig. 7.2 St. Mary's Existing Hospital Direct Heat Applications

S2 2428

Fig. 7.3 St. Mary's Hospital New Building Heating System Schematic

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

The St. Mary's Hospital geothermal heating project demonstrates the feasibility of utilizing a low temperature geothermal resource (108°F) for space and domestic hot water heating. On the basis of the positive results of St. Mary's geothermal project, others in this area could consider tapping the Madison aquifer. The geothermal water available in this region, even at 108°F, can provide a very effective supplementary heat source.

When water is discharged into the river, the flow should not be interrupted for a period of more than a few days to avoid silt filling the discharge ports.

An evaluation should be made of heat pumps using the lower water temperatures available from shallower aquifers that have substantially greater water volume (e.g., 1500 gpm at 92°F).

Other considerations, relative to the presently installed geothermal systems at St. Mary's Hospital, which could enhance it and other geothermal projects are:

- o The use of geothermal heat could be expanded by using coils when central air conditioning is added
- o Heat pumps could be used to extract additional heat from the waste water being discharged from the system
- o The potential for selling the waste water to area businesses for the purpose of providing heat to their buildings could be explored
- o Tapping the natural gas zones observed during drilling could be accomplished by sleeving the existing well to the appropriate depth and drawing off the gas.

5. THE RESOURCE

5.1 General

A low Precambrian ridge strikes west-southwest at the eastern end of the state. The ridge is known as the Sioux Quartzite and dips beneath younger strata, which cover the entire midsection of the state. These strata, significant to this project, consist mostly of webs of mesozoic and cenozoic age. Information about the strata had been collected from logs of deep wells drilled near Pierre (Figure 7.4), particularly one in the vicinity of the airport. The aquifer being tapped follows a broad plain of limestone, and the adjustment of a well siting by any distance within several thousand feet in any direction did not appear to be a factor. A site (Figure 7.5) was selected within the hospital grounds where it would not compromise further expansion and it would be accessible to the structures to be heated and the discharge point. The final selected site is a gravelled parking lot used for overflow parking. The hospital, located on the south side of Pierre, is about 1000 ft north of the Missouri River.

5.2 Drilling

Drilling of the project geothermal well started March 27, 1979, and was completed by Layne-Western of Denver, Colorado by the end of April. It was drilled to the base of the Madison Formation at 2176 ft. Details of the well are provided in Figure 7.6. The 7-in. liner across the porous zones of the Madison Formation were perforated twice to produce a flow of 283 gpm of 108°F fluid. The well was acid treated, increasing the average artesian flow to 400 gpm with a maximum shut-in pressure of 475 psi.

5.3 Well Testing

Four logs were run on the well. A short 3-h flow test with a 45-min recovery was conducted by the driller on May 30, 1979. Four pulse tests and two production tests occurred June 5-7, indicating that no more than 375 gpm could be produced from the well without the aid of a pump. Water

Fig. 7.4 Project location map

Fig. 7.5 Site Plan

Fig. 7.6 St. Mary's Hospital Well

samples were gathered and analyzed and a corrosion study was performed. It is known that the reservoir is filled from the limestone outcroppings in the Black Hills and that it is continuous 170 mi east to a point east of Pierre. From the limited draw upon this immense reservoir, and with no nearby wells to measure changes in pressure or flow, it is impossible to measure the total capacity except to say that it probably exceeds the requirements of this well by several orders of magnitude.

From the last production test it was concluded that a peak artesian flow of 375 gpm could be sustained, unless some unsuspected aquifer boundary existed just outside of the cone of influence reached in the 13.7-h test at 375 gpm.

6. THE ENERGY EXTRACTION AND USE SYSTEM

Geothermal fluid at 108°F passes through three flat plate Type 316 stainless steel heat exchangers, which are located in a wellhouse at the wellhead. The spent fluid is discharged at 75 to 80°F through 6-in. PVC pipe extending 1100 ft southward when it discharges through 40 ft of perforated pipe in the Missouri River.

The closed loop heating water supply and return is circulated by a centrifugal pump through an underground, pre-insulated piping system with filament-wound reinforced fiberglass plastic pipe, 1-1/2 in. polyurathane insulation, and a PVC outer jacket. The underground domestic hot water piping system consists of pre-insulated pipe with copper carrier pipe, urathane insulation, and a PVC jacket outer pipe. The calculated heat loss in the approximately 450 ft of underground supply line indicated an average temperature drop in the 100°F supply water of less than 1/2°F.

The existing hospital uses the preheated 100°F water in a closed loop from one heat exchanger to preheat domestic hot water. The existing steam system elevates the water temperature as required. The closed loop also provides for heating of makeup air for ventilation and space heating in existing room fan coil units.

The new building addition uses on demand, domestic water, preheated by heat exchangers No. 2 and 3, and stored in an insulated 4000-gal tank located within the heat exchanger building. Circulation of the domestic hot water is provided by centrifugal in-line pumps of single-stage, vertical split case design and cast iron bronze fitted construction.

The hot water for space heating the new building is transmitted by base-mounted pumps. These are single-stage centrifugal electric pumps with flexible connection to the motor. The pumps are vertical split case, end suction type, with iron casing. The hot water is used directly in the hot deck coil of the building's air handling units.

7. INSTRUMENTATION AND CONTROLS

Meters and recording equipment provide visual indication and seven-day charts for wellhead pressure and supply temperature. The temperature of the geothermal fluid exiting the heat exchangers, the well flow rate, and the closed loop heating water supply temperatures are also included. A Btu meter to indicate the Btu rate, and a Btu totalizer are used for both total geothermal fluid flow and the closed loop heating water system.

Closed loop heat pumps are manually turned on when heating is required, and domestic hot water is supplied on demand. The existing fan coil unit control was modified to provide for summer/winter changeover of the existing thermostat. (All control systems are pneumatic.) Heating control is provided in the new addition through dual duct mixing boxes controlled from room thermostats.

8. ALTERNATE CONSIDERATIONS

Consideration was given to implementing a geothermal system at Capitol Lake Plaza. This objective was omitted because geothermal fluid temperature and flow did not meet original expectations of 117°F at 1700 gpm.

Injecting spent geothermal fluid into the shallower Dakota Formation was rejected because of concern over drilling costs and the potential for serious environmental problems that could require extensive studies and monitoring to protect the subsurface environment.

9. SYSTEM OPERATION

The production system has worked without maintenance problems, with two exceptions: (a) The regulators were not set by the manufacturer, and the diaphragm ruptured at a pressure less than that given in the job specifications, and (b) The piping used to carry the geothermal water within the wellhouse was steel (although the heat exchangers were stainless steel). Within the first year of operation, the piping developed blisters on the interior, and one section just downstream of the pressure reducing valve developed a pinhole leak. Inspection of sections of the pipe adjacent to this section revealed the blistering.

As a precautionary measure, the system was shut down from December 8, 1981 through April 6, 1982. Most of the time was waiting for the delivery of replacement pipe which only required two weeks to install. About 130 ft of mild steel pipe was replaced with fibercast insulated piping from downstream of the pressure regulators to the heat exchangers.

The perforations in the discharge pipe in the Missouri River had to be cleaned of river silt when the system was down for more than a week, as was the case when pipe was replaced in the wellhouse. The hospital does not, however, plan to shut the well off completely for extended periods of time as a standard procedure. Therefore, the discharge flow will keep the perforations open.

The hospital staff have been reasonably satisfied with the design and operation of the production system, and with the method and design of the discharge system. The thermal dilution design was not well tested in 1980-81 as the winter was unusually mild, and little or no ice formed in this area of the river. In the winter of 1981-1982, piping was being replaced; no water was discharged from December 8 - April 6. During the next year, operation continued uninterrupted and only normal maintenance and inspection was required for the system.

10. SYSTEM COSTS, SCHEDULE AND ORGANIZATION

10.1 System Costs

The total project cost, including replacement of wellhouse piping is \$738,151. The hospital share is \$187,770 (25.5%) and the DOE cost share is \$550,381 (74.5%). The system has produced a maximum of 13.43×10^9 Btu per year or \$4.79 per million Btu. The savings during the first year were low (about \$65,000) because of partial operation and mild weather. Payback is expected in about 9.4 years.

Nonroutine maintenance costs were experienced because of the need to clean out silt in the river discharge pipe, adding pilot valves to correct variations in water pressure in the domestic water system, and replacing steel piping in the wellhouse. Excluding these costs, routine expenses for the first year were about \$30,800. However, the maintenance costs for the third year dropped to \$12,600.

10.2 Schedule

The project was initiated in the summer of 1978, and the system was operational in October, 1980. Monitoring continued through the 1983-84 heating season. Major project activities and their schedule are shown in Figure 7.7.

10.3 Organization

Figure 7.8 is the project organization chart identifying key participants and their project relationship.

Basic
Symbol

Meaning

Representative
Uses

Meaning

- Actual/Scheduled Milestone Initiation
- ◊ Scheduled Completion
- ◆ Actual Completion
- ◇ Previous Scheduled Completion-Still in Future
- ◆ Previous Scheduled Completion-Date Passed

- ◇ ◇ Anticipated Slip - Rescheduled Completion
- ◆ ◇ Actual Slip - Rescheduled Completion
- ◆ ◇ Actual Slip - Actual Completion
- ◆ ◇ Actual Completion Ahead of Schedule

Fig. 7.7 Project schedule

Fig. 7.8 Project Organization

11. LEGAL AND INSTITUTIONAL CONSIDERATIONS

The hospital owns the property on which the well and facilities are constructed. Hence, no purchase or lease was necessary to complete the project.

An easement was required to permit the hospital to cross a city street with pipes and to run the discharge pipe approximately 1100 ft under a city street to the Missouri River. The hospital attorney filed the easement with the city, and in a matter of 60 days the easement was granted following an appearance at a city council meeting.

Should the hospital sell the water to businesses in the area, the city had already advised the hospital that a franchise would be needed.

The state required a water permit and was involved in the issuance of the EPA permit. An application was made to the Water Rights Division of the Department of Water and Natural Resources of the State of South Dakota in April 1978, and the permit was received in August 1978. The greatest concern was apparently that the water drawn from the well not be used for any agricultural or domestic use but discarded into the Missouri River. In deference to this concern, the Board of Water Management issued a permit for a limited period, requiring the hospital to comply as follows: The well approved under this permit shall be valved and the flow reduced to the minimum amount required for the uses served. The well shall also be equipped with a pressure recorder, and a record kept of any pressure fluctuations. Such records shall be available to the commission upon request. If this well is abandoned or the permit cancelled, the well must be plugged in accordance with specifications of the Water Rights Commission.

The hospital was required to file for a Certificate of Need permit in order to be reimbursed for the expense of the new well with health care dollars from certain third party payers such as Medicare and Medicaid. The Certificate of Need process is unique to the health care field and is not common to the geothermal field. It is required to expend health funds in excess of \$150,000.

Two applications were filed with and approved by the Environmental Protection Agency. The initial one was to drill the well, the second for the disposition of the spent geothermal fluid.

The Corps of Engineers controls the shoreline of the Missouri River. They required a permit to allow the hospital to place a discharge pipe across the controlled shore and into the Missouri River. The initial application for this permit was filed with the Corps of Engineers in Omaha, Nebraska on October 25, 1979. A concern was expressed by both the United States Department of the Interior (Fish and Wildlife Service) and the South Dakota Department of Game, Fish and Parks that the warm water in the winter would cause a hazard to those using the ice in the vicinity of the discharge point, such as ice fishermen, snowmobilers, and ice skaters. Different methods of discharge were evaluated with final solution being accepted by the Corps of Engineers on June 20, 1980, 8 mo after the application. A permit was granted to run the discharge pipe 150 ft into the water insuring that at no time was the pipe closer than 5 ft from the surface of the water, to allow adequate clearance for any motorboats in the area. In addition, the last 40 ft of the pipe were perforated in order to diffuse the water on the floor of the river, thereby reducing the potential thawing effect that the water had on the surface ice. The Corps also required that the hospital erect a sign on the shore in the vicinity of the discharge pipe alerting the public to the weak ice that might be in the area.

12. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and the figures contained in this report are excerpted from the project final report prepared by St. Mary's Hospital and appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. St. Mary's Hospital, Geothermal Heating Project at St. Mary's Hospital, Pierre, South Dakota, Final Report, Report No. DOE/ET/28441-7, Cooperative Agreement No. DE-FC07-79ET28441, September 1984.
- *2. Aesco, Inc., Environmental Report, St. Mary's Hospital Geothermal Project, Report DOE/ET/28441-1 Cooperative Agreement No. DE-FC07-79ET28441, formerly No. ET-78-F-07-1731, July 1978.
- *3. Kirkham, Michael and Associates, Hydrothermal Retrofit Program, St. Mary's Hospital, Pierre, South Dakota, First Quarterly Report July 1, 1978 - October 1, 1978, Report DOE/ET/28441-2 Contract No. ET-78-F-07-1731, October 1978.
- *4. Ibid, Second Quarterly Report October 1, 1978 - January 1, 1979, Report DOE/ET/28411-3, January 1979.
- *5. Ibid, Third Quarterly Report January 1, 1979 - April 1, 1979, (Report DOE/ET-28411-4) April 1979.
- *6. Ibid, Fourth Quarterly Report April 1, 1979 - July 1, 1979 (Report DOE/ET/28411-5) July 1979.
- 7. Petroleum Supervision and Management, Inc., Drilling Prognosis, St. Mary's Hospital Hot Water Supply Well No. 1, Pierre, South Dakota, Cooperative Agreement No. DE-FC07-79ET28441, March 1979.
- *8. Dr. M. Howard, and Dr. D. D. Carda, Corrosion and Water Chemistry Analysis for the St. Mary's Geothermal Well at Pierre, South Dakota, Report DOE/ET/28441-6 Cooperative Agreement No. DE-FC07-79ET28441, June 8, 1979.

* Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

- *9. Kirkham, Michael and Associates, Specifications and Contract Documents, St. Mary's Hospital, Pierre, South Dakota, Cooperative Agreement No. DE-FC07-79ET28441, August 1979. (Includes drawings, 14 sheets and Addendum No. 1, September 27, 1979.)
- *10. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *11. ICF Incorporated, Resource Development: System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099 and DE-AC07-76ID01570, April 1984.

* Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

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UTAH STATE PRISON PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: Utah State Prison Heating

Project Data:

Project Description: The project demonstrates the feasibility of utilizing a moderate temperature (~180°F) geothermal resource to provide space and domestic hot water heating for the minimum security facility at the Utah State Prison located near Draper, Utah.

Location: Draper, UT (about 16 mi south of Salt Lake City, UT on Interstate 15).

Peak Heat Load: 5 million Btu/h

Annual Heat Load: 11 Billion Btu/yr (25% load factor)

Simple Payback: 15.5 yr

Status: The project was satisfactorily completed, but numerous factors have limited operation. Current plans call for the construction of a new prison facility that will utilize the resource. The existing service to the minimum security building will be discontinued.

Cooperative Agreement Data:

Number: DE-FC07-79ET27027

Period: March 14, 1979 to January 31, 1986

DOE Share: \$493,100 (59.6%)

Participant Share: \$334,500 (40.4%)

Total Cost: \$827,600

Principal Investigator:

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2. PROJECT HISTORY

The Utah State Prison demonstration project was initiated in 1978 by the Utah Energy Office responding to a DOE program opportunity notice request for proposals. Subsequent to selection, the geothermal resource at Crystal Hot Springs (adjacent to the Utah State Prison) was tested and evaluated during the period of 1978 through 1981. Test wells were drilled, and one well, USP/TH-1, had adequate flow and temperature to be used for production. CH₂M Hill, an engineering-consultant firm, developed a preliminary design in 1981 to provide hot water for use in the prison's minimum security building, a 72,000 ft² structure. The architect-engineering firm of Case, Lowe, and Hart was selected April 2, 1982 to prepare the final design and issue bids for construction. The project was primarily constructed by Stephan L. Cornwall Company between May 1983 and July 1984. Performance verification was performed by Case, Lowe, and Hart, who also conducted limited post-construction modifications to improve the system operation, completing the project by the end of 1985.

3. GENERAL DESCRIPTION

Geothermal fluid with a temperature of 180°F is flowed by artesian pressure into a surge tank, then pumped through two plate-type heat exchangers. (With the periodic loss of well artesian flow, an in-line pump will be installed as intended when the project was first being developed.) The heat exchangers are located close to the well site, and the secondary heating lines carry only "clean" domestic water. The existing hot water system in the minimum security facility was modified to accommodate the geothermally heated circulating loop to provide both space and hot culinary water heating.

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

User commitment and support were not obtained from Utah State Prison maintenance and operations personnel early in the project, leading to a potential abandonment of the geothermal system after completion. There is no advocate for the project at the prison to encourage and instruct the operators in the use of the system. As a countermeasure, current plans call for the construction of a new prison facility that is being designed to use the geothermal fluid that is provided for the PON project. Service will be abandoned to the minimum security facility after the new facility is built.

The existing hot water heating system in the minimum security facility was modified to accommodate a closed loop system that is heated by the geothermal fluids. The existing system, because of technical problems, leakage, and deterioration, resulted in more downtime and loss of performance than the geothermal system did. This emphasizes the need for greater attention to calibration and maintenance of controls, especially in existing systems that are modified to receive geothermal heating. There is a tendency to blame the new geothermal system for all problems that arise, regardless of their origin.

The majority of the energy contributed to the minimum security facility is used to heat culinary water. The contribution to culinary water could be increased if the geothermal heat exchangers in the facility were piped in series (instead of parallel) with the existing steam converters. All make-up and recirculated water should pass first through the geothermal heat exchangers and then through the steam converters. This would ultimately reduce the geothermal return water temperature.

The concept of maintaining a CO₂ blanket in the surge tank has apparently worked quite well. It seems that preventing aeration of the fluid, which could lead to corrosion problems, and preventing the loss of CO₂ reduces the scaling potential. Water quality problems were more apparent in the so called "clean" water than in the geothermal water.

Predicted scaling problems have not occurred, with only slight traces of scaling in the system. Greater attention to water treatment on the clean side of the system is recommended.

With the exception of resource concerns, the technical design, construction, and operation of the geothermal heating system is not too difficult. However, greater attention must be paid to material selection than in "normal" hydronic heating systems, but other design tasks are quite similar. The project has proven technically and economically feasible.

The combined effect of producing from two wells (USP/TH-1 and Utah Roses) has, as predicted, caused significant stress on the geothermal reservoir. The actual stress is greater than predicted, causing well USP/TH-1 to drop below satisfactory artesian flow. It will be necessary to install a downhole pump for continued production.

The system was operational for approximately 9 months during 1984 and 1985. Much of this time the energy contribution has been low, due mainly to operational problems with the minimum security building's heating system. Estimated savings to date are \$18,060, which accounts for 3199 million Btus of avoided energy consumption. Total cost for the project, including demonstration and reporting, is \$827,558.

Geotechnical testing and water chemistry, scaling, and corrosion testing should be completed as early as possible. If extra review is requested during design, the review should be carefully planned and expedited. Reviews during the early stages of design tend to cause fewer delays and should be used when possible.

5. THE RESOURCE

5.1 General

The project is located at the Utah State Prison near Draper, Utah, approximately 16 mi south of Salt Lake City (Figures 8.1 and 8.2). The Crystal Springs Resource area is on the west end of the prison complex, near the prison's farm and dairy operations. There are several thermal ponds on private property adjacent to the prison, and several developments using the resource. The largest user is Utah Roses, which uses geothermal water from a pumped well to heat greenhouses. Several smaller private operations use either the pond water or discharge water from Utah Roses.

The initial geophysical assessment of the geothermal resource at Crystal Hot Springs was initiated in October 1979 and consisted of aeromagnetic and gravity surveys. The geophysical reconnaissance program provided the structural details needed to focus the test drilling program on the most promising production targets available to the state prison. Subsequent drilling and well testing were conducted to provide additional data input in the siting and design of a production well and preliminary design activities. The results of that program provided preliminary baseline thermal, hydraulic, and chemical characteristics in the vicinity of Crystal Hot Springs.

5.2 Description of the Resource

The geothermal system is a deep convective system located at the eastern margin of the basin and range physiographic province. The thermal springs are located north of an east-northeast trending horst that is perpendicular to the structural trend of Wasatch Front grabens. The horst, known as the Traverse Range, consists of highly fractured mid-Paleozoic quartzites and Tertiary volcanics.

There are two separate aquifer systems: a shallow, confined to semi-confined aquifer, and a deep artesian geothermal aquifer containing

Fig. 8.2 Site map

water apparently heated at depth in the fractures of the quartzites. There is some interaction between the two systems; however, each has its own distinct waterbearing characteristics.

The shallow aquifer lies within the recent interbedded alluvium and lacustrine deposits and derives most of its recharge from surface sources such as rainfall, streams, canals, and irrigation. Several wells have been drilled into the shallow aquifer for domestic and irrigation water supplies. Many of these wells discharge warm water indicating leakage of the deeper thermal aquifer into the shallow ground water system.

The deep aquifer (geothermal reservoir) occurs at a depth of 400 to 700 ft and consists of a fractured system within Tertiary volcanic rocks. Thermal water, upwelling along spur faults of the Wasatch Range, provides the shallow geothermal waters. Recharge is thought to occur through deep circulation within the range front faults.

5.3 Drilling

The geophysical reconnaissance program provided the structural details needed to focus the exploration program on the most promising production targets available to the state prison. The objective of the subsequent test hole drilling program was to establish the presence of significant quantities of thermal water and to provide holes that could be used for preliminary reservoir testing. These objectives were markedly different from the simple gradient hole drilling program envisioned in the original proposal, and represented an evolution of project scope that was influenced by (a) the findings of the geophysical reconnaissance program, and (b) changes in the disposition of the land status in the vicinity of the springs adjacent to the prison.

Two test holes were drilled; SF-1, an existing shallow hole, was deepened and a new hole, USP/TH-1, was drilled. After preliminary testing, USP/TH-1 was designated as the production well.

Drilling at the USP/TH-1 site began October 13, 1980. A 14-in. hole was drilled to a depth of 40 ft, grouted into place, and was left to cure for 39 h. On October 15, the driller penetrated approximately 3 ft of grout as drilling continued.

A 10-in. diameter hole was drilled from the bottom of the 12-in. casing to the top of the bedrock surface. Water was used as a drilling fluid until, at a depth of 95 ft, the hole began to cave and the cuttings could not be cleaned from the hole. After reaching 120 ft, an inorganic polymer was used to increase the viscosity of the drilling fluid. Circulation of this fluid quickly cleaned the hole and drilling proceeded without major difficulty.

The bedrock surface was intersected at a depth of 268 ft and drilling continued to 278 ft. An 8-in. Schedule 40 standard wall casing was installed from the surface to a total depth of 272 ft and grouted in place. The grout was placed on the morning of October 20 and was allowed to cure for approximately 44 h. An 8-in. diameter gate valve was installed on the 8-in. casing, and a T assembly was fastened to the valve.

With the wellhead assembly in place and approximately 90 ft of drill collars behind the bit, drilling continued to a total depth of 1000 ft. Water was used as a drilling fluid. While evidence of fluid loss was noticed in drilling the upper portions of USP/TH-1, major losses did not occur until a depth of approximately 625 ft was reached. Large water losses continued from that point to total depth.

At the conclusion of drilling the geothermal fluid began to warm and decreased in density. After four days the fluid had warmed enough that the well began to flow at rates of 600 to 1000 gpm. As the liner could not be installed with the well flowing at these rates, cold water from a nearby fire hydrant was forced into the hole to control the flow. This method of flow control worked well because the wellhead pressures were on the order of 5 to 10 psi. After flowing cold water into the hole for 2 to 3 h, the hole was chilled. The blind flange on the vertical leg of the wellhead assembly was removed and the liner installed.

The hole was completed with a 6-in. diameter slotted liner. During installation of the liner a tool failed, allowing 245 ft of the liner to drop into the hole. It was recovered intact after two days of fishing, apparently intact. The completed liner string was lowered into place and secured with a K-packer.

Figure 8.3 shows the drilling log for USP/TH-1 with drilling rates, temperatures, and lithography. Figure 8.4 is the well's profile.

5.4 Well Testing

The production characteristics of Well USP/TH-1 were determined from a controlled 48-h artesian flow test. Analysis of surface and drawdown/recovery data indicated a highly permeable reservoir of somewhat limited area. Long term production characteristics of Well USP/TH-1 were estimated to be limited due to reservoir boundary effects. The well was considered capable of sustaining a flow rate of 100 gpm for 8 mo with a drawdown of 275 ft. Production temperature at the wellhead averaged 179°F during testing.

A longer term (30 day) artesian flow test was conducted on USP/TH-1 to more accurately model the resource and predict future performance and drawdown. During this test geochemical testing and corrosion testing were performed, and monitoring of adjacent wells and springs was continued. This longer term test was conducted in lieu of the recommended pumped flow test and provided a large amount of data that, for the most part, confirmed the previous predictions of reservoir performance.

Results of the water chemistry tests performed by the University of Utah Research Institute Earth Science Laboratory for Morrison-Knudsen (M-K) indicated a sodium chloride type water with a total dissolved solid content ranging from 1778 to 1898 ppm. Three surrounding wells exhibited similar water chemistry. A significant difference seen in nonthermal ground water supports the concept that the thermal water source is the deeper quartzites and the nonthermal source the overlying clay-rich sediments.

Fig. 8.3 Temperature Log, Drilling Rate and Lithologic Profile of Test Well USP/TH-1

Fig. 8.4 Production Well USP/TH-1 Profile

6. THE ENERGY EXTRACTION SYSTEM

The energy extraction process consists of the well and wellhead equipment, which discharges the hot geothermal water into a surge tank. A pump circulates the geothermal water from the tank, through the plate heat exchanger and into a gravity drain line. The drain line carries the water to a group of spray nozzles which discharge into a cooling pond. From the pond, the cooled water is discharged into a swampy area on the bank of the Jordan River.

The production well (USP/TH-1) was drilled in October 1980 to a depth of 1000 ft, consisting of 281 ft of 8-in. steel casing above 20 ft of 6-in. casing and 700 ft of 6-in. slotted steel liner as shown in Figure 8.4.

The well is topped with an 8-in. cast iron gate valve at existing grade and various instrumentation and flow testing ports above the gate valve.

The 8-in. riser is Schedule 40 mild steel. The remaining metal pipe carrying geothermal water is Schedule 10S stainless steel pipe with 304 ASSA 376.19 butt welded fittings and service flanges.

All valves exposed to the geothermal water, except the gate valves, are type 316 stainless steel construction with Viton or Teflon seats. The gate valves are Class 150 cast steel with full Stellite trim.

The water from the well flows directly into a sealed concrete surge tank. The tank is located approximately 10 ft from the wellhead and is insulated with foam insulation and earth berming.

The purpose of the sealed tank is twofold. First, it eliminates the surging that is inherent in the water flow from the well. Internal concrete baffle walls accomplish this and also hinder the flow of particulates from the tank inlet to the pump suction inlet. Second, the tank is used to maintain a carbon dioxide "blanket" over the water. Water chemistry tests indicate that calcium carbonate (the primary scale forming

material) will precipitate only when the carbon dioxide dissolved in the water leaves solution. It was hoped, and later proved to be correct, that maintaining a carbon dioxide "blanket" over the water reduces scale formation and corrosion.

One 5-hp geothermal water pump (Figure 8.5) is located in a pit in the geothermal heating equipment building. A second backup pump was added near the purgeout end to enhance system operation. The pump's purpose is to draw water from the surge tank, circulate it through the plate heat exchangers, and discharge it into the drainage catch basin on the south end of the tank. It is sized to provide 220 gpm of geothermal water and 42 ft of head. The pump is constructed of all iron, and is inexpensive and easily replaced.

The geothermal water flow through the pumps and two parallel heat exchangers is regulated by a V-ball flow control valve on the discharge of the heat exchanger.

These heat exchangers are the primary energy extraction equipment. They transfer heat from the geothermal water to the "clean" hydronic heating water. An inspection of the heat exchanger internals in September 1985 showed the geothermal side to be very clean, but the "clean" hydronic heating water had badly corroded the heating loop to the extent that a chemical treatment system will have to be added. The exchangers are constructed of embossed stainless steel plates clamped together and held in a steel frame. The fluids are circulated between alternate plates in a counter flow path. This type of heat exchanger gives a large heat transfer area in a small package.

After leaving the heat exchangers, the geothermal water is discharged into a catch basin on the south end of the surge tank. The water flows from the tank through a 12-in. ductile iron pipe into a manhole located approximately 15 ft south of the tank. The water flows from there by gravity through a 10-in. concrete pipe to a cooling pond near the Jordan River, 1-1/4 mi away. After cooling, the water flows into the river.

Fig. 8.5 System Schematic .

7. THE ENERGY USE SYSTEM

The energy utilization process starts with two pumps that circulate the geothermally heated clean water from the plate heat exchangers through a buried pipeline to the minimum security building (Figure 8.5). The heated water is used directly in the existing hot water heating system and in two shell and tube type heat exchangers to heat culinary water. The water is returned to the plate heat exchangers through a buried pipeline.

The pumps, located in the geothermal equipment building, are designed to run individually or together depending on the load requirement. With one pump running, the design flow rate is 170 gpm and increases to 200 gpm when both are operating. The pumps are standard base-mounted pumps, a type commonly used for hydronic heating systems. They operate at 3500 rpm with 10 hp motors and are approximately 70% efficient at design load.

Equipment associated with the pumping system includes an expansion tank with automatic water makeup, an air separator, suction diffusers, pressure gauges, and valves.

Buried 6 in. and 4 in. diameter pipes carry the heating water from the equipment building to the minimum security building mechanical rooms. The supply and return pipes are 6 in. to a point within the prison's security zone where they reduce to 4 in.

The 6-in. lines are Schedule 40 steel with 2 in. of field applied foam glass insulation jacketed with PVC. The 4-in. lines are fiberglass reinforced plastic pipe with 2 in. of factory applied urethane foam insulation, jacketed with 100 mil PVC.

When the water leaves the space heating system, it is used to heat domestic hot water for showers and kitchen use. By placing the domestic water heating system downstream, it is possible to lower the temperature of the water returning to the plate heat exchangers.

Two shell and tube heat exchangers are used to transfer heat from the hydronic water to the domestic water. They are designed with large heat transfer areas to achieve the lowest possible return temperature for the hydronic water. Domestic water is pumped from the existing storage tanks, through the heat exchangers, and back to the storage tanks.

8. INSTRUMENTATION AND CONTROLS

The wellhead control consists of a 6 in. V-ball flow control valve on the wellhead discharge piping, which is controlled by a float-type level controller mounted on the surge tank. The controller regulates the well flow rate to maintain a preset water level (approximately 4 ft) in the tank. The controller and valve are pneumatic and use compressed air from the equipment building.

The flow rate of geothermal water through the heat exchangers is regulated by a 4 in. V-ball flow control valve. This valve is controlled by a temperature controller sensing the geothermal discharge water temperature. The controller is set to maintain a 135°F discharge temperature and can be adjusted.

The circulating pumps are controlled by outside air temperature sensors. When the temperature is below approximately 60°F, one pump is on. When the temperature drops to around 25°F, the second pump starts.

Geothermally heated water flow in the minimum security building is regulated by 3-way mixing valves in the two mechanical equipment rooms. The valves are controlled by existing heating water reset controllers. These controllers adjust the water supply temperature depending on outside air temperatures. The valves are sequenced so that the valves are open to full geothermal flow before the steam valve on the heating water converter opens.

The domestic hot water temperature is regulated by operating a small circulating pump, which circulates domestic water from the storage tank through the heat exchangers. The pump is controlled by a differential temperature controller, which operates the circulating pump any time a large enough temperature difference exists between the storage tank and the geothermally heated water.

9. ALTERNATE CONSIDERATIONS

The original scope called for a variable speed vertical turbine lineshaft pump that would circulate geothermal fluid through underground pipelines to the minimum security building. Two separate plate-type heat exchangers were to transfer the geothermal energy to the existing heating systems located in existing equipment rooms. The spent fluids, still pressurized by the pump, would discharge into a cooling pond before gravity draining into the Jordan River. However, artesian flow was adequate to flow the geothermal fluid into a surge tank where it is pumped through plate-type heat exchangers with a much smaller pump than the originally planned lineshaft pump. Loss of artesian flow during the winters of 1984-85 and 1985-86 necessitated returning to the original design that required the lineshaft pump, and procurement action is proceeding to install the pump. The heat exchangers were relocated to the well site so that the distribution loop to the minimum security building carries clean water. Shell and tube-type heat exchangers were added to heat domestic hot water. The spent geothermal fluids are now gravity drained to the cooling pond.

A backup geothermal fluid circulating pump was added to the system, and a sensor for the geothermal fluid discharge temperature controller was relocated to provide better flow control through the heat exchanger.

10. SYSTEM OPERATION

The system, with the exception of a pipeline break, has been fairly free from operational problems and requires little more than periodic maintenance inspection. The heat exchanger interior was investigated in the fall of 1985, and it was observed that the geothermal fluid side was very clean; however, the circulating loop side was very dirty and had left deposits in the exchanger. This verified the validity of maintaining a carbon dioxide blanket in the surge tank to prevent aeration of geothermal fluid in order to stop corrosive action. It also stressed the need to maintain cleanliness in the circulating loop that ties into old existing components.

The lack of user commitment and support has led to frustration and resentment on the part of the prison maintenance staff, resulting in system rejection. Consideration was given at one time to contracting the system maintenance on an incentive basis, but the recent development of adding a new facility that is being designed for geothermal heating has eliminated that approach. The new building will use the present geothermal fluid supply. The minimum security building will be disconnected and will use its old heating system.

11. SYSTEM COSTS, SCHEDULE AND ORGANIZATION

11.1 System Costs

The total expenditures to date for the project are about \$827,600, with the incremental costs shown in Table 8.1. The projected operating and maintenance costs are estimates only because actual operating times are less than expected. The measured economic performance to date is substantially less than predicted because of deviations from planned operation of the minimum security building heating system. Cost savings projections for the project are estimates and assume that problems with the existing building system are corrected. The system model provides an estimated first year savings that should range between \$41,000 and \$55,400 with a direct energy savings of 8500 to 11,500 million Btu per year. Life cycle costs analyses indicate that with a 20 yr life the net present value of the system, using a 10% discount rate, varies from \$57,000 to \$265,000 depending on the assumptions used. With a 25 yr life the net present values increase to \$346,000 or \$732,000. Many factors, such as escalation rates and unpredictable performance variations, will affect the project's payback. The area with the highest potential impact on savings is operation and maintenance. If sufficient effort and finances are allocated (approximately \$10,000 per yr) the system should perform at or above these estimates and could have a life expectancy well in excess of 20 yr. However, current plans to use the geothermal fluid for a new prison facility instead of the minimum security building will eliminate the potential for verification of any cost and revenue projections.

11.2 Schedule

Figure 8.6 depicts the major task accomplishments and when they were performed. Due to problems with securing water rights and discharge permits, and delays during final design and construction, the project was finished approximately two years after the initially conceived completion date.

TABLE 8.1. PROJECT COST SUMMARY

<u>Item</u>	<u>Cost (\$)</u>
Resource Development	199,100
Environmental Reports and Disposal Studies	16,500
Design	64,900
Construction	392,500
Administration	60,000
Reporting	34,800
Performance Verification	<u>59,800</u>
Total	827,600
Yearly Operating Expenses	6,500
Yearly Maintenance Costs	3,500

Fig. 8.6 Project Schedule
8-25

11.3 Organization

Figure 8.7 represents the major participants in the project and their contributions.

Fig. 8.7 Project Organization
8-27

12. LEGAL AND INSTITUTIONAL CONSIDERATIONS

12.1 Environmental

Studies were conducted to determine potentially adverse environmental effects resulting from implementation of the Utah State Prison geothermal project. The completed study indicated that only minor, temporary environmental effects will result.

The drilling and development occurs entirely on prison property; project efforts were integrated into planned prison facilities construction and rehabilitation activities. Direct use of land is approximately one acre (for wells, equipment building, and pipelines). Because the development is small and was integrated with prison construction plans, the aesthetic quality of the area was not diminished.

12.2 Institutional Issues and Permits

An application was made in 1978 to the state engineer to appropriate water for production purposes. In early 1983 a permit was approved to use up to 700 gpm from the reservoir.

The Utah Energy Office was granted a surface disposal permit by the Utah Water Quality Board. This permit allowed for surface disposal of spent geothermal waters from the Crystal Hot Springs to the Jordan River via a pipeline.

In December 1981, the Department of Wildlife Resources determined the project would not degrade the Jordan River below a Class 3 fishery level and approved the discharge.

The Federal Environmental Protection Agency, in March 1982, granted a 30-day discharge permit for further testing, and in May 1983 granted a production discharge permit allowing discharge into the Jordan River from September to May of each year.

Although most of the proposed project is located on state prison property, one easement was required for the disposal line to pass under railroad tracks owned by the Denver and Rio Grande Western Railway Co. The easement was first requested in June 1982 and, after some modification required by the railway company, was granted in early 1983.

13. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and the figures contained in this report are excerpted from the project final report prepared by Case, Lowe and Hart, Inc. Appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. Case, Lowe and Hart, Inc., Geothermal Heating Retrofit at the Utah State Prison Minimum Security Facility, Final Report, March 1979 - January 1986, Report No. DOE/ET/27027-10, Cooperative Agreement No. DE-FC07-79ET27027.
- *2. Case, Lowe, and Hart, Inc., Geothermal Heating Retrofit at the Utah State Prison Minimum Security Facility - Design Report, Report No. DOE/ET/27027-9, Cooperative Agreement No. DE-FC07-79ET27027, March 1985.
- *3. Case, Lowe, and Hart, Inc., Utah State Prison Space Heating With Geothermal Heat - Annual Report for the Period January 1982 - December 1982, Report No. DOE/ET/27027-8, Cooperative Agreement No. DE-FC07-79ET27027, June 1983.
- *4. Morrison-Knudsen Company, Inc., Utah State Prison Geothermal Well Test, Report No. DOE/ET/27027-7, Cooperative Agreement No. DE-FC07-79ET27027, August 1981, September 1982.
- *5. CH₂M Hill (SLC), Preliminary Design, Report No. DOE/ET/27027-6, Cooperative Agreement No. DE-FC07-79ET27027, August 1981.
- *6. CH₂M Hill (SLC), Geothermal Water Disposal, Report No. DOE/ET/27027-5, Cooperative Agreement No. DE-FC07-79ET27027, August 1981.
- *7. Utah Energy Office, Utah State Prison Space Heating With Geothermal Heat - Resource Assessment Report, Crystal Hot Springs Geothermal Area, Report No. DOE/ET/27027-4, Cooperative Agreement No. DE-FC07-79ET27027, December 1981.

* Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

- *8. Utah Energy Office, Utah State Prison Space Heating With Geothermal Heat - Third Semi-Annual Report for the Period January 1981 - July 1981, Report No. DOE/ET/27027-3, Cooperative Agreement No. DE-FC07-79ET27027, November 1981.
- *9. Utah Energy Office, Utah State Prison Space Heating With Geothermal Heat - Second Semi-Annual Report for the Period June 1980 - December 1980, Report No. DOE/ET/27027-2, Cooperative Agreement No. DE-FC07-79ET27027, April 1981.
- *10. C. K. Blair, Utah State Prison Space Heating with Geothermal Heat - First Semi-Annual Report For the Period March 14, 1970 - June 14, 1980, DOE/IT/27027-1, July 1980.
- 11. Specifications for a Geothermal Test Drilling Program at the Utah State Prison, Draper, Utah, June 1980.
- 12. Terra Tek, Inc., Environmental Report, Utah State Prison Geothermal Project, Report No. TR 80-25, March 1980.
- *13. P. Murphy and J. W. Gwynn, Geothermal Investigations at Crystal Hot Springs, Salt Lake County, Utah, DOE/ET/28393-16 Utah Geological and Mineral Survey Report of Investigation No. 139, October 1979.
- *14. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *15. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DDOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April, 1984.

* Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

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WARM SPRINGS STATE
HOSPITAL PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: Geothermal Heating of Warm Springs State Hospital

Project Data:

Project Description: The project demonstrates the feasibility of utilizing a moderate temperature (154°F) resource to provide space and water heating for the hospital.

Location: Warm Springs, Montana

Peak Heat Load: 1.8 million Btu/h

Annual Heat Load: 14.6 billion Btu/yr (50% load factor)

Simple Payback: 9.7 yr

Status: The project is not operational because the state has not provided funding to replace the failed production well submersible pump.

Cooperative Agreement Data:

Number: DE-FC07-79ET27055

Period: January 30, 1978 to June 27, 1983

DOE Share: \$721,122 (95.3%)

Participant Share: \$27,845 (3.7%)
7,778 (1.0%) (Nonreimbursed-MultiTech)

Total Cost: \$756,745

Principal Investigator:

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Assistant Engineering Department Manager
MultiTech, Inc.
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Other Participants:

Geology & Drilling Supervision
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208/529-3064

System Review

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CH₂M-Hill Central Inc.
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Boise, ID 83707
208/345-5310

Well Drilling

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Holly, CO 81047
303/537-6974

Vertical Pump

Knudsen Irrigation and Pump Co.
P.O. Box 606
American Falls, ID 83221
208/226-5044

Architect/Engineer

Willard Johnson
Johnson-Graham and Associates/Con'eer Engineering
644 Grand Avenue
Billings, MT 59101
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General Contractor

Bob Schmid
4G Plumbing and Heating
P.O. Box 3538
Missoula, MT 59801
406/728-1515

2. PROJECT HISTORY

Warm Springs State Hospital is located in the Deer Lodge Valley of Montana, approximately 26 mi northwest of Butte, Montana (see Figures 9.1 and 9.2) adjoining Interstate Highway 90.

The natural artesian spring at the Warm Springs State Hospital site exhibits a temperature of approximately 172°F, with a flow rate of approximately 60 gpm. The spring has been flowing continually since before the early 1860's when the first buildings were erected.

The State Department of Natural Resources and Conservation (DNRC) provided funds to MERDI, MultiTech's parent company, to gather pertinent data on the total energy demand at Warm Springs State Hospital and to examine the feasibility of utilizing the on-site geothermal hot springs to satisfy some portion of this energy demand. Concurrent with the MERDI study, the Montana College of Mineral Science and Technology (Montana Tech) in Butte, Montana received funding from DNRC to perform a geophysical survey of the area surrounding Warm Springs State Hospital with the objectives of characterizing the geothermal resource and identifying an appropriate well site. The MERDI study indicated that the geothermal resource was sufficient to support the institution's domestic hot water system, and could possibly provide enough energy to heat several of the facility buildings. The Montana Tech study concurred with these findings.

It was then decided that MERDI would submit a proposal to the Department of Energy for a PON program to establish a geothermal demonstration facility at the Warm Springs site, and the PON project was initiated the end of January 1978.

The environmental portion of the project was completed during the onset of the project and the report was submitted in April 1979.

Fig. 9.1 Location Map

Fig. 9.2 Site and Well Location Map

The investigation of applicable state permitting procedures addressed the areas of water rights, energy planning, wetlands establishment, air and water quality, and archaeological considerations. All of these areas were investigated by legal counsel and the appropriate permits requested prior to any drilling activities.

The resource assessment was in process prior to the PON project award which comprised an energy demand evaluation, energy audits, and geothermal utilization. The geophysical investigation conducted under the project continued this assessment and led into the ensuing phases of the project.

After conducting a complete review of data gathered in the resource evaluation, the well was sited northwest of the existing hot springs mound, in the area of the facility's main heating plant.

Drilling activities began in mid-October 1979 and were completed in early December 1979 to a total depth of 1498 ft. Three logs were run in the well, and two water samples were taken to determine formation water resistivity. Some preliminary pump tests were run by the well driller and the decision was then made to perform matrix acid treatment of the well.

A lineshaft pump was installed for pump testing, but numerous problems resulted in removal of the pump, allowing the well to flow naturally.

In January 1981, an Energy Services, Inc., report supported recommendations for reworking the well and drilling an additional 50 ft into what was believed to be a zone of hot water. After cleaning the well to the total depth (1498 ft), a solid metal item (believed to be a lost drill pipe), was struck in the bottom of the hole. Since it was not possible to drill through or around the metal, the decision was made to perforate the bottom 120 ft of casing with two 1/2 in. jet perforations per foot.

A 50 hp submersible pump was installed on April 28, 1981 to a setting depth of 845 ft. The flow rates were well below the recommended operating range of the pump, and a decision was made to install and test a smaller (30 hp) submersible pump. It was installed May 19 at a depth of 987 ft.

Design of the conversion system proceeded and construction contracts were let to complete the production, disposal, and distribution systems. The utilization of the geothermal resource began on January 11, 1983 with the startup of the well pump and associated systems. Geothermal water flows ranged from 60 to 64 gpm at 154°F. The system effectively eliminated the steam heating requirement for the domestic water heated in the heating plant. On March 5, 1983, the 30 hp pump failed. The pump, with a potential payback of less than a year, has not been replaced because of methods used by the state to fund their facilities.

3. GENERAL DESCRIPTION

A well drilled to a depth of 1498 ft flows geothermal fluid at 60 to 64 gpm at 154°F. The fluid is pumped by a 30 hp REDA pump from the well through the production piping to a plate heat exchanger, which is the first component of the distribution system. Pressure and temperature gages are provided to allow for proper system operation.

The wellhouse, a frame building on a concrete pad, houses the well, pump, and wellhead components. The structure is designed with a removable roof to facilitate maintenance and repair of the well and piping. It is designed to incorporate a generally aesthetic quality to fit in with the existing facility buildings after an initial design for a removable insulated portable building was rejected by the state.

A solids separator is installed at the wellhead to remove any entrained fine materials present in the fluid. This aids in preventing solids deposition in the piping and in the heat exchanger.

Both carbon steel and Ameron bondstrand fiberglass reinforced epoxy piping are used in the production system. The distribution system (Figure 9.3) consists of a plate type heat exchanger in the domestic hot water system utilizing the geothermal fluid as a heat source. All cold water to be heated for domestic use flows through the heat exchanger where it extracts the available heat from the geothermal fluid. The heated domestic water then continues to an existing hot water accumulator for distribution throughout the hospital. A recirculation pump circulates water from the accumulator tank back into the heat exchanger circuit to maintain and stabilize the temperature in the existing storage system.

The application system consists of a hot water heater, hot water accumulator, two recirculation pumps, and associated piping, all of which were existing and in service. The system was previously heated with steam, and that steam now serves as a backup heating system.

MULTITECH

Fig. 9.3 Geothermal System Schematic

Geothermal fluid flows continuously through the heat exchanger. A 3-in. fiberglass-reinforced epoxy uninsulated pipe runs about 140 ft to an open drain ditch to be routed through a system of ditch diversions to a waterfowl wetlands area.

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

4.1 General

The project proceeded in a fairly straightforward manner, but several problems occurred which delayed and reduced the scope of the project. The major disappointment in the project was the lower-than-anticipated fluid volume delivered by the well. Acid treatment and reworking of the well improved the production capability, but fell short of the anticipated amounts. Failures of the lineshaft pumps were a disappointment; however, they provided an insight into pumping higher temperature fluids laden with particulate material and also identified the problems of that type of pump. Experience with submersible pumps was obtained which resulted in installation of the production pump; however, that pump failed on March 5, 1983. Replacement of the pump has been delayed because of the methodologies used by the state to fund operation and maintenance of their facilities.

4.2 Technical

The remoteness of the well site from necessary equipment and supply sources resulted in several delays, and plans were frequently altered to accommodate unavailability of equipment and services. The use of oil field sizes for tubular goods added to procurement problems because the project is not located where oil field work is common.

Difficulty was experienced in maintaining good control of mud properties. This was caused by several factors including: delays in delivery of mud chemicals, lack of mud-handling equipment, flow of formation water into the well, overnight shutdowns, and labor problems in shipping mud from Butte, Montana.

Attempts to log the upper sections of the hole before casing installation were unsuccessful due to mud problems, namely high mud gel strength and lack of hole stability. Both of these are most likely due to formation water flowing into the well. Mud weight should be kept high

enough to prevent formation water from inhibiting drilling, but not so high as to damage the formation. This, and the use of standard size oil field casing, would eliminate the need to drill out cement left inside the casing. The use of blowout prevention equipment allows for proper mud weight calculations.

Confining operation to only 8:00 a.m. to 9:00 p.m. caused major inefficiencies in drilling, and non-summertime weather compounded this problem. Drilling time was lost due to shutdown-startup operations. All lines and pumps had to be drained, and the drill pipe had to be tripped out of the hole before shutdown. To start up, the mud pits had to be circulated and conditioned, the drill pipe had to be tripped in the typically tight hole and sloughed material had to be reamed in order to get back to the bottom. Consequently, actual drilling time on a typical day was only 8 h, as compared to 24-h drilling normally conducted in oil field operations.

Some difficulties were encountered with each of the three pumps used in drilling and production. The duplex mud pumps lacked sufficient pressure and capacity to allow the use of jet nozzles to aid in hole cleaning; high flow rates from the pumps would have allowed operation with lower mud viscosity and gel strength which in turn, would have avoided the cleaning problem. The lineshaft pump, as supplied by the well driller, operated well, but not enough pipe and bowls were on hand to allow the pump to be set deeper than 250 ft. The electrical submersible pump also supplied by the well driller burned out, terminating the preliminary pumping trials.

Regular bentonite could be used instead of high yield bentonite. The high yield bentonite does not maintain its viscosity-building properties since it is more sensitive to contaminants.

A project representative could be assigned to "sit the rig" to observe unusual occurrences which may not show up in the drilling log records.

The use of steel mud pits and mud solids control equipment will help avoid possible surface contamination.

Wells should be pump tested to determine the production potential and provide information about the resource. The pump and controls should be able to provide a wide range of flow rates. Prior to pump tests, a wash tool, run on the end of drill pipe or tubing, can be used to circulate behind slotted casing to ensure that sloughed material is not blocking production.

To get additional production from similar wells, the following can be considered:

- o If pump tests indicate a deep zone of skin damage, the cause is likely from mobile fines. Certain oil field chemicals are available to fix these fines in place and prevent formation damage. Pilot tests can be run to evaluate this possibility.
- o Temperature and flow rate surveys can be run to determine the source or sources of present production of geothermal energy. Nonproducing zones lying behind the perforated casing can be isolated, broken down, and acidized.
- o The well zones at various levels can be tested for flows.
- o Depending on the pressure test results and interpretation, it may be more economical to simply drill additional wells to obtain the required production, rather than either reworking or drilling a single well deeper.
- o Some wells do not appear to be good candidates for conventional fracture stimulation since the formation may be poorly consolidated. This would make it extremely difficult to maintain a high conductivity fracture. However, porous-permeable cement might work as a fracture proppant.

Recognize site-specific problems as they relate to the resources, waste water drainage or reinjection, electrical service, point of use location, and operational and maintenance requirements.

Use reputable firms not only for basic site work but also for manufacturer's supplied equipment and engineering design.

Use of either corrosion coupon tests or monitoring samples with new electronic corrosion detection equipment will avoid costly material failures and loss of reliability in the operational system.

4.3 Institutional

The project's institutional interfaces tended to be simplified and straightforward because both the owner and user are the same entity; i.e., the State of Montana. However, there are some areas that require emphasis or checking to ensure that problems are minimized during similar projects. These include:

- o Coordinate all study and development efforts with landowners and organizations that may be impacted by the project, both initially and throughout the life of the project.
- o Check with regulatory agencies in regard to both the permits required and the applicable review requirements; this avoids unexpected and costly delays.
- o Develop adequate detail for all plans and designs to assure obtaining the most desirable product, or end result, and to satisfy the cognizant agencies in their review and/or bidding.
- o Allow sufficient time for agency review and approval of the various documents required for project finalization.

4.4 Economic

The amount appropriated for funding prevented any further exploratory efforts to develop additional geothermal resources; also, the approaching expiration of project funding prevented more extensive use of advanced control technology in the production portion of the final installed system.

The simple payback of 9.2 to 9.72 yr seems to be too lengthy and leaves a question as to the cost effectiveness of this project, but allowances have to be made in regard to the additional costs encountered with the well and pump problems. The life cycle analysis simple payback of 7.83 yr is encouraging and provides hope that the lessons learned in this project can be used in future projects, thereby reducing their payback periods. If the geothermal resource had produced the originally expected amount, the economic results would have changed materially. Development of a demonstration project requires some additional costs for publicity, which increase overall costs and directly affect final economic considerations. Finally, the major result of the project is that a geothermal resource was successfully obtained and developed into a functional system, even though at a reduced volume.

5. THE RESOURCE

5.1 General

A geophysical investigation of the Warm Springs area was conducted by Dr. Charles Wideman of Montana Tech College, plus a geophysical ground and aerial survey by Roger Stoker, MERDI consulting geologist. Mr. Stoker also reviewed a previous aerial and ground survey done by Dr. Hugh Dresser, geologist, Montana Tech College. These studies provided MERDI with necessary data for selection of the well site.

The composite gravity data indicated a northwest trending linear about 1300 ft northeast of the existing hot springs mound and a gravity high on the south side of this linear just east of the mound. The resistivity data showed a low (<5 ohm-meter) in the area of the mound and the main facility buildings.

The field and aerial study was undertaken to determine the fault structure in the valley. The geophysical data of the valley indicated a north-south fault connecting Warm Springs and Fairmont Hot Springs; surface expressions could not be located. The aerial surveys indicated some differences in the location of other area faults, but did agree on the geologic structure within and around the valley.

The production well could have been located anywhere within the immediate vicinity of the existing travertine mound (hot springs source) and was likely to encounter hot water at shallow depths. The well was located to deliver the highest level of benefit from the resource. This location planning placed the well (Figure 9.2) within 100 ft of the central heating steam plant which supplies domestic hot water; thus, the linear footage of transmission supply piping was minimized. The heat exchanger also could be located in the central heating plant to materially reduce the footage of distribution piping and eliminate the need for additional building structures.

5.2 Drilling and Well Testing

The Warm Springs well was spudded on October 12, 1979, and drilled to a total depth of 1498 ft by November 12, 1979. Figure 9.4 is a lithology log of the well.

Preliminary pumping tests indicated that the well was producing considerably less than might be expected from the well log-formation evaluation. A decision was made to perform a hydrochloric matrix acid treatment on the well. Testing and logging activities, including geophysical well logs, temperature surveys, flow, and water quality measurements, and pumps tests, continued until December 15, 1979, after which time the rig was moved from the site and the well was left flowing to await further pump tests.

Two lineshaft vertical turbine production pumps were then installed between April 28 and May 27, 1980 and pump tests resumed. Vibration problems plagued the test and a total running time of only 52 h was recorded before removing the second pump from the well.

An evaluation was conducted on the well to present significant data and to evaluate the well in terms of the project requirements. The two most promising zones of geothermal productivity were identified at levels of 1110 ft to 1180 ft and 1250 ft to 1340 ft. The well was identified as having low values of permeability (2.84-5.66 millidarcies) and pump tests seemed to indicate wide variations in the production characteristics of the well. With this information it was recommended that the well be reworked and deepened an additional 50 ft to penetrate what is believed to be another zone of hot geothermal water.

This recommendation was followed and rework started March 12, 1981. The bottom 220 ft of the well was bailed of drilling mud and rock chips. The apparent lost drill pipe was encountered at the bottom of the well and could not be retrieved; thus preventing increasing the hole depth an additional 50 ft. A decision was made to perforate the production liner

MERDI GEOTHERMAL WELL
Warm Springs, Montana

May 2, 1980
Lithology Log

Fig. 9.4 Lithology Log

from 1391 ft to 1496 ft with two 1/2-in. perforations per foot. A television camera was utilized to examine the production liner although the temperatures encountered prevented inspection to the total well depth. A proposal for screening was also abandoned as the well had been so plugged with drilling mud that screening would serve no useful purpose.

A submersible pump was installed on April 28, 1981 in the completed well (Figure 9.5) and initial testing indicated that the pump sizing was in excess of the producing capacity of the well. Another submersible pump was installed on May 19, 1981 at a setting depth of 987 ft. The well was then tested at rates of 50, 75, 95, and 110 gpm for 100 h each and 9-h step drawdown tests were run at 25, 50, and 75 gpm. The results of those tests indicate that geothermal water production of 70 to 90 gpm at 168°F can be maintained.

S3 9460

Fig. 9.5 Warm Springs State Hospital Production Well

6. THE ENERGY EXTRACTION AND USE SYSTEM

The geothermal fluid is pumped with a 30-hp REDA 22-stage submersible pump set at a depth of 987 ft operating between 64 and 93 gpm. A small frame wellhouse houses the well, pump, and wellhead components. Both carbon steel and fiber glass reinforced pipe are used in the production system. A solids separator is included in the system.

The distribution system consists of a type 304 stainless steel plate heat exchanger, a 20 gpm recirculation pump and associated copper piping and instrumentation that is totally located within the existing Warm Springs heating plant. The outline around the distribution system shown in Figure 9.3 presents the relationship of this distribution system to the entire geothermal installation.

Geothermal water continuously passes one side of the exchanger with the cold domestic water passing the other side. The heated domestic water continues to the hot water accumulator, which is part of the existing system. The recirculation pump circulates water from the main accumulator tank back into the heat exchanger circuit to maintain and stabilize the temperature in the existing storage system.

Minimal retrofit was needed to modify the existing domestic hot water system to accommodate the new geothermal system. The existing system consists of a hot water heater, hot water accumulator, two circulation pumps and associated piping and controls. The system was previously heated with steam, and that steam is used as backup.

A 3-in. fiberglass-reinforced epoxy pipe carries the spent geothermal fluid from the heat exchanger to an open drain ditch, about 140 ft away. The fluid is routed to the waterfowl-wetlands area through a system of ditch diversions.

7. INSTRUMENTATION AND CONTROLS

A number of control and monitoring features are incorporated in the system, as shown in Figure 9.3. The well pump is started by a push button on the well pump control panel. During abnormal operations, temperature and pressure switches in the distribution piping and a flow switch in the production piping can provide a shutdown signal to the control panel; the well pump then stops. The wellhead globe valve is the primary flow control device for the pump while the globe valve after the heat exchanger is the secondary control device and is used to adjust backpressure on the system.

The energy monitoring system consists of a Btu flowmeter and thermowell in the 4-in. cold water supply line to the heat exchanger and thermowell on the 4-in. hot water supply line to the accumulator. This system is used to measure the Btu's extracted from the geothermal water in the heat exchanger and is totalized on the Btu output panel located in the heating plant.

In the 4-in. hot water supply line to the accumulator are high pressure and high temperature switches, which are interconnected to the well pump control panel. An excursion of temperature and pressure beyond the setting of the switches will shut the geothermal pump down and activate an alarm horn and light on the alarm panel in the heating plant. A means of silencing the horn is included on the panel.

The control loop for the recirculation pump interlocks with the geothermal flow switch to the heat exchanger and to the aquastat located at the outlet of the hot water accumulator tank. This ensures that domestic water will only be recirculated to the heat exchanger when geothermal water is flowing and the aquastat switch is closed. There are two modes of operation on the recirculation pump selection switch (i.e., auto and manual). In the auto position, the aquastat measures the temperature of the water leaving the hot water accumulator and when this temperature is below 160°F, the geothermal recirculation pump begins operation and circulates domestic water through the heat exchanger. If geothermal flow

ceases, an additional set of contacts will shut down the recirculation pump. When the switch is in the manual position, it will operate the pump continuously, bypassing aquastat and flow switch circuits.

Flow control of spent geothermal fluid that is discharged by an open pipe into the drainage ditch is accomplished manually.

8. ALTERNATE CONSIDERATIONS

After reviewing the information gained from the Montana Tech geophysical study conducted in 1978, it was determined that a further geophysical study was necessary to confirm that study and gather other pertinent data.

When it became evident that the integrity of the well had not been maintained due to sloughing and caving within the formation, the decision was made to rework the lower 100 ft of the well and drill an additional 50 ft into what was believed to be a zone of a hotter geothermal resource. After the unsuccessful attempt to use a vertical shaft pump for the production well, and the lack of success in drilling the hole deeper (due to the lost drill pipe obstruction), it was determined that the well would not produce sufficient flow for both the domestic hot water system and the building space heating requirement. The domestic hot water system was chosen.

During the initial stage of this project it was proposed that a reinjection well be used as the disposal method. MultiTech approached the Montana Department of Fish, Wildlife, and Parks, who operates a migratory bird refuge adjacent to Warm Springs Hospital grounds, with the possibility of using the spent geothermal water to supplement their wetlands. After statutory review and environmental assessment, it was determined that the wetlands would afford an acceptable alternative to reinjection and the decision was made to dispose of the spent geothermal water to the wetlands.

9. SYSTEM OPERATION

The use of geothermal fluid effectively eliminated the steam heating requirement for the domestic water heated in the existing heating plant. However, the 30-hp submersible pump failed on March 5, 1983. To date, the pump has not been replaced even though the payback period is less than one year. The replacement has not been made because the state's funding methodologies cause any saved funds to be returned to the general fund rather than to offset purchase costs, and the 1985 legislature's denial to provide about \$70,000 for the pump.

The system has been operating at a nominal geothermal fluid flow of 64 gpm at 154°F, with a net reduction to 104°F. Assuming an arbitrary use factor of 60%, the calculated energy use is about 20 million Btu per day. Approximately 24,000 gal per day of soft water are heated from 48 to 145°F by flowing through the heat exchanger.

10. SYSTEM COSTS, SCHEDULE AND ORGANIZATION

10.1 System Costs

The project was jointly funded by the State of Montana and DOE under its PON program. The total project cost of \$756,745 comprised DOE reimbursable costs of \$721,122 (95.3%), State of Montana participation costs of \$27,845 (3.7%), and additional unreimbursed MultiTech costs of \$7778 (1.0%). The Department of Institutions (DOI) supplied security personnel at no charge to the project. Project costs through fiscal 1983 are shown in Table 9.1.

TABLE 9.1. WARM SPRINGS STATE HOSPITAL PROJECT COSTS

<u>Item</u>	<u>DOE (\$)</u>	<u>MT. (\$)</u>	<u>Total (\$)</u>
Environmental Report	14,495	9,000	23,495
Legal Support	2,119	--	2,119
Resources Definition	4,180	13,475	17,655
Well Drilling	437,885	1,119	439,004
Domestic Hot Water Heating	117,340	2,736	120,076
Space Heating	2,690	--	2,690
Publicity	11,205	967	12,172
Project Management	<u>138,986</u>	<u>548</u>	<u>139,534</u>
TOTALS	728,900	27,845	756,745

Assigning an arbitrary use factor of 60% and using about 20 million Btu per day to heat domestic water, the simple payback period is 9.7 years, assuming natural gas costs of \$4.68 per 1000 cu. ft. The calculated operating and maintenance costs for 1983 are about \$4500. Actual operating expense data are lacking because of the nonoperation occasioned by the failure to replace the submersible pump.

10.2 Schedule

The development of the Warm Springs State Hospital PON project consisted of a number of tasks. They are:

- o Environmental report and monitoring
- o Legal support (permits, etc.)
- o Geophysical survey supplement
- o Well drilling and development
- o Hot water system retrofit
- o Publicity
- o Project management.

Figure 9.6 shows the overall arrangement of these tasks. The project that started in January 1979 did not achieve its original scheduled completion date of January 1981 due to problems of maintaining well integrity, drilling delays, and failure of the first production lineshaft vertical turbine pump.

10.3 Organization

The project team was comprised of the State of Montana Department of Institutions, Helena, Montana; MultiTech, Inc., Butte, Montana; and various contractors and subcontractors.

Organizational elements and key project personnel are shown on Figure 9.7. General management prior to driller selection was handled by M. Eugene McCloud. Just prior to well drilling (by the Dreiling Company), Mr. McCloud left MERDI and Ms. Karen Barclay assumed the project, including

1 Testing during this period was intermittent with little or no success.
 2 During the time from July 1980 through March 1981, design was intermittent due to unsuccessful pump tests.
 3 Design of the heating system retrofit was stopped when it was determined that production was not going to be adequate.

Fig. 9.6 Project Schedule

Fig. 9.7 Project Organization

subcontractor selection, publicity, and safety oversight until the end of 1980 when Daniel Stowe assumed the project. Mr. Stowe was responsible for the completion of the pump test and the beginning of the retrofit design.

In June of 1981, Mr. Allan Miller assumed the duties of project manager. He was responsible for the completion of the retrofit design and construction as well as startup of the system.

11. LEGAL AND INSTITUTIONAL CONSIDERATIONS

A comprehensive review of Montana geothermal laws and a thorough search of the statutes of the State of Montana indicated that many shortcomings exist in the areas of clear definition of terms, regulatory requirements, and state agency jurisdiction over geothermal development.

The environmental impact report indicated, and it was verified later, that very little negative environmental impact at Warm Springs would result from the development and demonstration of the geothermal resource. It was determined that the possibility either of subsidence or seismic activity associated with the use of geothermal fluid could be minimized.

A review of historical water data indicated widespread industrial degradation of water resources in the Warm Springs area; thus, it was critical that the fresh water aquifer and nearby stream be protected during the drilling and operational phase of the project.

Warm Springs State Hospital is the State of Montana's facility for the mentally ill. Title to all mineral and water rights for essentially all of the site is owned by the State of Montana. The State holds title to all land and buildings at the site. There are no private lands involved in the immediate vicinity of the project and there was no necessity for any private agreements.

Warm Springs State Hospital does not lie within the boundary of any incorporated city in the State of Montana; therefore, no city regulations were applicable.

Warm Springs State Hospital is a state-owned institution and within Deer Lodge County and no county regulations apply within the facility boundaries.

An investigation of applicable state permitting procedures was performed by legal counsel prior to drilling activities. The investigation addressed the areas of: (a) water rights permitting; (b) energy planning; (c) wetlands establishment; (d) air and water quality permitting; and (e) archaeological assessment.

The State Department of Natural Resources and Conservation (DNRC), Health and Environmental Science (DHES), and the State Historical Society were contacted concerning their regulatory jurisdiction over the geothermal project.

The DNRC Water Rights Division requires a permit for exploratory and production wells. The exploratory well required an interim permit. The production well required a water use permit. Due to the small size of the well, the cost of these permits is minimal. Under the law, the production well permit application must be for the gross volume withdrawn rather than for consumptive use.

Due to the small scale of the Warm Springs well, DNRC did not require an Environmental Impact Statement (EIS). DNRC regulation exempts wells with a capacity of less than 10,000 acre feet/year (15 cfs) from the EIS requirement. The Warm Springs well falls well below this limit.

DHES has essentially two mechanisms for enforcement of the water quality law: (a) granting permits for the discharge of pollutants into state waters from "point sources," and (b) issuing orders for the prevention or abatement of pollution. The discharge of waste water from the Warm Springs geothermal project is not a point source discharge, since it flows into a wetlands area, and the wetlands, an artificially created impoundment, is not considered "state waters." At the present time, there are no ambient water quality standards in existence for underground waters and it is not likely that any will be adopted within the next few years. Consequently, there is no functional permit program for discharge into groundwater.

Initially, it was advisable to maintain regular communication with the Water Quality Bureau of the DHES in order to determine what precautions, if any, they might recommend to avoid ongoing adverse water quality impacts. Furthermore, pollution prevention orders by DHES necessarily are based on knowledge of the existing natural water quality in the affected area, and on the characteristics of the pumped water which may be introduced into the ambient water. They therefore require, and should be provided, any information obtained during exploration, testing, and production regarding the quality of the geothermal fluid and ambient ground and surface water.

The State Historical Society requests that an archaeological study be conducted in areas of new development. The applicable study was performed as part of the Environmental Impact Report prepared by MERDI for DOE. The Soil Conservation Service (SCS) completed tests and feasibility studies, estimated cost and manpower needs, and presented its engineering designs for the wetlands project. These were accepted and the Federal Job Corps (youths from Anaconda) performed all work for the wetlands modifications.

Federal regulations relating to procedures for funding or licensing water diversion or impoundment projects are currently being revised under the Fish and Wildlife Coordination Act and it is unknown whether an amendment would affect this project.

12. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and figures contained in this report are excerpted from the project final report prepared by MultiTech, Inc. and appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. MultiTech, Inc. Direct Utilization of Geothermal Resources of Warm Springs State Hospital, Warm Springs, Montana, Final Report for the Period January 31, 1979--June 30, 1983 Report No. DOE/ET/27055-10, Cooperative Agreement No. FC07-79ET27055, June 1983.
- *2. K. Runnion, Environmental Report for the Geothermal Heating of Warm Springs State Hospital, Montana, Report No. DOE/ET/27055-1, Cooperative Agreement No. DE-FC07-79ET27055, April 1979.
- *3. R. C. Stoker, Geothermal Resource Evaluation of the Warm Springs, Montana Area, Energy Services, Inc. and MERDI, Subcontract No. 9-A564-F, Report No. DOE/ET/27055-2 Cooperative Agreement No. DE-FC07-79ET27055, June 1979.
- 4. R. C. Stoker, Technical Specifications for Geothermal Well Drilling at Warm Springs, Montana, Report No. DOE/ET/27055-3 Energy Services, Inc. and MERDI, Subcontract No. 9-A564-F, Cooperative Agreement No. DE-FC07-79ET27055, June 1979.
- 5. E. M. McLeod, Technical Progress (Feb 79 to Aug 79) Report on Geothermal Heating of Warm Springs State Hospital, Warm Springs, Montana, Report No. DOE/ET/27055-4 MERDI, Cooperative Agreement No. DE-FC07-79ET27055, August 1979.
- 6. Well Logs, Dual Induction - Laterlog, Compensated Neutron-Formation Density, Temperature, Schlumberger and MERDI, Subcontract, Cooperative Agreement No. DE-FC07-79ET27055, November 1979.
- *7. J. R. Carlson, Drilling Report Warm Springs State Hospital Production Well No. 1, Report No. DOE/ET/27055-5 Montana Tech Foundation Mineral Research Center and MERDI, Subcontract, Cooperative Agreement No. DE-FC07-79ET27055, April 1980.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

- *8. R. C. Stoker, Preliminary Resource Evaluation of the Warm Springs, Montana Geothermal Well, Report No. DOE/ET/27055-6 Energy Services, Inc. and MERDI, Subcontract 9-A564-F, Cooperative Agreement No. DE-FC-07-79ET27055, November 1980.
- *9. R. W. Gould and J. F. Kunze, Evaluation of Data and Recommendations for the Warm Springs, Montana, Geothermal Well, Report No. DOE/ET/27055-7 Energy Services, Inc. and MERDI, Subcontract 1-K014-T, Cooperative Agreement No. DE-FC07-79ET27055, January 1981.
- *10. R. W. Gould, Evaluation Report: Remedial Work Warm Springs Well, Report No. DOE/ET/27055-8 Energy Services, Inc. and MERDI, Subcontract 1-K017-T, Cooperative Agreement No. DE-FC07-79ET27055, April 1981.
- *11. D. C. Brodahl, Preliminary Report on Summer 1981 Pump Tests of Warm Springs State Hospital Geothermal Well, Report No. DOE/ET/27055-9 Montana College of Mineral Science and Technology and MERDI, Subcontract, Cooperative Agreement No. DE-FC07-79ET27055, 1981.
- 12. Compendium of Warm Springs Well Water Analysis Reports and Corrosion Analysis MERDI, 1979-1983, (informal report).
- *13. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *14. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

DOUGLAS HIGH SCHOOL PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: Douglas High School Heating

Project Data:

Project Description: Geothermal fluid, hopefully above 120°F, would have been routed through underground insulated piping to heating tunnels in the Douglas High School where the heat would be extracted using new air fin-tube heat exchangers. The spent fluid would then be treated and distributed to customers as culinary water.

Location: Box Elder, South Dakota, approximately 6 mi east of Rapid City on Interstate 90.

Status: The production well, with a planned depth of 4500 ft, was drilled to 3639 ft only after numerous drilling problems. The funds for drilling were not a part of the PON project, but some PON funds were directed towards the drilling. Drilling was halted because of the lack of commitment and additional funding needed to complete the well.

Cooperative Agreement Data:

Number: ET-78-F-07-1727

Period: June 30, 1978 to January 26, 1979

	<u>Planned (\$)</u>	<u>Actual (\$)</u>
<u>DOE Share</u>	212,180 (40%)	30,000 (15.8%)
<u>Participant Share</u>	317,642 (65%)	162,410 (84.2%)
<u>Total Cost</u>	529,822	462,870

Principal Investigator:

F. J. Issler, Jr.
Douglas School System
Box Elder, SD 57719

Other Participants:

Initial Design and Monitoring

Dr. C. W. Chiang and D. D. Corda
South Dakota School of Mines and Technology
Rapid City, SD 57701
605/394-2496

Final Design and Construction Management

George F. Dunham, P.E.
Dunham Associates
528 Kansas Street
Rapid City, SD 57701

Drilling

Venekamp Drilling Company
Newell, SD

2. PROJECT DESCRIPTION AND HISTORY

The Town of Box Elder, South Dakota, located about 6 mi east of Rapid City on Interstate 90 (see Figure 10.1) planned to drill a domestic water well into the Madison aquifer at a depth of 4500 ft. This was necessitated because of a significant water table drop in 1977 from the town well drilled into the Lakota aquifer, located above the Madison. Representatives of the South Dakota School of Mines and Technology suggested that the potential use of the Madison aquifer fluid for heating as well as drinking. The PON cooperative agreement, wherein the heat would be used by the Douglas School System before it was discharged to the Town of Box Elder's community water system, was signed June 9, 1978. Most of the drilling funds were provided through the local public works program of the Economic Development Administration, and the well drilling was not to be a part of the PON project.

Serious drilling problems resulted in halting drilling activities, and the school board elected not to commit to drilling a new well, resulting in project cessation on April 27, 1979.

If the well had been successful, the fluid would be carried in insulated underground piping to heating tunnels beneath the Douglas High School building. The fluid would be piped through 40 new air fin-tube heat exchangers installed in front of existing air fin-tube reheat coils. This would provide heating for about 44,350 sq ft of a total 96,437 sq ft. Retrofitting the remaining heating units was not feasible and was not included in the PON project scope. The spent geothermal fluid would be transmitted to the Town of Box Elder where it would receive chlorination and fluoridation treatment for domestic use.

Fig. 10.1 Location Map

3. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

The drilling effort failed for a number of reasons. The lack of a properly maintained mud program and the inability to modify the drilling methodologies because of the footage drilling contract payment method and the drilling contractor's unwillingness to modify it were contributory. The drilling equipment may have reached its limit of capability. The lack of adequate experience on the part of the decision-making personnel, even though outside expertise was called in, also was a factor because of the inability to ask the right questions of the experts.

Numerous factors were considered to terminate the project when it was determined that a new well would be required. The obvious increased expenditures that would be required, plus having observed the failure of one well drilling effort and the attendant commitment of personal man-hours of support, were significant considerations. The developer was also faced with the concern of owning and maintaining the well. Disposal of the wastewater required legal agreements not yet in place. Modifications of school buildings requires various state approvals, including the preparation of environmental impact statements. Uncertainty of obtaining additional DOE funds was a concern, as was the potential for litigation in a new well drilling effort. Initially, the payback period was about 20 yr--with a new well it would be about 54 yr, an unacceptable period. Accordingly, all of these factors contributed to the decision not to continue the project.

4. DRILLING

The drilling contractor, who was drilling a water well (later to be classified as the geothermal production well) in May 1978 for the Town of Box Elder, began experiencing difficulties at about 3800 ft depth. The drill bit became stuck and it could not be removed. A consultant was called in to determine if the drill bit could be extricated and the well completed. He concluded that standard methods had been used and the drilling operation appeared capable of project completion. A directional drilling effort, supported by DOE, was instituted in October, with numerous problems occurring thereafter. Equipment failures, mud program problems, and the drill stem being stuck twice all contributed to the drilling failure. A depth of 3639 ft was achieved, but the drill bit and other components still remain in the hole.

5. PRODUCTION SYSTEM

Substantial progress was made on the design of the geothermal heating system prior to project termination. An analysis was made of the relative merits of using cleanable headered terminal heating coils versus serpentine tube coils. A piping and control scheme using the cleanable coils was devised, and a partial investigation of the existing tunnel system was performed. A preliminary selection of the terminal heating coils was made, contingent on data to be established by well completion. Construction drawings were partially completed and a preliminary analysis of the pumping and control interface with the city water system was performed.

6. SYSTEM COSTS, SCHEDULE AND ORGANIZATION

6.1 System Costs

About \$192,900 was spent on the project, with DOE contributing about \$30,500 and the remainder of \$162,400 provided by the Douglas School System and the Town of Box Elder. In addition, about \$70,000 was spent by DOE for the directional drilling effort that attempted to save the well.

6.2 Schedule

The PON cooperative agreement was signed June 9, 1978. Completion of the well was slated for the end of May, 1978; the well drilling effort was abandoned November 15, 1978. Consideration was given to drilling a new well, but the decision not to do so led to project termination on April 27, 1979.

6.3 Organization

The principal investigator for the project was F. J. Issler, Jr., of the Douglas School System. Initial design and monitoring were performed by the South Dakota School of Mines and Technology (Dr. C. W. Chiang and D. D. Carda). Final design was assigned to Dunham and Associates (Dr. W. Reuter and G. F. Dunham). Francis-Meador-Gellhaus, Inc. (FMG), well designer for the Town of Box Elder, was responsible for any well redesign required after the production well would have been completed by the Town of Box Elder. Utility Engineering Corporation prepared the environmental impact statement for FMG. Venekamp Drilling Company performed the unsuccessful well drilling work for the Town of Box Elder.

7. LEGAL AND INSTITUTIONAL CONSIDERATIONS

The Town of Box Elder (BE) entered into a legal agreement with the Douglas School System (DSS) wherein DSS would give BE a 50 x 75 ft plot of school property upon which the well would be located, in return for all of the geothermal energy in any and all waters extracted from the Madison aquifer

An environmental impact statement was prepared for the project for BE, and the same firm would have prepared any update required for the DSS.

8. REFERENCE

The information contained in this report was obtained from the following report prepared for the project.

- *1. Douglas School System District No. 51-1, Geothermal Heating of Douglas High School Cooperative Demonstration Project, final report for project, terminated January 26, 1979, Report No. DOE/ET/01727-1, Cooperative Agreement No. ET-78-F-07-1727, March 30, 1979.

*Available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

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11. DISTRICT HEATING PROJECTS-INTRODUCTION

Three of five district heating projects developed through the PON program are operational. The Boise City, Idaho, project, the largest of the systems installed, very effectively provides space heating to state and commercial buildings and numerous local residences. However, the project is currently in jeopardy because of the lack of adequate revenues. In Elko, Nevada, district heating is provided to businesses, and geothermal fluids are used directly in a laundry. The system is currently being expanded to serve additional customers. The Pagosa Springs, Colorado project provides heating to numerous businesses and schools, and some residential work has developed. Water rights have not been resolved to date, and this has limited the expansion of service. A well drilled for the Madison County district heating/food processing project produced inadequate temperatures and the project was not completed. The Monroe City, Utah project well could produce 600 gpm of geothermal fluid at 164°F, but this was inadequate for the city's needs, and the project was stopped for this and other reasons.

This section of the report provides summary data, project history and development, resource and drilling information, how the geothermal fluid was used, alternate considerations, legal and institutional factors, and cost, schedule, and operational data. Significant observations and conclusions relative to each project are also given.

BOISE CITY PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: Boise City Geothermal District Heating

Project Data:

Project Description: This project demonstrates the feasibility of utilizing a moderate temperature (170°F) resource to provide district heating in the City of Boise, Idaho. The project is composed of two separate systems, (a) Boise City, and (b) Boise Warm Springs Water District (BWSWD).

Location: Boise, Idaho

Peak Heat Load: 100 million Btu/h

Annual Heat Load: 200 billion Btu/yr (23% load factor)

Simple Payback: 6.1 yr

Status: The systems are complete and operating. However, additional users are needed to obtain positive cash flows. New customers would necessitate pipeline extensions and/or retrofitting.

Cooperative Agreement Data:

Number: DE-FC07-79ET27053

Period: March 23, 1979 to September 30, 1985

DOE Share: \$3,626,000 (53.7%)

Participant Share: \$3,131,020 (46.3%)

Total Cost: \$6,757,020

Principal Investigator:

Phillip Hanson
Boise Geothermal
P.O. Box 308
Eagle, ID 83616
208/939-0653

Other Participants:

Project Engineering
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CH₂M-Hill Central, Inc.
Box 8748, 700 Clearwater Lane
Boise, ID 83707
208/345-5310

Geology and Well Testing
Jack Kelly
Anderson and Kelly
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208/375-9220

Partnership Boise City Wells
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Boise Geothermal, Ltd.
331 West Idaho Street
Boise, ID 83704
208/336-8700

Boise City Pipeline Construction
Monte McClure
Owyhee Construction Co.
P.O. Box 5095
Boise, ID
208/336-5025

BWSWD Pipeline Construction
Gell Shunn
Shunn Construction Inc.
125 South Oregon Street
Ontario, OR 97914
503/889-9677

Boise City Well Driller
Holman Drilling
Spokane, WA

BWSWD Well Driller
Tom Engleman
Engleman Drilling
Rt. 3, Box 3397B
Nampa, ID 83615
208/336-8589

Boise City Inspection Marketing Operations and Administration
Charles Mickelson
Boise City Public Works
P.O. Box 500
Boise, ID 83701
208/384-4292

BWSWD Operations
Bob Griffiths
Boise Warm Springs Water District
2440 Old Penitentiary Road
Boise, ID 83702
208/342-3162

2. PROJECT HISTORY

Geothermal energy has been used in Boise since the 1890s to heat buildings. Interest in geothermal was renewed in the early 1970s with the beginning of the oil shortage. The state government and Boise State University began preliminary work in 1973 and 1974, which resulted in documentation of local heating loads and exploratory well drilling. In 1975, the City entered into a cooperative agreement with the Department of Energy to explore the feasibility of a geothermal district heating system. The favorable conclusion of this study produced a response to a Department of Energy Program Opportunity Notice to implement study results.

An application was made to the U.S. Department of Energy jointly by Boise City and Boise Warm Springs Water District (BWSWD). BWSWD had been using geothermal water for space heating since the 1890s, and it was their intention, under the application, to refurbish the system wells and main line. The City's objective was to build a heating system to serve the central business district (see Figure 12.1). The City and Warm Springs were notified at the end of 1978 that they had been awarded a contract by the Department of Energy. Work formally began on cooperative agreement number DE-FC07-79ET27027 in March 1979, and BWSWD system was refurbished and the new City system completed by March 1983. Full scale operation began in October 1983.

This project began in the City Office of Energy, shifted to an organization (Boise Geothermal) specifically structured for the project, and will continue under the operational responsibility of the Public Works Department for the City of Boise and the Board of Directors for the BWSWD. The project has resulted in refurbishing two old wells, drilling one shallow well (600 ft) that proved unproductive, drilling four deep wells (1000 ft or more) that have proven to be productive, and laying more than 50,000 ft of distribution pipeline.

Fig. 12.1 Location Map

3. GENERAL DESCRIPTION

The project is made up of two pieces or systems, the Boise Warm Springs Water District (BWSWD) and the Boise City project. Their general location is shown in Figures 12.2 and 12.3. The BWSWD system began in the late 1890s, originally providing service to about 400 houses. This number dropped considerably with the advent of natural gas, then later increased to its present service of about 250 homes and 150,000 sq ft of state office buildings. This project was used to modernize the system by renovating the two historic wells, drilling a third well (that proved unproductive), and totally replacing the main distribution pipeline, 10,700 ft in length. The BWSWD system is designed to handle 2000 gpm of 170°F geothermal water. Its general location is shown in Figure 12.2. The Boise City system, Figure 12.3, includes four production wells, 40,000 ft of system pipeline (distribution and connection line), and a river disposal system. The system will accommodate 4000 gpm of 170°F geothermal water.

Fig. 12.2 Boise Warm Springs Water District Location of Wells and Pipelines

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

The objective of the Boise geothermal project to demonstrate the feasibility of utilizing a moderate temperature resource to provide space district heating was very successfully achieved. Perhaps the most complex of the numerous PON projects, the Boise project is an excellent example of what can be achieved through proper technical direction and dedicated management. However, the technical successes have been marred by lack of adequate revenues occasioned by the unwillingness of potential customers to bear the expense of retrofitting or to convert to a different energy source. New facilities in the district heating area are more prone to starting with geothermal energy systems, but the infrequency of completion of these facilities extends the revenue producing potential over too long a period to meet current obligations. The project did not include existing facility heating systems retrofitting funds, and in retrospect, their inclusion may have provided the revenues to make the project more financially viable.

Significant effort was directed towards resolution of legal and institutional issues, indicating their importance in the development of geothermal district heating systems. The solving of technical concerns was overshadowed by such items as the development of a project by two governments (Boise City and Boise Warm Springs Water District), numerous sources of private and public funding, establishing a new utility, the impact of governmental regulatory requirements, etc. Subsurface rights were resolved, but only after a public law was passed that gave those rights to the project. Designation of the BWSWD pumphouse as a historical place precipitated the expenditure of considerable time, effort, and cost, with the ultimate renovation being performed outside the scope of this project. Disposal of spent geothermal fluids into the "pristine" Boise River (initially considered the least expensive alternative) produced a great deal of reaction, but was finally achieved after much effort and expense. Disposal of fluids in excess of the current capacity of the present system will probably require the use of injection wells; this could conceivably be more cost-effective and less emotionally painful in the long term.

Fig. 12.3 Boise City Geothermal Pipeline System

Pressure surges brought about in a multi-pump system can be significant, as was observed in the Boise City system. It became necessary to modify the installed system to permit gradual flow rate changes during sequencing of pumps with different capacities. An in-line booster pump was also added to the system to reduce operating costs during the summer operating period by reducing the amount of fluid needed from the wells to maintain minimum system pressure.

5. THE RESOURCE

5.1 General

The ready availability of geothermal fluids in the State of Idaho is evident in all of the hot springs sites and small hot water projects throughout the state. The use of geothermal energy in the Boise area has been common knowledge and part of recorded history since first contact with the Indians. The best known early use in the area was by the Boise Hot and Cold Water Company that developed wells for use by the Natatorium, primarily for recreational purposes. Subsequently, this company and its successors have developed a distribution system so that the water can be used for space heating and domestic purposes.

There are many other wells along the Boise front that have found usage for a broad range of purposes. A study by Boise State University faculty in 1975 established the geothermal potential of the front as reflected in all of the wells in that area. This and other related studies led to the drilling of the first large scale exploratory wells in 1975. This drilling and related geological survey activity reconfirmed the geothermal potential in addition to establishing more specific boundaries and characteristics of the resource area. The developed wells and their uses were cataloged in a 1977 report. This work found 140 wells with temperatures in excess of 20°C being used for irrigation, watering livestock, heating dwelling units, heating greenhouses, watering greenhouse plants, and heating swimming pools.

This history of well development and geological study culminated in planning for the proposal in response to the DOE Program Opportunity Notice (PON). This proposal specified the area of emphasis to be on property owned by the City and in the geothermal resource area as thus far defined. The specific area chosen was Camelsback Park at the base of the foothills relatively near the central business district (CBD). The proximity to the CBD was also a very important consideration in view of pipeline costs and the density of service in downtown commercial buildings. No additional geological studies were completed for this park before submission for the PON proposal.

5.2 Pre-Drilling Assessment--Boise City Segment

Pre-drilling assessment work began immediately after the PON cooperative agreement was entered into. This involved three activities: (a) having a geology consulting firm, GeothermEx, to study available data to decide if it was adequate to select specific well drilling sites, (b) a peer review of their findings, and (c) planning the specific site for the first production well. The majority of the pre-drilling assessment was based on previous studies and surface exploration.

Selection of drill sites was about equally based on geological knowledge, ownership, and location of the service area. The drill sites, selected in the Military Reserve Park, are shown in Figure 12.4.

5.3 Geology--Boise City Segment

In general, the available information indicated that beneath that part of the Military Reserve Park southwest of the easterly major fault trace, and toward the southeast, the volcanic and sedimentary deposits contain permeable zones irregularly distributed which receive and transmit a regional, deep, confined groundwater body. This body is replenished from near-surface and surface runoff from the mountainous area to the northeast, and from recharge from the Boise River area to the southeast. Regional groundwater movement within the system is westward and southwestward. Superimposed upon this groundwater flow system is the discharge into the basal part of the deposits of thermal waters from cracks, fractures, and fault-zone fractures in underlying granitic basement rocks. The thermal system appeared also to be replenished by infiltration of meteoric water to the granitic rocks over high areas to the north and east. In the vicinity of the park, the thermal system appeared to have the greater pressure head, and thus may be dominant within the flow system.

It was concluded from the available geologic and hydrologic information that thermal water wells would be successful anywhere within

Fig. 12.4 Drill Site Locations

Military Reserve Park west of the easternmost major fault trace. Only three locations appeared to have maximum potential for meeting the requirements for production wells.

5.4 Pre-Drilling Assessment--BWSWD Segment

The preliminary assessment and selection of drilling sites was at all times part of the overall geology work, but it was considerably more straightforward because of the long production history of the two other BWSWD wells and the availability of land owned by BWSWD. Nonetheless, a consulting firm was retained to conduct a reconnaissance of the resource area (a ten-acre parcel owned by BWSWD) to choose a drilling site. Part of the support to this work involved measurements at the two existing well sites. This included lowering a television camera with a light source down each well to ascertain well conditions and to gain insight into the subterranean geology. In line with the prior emphasis on stepping out along known structural trends, the geologists chose a site approximately 400 yards from the existing wells. The location is shown in Figure 12.5.

5.5 Well Drilling

5.5.1 General

The Boise project originally contemplated drilling three wells: One for Boise Warm Springs Water District, and two for the Boise City portion of the system. The Boise Warm Springs Water District well was bid and drilled in 1981 at a cost of approximately \$37,000. The two wells originally planned for the city portion of the project were not funded by public funds, but were funded by a private drilling partnership. Instead of the original two wells contemplated, the private fund drilled a total of four wells. Cost of the four wells was approximately \$2,000,000, which included the wells, pumphouses, and all improvements. Drilling of the city wells was completed on Military Reserve Park in 1981.

Fig. 12.5 BSWD Well Site

5.5.2 Drilling Summary

The Holman drilling equipment used to develop the Boise City wells involved a large rotary drill with a capability of developing wells up to 5000 ft deep. The original specifications called for drilling, casing and developing between three to five geothermal water supply wells for the City. The specifications called for the drilling equipment to produce a well with a 12-in. inside diameter casing from the land surface, through the unconsolidated sediments in the upper part of the volcanic sequence, to about 800 to 900 ft, and from that point, an 8-in. internal diameter screen assembly consisting of a blank casing and stainless steel well screen from the bottom of the 12-in. casing to total depth.

The drilling rig configuration included blow-out prevention (BOP) equipment. It was not anticipated at the time the specifications were prepared that the shut-in pressure would exceed 50 lb psi, based on wells with a nominal 1300 to 1500 ft depth. However, the contractor was requested to provide BOP equipment, consisting of blind and pipe rams, and related necessary equipment. This BOP equipment was installed after the permanent wellhead assembly had been attached to the 12-in. casing. The wellhead assembly, in turn, consisted of a 12-in. full opening valve attached to the casing, with a minimum 250 psi casing head or flange welded to the 12-in. casing.

Upon completion of the well, the BOP equipment was removed, and a 12-in. tee with an 8-in. side outlet with a flanged 8-in. valve was installed on the 12-in. valve. The top of the tee was fitted with a blind flange for future access and a standard one-quarter-inch fitting for pressure gage assembly.

Specifications originally called for three to five wells to be drilled to a nominal depth of 1500 ft below ground. Boise Geothermal Limited (BGL) well No. 1 was drilled to 2010 ft, BGL-2 to 880 ft, BGL-3 to 1897 ft (being used as a monitor well), BGL-4 to 1103 ft, and BWSWD-3 was drilled to 600 ft, but proved to be unsuccessful.

The bid specifications called for, and the contractor completed, a complete suite of well logs. The well logging company ran SP and resistivity, multi-arm caliper, gamma ray compensated density with caliper logs in the open hole from total depth to casing bottom. Gamma ray neutron logs and temperature profile logs were run from total depth to the surface.

After completion of drilling, casing, and logging, the driller cleaned and developed the well by airlift pumping to determine production.

5.6 Resource Testing--Boise City

Wells BLG-2 and BGL-4 were tested in April and May of 1982 in order to determine discharge drawdown relationships at individual wells, aquifer characteristics from the data collected at various observation wells, the effect at Warm Springs Water District wells, the effect on the overlying cold water aquifer system, and other parameters that could be used in an evaluation of the geothermal aquifer system. The principal objective of the testing and evaluation was to demonstrate the capability of these two wells to supply a peak demand of 2000 gpm for the Boise City Geothermal space heating project.

A number of the wells in the area had previously been tested before 1980. Several of the geothermal wells in the Boise area had been tested for short periods of time in 1980 and 1981. In addition, a baseline data collection program had been established and was under way concurrent with the BGL testing that involved periodic water level measurements at most of the local geothermal wells. Consequently, the trend of seasonal water level variations, the sensitivity to barometric and earth tidal activities, and general magnitude of response to flow testing could be anticipated.

The testing of the BGL wells consisted of flowing each well at a constant discharge rates for two to seven days, as well as to flow each of the wells at both the lower and higher rates for shorter periods of time. BGL-2 was flowed first because of its well-known high discharge capacity.

BGL-2 was step tested on April 7, 1982 with the first step at 400 gpm. The well was flowed for 65 min and recovery measurements were made until the next step began about 2-1/2 h later. The next step was at 1000 gpm for 1 h. Recovery measurements were made until the next morning when the long term test started. This test was run for 7 days at a constant rate of 900 gpm and recovery measurements were taken for 10 days. The maximum temperature at the end of the 7 day flow period was 171°F. This well is the principal supply well for the first phase of the Boise City project because of its extraordinary yield.

BGL-4, which had not been previously tested, was flowed briefly on April 26 to determine the general magnitude of discharge capability. It was discovered that the 12-in. wellhead valve, which had been almost impossible to move manually, was open only partially, and may have been almost completely closed. Consequently, a multiple step flow test was run the next day to determine if this condition would be detrimental to data collection during the planned testing. The multiple step testing was started at a rate of less than 35 gpm and increased to a minimum rate of about 180 gpm. The consistent discharge drawdown relationships indicated that future testing could proceed as planned. A constant discharge flow test was run for slightly less than two days at 160 gpm starting on April 28. The maximum temperature measured at the end of the test was 170.1° F.

5.7 Resource Testing--BWSWD

Extensive testing was conducted of two existing BWSWD wells refurbished under this project. Renovation included removing the pumps, inspecting them, renovating or replacing them, and improving the pump control system. Because the third well (Figure 12.6) drilled as a part of the PON project was not productive, the BWSWD will continue to be a 1000-to-1600 gpm system until a new resource is developed. However, current drawdown limits total flow to 850 gpm. Individually, the west well can deliver 750-800 gpm and the east well 400 gpm.

Fig. 12.6 BSWD Production Well 3

6. THE ENERGY EXTRACTION AND USE SYSTEMS

6.1 Boise City

6.1.1 General

Four production wells were drilled to depths of 800-2000 ft in conformance with Idaho Department of Water Resources (IDWR) standards for geothermal drilling. The general design for the wells ultimately drilled by Boise Geothermal Limited on the Military Reserve Park is shown on Figure 12.7, and the production well mechanical plan is shown in Figure 12.8.

The pipeline is designed and constructed to provide a total service of up to 4000 gpm of 170°F+ water. The pipeline is a double pipeline system that includes an insulated line in a trench to deliver the hot fluid to a building and a second line, uninsulated, in the same trench that collects the fluid from a building after use, and delivers it to the disposal pipeline and ultimately to the Boise River trenches. The supply pipe is insulated asbestos cement epoxy-lined Johns Manville class 150 temptite. The collection pipe is standard class 150 asbestos cement pressure pipe, epoxy lined, and is also a Johns Manville product. Some portions of the distribution system may have only a supply pipe or collection pipe depending on the location in the system. Several types of valves are installed throughout the distribution system that was constructed in 1982 and early 1983.

6.1.2 Disposal

An important constraint on system operation is the ability to dispose of the used geothermal water. At the outset a study was completed to evaluate the various disposal options. This study investigated use of a wastewater treatment plant, disposal to injection wells, spreading on holding ponds near the river's edge, and disposal to the river. The initial engineering conclusion was that the disposal to the river would be the least expensive of the alternatives.

Fig. 12.7 Boise Production Well Profile

Fig. 12.8 Boise Production Well Mechanical Plan

River disposal involved at least three major issues which were very complex and constituted the source of some delay to the project. The first of these was the inability to simply and clearly settle technical issues related to disposal in the absence of any data regarding specifically how disposed water would disseminate into the river.

The second area of concern was completing those bureaucratic steps that were required for approval and providing sufficient information to satisfy the regulatory agency possessing responsibility for this portion of the river.

The final consideration involved the prevailing sentiment regarding the quality of the water in the Boise River near the point of disposal and the uses of that stretch of the river.

Alternate disposal locations were considered. After selection of a site at the Settlers Canal diversion dam, a number of different options were considered for disposal, including laying a pipe in the bottom of the river to diffuse the spent water. Ultimately, the option chosen was to construct a diffusion system that consists of a pipe stretching the width of the river, mounted on the upstream face of the diversion dam, and including a series of ports to control the plume of diffusion across the width of the water surface.

The water arrives at the diffuser line through a monitoring station constructed below grade in the bank of the river and adjacent to the river's edge. The monitoring station consists of a series of valves and gages to measure and control system operation. It controls backpressure in the entire collection and distribution pipeline system.

6.1.3 Instrumentation and Controls

Geothermal water is pumped from three production wells through pressure control valves into a common transmission line. System pressure is remotely sensed and automatically maintained by adjusting the pressure control valves. Customers on the Boise City system automatically adjust

flow to maintain temperature; hence, the system is automatically controlled to meet load changes which would be more precipitous than those presently experienced by the BWSWD. System flows, temperature, and pressures are monitored and recorded.

Customer service connections are made between the transmission and collection pipelines by using a primary-secondary crossover hydronic circuit. This arrangement tends to hydraulically isolate customer system characteristics from the geothermal system characteristics. Individual flowmeters and temperature control valves measure and regulate flow to the customers.

6.2 BWSWD

6.2.1 General

The design selection process for the BWSWD system was guided by the existing facilities. The pumphouse and wells for this system had been in use, in one way or the other, since beginning of the district in the 1890s. Thus, the design approach used was to refurbish and upgrade the existing equipment to modern standards.

Refurbishment of the BWSWD wells 1 and 2 was broken into two phases. The existing wells, pumps, and motors were inspected and refurbished to meet the immediate needs of the BWSWD and to assess their condition for incorporation into the new project. This work was carried out in October and November of 1979. Layne of Idaho was the prime contractor. Northwest Underground Surveys subcontracted to inspect the wells with a camera and to record the results on a video tape. The consulting firm of Anderson and Kelly subcontracted to perform pump tests on wells 1 and 2.

The second phase of the refurbishment involved upgrading the pumphouse, mechanical system, and electrical system.

Renovation of the existing historical pumphouse structure was performed by BWSWD outside the scope of this agreement.

The transmission/system, capable of delivering up to 3000 gpm, involved placement of new insulated asbestos cement (AC) pipe (the same as for Boise City) in the existing right-of-way adjacent to the old pipeline. The pipes range in size from 6 to 12 in. in diameter and travel from the well head on Penitentiary Road to the termination point at approximately the intersection of Sixth and Idaho streets. Along the main transmission line there are a series of control points which provide for isolation of segments of the line and tees, for extension of service to surrounding areas.

6.2.2 Disposal

Disposal methods for the spent geothermal fluids continued unchanged, using the existing sewer system, old canals, and other surface discharge means.

6.2.3 Instrumentation and Controls

The existing control system remains unchanged. Two vertical turbine pumps each discharge through pressure control valves into a common transmission line. A pressure recorder located in the existing well house monitors pressure at the termination of the distribution system.

The BWSWD pump operation and pressure control valves are manually adjusted daily to maintain a minimum system pressure of 15 psig. A third pressure control valve is located downstream in the common transmission line near the customer load.

Main line valves in the supply and collection pipes are primarily used to isolate sections of pipe for installing new service connections or for repairing broken pipes.

The primary system load is from residential units where flow is controlled by orifice plates, and building temperatures are primarily controlled by manually regulating flow to heating radiators.

7. ALTERNATE CONSIDERATIONS

7.1 Disposal System

The initial consideration for disposal of the Boise City geothermal fluids was to build a disposal line to run approximately 5 mi from the use area for disposal of the water to the river near Veterans Park. This proved to be too expensive, and it appeared more appropriate to dispose of the water near the point of use. Other considerations included disposal to the river, drilling of injection wells, placing the spent water in holding ponds along the river, building a geothermal display park to dispose of the water, disposing of the water through other uses such as downstream buildings, and disposing of the water into existing wells, especially those on State Capitol Mall.

The final solution for the initial phase of this project, i.e., the phase that involves up to 4000 gpm flow, is disposal of the spent water into the Boise River near Settlers Dam. The experience and knowledge gained through the process of looking at alternatives brought the conclusion that disposal to the river is a distinctly short term solution, especially if the system should expand through use. The long-term solution is probably the drilling of injection wells to accommodate any system expansion.

7.2 Pipeline Routes

Five potential pipeline routes were considered. The pipeline route servicing the maximum potential load was selected. This selection considered the technical ability of a building to be retrofitted, the retrofit cost, the size of the heat load, and the willingness of the owner.

7.3 Pipeline Materials

Various materials were considered for the geothermal fluid pipeline. A pipeline material was needed that retained the energy content of the water and was not susceptible to corrosion by surrounding soils. The various candidate materials investigated included polybutylene, plastic

reinforced fiberglass, concrete, asbestos cement (AC), and cast iron pipes. The final conclusion, after reviewing all of these, was that the asbestos cement pipe with polyurethane foam insulation would constitute the best possible piping material for both systems. Consequently, AC pipe was ordered for both the Warm Springs Water District system and for the Boise City system.

Several insulation systems for the transmission pipeline were considered. Pipe can either be purchased as a preinsulated system (e.g., Rovanco, Thermacor, Ric-Wil, or Temptite) or can be insulated after it is installed (e.g., Gilsulate, Protexulate, and spray-on urethane). Temptite pipe was installed for both systems.

The insulation systems were compared by summing the material costs, installation cost, and heat loss cost. The preinsulated pipe is slightly less expensive than the other alternatives. The spray-on urethane insulation was not considered due to the difficulty in controlling the quality of installation and the potential for moisture penetrating the insulation.

8. SYSTEM OPERATION

The City of Boise contracted with Boise Geothermal Limited to operate and maintain the pumping facilities. This allows for an integrated operation of the entire system.

The City took over operation of the pumphouse facility during the summer of 1983, approximately six months after the production facility had been completed. Major production facilities include a 50-hp motor with pumping capabilities of 800 gpm, a 125-hp motor with pumping capabilities of 1500 gpm, and a 200-hp motor with pumping capabilities of 2000 gpm. These pumps are integrated so that on a rising flow curve, the pumps will sequence on and off to allow the full production of the facility up to 4000 gpm; in a falling flow regime, the pumps will sequence on and off to take it back down to flows below 750 gpm.

When the City of Boise took over the operation of the BGL pumping system, pump testing was done to check the pump sequencing operations as flow levels increased. It was immediately apparent that pressure surges were significant within the pipeline system as higher capacity pumps came on-line. The motors specified were not variable-speed, but were constant-speed motors. Thus, when a 50-hp motor shut off at a production of 750 gpm with an automatic control valve wide open, and the 125-hp motor and pump came on capable of pumping 1500 gpm, pressure surges were significant and system modifications were necessary.

An electric actuator was purchased and installed on a butterfly valve on the No. 2 pump and was set such that the No. 2 pump output at turn-on would match the full output of the No. 4 pump. This electric actuator opens over a period of three minutes to allow the higher production of the No. 2 pump to enter the system. The automatic control valve on the system closes as higher downstream pressures occurred over this three-minute period. Once the electrically actuated valve reaches the full-open position, the automatic control valve maintains system pressures at the proper setting. When the No. 2 pump shuts off and the lower capacity pump

comes into production, the electric actuator will close the valve to the pre-set condition so that at the next startup of No. 2, pressure surges will be avoided.

An in-line booster pump was also installed during the summer of 1984 to provide for lower operating costs during the summer operating period when the artesian condition in the aquifer has occurred, usually in May or June. The in-line booster pump can be utilized to provide the necessary capacity for the summer users. This installation has paid for itself in less than six months' operation.

Operators of the system have generally been satisfied with the operation with the exception of the pump failures that have occurred. Based upon the changes in the bearing material and repairs that have been made, operators are quite confident in the operation of the system and very little operator time is required except for routine maintenance and major repairs.

Based on two years of operating records, it appears that the water level regime in the geothermal aquifer may have reached a new state of equilibrium. The temperature of the Boise City wells is dependent on the pumping rate and/or duration of pumping, with greater pumping producing higher temperatures, varying between 172 and 176°F. The discharge mixing in the Boise River is excellent, and there has been no performance problems except for occasional removal of debris that hangs up at the discharge point. The supply pipeline has performed satisfactorily. Heat loss during non-peak periods produces system inefficiencies because of the need to manually control flow geothermal fluids to maintain the 176°F discharge temperature to meet customer needs. Future extensions will use automatic temperature control valves. The distribution system operates satisfactorily except for the need to periodically remove and replace the flowmeters.

9. SYSTEM COSTS AND SCHEDULE

Table 12.1 summarizes the sources of funds and the expenditures for the Boise district heating PON project.

The project budget received 53.7% of funding from DOE, 29.6% from private sources, 7.4% from EDA, and the balance (9.3%) from local government sources. A majority of the local funds (68.8%) were raised through a limited partnership, and these funds were used exclusively to drill and improve the four city system wells. The funds received from all these sources were spent 23.5% on the Boise Warm Springs Water District and 76.5% on the Boise City system. The money spent on BSWD was to renovate an old system while the city system had to be developed from scratch. More than 87.4% of all project funds were spent on hard construction (\$5.7 million), wells or pipelines.

Preliminary work on the project was begun soon after the notice of contract award in October 1978. The time period up to March 1979 was mostly concerned with developing the cost sharing agreement with DOE, geology, organizational issues, and some work on environmental questions. For practical purposes the major work began in March 1979. The principal work from March 1979 to mid-1980 was concentrated on issues of access to subsurface rights at Military Reserve Park, final review of geology, and searching for additional funds.

The schedule of tasks beginning in 1980 to completion of work is shown in Figure 12.9. The completion date shown on the figure is the first quarter of 1982 when, in fact, work was completed the first quarter of 1983. Completion refers, in this case, to pipeline construction and system testing. There has been other work required since March 1983 to correct system bugs, finish work that couldn't be completed due to weather, and continue to obtain other building service connections in order to attain a maximum system load. For practical purposes, the project schedule ran from October 1978 to October 1983.

TABLE 12.1. SOURCE AND APPLICATION OF FUNDS

	Amount (<u>\$</u>)	<u>Percent</u>
SOURCE OF FUNDS		
Reimbursements (1)	34,885	0.51
Bonneville Power Administration (2)	120,750	1.78
DOE Public Buildings Program (3)	8,500	0.12
Interest Income	61,356	0.9
Boise Warm Springs Water District	256,700	3.79
Limited Partnership	2,000,000	29.59
City of Boise	148,529	2.19
Department of Energy	3,626,000	53.66
Economic Development Administration	500,000	7.39
TOTAL REVENUES	6,757,020	
EXPENDITURES		
BWSWD Wells	118,357	1.75
BWSWD Geology	42,849	0.63
BWSWD Market/Rate Studies (1)	5,000	0.07
BWSWD Environmental Study	20,958	0.31
BWSWD Public Awareness	2,307	0.03
BWSWD Construction	1,038,182	15.36
BWSWD Administration	114,640	1.69
BWSWD Design/Engineering	249,010	3.68
Boise City Wells	2,020,877	29.9
Boise City Geology	34,364	0.5
Boise City Market/Rate Studies	20,348	0.3
Boise City Environmental Studies	62,774	0.92
Boise City Public Awareness	15,184	0.22
Boise City System Design/Engineering	278,532	4.12
Boise City Construction	2,445,702	36.19
Boise City Administration	287,936	4.26
TOTAL EXPENDITURES	6,757,020	100.0

NOTES: (1) BRA, Terteling Co., etc. transfers
 (2) Retrofit City Library Building and Fort Boise Community Center
 (3) Funds to study retrofit-potential of other City-owned buildings.

All other costs excepting construction and wells are divided between BWSWD and Boise City on the ratios of 25% and 75%, respectively.

* Groundwork tasks preceeding the Boise Geothermal tasks
 ** Double tasks covering Boise City and BWSWD

Fig. 12.9 Project Schedule

Some steps could have been taken to speed up the project schedule based on planned tasks, but most of the time delays can be traced to obtaining geothermal rights to Military Reserve Park, searching for additional funds once it had been determined that engineering cost estimates exceeded the budget, and the time required to complete work with various regulatory agencies, especially those related to waste water disposal. The net effect of these unplanned project activities was to add 18-20 months to the project schedule.

10. LEGAL AND INSTITUTIONAL FACTORS

The magnitude of the institutional issues and requirements can best be illustrated by noting that this project entailed establishing a completely new utility for which few of the attendant circumstances were clearly defined or definable. This caused a major amount of work and cost as the project progressed. The work involved agencies at all levels of government as well as private individuals and organizations. The costs included funds spent and time or opportunity lost. One could state, in general, that most of the institutional problems concerned the "new" Boise City system, not the "old" BWSWD system. Presumably, this situation resulted from the older system having long since answered most institutional questions.

The involvement of two governments (the City of Boise and the Boise Warm Springs Water District) in this project required selecting the type of organization that could best manage project business. The institutional problem was that neither government would relinquish full control to the other to administer or manage project work and funds on behalf of the other. This problem was resolved by creating a "non-organization" between the two governments that could act as a neutral ground for discussing common problems and presumably manage the project in an objective manner to best serve the independent interests of both governments. The arrangement is shown in Figure 12.10.

Further complexity arose from the impact of other government regulatory agencies and the presence of other projects. Perhaps the most complex situation involved the state government. The city was required to fulfill the regulatory requirements of Health and Welfare about disposal and the Department of Water Resources requirements about drilling permits and water rights, in addition to dealing with the state geothermal district heating project. The regulatory agencies were the source of delays largely attributable to the novelty of requirements related to geothermal, and the potential for competition posed by the state project.

Fig. 12.10 Project Organization

The Boise City wells are located in a military reserve park. Surface rights had been deeded to the city for various uses, but subsurface rights were not. The federal government was willing to give these subsurface rights to the city, but had to change federal law to allow the transfer. This was accomplished through Public Law 95-586, sponsored by Idaho Senator Frank Church.

The BWSWD historic pumphouse became a source of concern to the project even though it did not involve environmental issues. The BWSWD pumphouse is listed on the National Register of Historical Places. The project contemplated expenditures to completely replace the building with a new one, but that proved to be impossible because federal funds were involved. The use of federal funds entailed adherence to strict guidelines applied to historical places or buildings. These guidelines included involvement of the local historical agencies as well as those at the federal level. The result, after more than nine months of inconclusive meetings and paperwork, was deletion of this task from the project. The existing building was later renovated by the BWSWD at their expense.

At the beginning of the project, an environmental assessment report was required instead of an environmental impact statement (EIS). An EIS was not required because of regulatory options, but also because of the patently benign overall impact of the project. Later in the project, a number of environmental concerns arose when the choice was made to dispose of system water to the river. These concerns were settled with briefer studies and administrative decisions allowing this form of disposal. In being allowed this disposal option, the system has incurred a continuing obligation to monitor impacts on the river and reporting those impacts.

There have been more legal issues requiring study on this project than were anticipated when work began. The legal work included, in addition to routine resolutions, ordinances and contracts, preparation of legislation to transfer federal property to the city, lawsuits, work with regulatory agencies on water disposal, negotiations to develop the limited partnership resource lease, and water rights.

11. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and figures contained in this report are excerpted from the project final report prepared by Boise Geothermal, and appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

1. Boise Geothermal, Geothermal Retrofit of the State of Idaho Industrial Administration Building, October 1981.
2. Boise Geothermal, Proposed Pipeline Network (for) Boise Geothermal District Heating System, August 1981.
3. Boise Geothermal, Operations and Maintenance Manual; City of Boise Geothermal District Heating System, March 1983.
4. Anderson and Kelly, Baseline Assessment of Geology and Hydrogeology; Boise Geothermal Project, April 1982.
5. City of Boise Energy Office, Boise Geothermal Energy Systems Plan, January 1979.
6. Grant Application for Energy Conservation Measures: St. Lukes Hospital.
7. Anderson and Kelly, Flow Testing of Boise Geothermal Ltd. Wells Nos. 2 and 4, June 1982.
8. Bureau of Land Management, City of Boise, Idaho Geothermal Resource Conveyance - I-15249, December 1979.
9. Anderson and Kelly, Boise Geothermal Ltd.: Specifications and Contract Documents for Drilling Geothermal Wells, November 1980.
10. CH₂M-Hill, Technical Assistance Study Prepared for Fort Boise Community Center, May 1983.
11. S. L. Chapman, Consultant, Environmental Impact Assessment for the Boise Geothermal Project, (undated).
12. Anderson and Kelly, Analysis of Hydrogeologic Test Data for Wells 1 and 2, Boise Warm Springs Water District, December 1979.

13. Anderson and Kelly, Considerations Related to Injection of Spent Thermal Water, Boise Geothermal Project, June 1980.
14. CH₂M-Hill, Preliminary Engineering Design: City of Boise and Boise Warm Springs Water District Heating Systems, 1980.
15. CH₂M-Hill, Contract Documents for the Construction of Boise Geothermal Pressure Control, February 1983.
16. City of Boise, Energy Rutunes Conference, July 15, 1981.
17. G. Simmons, University of Idaho, A Proposal on Modeling and Control Strategy for the Boise City Geothermal System, October 22, 1981.
18. CH₂M-Hill, Preliminary Investigation of Potential Low Temperature Geothermal Water Application for B.W.U., April 1980, (52 pages).
19. CH₂M-Hill, Environmental Report for the City of Boise Geothermal Space Heating System, February 1980, (150 pages).
20. Bureau of Land Management, Environmental Assessment Record No. ID-010-7-88 Geothermal Leasing on Boise Front, June 8, 1977, (27 pages).
21. CH₂M-Hill, Direct Utilization of Geothermal Energy; Boise Geothermal Design Review, February 5, 1980, (24 pages).
22. CH₂M-Hill, Geothermal Water Disposal; City of Boise and Boise Warm Springs Water District Geothermal District Heating Systems, August, 1980 (60 pages).
23. McKellip Engineering, Ft. Boise Community Technical Assistance Analysis, April 28, 1981 (85 pages).
24. CH₂M-Hill, Technical Assistance Study: Ft. Boise Community Center, May 1983 (200 pages).
25. CH₂M-Hill, Preliminary System Design Report - Heat Pumps and Cascade Systems, December 1978 (24 pages).
- *26. City of Boise/Boise Warm Springs Water District, A Field Experiment: Commercial and Residential Space Heating DOE, PON EG-78-N-03-2047, July 1978 (104 pages).
27. D. M. Nonbals, Glad to Be in Hot Water; Geothermal Development In Boise, Idaho, 1890 - 1983, (a book), (50 pages).
28. CH₂M-Hill, Appraisal of Natatorium Hot Water, December 31, 1973 (30 pages).

29. K. Hullenburgh, Water Quality and Flow Volume as Factors Sheet Limit the Surface Discharge of Geothermal Water to the Boise River, June 15, 1978 (20 pages).
30. CH₂M-Hill, Preliminary System Design Report: Geothermal Space Heating Applications; City of Boise, November 1978 (60 pages).
31. Boise City, Institutionalization of a Low Temperature Geothermal Energy Resource For Boise, Idaho, (undated) (41 pages).
32. J. K. Applegate, et al., Boise State University, An Investigation of the Geothermal Potential of the Boise Area, Idaho, (undated) (64 pages).
33. EW & Co., Idaho, Inc., Geothermal Potential of the West Boise Area, October 1977 (33 pages).
34. Anderson and Kelly, Recommended Sites and Geology Related to Geothermal Reduction Well in the Vicinity of Military Reserve Park, July 1980 (11 pages).
35. Anderson and Kelly, Recommended Site for a Geothermal Production Well in the Boise Warm Springs Water District Well Field, May 1980 (4 pages).
36. P. R. Donaldson, Views on Geothermal Resource Disposition, (memo), March 6, 1980 (14 pages).
37. Geotherm-Ex. Inc., Geological Data Review of the Boise Geothermal Area, January 1980 (14 pages).
38. Anderson and Kelly, Revised Testing Plan for Boise Geothermal Ltd. Wells No. 2 and 4, March 1982 (7 pages).
39. Anderson and Kelly, Considerations Related to Injection of Spent Thermal Water, Boise Geothermal Project, July 1980 (17 pages).
40. B. Behling, Geothermal Conversion Cost Study Boise, Idaho, February 1980 (29 pages).
41. B. Behling and M. Mery, Geothermal Rate Study: BSWD and Boise City, October 1979 (52 pages).
42. B. Behling, Geothermal Project Well Drilling Expense Update, December 21, 1978 (3 pages).
43. CH₂M-Hill, Market and Rate Study; City of Boise and Boise Warm Springs Water District Heating Systems, August 1980 (55 pages).
- *44. Boise Geothermal, Boise Geothermal District Heating System Final Report March 1979-September 1985, Report No. DOE/ET/27053-6, Cooperative Agreement No. DE-FC07-79ET27053, October, 1985.

- *45. ICF Incorporated, Resource Assessment For Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *46. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

ELKO PROJECT

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1. PON PROJECT SUMMARY

Project Title: Elko, Nevada Geothermal District Heating

Project Data:

Project Description: This project demonstrates the feasibility of utilizing a moderate temperature (177°F) resource to provide space, process water and domestic water heating for three buildings in Elko, Nevada.

Location: Elko, Nevada

Peak Heat Load: 11.4 million Btu/h

Annual Heat Load: 31.6 billion Btu/yr (27% load factor)

Simple Payback: 11 yr

Status: The project is operating satisfactorily.

Cooperative Agreement Data:

Number: DE-AC07-79ET27033

Period: March 10, 1979 to October 9, 1983

DOE Share: \$827,504 (59.2%)

Participant Share: \$289,765 (20.7%)

End Users Share: \$281,000 (20.1%)

Total Cost: \$1,398,269

Principal Investigator:

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2. PROJECT HISTORY

Geothermal energy was being used on a limited basis in the Elko area before this project. There are a number of locations within the City of Elko (and in the immediate vicinity) where the geothermal resource was evident in one form or another. The geothermal resource in Elko was evident as surface expressions, such as the Elko Hot Hole and numerous springs and seeps in the vicinity. In addition, there have been a number of attempts to drill cold water wells which encountered thermal zones. Historically, geothermal energy had been used for purposes such as heating the Elko swimming pool, which was located at the Elko Hot Hole, and in the late 1800s, a spa was built southwest of the city. Present uses of geothermal energy in Elko consist of a geothermal spring at the former Elko County Home for the Aged, supplying domestic water for a number of residents in the vicinity, and a greenhouse operation using 140°F water obtained from a shallow well in the vicinity of the Elko Hot Hole.

Elko Heat Company was formed in 1979 by a group of individuals who were interested in developing the geothermal resource in the Elko area. The U.S. Department of Energy Program Opportunity Notice regarding geothermal energy demonstration projects lent itself ideally to the goals and objectives of Elko Heat Company. The company was selected as one of the 22 demonstration projects to be partially funded by the Department of Energy.

Project activity started in 1979 with an evaluation of the geothermal resource. Temperature gradient probes were drilled, a production drilling site was selected, and the well was drilled during the summer of 1981. The successful well was flow tested in the spring of 1982, and an open loop distribution system was installed to provide service to three users. System operation began in December 1982, and is continuing to provide satisfactory service.

3. GENERAL DESCRIPTION

The Elko, Nevada district heating project effectively utilizes a moderate temperature (177°F) resource from an 852 ft deep geothermal well to provide space and domestic water heating, and process water to three users; the Vogue Laundry, Henderson Bank, and the Stockmen's Motor Hotel. The open loop system effluent is disposed in an infiltration percolation pond combined with surface disposal into the Humboldt River. The project location is shown in Figure 13.1.

The project was developed in four phases. The first phase involved program startup and resource confirmation, including an environmental assessment, water rights permit procurement, shallow hole ground temperature surveys, electrical resistivity and magnetic surveys and gradient hole drilling and logging. Based on the results of these preliminary surveys, a production well was sited.

The second phase covered the conceptual and final design, including the design of surface facilities to handle the geothermal fluids including wellhead and disposal facilities, determination of flow requirements based on end users demand, and an evaluation of future requirements and flexibility for future expansion. After completion of the conceptual design phase and review by the U.S. Department of Energy and their subcontractors, the DOE notified Elko Heat Company to proceed with the detailed design. The final design phase consisted of the preparation of final design drawings and specifications and contract documents for the geothermal energy distribution system. During this phase, the three end users procured the services of engineering consultants to complete the final design of their building retrofit systems.

The third phase was project construction, consisting of the construction of the wellhead equipment, the disposal facility, and the geothermal energy distribution system. Although not directly a part of the project, the end users completed their building retrofitting during this phase.

Fig. 13.1 Location Map

The fourth and final phase involved system operation and performance evaluation consisting of evaluating the performance of the geothermal energy distribution system. This included monitoring all aspects of system operation from the wellhead to the disposal facility and incorporating this information in the final analysis of the technical and economic feasibility of the project. During this phase, an operation and maintenance manual was prepared for the geothermal energy distribution system.

There were no changes in the basic scope of the project during the duration of the project. The project was successful in demonstrating the technical and economic feasibility of utilizing a hydrothermal resource in a direct use application.

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

The initial user base was not large enough to warrant the substantial investment required to construct the system, but Elko Heat Company, recognizing the future expansion potential, was willing to subsidize system costs until additional customers could be added. Without federal funding, the project would not have been feasible. Establishing an adequate user base is very critical, and every effort should be expended to respond to the users' concerns over system reliability and efficiency, the ability to meet projected heating demands, and the energy cost savings.

Flow testing revealed leakage in the wellbore. Two lessons were learned from this testing: (a) when formation stability is marginal, open hole methods of well completion should not be used, and (b) special precautions should be taken in the design of wells which encounter artesian conditions. If the casing joints in the geothermal well are not properly sealed, the shut-in pressure of these wells can be enough to force geothermal fluids out of the wellbore into the formation, causing potential groundwater quality problems and possibly causing springs and/or seeps to develop in the vicinity of the well.

Unfortunately, many times during well drilling, it is necessary to commit to a completion plan before knowing that artesian conditions are to be encountered. In the case of Elko Heat Company, an attempt to save \$10,000 in initial well construction costs ended up costing \$75,000 in well repair work. The repair work was not an optimum solution to the problems, and caused a two-month delay in completing the project along with a risk of losing the well during the repair work.

Spinner logging is a valuable tool to be used to gain more knowledge about a completed well, and along with temperature logging, is a method of gaining more knowledge about the particular geothermal resource.

Selection of materials for the energy distribution system presented many unknowns. There was a lack of historical applications of materials

being used in the system. Manufacturers of one type of material were quite willing to provide reasons for not selecting materials manufactured by a competitor. Project engineers were knowledgeable in conventional water system design and had to rely on this knowledge to design the geothermal energy distribution system. Various metallic materials were corrosion tested to determine the rate of corrosion caused by the geothermal fluids. To derive maximum benefit from testing, test procedures should be designed to simulate actual operational conditions. Significant changes in rates of corrosion result from changes in fluid characteristics such as temperature, pressure, velocity, and turbulence. In addition, electrolysis can occur between different types of metallic piping and fittings in the system. The designer should consider the possible effects of exterior corrosion of buried piping and provide necessary protection. As more experience is gained in design and operation of geothermal energy distribution systems, materials selection will be better understood, which should result in reduced system costs and improved systems, which will result in lower operation and maintenance costs.

An insulated versus uninsulated piping system was one major decision that had to be made. The insulated pipe material typically cost 500% of uninsulated piping and installation is 50% more. A significant cost savings can result by utilizing uninsulated pipe. From studying temperature losses in the Elko Heat System, it appears that uninsulated pipe may provide acceptable service in many localities. Of course, this would be dependent on resource temperature, soils conditions, system flow rate, allowable losses, and proposed end use.

Securing the necessary permits and approvals to construct a geothermal energy distribution system is a lengthy process. This is a result of reviewing agencies being unfamiliar with this type of system. As these agencies gain experience, the time for review and approval of new projects should decrease. The permitting process requires immediate attention during the initial project phases so as not to proceed with the project and not have permits to operate. Permits of most significance in this project were water rights, disposal permits, and operational permits.

A number of lessons were learned regarding water rights.

1. Necessary permits containing acceptable terms should be acquired early in the project. In Nevada, a minimum of 120 days is required to process an application.
2. In attending public hearings and meetings involving water rights, one should be well prepared to present his case. These hearings have considerable influence on the outcome of the State's decision involving pending water rights.
3. Thorough acquaintance with the status of all water rights in the area of a project is needed, and if possible, sufficient testing should be conducted to determine if the proposed project will have any effect on existing rights.

From the standpoint of permits, the disposal system presented the most perplexing problem. This resulted in a number of disposal alternatives being evaluated, and the final decision was not made until late in the project. The disposal method decided upon was surface disposal. Because the fluid would not be returned to the same aquifer as originally planned, Elko Heat Company had to go through the entire water rights permitting process again. If this disposal alternative had been selected earlier in the project, duplication of the water right permitting process would have been avoided and a significant amount of time saved.

The budget for this project was continually changing. The project budget could not be accurately determined until the production well was completed and disposal alternative selected. It was necessary to modify the project on a number of occasions to remain within budget. Because of the variables involved in well drilling, this was the most difficult item to assign a budget cost figure. Other cost items could be estimated accurately once final design criteria were established.

5. THE RESOURCE

5.1 General

The geothermal resource in the Elko, Nevada area has been utilized on a limited basis for many years before this project. The resource is evident from surface expressions, such as the Elko Hot Hole and numerous springs and seeps. Thermal zones have been encountered while drilling for cold water. A spa was built in the late 1800s, and present uses include utilization of a spring at the former Elko County Home for the Aged, supplying domestic water for a number of residences, and a greenhouse operation using 140°F water from a shallow well near the Elko Hot Hole.

A report prepared by Geothermal Surveys, Inc. in 1977 indicated an anomalous trend of higher temperatures extending from a group of hot springs to the northeast beneath the city. This discovery encouraged further interest and led to the forming of the Elko Heat Company to develop the resource.

Geothermal Surveys, Inc. was retained to complete the resource assessment work for the project. Their work set forth the geologic setting in Elko, including geologic mapping and geothermometry of fluids from existing springs. Ground temperature surveys, consisting of an array of 95 holes drilled 10 ft deep, were conducted. Downhole temperature logging of existing wells, vertical resistivity surveys, and horizontal-loop electrical magnetic profiling were also performed. Four temperature gradient test holes were drilled, with site No. 3 being selected for the production well, which proved to be successful.

5.2 Geology

Intrusive igneous rocks and intermediate sediments underlie many of the mountain ranges in the northern part of the Humboldt River subbasin. Older Paleozoic formations predominate in the central and southern portions. The various mountain ranges are thought to be both Paleozoic

granite formations and Mesozoic outcrops and caps combined with Tertiary lava flows. The subbasin lies between two massive granite intrusive thrusts. The satellites of the great Sierra Nevada Batholith, occurring in the late Jurassic period, extend into the southwest portion of this subbasin and the Paleozoic and Triassic sediments. Another area of intense folding and granitic thrusting occurred in the Tertiary period, and extends into the eastern portion of the subbasin. Lava flows settled on the basin floors in the late Tertiary period. The Elko "Hot Hole," a hot spring in Elko, is remaining evidence of recent volcanic activity. In the Quaternary period, tilting and faulting of the mountain ranges and basins were accompanied by the deposition of deep limestones, clays, silts, and alluvial fans.

The rocks of the Elko area may be divided into three general groups: (a) the older rocks, Paleozoic limestones and quartzites which crop out in the River and Elko ranges; (b) Tertiary alluvial and lacustrine sediments with interbedded pyroclastic materials, which partially fill the basin between the two ranges, and Tertiary lavas which, in some parts of the area, are interbedded with, or rest upon, the Tertiary alluvial and lacustrine deposits; and (c) surficial Quaternary alluvial deposits which underlie the plain of the Humboldt River and the channels of its tributary drainage.

5.3 Well Drilling

The Elko Heat Company Production Well No. 1 was drilled in July and August 1981. During a long-term flow test conducted during April, May, and June 1982, problems with the well construction were discovered. These problems consisted of leakage at the casing lap (242 ft) and bridging in the open hole portion of the well. This necessitated moving a rig back on site to undertake a rework program to repair the problems. Figure 13.2 illustrates the original planned completion program versus the actual, and Figure 13.3 illustrates the planned rework program versus the actual completed rework program. Though the rework program was successful, it was very expensive and risked losing or damaging the well. The expense

Fig. 13.2 Production Well

Fig. 13.3 Production Well Rework

of the rework program was approximately \$70,000, which exceeded the cost of the original well. The low cost of the initial well drilling turned out to be no bargain in the long run.

The original well completion depth was 852 ft, and a natural artesian flow was produced without any stimulation. The flow rate at the time of completion was estimated at 800 gpm with a temperature of 180°F. The well had a shut-in pressure of over 50 psi. Flow testing confirmed that the well was capable of producing significant quantities of geothermal fluids for an extended period of time.

The Elko Heat Company production well was a "wildcat" well. The drilling was into an unknown area and there was no advance knowledge that artesian pressures in excess of 50 psi would be encountered.

Looking back on the initial production well drilling, it can be said that the design of the well completion program was based upon insufficient information. Because of this, the initial well was completed and had a leak in the wellbore at the 242 ft depth. The leak was introducing hot water into a shallow cold water aquifer. Had it not been discovered, this condition could have resulted in the warming of the cold water aquifer and/or the development of springs or seeps in the vicinity of the well.

5.4 Well Testing

The Elko Heat Company production well was flow tested twice. The first series of tests was in August 1981 immediately after drilling was completed. This test was done under the supervision of Energy Services, Inc. of Idaho Falls, Idaho. The second series of tests was conducted during April and May 1982 under the supervision of Chilton Engineering, Chartered.

Testing apparatus for the first tests consisted of an in-line orifice plate with differential pressure gages. This equipment was connected

either directly to a tee mounted on the wellhead or to the discharge head of the test pump (depending on whether an artesian flow test or a pumped flow test was being conducted).

During the pumped flow testing, a 1/4-in. copper "bubbler tube" was installed in the casing to a depth of 195 ft to measure drawdown in the well. A nitrogen cylinder and pressure gage were connected to the line to measure pressure in the wellbore at the 195 ft level during the pumping tests (nitrogen was used because it is an inert gas that will not react with the steel casing or elements contained in the fluids).

Water from the test was disposed of in existing ditches in the vicinity of the well. The ditch system was not capable of draining off all the water during the high rate pumping tests, and a flow rate reduction was required to avoid flooding in the area. Therefore, a sustained high flow test (860 gpm) was never completed.

In the second set of tests conducted in April and May 1982, 6 ft of 6-in. diameter steel discharge pipe were connected to approximately 1250 ft of 5-in. diameter aluminum irrigation pipe. A 3 1/2-in. diameter end orifice plate with a plastic manometer was installed on the 6-in. steel discharge pipe at the end of the line. A 6-in. diameter gate valve attached to the wellhead was used as a throttling device to maintain a constant discharge rate. After initial startup, occasional adjustments to this valve were necessary.

The aluminum irrigation pipe conveyed the water to a drainage channel which had sufficient capacity to dispose of the water. The water was eventually discharged into the Humboldt River approximately 3000 ft from the well. There was some concern that the exterior of the aluminum pipe might corrode where it contacted the ground. To avoid this problem, the pipe was placed on wood blocks to elevate it aboveground approximately 2 in. Even where it was not possible to elevate the pipe, no serious corrosion problems were noted.

The discharge arrangement for the second series of tests was selected for two reasons: (a) the water would be conveyed to an undeveloped portion of the city rather than a highly developed area; and (b) the well-defined drainage system provided sufficient capacity to dispose of the water over a long test. Disposal of the fluids was an important consideration because a long-duration, 30-day flow test was planned.

From the drawdown tests of August 1981, an 800-gpm design level for future demands was established. The tests of April and May 1982 confirmed that the resource could produce the design flows (400 gpm) over a period of time, without being pumped.

Monitoring of geothermal surface expressions in the area showed that the Elko Heat Company Production Well 1 has no effect on them. Although the source of geothermal fluid might possibly be the same, no sign of interference or communication was noted during the long-term flow test.

6. THE ENERGY EXTRACTION AND USE SYSTEM

A schematic diagram of the wellhead configuration is shown in Figure 13.4. A four-way tee provides artesian, pumped, and relief flow functions. The top of the tee serves as the mounting base for the pump discharge head. The lower branch provides the outlet for system flow under artesian conditions and the relief branch provides a means to eliminate pressure during maintenance of the wellhead facilities or when working on the pump.

The production well had a shut-in pressure of 56 psi and sufficient artesian pressure was available to operate the system without pumping except during periods of peak flows. During periods of peak demand, when flows exceed 400 gpm, it is necessary to boost the wellhead pressure by pumping. A line shaft turbine pump was installed at the 60-ft level in the well.

The Elko Heat Company selected a two-pipe distribution and disposal system (Figure 13.5). The design of the system is very nearly identical to a conventional water distribution system, in which each user removes the fluids needed from the system on a demand basis.

An insulated Temptite supply pipeline conveys the geothermal fluids to the end users. The end user withdraws fluids from the supply pipeline and extracts heat or uses the fluid consumptively within the user's building. If only heat is extracted, the user disposes of the fluids into an uninsulated return pipeline, and Elko Heat Company is responsible for the ultimate disposal of the spent geothermal fluids.

Elko Heat Company is responsible for supplying the hot water to each user, and users are responsible for designing their application system. The design and retrofitting of the user systems was not included in the agreement. Each user is using the water as follows:

Fig. 13.4 Wellhead Equipment and Piping

Fig. 13.5 Open-Loop Distribution System

- o The Stockmen's Motor Hotel uses the geothermal water to heat the water used in the motel and casino operations via heat exchangers. The existing steam boilers, coupled with a heat exchanger, provide backup service if the geothermal system fails.
- o The Vogue Laundry uses the geothermal water for washing linen products. The geothermal fluids are softened by a zeolyte water softener. Space heating is provided by directly running untreated geothermal fluids through existing fan coils.
- o The Henderson Bank Building uses the geothermal fluids to heat water for domestic use via a heat exchanger and also uses untreated geothermal fluids directly for space heating through the building's cast iron radiators.

Elko Heat Company selected infiltration/evaporation as the method of disposal. Cooperative agreement funds were not used to construct the disposal system. After the end users extract the heat from the geothermal fluids, the water is discharged into the return line and conveyed to the percolation/evaporation disposal pond which is located on city land adjacent to the Humboldt River. The pond is sized to dispose of 500 gpm continuous flows (design flow). The surface area of the disposal pond is approximately 1.5 acres, and the total area of the disposal facility is 2.5 acres.

The perimeter of the disposal facility is fenced with a 6-ft high chain link fence, with a 3-wire anticlimb device. Within the fenced area is a small wood frame building housing the return line pressure sustaining valving and various other valves and fittings.

Because of the relatively good quality of the fluids, there were no associated environmental problems. Since the waters were not being introduced into a groundwater aquifer, no state or federal permits were required.

The storage of water in the infiltration/evaporation pond allows for the water to be withdrawn for other uses, such as irrigation by the city. The City of Elko agreed to allow Elko Heat Company to use approximately 2.5 acres of their land on which to build the pond if the city could have the right to use the spent fluids. Elko Heat Company agreed to allow the city to use the water for irrigation, but retained the right to the thermal properties of these fluids.

Postconstruction modification to the geothermal transmission and distribution systems consisted of replacing screw-type fittings that began leaking. These fittings were buried, and mechanical-type couplings were used in lieu of the originally installed screw-type fittings where possible. In addition, the air release valves on the supply line (2 of 3 valves) had to be shut down to stop corrosion on the nipples connecting these valves to the pipeline. Other than the above, no other transmission and distribution system modifications have been made.

A number of the problems that occurred shortly after the system was started can be attributed to the recently completed construction. A certain time for getting the "bugs" out of a newly constructed system should be expected. No major problems have occurred. A number of minor problems were experienced which required operator attention. Of the six problems experienced, five were associated with leaking screw-type fittings. These five leaks were a result of crevice corrosion and possibly stress-related corrosion. This type of problem can be avoided by eliminating screw-type fittings in the system.

Other than normal inspection of the system and routine operation of various valves (exercising), no operational and maintenance requirements have been found.

7. INSTRUMENTATION AND CONTROLS

The only production system control is a Mercoid pressure switch which is used to control starting and stopping the pump. The pressure switch is adjustable; the pump starts when the system pressure drops to 35 psi and stops when the pressure reaches 85 psi. Time delays are provided on the starting and stopping features to ensure that a sustained pressure signal is being received, which prevents unnecessary cycling of the pump.

Energy monitoring consists of measuring flow, temperature, and pressure at the wellhead. A 24-h circular chart recorder continuously records temperature flow and pressure. A mechanical register totalizes flow.

The only environmental control in the wellhead building is a thermostatically controlled exhaust fan, which maintains a maximum temperature of 90°F. A frame structure houses the disposal control system (Figure 13.6). Pressure regulating and pressure sustaining valves are provided. Gate valves were added for maintenance and flow control. Provisions are provided to bypass the pressure sustaining valve in the event that replacement or repairs are needed.

Fig. 13.6 Disposal Pond Control Piping

8. ALTERNATE CONSIDERATIONS

Two pumping alternatives were considered: (a) a pump installed in the wellbore and (b) a pump installed at the surface.

It was decided that the pump in the wellbore was desirable from the standpoint that higher suction pressure would result and this would minimize scaling problems.

The two types of pumps considered for installation in the wellbore were a line shaft turbine and a submersible pump. Because of a number of reported problems with an electric motor on submersible pumps installed in geothermal wells, a line shaft turbine pump was selected. The relatively shallow setting (60 ft), required for this application also supported the selection of a line shaft turbine pump.

An adjustable speed drive was also considered for the line shaft turbine to provide constant system pressure under pumped conditions and to eliminate surges when turning the pump on and off. Because of funding limitations, the adjustable speed drive was eliminated from the final design.

Six geothermal fluids disposal methods were evaluated: (a) reinjection to the geothermal aquifer, (b) disposal through an infiltration/evaporation system, (c) discharge to the City of Elko sanitary sewer system, (d) surface disposal to the Humboldt River, (e) reuse as potable water, and (f) reuse for agricultural purposes. The final selection, made late in the project, was disposal through an infiltration/evaporation system. This choice was made because of the good quality of the geothermal fluid, simplicity, low expense, and environmental acceptability. No major operational or maintenance expenses are associated with the selected surface disposal system.

Open and closed loop transmission systems were considered, and the open loop system was selected. This choice was made on the basis of

simplified operation and maintenance, lower initial capital cost, flexibility for expansion, more efficient geothermal fluid use at the Vogue Laundry, and allowing for charging on the basis of gallons used.

Insulated pipe (Temptite) was selected over noninsulated pipe. However, temperature losses in the Elko system indicate that the much less expensive uninsulated pipe could be acceptable in many localities, depending on local conditions.

9. SYSTEM OPERATION

The transmission system has been in service for approximately 13 months and no major problems have occurred. A number of minor system problems have occurred that are primarily related to leakage of screw-type fittings, which were corrected by retightening after the system heated up. The transmission system consists of a dual pipe system with an 8-in. insulated pipeline and an 8-in. uninsulated return pipeline. The pipeline is presently transporting water from the wellhead at a temperature of approximately 177°F. The delivery temperature to the last user on the line, at normal flow rates, is above 170°F. Under high flow conditions, this temperature is above 175°F. There are no significant losses of temperature of the fluid in the approximately 4000 ft of pipeline.

There is some concern regarding the corrosion of the exterior of steel fittings and valves in the system. A significant amount of exterior corrosion has been noticed on these steel fittings. This is probably a result of the high temperature of the fittings accelerating the normal soil corrosion process. These fittings have all been coated, but the corrosion problem still exists and appears to be faster than initially anticipated.

To date, all application systems installed have functioned satisfactorily. There have been no problems meeting peak heating demand loads and all planned building requirements have been met 100% of the time with no need to resort to a supplemental source of heat or energy. The end users are extracting approximately 30° out of the geothermal fluids. This results in 250,000 Btus being extracted from each 100,000 gal furnished the user. The Vogue Laundry, which is using most of its fluids directly for washing, is obtaining the most benefit of the energy contained in the geothermal fluids. Before using geothermal energy, the laundry was required to heat 65° water to 175°F. The geothermal system eliminates the need for heating this water and replaces previously used city water with geothermal fluids that are used directly in the linen washing process.

Spent geothermal fluids have been disposed of in the Elko Heat Company disposal pond since the system started operation in December 1982. About two months after the initial system startup, the pond filled and began overflowing. The overflow then discharged to the Humboldt River. The overflow was initially attributed to the high groundwater table present in the area due to a very wet winter and high flows in the Humboldt River. Excavation at the pond site later revealed a very hard impervious layer of cemented sands at a depth of 16 ft that restricts the pond's percolation capability. This layer was not discovered during the initial testing done at the disposal facility.

10. SYSTEM COSTS, SCHEDULE, AND ORGANIZATION

10.1 General

The project was jointly funded by Elko Heat Company and the U.S. Department of Energy under its PON program. The total project cost, \$1,398,269, was broken down \$827,504 (DOE), \$289,765 (Elko Heat Company) and \$281,000 (three end users).

The project financing was structured such that the DOE funded the entire front-end cost for the high risk items, with Elko Heat Company's cost share increasing as it appeared the project would be successful and the three end users would be entirely responsible for funding the cost of retrofitting their buildings. Actual project costs by phase and task are shown in Table 13.1.

10.2 Operating Costs and Revenues

The total annual operating costs for the Elko Heat Company system is about \$21,000. This is generated out of revenues generated from user charges that amount to approximately \$65,000 annually. The customers are billed on a flat rate basis or at a metered rate. The rates are about 50% of natural gas costs. At present capacity, the simple payback period for the system is 25.6 years. Capacity operation would reduce this to 11.4 years.

10.3 Schedule

The project was broken down into four phases: resource confirmation, design, construction, and completion. For the most part, a phase was completed before initiating the next. Water rights permitting was the only serious delaying factor. The original and revised project schedule is shown in Figure 13.7.

TABLE 13.1. SUMMARY OF PROJECT COSTS BY PHASE AND TASK

PHASE	TASK	US DOE	ELKO HEAT CO.	OTHER	TOTAL
I	1. Environmental Report	12,236	0	0	12,236
	2. Resource Assessment	169,739	0	0	169,739
	3. Production Well Drilling	166,314	0	0	166,314
II	4. Conceptual Design	58,036	0	0	58,036
	5. Final Design	91,219	0	0	91,219
	6. Special Testing and Evaluation	0	4,579	0	4,579
III	7. Construction Management	47,540	0	0	47,540
	8. Pump House and Production Well Equipping	34,082	12,414	0	46,496
	9. Distribution System	235,756	84,539	0	320,295
	10. Effluent Disposal System	0	34,255	0	34,255
	11. Land Purchase and Easements	0	33,224	0	33,244
	12. Project Legal, Permits, Etc.	0	115,815	0	115,815
	13. Building Retrofitting	0	0	281,000	281,000
IV	14. Project Monitoring and Evaluation	12,582	4,939	0	17,521
		827,504	289,765	281,000	1,398,269

Fig. 13.7 Project Schedule

10.4 Project Organization

The project team (Figure 13.8) responsible for carrying out the various projects' tasks consisted of Elko Heat Company serving as the prime contractor; Chilton Engineering, Chartered, of Elko, Nevada, was the subcontractor responsible for overall project management and civil and mechanical engineering design; and Geothermal Surveys, Inc., Pasadena, California, was responsible for resource evaluation. Energy Services, Inc., was responsible for production well design and drilling supervision.

The well drilling contractor was Billings Drilling Company from Salt Lake City, Utah. The pipeline system was installed by Owyhee Construction, Inc., Boise, Idaho, and the wellhead and disposal facilities were constructed by Canyon Construction Co., Elko, Nevada.

Other consultants involved in the project included Earth Science Consultants, Reno, Nevada (soils and foundation investigations) and Therma Source, Inc., Santa Rosa, California (drilling supervision for production well rework).

PRIME CONTRACTOR
ELKO HEAT COMPANY
MR. JAMES H. MEES
PRESIDENT & PROGRAM MANAGER

US DEPARTMENT OF ENERGY
IDAHO OPERATIONS
EG&G IDAHO, INC.

PROJECT ENGINEERS
AND MANAGERS
CHILTON ENGINEERING
IRA S. RACKLEY
Resource Assessment
& Production Well Drilling
MICHAEL W. LATTIN
System Construction, Fabrication
Monitoring & Evaluation

ENVIRONMENTAL
REPORT

Sheldon S. Gordon

RESOURCE
ASSESSMENT

GSI, Mr. Joe Birman

PRODUCTION
WELL DRILLING

Energy Services, Inc.
Ray Gould

TSI, Inc.
Louis Capuano

ENGINEERING
DESIGN

Sheldon S. Gordon
Robert Hoppe
David Powell

CONSTRUCTION

Robert Hoppe

PIPELINE

Owyhee Construction

CONSTRUCTION

WELL HEAD EQUIPPING &
DISPOSAL FACILITIES

Canyon Construction

WELL DRILLING &
REWORK PROGRAM

Billings Drilling

Fig. 13.8 Project Organizations

11. LEGAL AND INSTITUTIONAL CONSIDERATIONS

11.1 Environmental

An environmental impact study, completed in May 1979, concluded that there would be no adverse effects from development of the geothermal resource. Actual drilling of the well and construction of the transmission line appears to have validated that conclusion on a near term basis.

11.2 Legal and Institutional Considerations

11.2.1 Private

The development of a geothermal energy district heating system was something relatively new and unique in Nevada, and especially the City of Elko. Because of the type of project, it generated interest and cooperation from the various agencies involved. On the other hand, these agencies had no or very little experience regarding this type of project and they moved rather slowly in some cases during review and permitting.

Elko Heat Company was primarily involved in securing necessary land and rights-of-way to construct the system. This included access to sites of test holes, land for production well drilling, and various rights-of-way to cross properties owned by the Southern Pacific Transportation Company and Western Pacific Railroad.

11.2.2 City

The City of Elko played an important role in the Elko Heat Company project. They were actively involved in the development of alternative plans for disposing of spent geothermal fluids. The City also had control of the streets in which the majority of the distribution system pipeline would be installed.

The City owns and operates the local water system which relies exclusively on deep wells in the local area to supply this system. When they became aware that large quantities of geothermal fluids were going to be extracted they became very concerned about potential effects on the community wells, especially through reinjection. The City of Elko and Elko Heat Company entered into a mutually beneficial agreement, and the successful completion of the project is attributed largely to the resulting cooperation.

11.2.3 County

Since the Elko Heat Company project was constructed entirely within the Elko city limits, the county was not directly involved. It was found advantageous to keep county officials informed as to the project status, especially since they had a water right on a geothermal spring within 1 mile of the Elko Heat Company production well site.

11.2.4 State

The state was involved in the Elko Heat Company project primarily in three areas: (a) water rights, which are controlled by the Office of the State Engineer, (b) surface water discharge permits issued by the Nevada Department of Environmental Protection, and (c) utility regulations, which come under the jurisdiction of the Nevada Public Service Commission.

Drilling and operation of geothermal wells is permitted under regulations administered by the State Engineer's Office. The Elko groundwater basin is a "designated basin," and under State statutes, no drilling other than domestic wells is allowed without a permit issued by the State Engineer.

11.2.5 Federal

The Elko Heat Company project is not on federal lands and no federal permits were required.

12. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and the figures contained in this report are excerpted from the project final report prepared by Chilton Engineering. Appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. Chilton Engineering, Chartered, Direct Use of Geothermal Energy; Elko, Nevada District Heating Final Report March 1979-June 1983, Report No. DOE/ET/27033-6, Cooperative Agreement No. DE-AC07-79ET27033, June 1983.
2. Geothermal Surveys, Inc., Phase I-Resource Assessment, Geological and Geophysical Surveys, November 16, 1979.
3. Energy Services, Inc., Elko Heat Company Geothermal Well Testing, August 1981.
4. Chilton Engineering, Chartered, Field Experiments for Direct Uses of Geothermal Energy, Elko, Nevada, Conceptual Design Report, November 25, 1980.
5. Ibid, Field Experiments for Direct Uses of Geothermal Energy, Final Design Report, March 1982.
- *6. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *7. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

PAGOSA SPRINGS PROJECT

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1. PON PROJECT SUMMARY

Project Title: Pagosa Springs Geothermal District Heating

Project Data:

Project Description: This project demonstrates the feasibility of utilizing a moderate temperature (131 to 149°F) resource to provide district heating in the town of Pagosa Springs, Colorado.

Location: Pagosa Springs, Colorado

Peak Heat Load: 9.1 million Btu/h

Annual Heat Load: 23.2 billion Btu/yr (29% load factor)

Simple Payback: 20 yr

Status: The project is operating satisfactorily. Resolution of water right remains to be finalized. This is needed to obtain more customers to improve the revenue stream.

Cooperative Agreement Data:

Number: DE-FC07-79ET27030

Period: March 23, 1979 to April 30, 1986

DOE Share: \$1,213,000 (82%)

Participant Share: \$274,620 (18%)

Total Cost: \$1,487,620

Principal Investigator:

Joe Dan Martinez
Manager Water Department
(Previously Ronald Backus, Worthe Crouse, Bill Ray and Fred Eberling)
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2. PROJECT HISTORY

Natural hot waters have been used since the early 1800s in the Pagosa Springs area, which is located in the San Juan Basin in the southwestern Colorado mountains (Figure 14.1). First used for medicinal and religious purposes by the Indians, the geothermal resources were drilled into between 1900 and 1910 for natural hot water heating. There are 30 known hot wells in Pagosa Springs; about 13 of these were being used before the PON project was initiated. The town of Pagosa Springs, Archuleta County, and Archuleta School District Joint-50 officials applied for, and received, a DOE cost-shared PON cooperative agreement in June, 1979. Subsequently, the resource was evaluated, new production wells were drilled, the system developed, and service was initiated during the 1982-1983 winter season for public sector buildings; additional service was provided to school buildings and the private sector in the 1983-1984 winter season. Significant efforts have been and are being spent to establish adjudicated water rights for the production wells under Colorado water law. Two heating seasons, operating under a temporary permit, have proven to be trouble free and effective, except for metering inadequacies that resulted in revenue losses.

Fig. 14.1 Location Map

3. GENERAL DESCRIPTION

The Pagosa Springs geothermal district heating project involved an assessment of the hydrological regime and the production characteristics of the Pagosa Springs Reservoir, drilling three production wells (one of which had inadequate flow and temperature), and constructing a distribution system. One well is capable of producing 600 gpm of 131°F fluid, and the other 1,200 gpm at 149°F. Water quality is good with TDS levels of about 3000 mg/L. The geothermal water is pumped through a plate type heat exchanger and subsequently discharged into the nearby San Juan River. The clean heated city water is circulated in two closed loops (Figure 14.2) by means of one to four pumps, depending on user demand. The heated water is provided through a flow control valve to each user who is responsible for the design and installation of their own heating system.

fig. 14.2 Site Map with Piping Loops

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

The Pagosa Springs geothermal district heating PON project satisfactorily demonstrates the technical and economic feasibility of utilizing a moderate temperature (131 to 149°F) resource. The constructed system effectively provides space heating for diverse customers of both the public and private sectors in a harsh winter-mountain environment where outdoor temperatures are as low as -40°F.

Simplicity of design is important to trouble free operation and acceptance of the operators. The system is not complex, but rather is similar in nature to typical water supply systems. Primarily, manual controls are used, and although system efficiencies would improve with automation, system reliability, performance, and operator acceptance verify the need for system simplicity. However, when system flows increase to the point that higher efficiencies are needed to preserve reservoir capacity, automation will have to be added.

The need for strong supporters for the installation and use of the geothermal systems was strongly proven at Pagosa Springs. Concerns over water rights required constant interfacing among town project personnel, other users, regulating agencies, and technical support groups. System acceptance and water rights are being positively resolved because of this effort.

Process design and materials selection should consider geothermal water quality for long term, trouble free system operation. These and other factors that result in system reliability are keys to customer acceptance.

Predicting the existence, type, and extent of geothermal resources without actual drilling is not reliable even in close proximity to existing wells.

Drilling geothermal wells, particularly artesian wells, presents problems not encountered in usual water well drilling because of the effects of temperature, pressure, and geologic substrata associated with geothermal conditions.

The water rights issue is highly visible and extremely important to the public. Since geothermal energy is a developing energy source with new implications for water use patterns, the regulatory authority governing water permitting has not always been clearly identified. Rigorous efforts should be expended to ensure the successful and timely resolution of permitting issues.

Keeping state agencies and local government bodies informed on the progress of the project, and particularly about well drilling, is of great value in assisting various permitting and approval requirements. This also applies to the public to promote acceptance and minimize the effects of wrong information and rumors.

Many of the laws and regulations pertaining to geothermal are new and leave many holes regarding their interpretation. It is necessary to plan on spending more time than initially anticipated in dealing with these issues. Precedents have not been set for all these new laws.

If possible, a local contractor with interest in the project should be used. Since a local contractor's reputation will be under close scrutiny, it is likely he will do a better job. Background checks should be made on all contractors by contacting the owner of their two or three most recent jobs. Past reputation may not always be accurate.

Additional light industrial, year-around process heat utilization would substantially improve the economics of the overall system since geothermal systems are capital intensive.

5. THE RESOURCE

5.1 General

The geothermal resource has been analyzed extensively over the past 50 yr, financed primarily through government projects and university research programs. Detailed geologic studies, electric resistivity studies, shallow temperature gradient hole drilling, chemical analysis, and modeling have been conducted. DOE funding to the Colorado Geologic Survey resulted in the drilling of two exploratory wells, and hydrogeologic studies were performed before this project.

5.2 Geology

The town of Pagosa Springs is located within the San Juan Basin that is bounded to the north and east by the San Juan Mountains of volcanic and sedimentary origin. The geology of Pagosa Springs is characterized by outcrops of Mancos Shale and Dakota Sandstone dipping to the northeast at 46 to 50 degrees. The dipping sedimentary units are the result of the Archuleta Anticlinorium, a regional tectonic feature west of Pagosa Springs. At the crest of the anticlinorium are smaller anticlinal features that alter the regional dip. Two miles southwest of Pagosa Springs is an extension of the Nacimiento Fault zone which trends from north-central New Mexico into the San Juan Basin. Locally, the Nacimiento Fault uplifts the Dakota Sandstone into contact with the younger Mancos Shale. There are several smaller faults splaying in a northerly direction from the Nacimiento Fault. Between 1300 and 1500 ft of Upper Cretaceous to Upper Triassic sediment rests unconformably on Precambrian igneous and metamorphic rocks.

Geothermal resources at Pagosa Springs are known to exist by surface manifestations and hot water wells throughout the area. These hot wells have been used since the early 1900s to heat commercial businesses and public buildings, melt snow and deice streets, and for aesthetic tourism purposes. Temperatures of these wells range from 93 to 153°F, with most wells averaging 131°F. Depths of the hot wells range from 85 to 468 ft, with an average depth being 300 to 400 ft. All hot wells produce from

either the Dakota Sandstone or the Mancos Shale which dip to the northeast. Because of this natural dip, wells in the eastern portions of town are much deeper than those to the southwest. Dipping Dakota Sandstone is capped by impermeable Mancos Shale. This causes artesian flow in all hot wells in Pagosa Springs.

5.3 Well Drilling

Hydrological testing was performed as part of this project to help determine aquifer transmissivity, permeability, storage coefficient and other characteristics. The findings showed that new production wells would be required and existing wells could not be used. Drill sites were selected at locations that would penetrate the Dakota sandstone for flows at depths of 250 to 300 ft. In the summer of 1980, the first well, PS-3, (Figure 14.3; PS-5 is similar) was drilled, producing 600 gpm artesian at 131°F from a total depth of 300 ft. PS-4 well, drilled to 299 ft, did not provide adequate flow and was abandoned. The third well, PS-5, was drilled to a depth of 274 ft and produced 1200 gpm at 149°F, making it the hottest and largest-flowing well in the Pagosa Springs area. Considerable drilling difficulty was experienced in drilling 26-in. diameter holes into large amounts of river gravels and boulders.

5.4 Well Testing

Well testing involved 12- and 72-h flow tests at each of the two production wells, and a 7-day multiwell flow test. Short-term flow tests were conducted in both production zones; immediate pressure reductions were noted in nearby observation wells and the Pagosa Hot Spring when flow occurred from the upper (Mancos Shale) zone. Testing was therefore stopped, and drilling was continued into the lower (Dakota Sandstone) zone. Temperature measurements remained relatively constant. Extrapolated estimates of pressure reductions indicate that wells PS-3 and PS-5 could be flowed at 200 and 700 gpm, respectively, for about 50 yr without having to install a pump at either well.

Fig. 14.3 Production Well PS-3

Additional testing was performed during 1983 and 1984 to obtain operational data, for water rights purposes, and to better understand the effect of this project on nearby wells. No adverse conditions were observed, but the water rights issue has not been finalized at the time of issuance of this report.

6. THE ENERGY EXTRACTION AND USE SYSTEMS

6.1 General

The production system includes the production wells, well piping and valving, well pumps, and controls. The wellhead assembly for Wells PS-3 and PS-5 are shown in Figure 14.4. The well pumps pump the artesian untreated geothermal fluid to a control building that houses a plate type heat exchanger, through the exchanger, and on to the San Juan River for disposal. (In the case of Pagosa Springs, the preferred alternative is surface disposal.) The flow is controlled by the discharge temperature of the closed loop water.

The closed loop distribution system includes two independent loops, one for the east side of town and the other for the west side, to provide a safety factor in the event of a pipeline breakage. The east loop is designed to carry 1350 gpm. The west loop is designed for 1000 gpm; however, initially, it carries only 500 gpm. This is to permit future expansion of the distribution system into the growth areas of Pagosa Springs.

The clean heated city water is circulated in two closed loops by means of two pumps, depending on user demand. Each of the loops consists of large diameter, 6- to 10-in., concrete asbestos pipe, referred to as trunklines, and smaller diameter service pipes carrying the water to the individual users. Two parallel trunklines are in each loop. An insulated supply trunkline carries the heated circulating water, and an uninsulated return trunkline directs the cooled circulating water back to the heat exchanger. At the terminal point of the supply line in each loop there are flow control valves to ensure that a minimal amount of hot water is being circulated at all times. The circulating water is collected in the return trunkline and then routed to the heat exchangers where the process is repeated.

Fig. 14.4 Wells PS-3 and PS-5 Wellhead Assembly

6.2 Control

The distribution system operates over a broad range of conditions that fluctuate daily as well as seasonally. The main intent of the control system is to minimize both the operating costs and manpower requirements to operate the system. The control scheme regulates the circulating pumps, the number of heat exchangers in operation (only one is installed at present), flow from the geothermal wells, and temperature of the circulating water leaving the heat exchangers. The system schematic presented in Figure 14.5 shows four circulating pumps. However, only two are currently installed. These two are operated based on user demand plus 150 gpm, which continuously circulate hot city water through the piping system.

6.3 Application (User) Systems

The project personnel did not actively participate in the design of the residential, commercial, and public sector users systems. This was performed by each individual customer. Conceptual reviews of user system designs were performed and cost estimates for these systems were then developed. However, this was performed only for public buildings because of funding limitations. A 20°F temperature drop was assumed for all users.

User system control consists of two block valves, one each on the supply and return pipelines. This allows isolation of home heating systems for any routine maintenance or servicing. A constant-flow valve assures a uniform flow entering the home. A water meter (not shown in Figure 14.5) measures usage. The thermostatic controller operate a solenoid valve that controls the flow of hot water into the house.

Fig. 14.5 System Schematic

7. ALTERNATE CONSIDERATIONS

Drilling of new production wells was chosen over using existing wells after the options were evaluated.

Consideration was given to utilizing the geothermal fluids directly because the water quality was relatively high. However, the corrosive effect of H_2S present in the fluids on copper components found in most user's systems necessitated the use of isolation loops using a plate type heat exchanger. User acceptance was also enhanced through the isolated loop approach.

Substantial system cost escalation forced a reduction in the system service area, mostly eliminating residential services. Because of funding limitations, the completed system has one heat exchanger and two primary circulating pumps as compared to the original plan to install two heat exchangers and four pumps.

Two producing wells are available for the system, but for reasons unknown, Well PS-3 has never been connected to the system. Therefore, there is no operating backup for the other production Well (PS-5). The original design called for a remotely located microcomputer to monitor and control temperature, pressure, and flow. Due to budget restraints, this was not installed, and the monitoring and control functions are being performed manually. Flow control is manual, rather than through an automatic control valve, also due to economic restraints. Performance has been reliable, but not as efficient.

8. SYSTEM OPERATION

Geothermal fluid production has been maintained without interruption during two heating seasons since production startup and acceptance testing in the fall of 1981. Only minor difficulties have been experienced. A split casing centrifugal production pump experienced vibrational problems after about six months operation. The pump was taken out of service and repaired under contract warranty. The reservoir artesian flow from well PS-5 is sufficient to meet all system heat energy requirements and the pump has not been reinstalled into the system.

Systems controls were not installed according to specifications, and system efficiency, defined as the Btus of heat energy extracted per pound of water, has been variable. System efficiency for extracting heat is an important factor when considering long-term reservoir life. However, operator satisfaction for the system is high and no unusual or difficult operating or maintenance problems have surfaced.

The geothermal distribution system has performed very well and without significant problems during the two heating seasons. Several operational problems were noted during initial startup and acceptance testing in late 1981. The first problem related to construction techniques used in laying the trunkline distribution piping. The trunkline piping is of large-diameter asbestos-cement construction; large O-rings provide the seal between the pipe sections. During construction, some of the O-rings either were damaged or were not sealed properly due to "stabbing methods" used to bring the pipe sections together. The resulting poor seal was soon apparent in the pressurized pipeline testing, when high leakage was immediately noted. The contractor was required to identify and correct the faulty joints prior to system acceptance.

A second problem related to pressure fluctuations in the system was noted during the first-year operation of the system. During initial operations, pressure gages recorded a continual upward creep in the distribution and collection system pressures. Ultimately, the pressure relief valves, which are preset at 150 psi, activated automatically for system protection. Review of the problem, coupled with field inspection, indicated that control valves had not been installed in the flow lines between the supply and return line. This problem has been solved and the system is no longer experiencing operational difficulties.

The system has mechanically performed very well during initial heating seasons. No significant operation problems have been experienced in the pipes, pumps, and heat exchanger systems. The 316 stainless steel heat exchanger has performed well, with approach temperatures consistent with design specifications. The system has not been taken from service and inspected for presence of scale; however, the good operation indicates that scale is not significant. The manual control systems have operated without difficulty, but the lack of automatic controls has caused reduced operating efficiencies.

9. SYSTEM COSTS, SCHEDULE, AND ORGANIZATION

The construction costs for the Pagosa Springs geothermal PON project are presented in Table 14.1. These include the reservoir evaluation and well drilling costs, and the 1981-1982 transmission, distribution, and disposal system costs. Costs related to establishing adjudicated water rights and all other permitting costs are also included. Complete and final system costs are not available as of the report date due to ongoing program activities related to water-rights issues and minor equipment additions and changes. Total program costs as of June 1984 were \$1,487,620.

Operating and Maintenance (O&M) costs include those related to electric power, labor, and repair or replacement of materials. System power costs are primarily related to pumping requirements. Since the production wells are artesian, the pumping costs are solely distribution pumping costs. These are billed on a demand basis and have averaged approximately \$660 per month. Negotiations are in progress to change the billing basis to a kilowatt hour consumption basis.

Rigorous system economic evaluations were not performed by the town during the project duration. Capital cost, anticipated revenues, and anticipated O&M costs are presented in Table 14.2.

The generalized project schedule is shown in Figure 14.6. The project organization is presented in Figure 14.7.

TABLE 14.1. PAGOSA SPRINGS GEOTHERMAL PROGRAM COSTS AS OF JUNE 1984

1.	Resource Assessment and Preliminary Design		
	Feasibility Study and Conceptual Design	\$ 33,000	
	Permitting	59,900	
	Geological and Geophysical Survey	10,000	
	Environmental Report	<u>3,880</u>	
	TOTALS		\$ 107,780
2.	Production Well Costs		
	Tangible	\$ 28,526	
	Intangible	<u>262,306</u>	
	TOTALS		\$ 290,832
3.	System Final Design and Construction		
	Final Design and Bidding	\$ 70,412	
	Construction	<u>929,568</u>	
	TOTALS		\$ 999,980
4.	G&A Expenses		\$ 40,000
5.	DOE Program Costs, Publicity, Technology Transfer, Reporting		\$ 40,028
6.	Pagosa Springs School System and Municipal Building Retrofit Assistance		\$ <u>10,000</u>
	JUNE 1984--TOTAL PROGRAM COSTS		\$1,487,620

TABLE 14.2. SYSTEM ECONOMICS COST SUMMARIES

Total Project Cost	\$1,487,620
Anticipated Annual Revenues	120,710
Anticipated Annual O&M Costs	27,600
Annual Net Revenues ^a	93,110

a. Debt service is not a listed expense since all capital construction was accomplished through grant money.

WORK SCHEDULE											
TASK DESCRIPTION	1979	1980	1981	1982	1983	1984					
PHASE I											
1. Environmental Assessment	—										
2. Resource Assessment, Hydrological Analysis and Testing	—	—									
3. Public Meetings, Homeowner and Business Survey	—	—									
4. Preliminary Engineering Design and Cost Estimate	—	—									
5. Economic Pricing Evaluation		—									
6. Water Rights Evaluation	—	—									
PHASE II											
1. Production Well Drilling and Completion		—									
2. Production Well Testing and Assessment		—	—								
3. Final Engineering Design, Cost Estimating, and Economic Analysis		—									
4. Bid Document Issuance			—								
5. Environmental Permitting and Water Rights Applications		—	—	—	—						
PHASE III											
1. Transmission, Distribution and Disposal System Construction			—	—							
2. User Adaptation/Retrofit of Schools and Public Buildings			—	—							
3. Methodist Church System Expansion			—	—	—						
4. Startup and Acceptance Testing			—	—							
PHASE IV											
1. System Performance Evaluation and Water Rights Testing				—	—	—					
2. Public Awareness and Education	—	—	—	—	—	—					
3. Final Report						—	—	—			

Fig. 14.6 Project Schedule

Fig. 14.7 Project Organization

10. LEGAL AND INSTITUTIONAL CONSIDERATIONS

An environmental assessment of the impacts of establishing a geothermal district heating system at Pagosa Springs was completed in 1979 by Coury and Associates, Inc. This study concluded that the impacts resulting from such a system would be minimal and that any specific issues of concern could be reasonably mitigated.

Subsequent to the geothermal resource assessment performed in 1979 and 1980, two production wells to supply the district heating system were drilled and completed. No significant new environmental impacts were experienced as a result of this project requirement.

The cooled fluids that are discharged into the San Juan River are comparable in quality and quantity to previous discharges. The Colorado Department of Health, Water Quality Control Division, approved the surface discharge into the river option and did not require a formal NPDES discharge permit.

The impact of the new production wells on nearby existing wells became a visible and public issue in later project stages. All water-property rights of those well owners have been protected and adjudication procedures for rights from the new wells are in progress.

The overall water rights issue is a complex, visible issue, especially in the arid Western United States, and professional, legal and engineering consultation is recommended at all project stages. Legal issues relating to reservoir modeling and testing, utilization of water rights from existing wells, historical beneficial use of adjudicated flows from existing wells and transference of rights to new wells all played a role in the denial of the permanent production permits for the Pagosa system. Throughout the course of the project development, Pagosa Springs town management, along with the engineer's consultant team, continuously communicated with state officials. At one point, verbal production approval was given to town officials. At various times, lack of definition with respect to state

agency regulation and decision-making authorities has complicated the process. All parties are currently cooperating to resolve this important issue such that the system can operate efficiently and at design capacity in the future. The adjudication of water rights for the Pagosa system is expected in 1986.

The Pagosa Springs production wells were originally located such that the production wells, transmission piping, heat exchanger-control house, distribution piping, and the disposal piping were all on public lands and public right-of-ways; therefore, no purchase or leasing of land or right-of-ways was initially pursued or required. Midway through the project, it was realized that original county platting maps had been misinterpreted and, as a consequence, the production wells were located on private land. The town then exchanged public land for this privately held land such that clear title was established. No other private acquisitions or lease agreements were necessary during the duration of the project.

Permitting at the local level was not significant. No special city or county zoning permits were required.

The principal permitting agency governing geothermal energy development during the project timeframe (1979-1984) was the Colorado Oil and Gas Conservation Commission. The Colorado State Water Engineer, Groundwater Section, provided input to the Oil and Gas Commission related to the protection of groundwater and surface water supplies. Colorado Geothermal legislation was changed in 1984, and the State Engineer now governs geothermal developments similar to the Pagosa Springs project.

Permanent production well permits for wells PS-3 and PS-5 were to be obtained originally through the Oil and Gas Commission. In 1982, those permit applications were denied due to objections by the State Engineer; those objections were advanced due to potentials for water-right interferences. Because of legislative changes, all future permitting is to be directly through the State Engineer only. During the 1982-1983 heating

season, a temporary nine-month production permit was issued. Again, during the 1983-1984 heating season, a second temporary production permit was granted, conditional on the performing of a geothermal system testing program designed to identify interference that the new system may have on existing wells with established water rights.

11. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information contained in this report is excerpted from the project final report prepared by Coury and Associates, Inc., and appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

1. L. K. Garing, Direct Utilization of Geothermal Energy for Pagosa Springs, Colorado, Semi-Annual Progress Report, June-December 1979, Report IDO-7031-1, Contract No. DE-FC07-79ET27030.
2. Hydrosiences, Inc., Geohydrological Analysis of the Geothermal Reservoir, Pagosa Springs, Colorado, Cooperative Agreement No. DE-FC07-79ET27030, October 18, 1979.
3. Coury and Associates, Inc., An Environmental Report on the Construction and Operation of a Geothermal District Heating System in Pagosa Springs, Colorado, Contract No. DE-FC07-79ET27030, January 1980.
4. Coury and Associates, Inc., Chaffee Geothermal, Ltd., and Hydrosiences, Inc., Geothermal Resources Report, Pagosa Springs, Colorado, Contract No. DE-FC07-79ET27030, January 1980.
5. Coury and Associates, Inc., Direct Utilization of Geothermal Energy for Pagosa Springs, Colorado, Preliminary Design Report, Contract No. DE-FC07-79ET27030, September 1980.
6. Coury and Associates, Inc., Direct Utilization of Geothermal Energy for Pagosa Springs, Colorado, Final Design Report, Contract No. DE-FC07-79ET27030, September 1980.
7. Chaffee Geothermal, Ltd., Direct Utilization of Geothermal Energy for Pagosa Springs, Colorado, Geothermal Drilling Activities, 1980, Contract No. DE-FC07-79ET27030, November 1980.
8. Hydrosiences, Inc., 1980 Hydrological Testing Program at Geothermal Production Wells PS-3 and PS-5, Pagosa Springs, Colorado, Contract No. DE-FC07-79ET27030, February 10, 1981.
9. Coury and Associates, Inc., Summary Report--Pagosa Springs Geothermal Heating System, System Testing: October 1, 1983--February 29, 1984, Prepared for the Town of Pagosa Springs, Colorado, for submittal to the Colorado Oil and Gas Conservation Commission and the Colorado Department of Natural Resources, Division of Water Resources, State Engineer, March 30, 1984.

- *10. Coury and Associates, Inc., Direct Utilization of Geothermal Energy for Pagosa Springs, Colorado, Final Report June 1979-June 1984 Report No. DOE/ET-27030-7, Cooperative Agreement No. DE-FC07-78ET27030, August 1984.
- *11. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *12. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

MADISON COUNTY PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: Madison County, Idaho Food Processing and Space Heating

Project Data:

Project Description: The project planned to use geothermal fluid for heating a large junior college, public schools, and other large buildings in Rexburg, Idaho. The fluid was also to be used in a local potato processing plant.

Location: Rexburg, Idaho

Peak Heat Load: 85 million Btu/h

Annual Heat Load: 630 billion Btu/yr (85% Load Factor)

Simple Payback: 1.7 years

Status: A production well was drilled to 3932 ft, but the maximum temperature was only 72°F, resulting in a decision to stop the planned project.

Cooperative Agreement Data:

Number: DE-FC07-79ET27028

Period: February 16, 1979 to August 31, 1982

	<u>Planned (\$)</u>	<u>Actual (\$)</u>
<u>DOE Share</u>	1,650,900 (49%)	797,000 (90%)
<u>Participant Share</u>	1,717,385 (51%)	92,167 (10%)
<u>Total Cost</u>	\$3,368,285	889,167

Principal Investigator:

Dr. J. Kent Marlor, Chairman
Madison County Energy Commission
Madison County Courthouse
Rexburg, ID 83440
208/356-3431

Other Participants:

Project Engineering, Geology, Drilling Supervisor
Dr. Jay Kunze and Ray Gould
Energy Services, Inc.
Two Airport Plaza
Skyline Drive
Idaho Falls, ID 83402
208/529-3064

Driller
CRC Colorado Well Service
Rangely, CO 81648
303/675-8281

2. PROJECT DESCRIPTION AND HISTORY

The County seat for Madison County, Idaho is the town of Rexburg, with a population of about 11,600 permanent residents and 7000 college students who attend Ricks College, a two-year (junior) private college (see Figures 15.1 and 15.2). The town attained a certain national prominence when, on June 5, 1976, it was inundated by the flood waters from the Teton Dam, which collapsed and flooded the town with 6 ft of water, except for the hill on which the college is located.

As a result of reconstruction efforts to rebuild the town and surrounding area, the county government established an energy commission to help guide the area's future course of action in regard to effective utilization and development of various types of energy. In the summer of 1978, the Madison County Energy Commission applied to the U.S. Department of Energy for a cost-shared field experiment (PON) project based upon the known geothermal anomalies along the boundaries of the Snake River Plain, certain temperature anomalies in Rexburg City wells, and still higher temperatures in Newdale city wells, 7 mi northeast. In April 1979, the Department of Energy entered into a cooperative agreement with the Madison County Energy Commission, on an approximately equal cost sharing basis, with the federal government's share directed mostly to the high risk portion of attempting to find the resource.

This award was given with the intent that the developed resource could be used for the local Rogers Foods processing plant and also for the space heating of the local college, county, and school buildings. Also, it could have been possible to use the resource for heating some local residences.

The Snake River Plan boundary passes through the southeast edge of Rexburg. It was in the vicinity of this fault that it was decided to drill the deep exploratory test well. Prior to selecting this site, it was decided to further probe the area with two relatively inexpensive, small diameter, intermediate-depth test borings. One of these, HTW-1 showed the

Fig. 15.1 Location Map

Fig. 15.2 Rexburg Area Geothermal Well Locations

most promising temperature gradient, and it was decided to drill the deep well at this location.

The drilling budget was set at \$450,000 and the drilling operation began on May 20, 1980. By July 4, a total depth of 3932 ft was reached. Logging of the hole revealed no temperatures higher than 72°F, with the water level in the well nominally 15 ft below the surface.

The well was airlifted in an attempt to cause the well to flow. After three days of pumping, there was no change in the temperature profile in the well, and drilling was stopped.

Several months after dismissing the drill rig, a temperature log showed no changes in the maximum temperature (72°F), but a flowmeter log revealed a very significant downward flow of cold water from just below the casing. A solid liner to block this cold water flow was installed after considerable investigation. Packer leakage occurred, but was later sealed. Numerous airlift tests were conducted, but the fluid temperature did not exceed 72°F. However, the packer in the liner hanger failed to close, allowing cold water to enter inside the hanger and continue to flow down the hole. An airlift flow test, conducted in June 1981, produced about 250 gpm flow, but with no significant temperature change.

From this testing, it was concluded that the fault that was penetrated by the drilling was either a recharge fault for the Snake River aquifer, or that the massive Snake River aquifer had successfully "killed" the geothermal potential in this region of the Snake River Plain Fault. It was agreed to wait until the next spring or summer to determine if any heating was occurring at the bottom of the well. A temperature log was taken on September 3, 1982, which gave the same results as five months earlier.

It was concluded that there was no usable geothermal resource at depths of less than 6000 ft in the vicinity of the well. That could be an excellent reinjection well. Budget constraints removed the possibility of drilling a second well that had been originally considered. However, a high quality domestic water well exists and is expected to be used for future needs of the city or county as the area develops.

3. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

3.1 Technical

The deep well fell far short of achieving the desired temperatures, with only 72°F water found near the bottom of the well (3942 ft). Apparently, this region of the Snake River Plain Fault is a recharge zone for waters at greater depth that are assumed to be geothermal aquifers. Specifically, the near-surface water is going down to depth rather than geothermal water rising along the fault.

The well did succeed in intercepting the fault at the target depth of about 3000 ft, and the permeability and productivity of water for this well are outstanding. How much deeper one would have to drill to find hot water and case out the downward flowing cool water is not known. At the time the drilling was terminated, it was decided that at least an additional 2000 ft of depth (to a total depth of 6000 ft) would be necessary to find water temperatures of the minimum usable level (120°F).

Drilling was terminated because of lack of sufficient budget for the first well to permit the installation of a second production string. The casing would have been the only means of drilling deeper. Without the casing, drill cuttings could not be brought to the surface because of lost circulation zones, which were temporarily capturing the cuttings during circulation, then releasing these cuttings into the hole when circulation was stopped. When the subject of adding funds to the budget for this well was considered, the poor showings of temperature prompted project management to decide to save as much of the project as possible for a second well. The Department of Energy agreed that no further monies should be spent on the well.

Neither the use of air drilling or of heavy muds to stop lost circulation were practical and the only feasible means to permit drilling to greater depths in this hole would have been the installation of a second string of production casing, probably 7 in. in diameter and hung from the 2200 ft level. In retrospect, adequate contingency should have been

allotted to the budget of this well. This was needed to allow for such problems as the casing of the well to eliminate the lost circulation problem which would have permitted drilling or exceeding the 5000 ft target depth.

3.2 Institutional

State bonding requirements for geothermal wells appear to be unnecessary for governmental entities, such as counties. Such public organizations are permanent, and are essentially chartered by the State as an extension of state government authority. The geothermal bonding requirements were specifically designed for private organizations whose permanence, presence, and involvement in geothermal activities at a particular location were likely to be temporary. The \$10,000 bond is to ensure that the well will be properly abandoned, if that action is required. Certainly the county government is as concerned as is the state government that wells are not abandoned without proper completions.

Idaho counties are severely limited in their ability to develop capital projects, since State Constitutional requirements dictate that counties have a debt-free budget. The only mitigating factor to this dilemma rests with a county's ability to contract with the Idaho Department of Water Resources for a State bond issue. Such an arrangement is never guaranteed and could be most complex.

The State's testing requirements for blowout preventers insist on the presence of a representative from the Idaho Department of Water Resources (IDWR). In this case, only personnel in Boise were deemed qualified by the State, and much time and expense was lost awaiting the arrival of this representative. Even though the State was most cooperative in trying to minimize the lost time, it would seem that this requirement could be modified, such as permitting the witnessing of the test by an independent, qualified engineer or local representative of the IDWR.

3.3 Economic

Although this project failed to produce a usable geothermal resource, it needs to be recognized that the search for a natural resource underground is a risk, and that unsuccessful attempts will occur.

It is not known for certain at what depth or how much additional cost would have been required to tap the hot water of the desired temperature (hotter than 120°F). Nor is it known if there would have been a more promising drilling site near Rexburg; one that would not have been plagued by the downward flow of cool water.

The original budgetary plan called for two wells, recognizing that an unsuccessful attempt at a production well might result from the first drilling, and yet this well could be a useful injection well. The latter is indeed the case, for the well would make an ideal injection well in its present condition, readily able to accept up to 1000 gpm with a reasonable pumping head. Drilling was terminated at the advice of the drilling engineers and the Madison County program manager, based on fiscal prudence and the desire to save as much project funds as possible for the second well.

As to the present economic outcome of the project, the well is a prolific producer of drinking water, and could be inexpensively modified to produce even more. Thus, it has value for the future when the City of Rexburg needs an additional well for its water system. A new water well would cost the City approximately \$100,000 to drill. It is currently planned to leave the well capped until it is needed and to request the State to release the bond, since the well is not considered a geothermal well.

4. THE RESOURCE

The area around Rexburg had several features that indicated excellent geothermal resource potential. Natural hot springs in the area discharged water up to 120°F at the surface. Some irrigation wells had above-normal temperatures (i.e., above 50°F). Geochemistry reports predict temperatures for the geothermal aquifer that could range from 160 to 400°F.

The distribution of hot water in the area appeared to be concentrated along the major late cenozoic linear and arcuate fault zones. Maps showing contoured reservoir temperatures calculated from the water chemistry also showed a possible concordance with major structures. Other intersections of major structures may have had geothermal potential, despite the lack of shallow indications of hot water.

The most promising area for geothermal exploration on the Rexburg bench was determined to be where two calderas overlap, resulting in a maximum depth of fill and intersecting fracture or fault system.

The northeast normal faults opposite the Snake River Plain may have had special geothermal significance because they interrupted plainward migration of ground water and provided channelways for water to descend to hot depths.

The geological structure indicated Rexburg was situated on the edge of a huge rift (known as the Snake River Plain) and within the influence of a young complex caldera feature. Local high angle normal faults were located in the immediate area which appeared to influence the warm water occurrence.

It was decided to initially probe the area with at least two moderately deep, small diameter test holes. There were two areas considered as likely regions to probe. The one was a small graben intersecting the Snake River Plain fault at nearly a right angle near the extreme eastern edge of the city. The other area of interest was the bench area in the region directly south of the city. The latter area was eventually selected as the area to probe, primarily because geological

evidence and interpretation indicated that this area had numerous fault intersections and was more closely centered in one of the calderas.

Two moderately deep, small diameter exploratory wells were drilled after reviewing the available geological evidence. The 1200 ft deep (HTW-1) and 1500 ft deep (HTW-2) exploratory wells indicated that extensive fracturing and voids existed, which provide excellent porosity and permeability.

Based on data gathered from these two small diameter exploratory wells, it was considered feasible to proceed with a deep drilling geothermal program near the site of the HTW-1 well. That well showed a significant increase in temperature gradient over the last 500 ft of its depth, whereas the HTW-2 well, some three miles to the south, indicated a temperature reversal over the last 300 ft of its depth.

The site was recommended following a review of available data by geologists and hydrologists from the Department of Energy, U.S. Geological Survey, EG&G Idaho, Ricks College, and Energy Services. The site was offset approximately 400 ft west of the suspected surface trace of the 82°F dipping Snake River Plain Fault, so as to intersect this fault at a depth of approximately 3000 ft.

It was determined that the deep well would be a minimum depth of 3000 ft with a target total depth of 5000 ft. This was based on the "normal" high temperature gradient (3.25°F/100 ft) that generally exists in the area and in particular was found in the bottom of HTW-1. The location of the well was targeted to intersect the major Snake River Plain Fault and a minor fault trending NNW-SSE from the area of the bench south of Rexburg.

The primary selection criteria was geological, based on the evidence of faults and of the temperature gradients measured in the moderately deep exploratory holes. There was little question about the presence of water in these faulted systems, but there was concern about the possible overwhelming influence of cold water flooding from the Snake River Plain. This was one of the reasons that the graben area at the eastern edge of

Rexburg was not chosen for further probing by the test exploratory holes. There was obviously concern as to why the HTW-2 well (some three miles to the south of the deep hole site) had shown such a dramatic reversal in temperature over its bottom 300 ft of depth. It was assumed that there was cold water intrusion occurring at that location from runoff from the mountains to the southeast.

Another major criterion for drill site selection was the proximity of the well to the ultimate users in Rexburg. To put the well more than about two miles from these users would result in a pipeline cost that would be approximately equal to the well cost.

Land ownership was not an issue. Madison County had the cooperation of most landowners in the likely drill site location regions, and had leases or options for geothermal leases on some 3000 acres of land.

5. DRILLING AND TESTING

The drilling of the deep well (Figure 15.3) reached a final depth of only 3942 ft before it was decided to terminate drilling based on disappointing showings of temperature. Subsequent measurements of a large volume of water entering the well just below the casing (at about 2300 ft) and flowing down the wellbore led to remedial efforts to case off this flow. Even after this effort was accomplished, temperatures in the bottom of the well were only in the range of 75°F, far below what would be expected from the normal temperature gradients in the area, or in the Snake River aquifer.

The only logical conclusion drawn to date is that this portion of the Snake River plain fault is one where cold near surface water is traveling downward, perhaps recharging the geothermal reservoir(s) that must exist somewhere nearby. It is expected that this may be the condition in general along this portion of the Snake River Plain Fault within a few miles of Rexburg, although of course this conclusion is only based on inference. As a result of the low temperatures resulting from the apparent huge convective flows, project engineers and geologists are not unanimous in proposing (after the fact) a better drilling location.

The final configuration of the production well (Figure 15.4) includes 110 ft of 20-in. conductor pipe, cemented, 735 ft of 13-3/8-in. surface casing brought to the surface and cemented, and 3942 ft total depth of 8-7/8-in. hole.

In May 1981, a workover rig was brought in to install a liner hanger and 5-1/2-in. liner for the purpose of sealing off flow that was entering the well at about the 2300-ft level and flowing down the hole. The top of the hanger was set at 2208 ft and the 5-1/2-in. solid liner (casing) was hung from 2215 to 3540 ft. The liner hanger failed to close and seal the cementing ports. In October 1981, a lead packer double seal was successfully installed inside the liner hanger to seal it. However, an obstruction was still present at the 2300-ft level. In November 1981, a cable tool rig unsuccessfully tried to clear the well. On April 5, 1982, a

Fig. 15.3 Drilling Activities

All Levels Referenced to Ground Level

Fig. 15.4 Well Profile

cable tool rig with a heavier hammer was able to push the obstruction to the bottom of the well. It was determined at this time that the obstruction was rubber and cement debris from various attempts to seal the packer.

The well never received "stimulation" in the normal sense. Air was used to pump test the well, but the drawdown did not exceed approximately 20 ft, even when "pumping" at a rate of 600 gpm.

The original airlift, with the drill rig still over the hole, was conducted with a 900 cfm, 125 psi compressor, injecting air at the 155 ft level through a 4.5-in. diameter drill pipe.

Subsequent airlifts, after the drill rig was off the hole, used the same air compressor or a smaller 300 cfm unit. The pumping was done from the 140 ft level through a 2-in. pipe.

The well was logged after most of these airlifts (pumping), and in no cases were temperatures above 72°F found, even at the bottom of the well. Near the surface, the water temperatures were a constant 53°F. Static water levels varied throughout the two-year period that they were monitored, from 12 to 18 ft below ground level. These were considered to be normal seasonal variations.

The results indicate that the formations are a prolific producer of cool water. Production rates from the bottom of the liner (below 3540 ft) were a bit less than from higher levels, such as the extremely high productive zone near the 2300-ft level. The difference is believed to be largely the result of pressure drop in the 5-1/2 in. liner, rather than being indicative of different productivity potential between these zones.

Numerous temperature logs were run on the well. Lithology, porosity, and geophysical logs (Figure 15.5) were prepared.

Fig. 15.5 Lithology Log

Fig. 15.5 Lithology Log (cont'd)

6. SYSTEM COSTS, SCHEDULE, AND ORGANIZATION

6.1 System Costs

The cost of the project was approximately \$895,000, with 90% of this being provided by the U.S. Department of Energy and the remainder by Madison County and Rogers Food. Of this total, 67% was spent on the deep well, including the remedial work. The two initial slim holes, the environmental report, and resource assessment report accounted for 25% of the expenditures. The remaining 8% of the expenditures were used for dissemination of information and various reporting functions to the Department of Energy. The cost summary is shown in Table 15.1.

The original estimate for the project was \$3,368,285 with \$1,650,900 (49%) furnished by the Department of Energy, and \$1,717,825 (51%) by the participants. DOE's contribution was primarily for the resource assessment and the first two deep wells. A small portion of this high risk phase of the project was contributed by Madison County, primarily for the remedial work efforts on the well. It was projected that Madison County and Rogers Food (now American Potato Company) would be spending approximately \$1.7 million to supply the water delivery and utilization systems, and the disposal facilities. Of course, funds were never expended for those purposes.

6.2 Schedule

Table 15.2 provides the scheduled and actual task completion dates.

6.3 Organization

The project organization is shown in Figure 15.6. The original project principal team consisted of Madison County and Rogers Foods. The decision to drill the well off Rogers Foods property, the sale of Rogers Foods to American Potato Company, and the poor performance of the

TABLE 15.1. COST SUMMARY

	<u>U.S. DOE</u>	<u>Madison County</u>	<u>Rogers Food</u>
Phase 0			
Proposal to DOE	\$ --	\$ 8,085	\$3,600
Phase 1			
Drilling Preparation	3,000	1,400	--
Environmental Report	7,500	--	--
Explorational Test Wells	178,522	600	--
Project Management	14,500	10,522	--
Phase 2			
First Exploratory Well Design, Bid, Selection	4,500	1,000	--
Drilling	455,600	3,000	--
Logging	11,000	4,000	--
Remedial Work	32,500	42,760	--
Testing and Analysis	29,600	1,000	--
Project Management	12,800	10,900	--
Phases 3 to 6			
Never Activated	0	0	--
Phase 7			
Reporting	34,000	3,000	--
Phase 8			
Public Information	<u>12,900</u>	<u>2,300</u>	<u>--</u>
Totals	\$797,000	\$88,567	\$3,600

TABLE 15.2. PROJECT SCHEDULE

<u>Activity</u>	<u>Completion Dates</u>	
	<u>Scheduled</u>	<u>Actual</u>
Contract Award	06/30/79	6/30/79
Environmental Assessment	08/15/79	9/30/79
Additional Leases and Permits	08/15/79	9/30/79
Well Design	10/30/79	1/31/80
Drilling Selection	11/30/79	4/30/80
Well Drilling	07/15/80	7/04/80
Other Phases	Cancelled

Fig. 15.6 Project Organization

production well resulted in the potato company withdrawing from the partnership. The City and Ricks College representatives continued to be active in supporting the project.

7. LEGAL AND INSTITUTIONAL CONSIDERATIONS

An environmental report was prepared for the project, with no significant impacts being observed. The entire drilling operation was supervised by qualified personnel and conformed to all state regulations. Since a usable resource was not encountered, the hole will:

1. Be plugged in accordance with Idaho Department of Water Resources standards for well abandonment; or
2. Be left capped and in a standby condition awaiting eventual use by the City as a domestic well for its water system.

Upon completion or abandonment of the project, the reserve pit will be backfilled. The disturbed site will be graded and reseeded, and all equipment, structures, and waste materials will be removed.

At the beginning of the project, while the environmental and resource assessment studies were under way, the areas of critical interest were identified and options to obtain a geothermal lease were signed with a number of property owners. Over 3000 acres were optioned in this manner.

Once the deep drilling site had been selected, a drilling site lease was entered into with property owner Dick Davis.

Rexburg City was associated with the project and thus, a right-of-way agreement for the distribution system with the City was unnecessary. The drilling site was outside of city limits.

Since Madison County owned rights-of-way corresponding to the County road system, no distribution system right-of-way agreements were necessary.

The application to appropriate public water was approved November 7, 1978. A Geothermal Application was approved by the Idaho Department of Water Resources on June 5, 1980. Because of the problems encountered in downflow of water in the well, it became necessary to submit an application for a permit to alter a geothermal well. The permit to alter was granted to perform remedial work and install a liner in the well.

Informal contacts with Idaho Department of Water Resource staff and providing weekly drilling progress reports enhanced the permit application process.

Madison County provided, on October 16, 1980, an escrow (\$10,000 savings account) in lieu of the \$10,000 bond required by the Idaho Department of Water Resources.

County officials were disappointed with State bond requirements which gave no recognition of the County's special relationship with the State as a legal subentity. County officials perceived that having such a legal status should have exempted them from a lengthy, cumbersome, and unnecessary process for compliance with bonding requirements. Ordinary bonding companies, not having dealt with the County previously, and not having any other business (such as insurance business) with the County were reluctant (in fact refused) to bond the County on the well, for what, in effect, could be a bond in perpetuity.

8. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and the figures contained in this report are excerpted from the project final report prepared by Energy Services, Inc., and appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. Energy Services, Inc., Industrial Food Processing and Space Heating with Geothermal Heat, Final Report, February 16, 1979-August 31, 1982, Report No. DOE/ET/27028-5, Contract No. DE-FC07-79ET27028, August 1982.
2. Madison County Energy Commission, and Rogers Foods, Inc., Madison County Geothermal Project Proposal (2 Vol.), Report No. M.C.E.C.-78, July 1978 (41 and 53 pages).
- *3. Energy Services, Inc., Environmental Report for Madison County, Idaho Geothermal Project, Report No. DOE/ET/27028-1, Cooperative Agreement No. DE-FC07-79ET27028, September 1979 (106 pages).
4. Energy Services, Inc., Madison County Rogers Potato Geothermal Space/Process Heating Project, Semi-Annual Technical Report, February 1979--August 1979, Report No. DOE/ET/27038-2, October 31, 1979 (32 pages).
- *5. Energy Services, Inc., Evaluation of the Geothermal Potential Around Rexburg, Idaho, Report No. DOE/ET/27028-3, Cooperative Agreement No. DE-FC07-79ET27028, April 30, 1980 (154 pages).
- *6. Energy Services, Inc., Madison County Geothermal Project, Preliminary Well Drilling Report, Report No. DOE/ET/27028-4, Cooperative Agreement No. DE-FC07-79ET27028, January 1981 (85 pages).
- *7. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *8. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

MONROE CITY PROJECT

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1. PON PROJECT SUMMARY DATA

Project Data:

Project Description: This project planned to use a low temperature geothermal resource to provide space and water heating to commercial, municipal, and domestic users.

Location: Monroe, Utah, about 160 mi south of Salt Lake City, Utah

Peak Heat Load: 20.2 million Btu/h

Annual Heat Load: 31.9 billion Btu/yr (18% Load Factor)

Simple Payback: 38.3 years

Status: The production well produces 600 gpm of 164°F fluid, but this is only 45% of the needed capacity. The estimated capital costs increased about 50%, and the uneconomic district heating system was stopped. The city is seeking a use for the well.

Cooperative Agreement Data:

Number: DE-FC07-78ET27054, formerly ET-78-F-07-1730

Period: July 17, 1978 to July 13, 1981

	<u>Planned</u> <u>(\$)</u>	<u>Actual</u> <u>(\$)</u>
<u>DOE Share</u>	927,900 (58%)	487,000 (43%)
<u>Participant Share</u>	665,000 (42%)	648,000 (57%)
<u>Total Cost</u>	1,592,900	1,135,000

Principal Investigator:

Mayor (previously Duane F. Nay)
Monroe City
Box A, Monroe, UT 84754
801/527-3511 City Hall

Other Participants:

Project Engineering
Dr. Lawrence B. Owen
Terra Tek, Inc.
420 Wakara Way, Salt Lake City, UT 84108
801/584-2400

Preliminary Design and Cost Estimate
George Poulsen
Caldwell, Richards & Sorensen
26 South State, Salt Lake City, UT 84111
801/364-5691

Design and Cost Estimate Evaluation
Dr. Jay F. Kunze/Ray W. Gould
Energy Services, Inc.
1084 No. Skyline Dr., Plaza No. 2
Idaho Falls, ID 83402
208/529-3064

2. PROJECT DESCRIPTION AND HISTORY

Monroe City is a small central Utah community (Figures 16.1 and 16.2) with a population of approximately 2000. It is located about 160 mi south of Salt Lake City in the Sevier River Valley, to the immediate west of the Sevier Fault. The fault rises to the surface within 2000 ft of the town's eastern boundary. The Monroe KGRA (known geothermal resource area) is situated along this fault and is characterized by two large tufa mounds from which springs discharge up to 380 gal per min of warm water.

Mundorff (1970) described the hot springs of the area, furnishing analytical data and flow estimates. The dissolved solids concentration of the Monroe Springs discharge was measured at 2770 ppm with the major constituents being: silica, 54 ppm; calcium, 282 ppm; sodium, 562 ppm; bicarbonate, 354 ppm; sulfate, 898 ppm; and chloride, 630 ppm. Utilizing these data, Parry, et al. (1976) calculated the minimum geothermal reservoir temperatures (temperature of last wall rock equilibration) as 387 and 379°F, respectively. Measured surface discharge temperatures of the Monroe and Red Hill Springs were 149 and 169°F, respectively.

In the summer of 1977, the University of Utah (Mase, et al., 1978) performed a comprehensive resource assessment of the Monroe KGRA under U.S. Department of Energy funding. This resource assessment indicated that maximum possible temperatures of 250°F might be realized at a depth of 1000 ft, with recharge to the system being provided by the watershed area to the east. The University of Utah concluded that the resource was suitable for low temperature applications and commercial development.

Monroe City, supported by Terra Tek, Inc., submitted a proposal in response to PON EG-77-N-03-1553 in November 1977 to develop a district heating system for the city utilizing the Monroe KGRA resource.

During earlier investigations by the University of Utah and during the course of this project, an assessment of the capability of the Monroe KGRA was completed. After extensive geophysical investigation by University of

Fig. 16.2 Site Plan

Utah personnel, a production well was located, drilled, and tested. Production well test data, compiled and analyzed by Terra Tek, Inc., indicated a low temperature resource (less than 180°F) with a well artesian flow capacity of 260 gpm and a short-term (100 h) pumped-flow capacity of approximately 600 gpm.

A preliminary design of the district heating system (production, transmission, disposal, distribution, and application subsystems) was completed based upon determined resource characteristics. In part because initial assumptions regarding resource characteristics were not realized, estimated capital costs and system operating costs for the development were significantly greater than originally anticipated. The need for a more remote disposal site than planned and the large area/low population density affected the costs. Projected system revenues during the early years of operation were found to be less than predicted operating costs. Due to these factors, the proposed district heating system was considered not to be economically viable.

Possible alternative uses of the existing geothermal resource were investigated. However, the primary interest of the citizens of Monroe City was in providing space and hot water heating to individual residences. The Monroe City Council elected not to pursue alternative uses of the resource by commercial interests at that time, and project activities were terminated.

3. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

3.1 Technical

During the course of the project, a production well capable of servicing the proposed initial development was completed. A preliminary design of a district heating system based upon determined well production characteristics was formulated. Failure to achieve the primary objective of the program, providing an operable geothermally-supplied district heating system for Monroe City, was due to economic rather than technical considerations.

3.2 Organization/Institutional

The program was conducted in three distinct phases: (a) field development, (b) central plant design, construction, and commissioning, and (c) central mains construction. Although a preliminary analysis of system capital costs, system operating/maintenance costs, and project economic feasibility was completed during preparation of the project proposal, a comprehensive analysis was not completed until the second phase of the project. Upon completion of this comprehensive analysis, it was determined that the originally envisioned district heating system was not economically viable even though a successful production well was developed during the first project phase.

Based upon the experiences of this project, it is recommended that future programs of this nature be organized such that a detailed project feasibility analysis be conducted as the initial project phase prior to the development of field production facilities. cursory analyses conducted on a non-funded proposal basis are not adequate to warrant considerable funding expenditures on production well facilities as was done in the Monroe Project. Subsequent delays encountered in the resource development phase should also be minimized to avoid adverse impacts of annual inflation on overall project costs.

3.3 Economic

The primary economic conclusions resulting from the Monroe Project are as follows:

- o To effectively utilize a low temperature geothermal resource, it is necessary to have a centrally located user load, which is in close proximity to the resource. Low user load densities, such as those existing in Monroe City, result in prohibitive system capital costs.
- o To generate sufficient revenues to cover system operating and maintenance costs, it is necessary to attract a majority of the ultimate system user loads during the early years of operation.
- o Spent geothermal fluid disposal considerations can have considerable impact on the economic viability of a project to develop a low temperature geothermal resource.

4. THE RESOURCE

The Monroe and Red Hill Hot Springs are located on the east side of the central Sevier Valley near Monroe, Utah. They issue from the Sevier fault which is a major, west-dipping normal fault that separates the Tertiary volcanic rocks of the Sevier Plateau from the alluvium of the Sevier Valley (Kilty, et al., 1978).

The first detailed studies of these hot springs were concerned with the geochemistry and alteration mineralogy of the systems and provide valuable constraints of the origin and history of the thermal waters (Parry, et al., 1976; Miller, 1976). During the autumn of 1976 and throughout 1977, geophysical surveys including precision gravity, ground-magnetics, and dipole-dipole electric soundings were conducted and a borehole drilling program was undertaken to provide direct subsurface temperature information (Mase, et al., 1978).

Chemical geothermometry suggests that the maximum Monroe Mound/Red Hill Springs temperature is between 175°F (chalcedony geothermometer) and 237°F (Na-K-Ca-Mg - corrected geothermometer) with the most likely reservoir temperature of 109°C (quartz conductive heat loss). The maximum temperature measured at total depth was 180°F.

From the information obtained it was apparent that the geothermal system at the near surface is rigorously confined within the zone of faulting. It would appear essential to intersect this zone to ensure that the highest water temperatures and transmissivities are encountered. Unfortunately, alluvial valley fill and travertine deposits mask the surface trace of the fault in the Monroe-Red Hill area.

Test holes designated MC1 and MC2 were drilled at the site in 1978. The Sevier Fault Zone dip of $67^{\circ} \pm 3^{\circ}$ was determined from encountering consolidated volcanic bedrock at depths of 310 ft in MC1 and 610 ft in

MC2. This value is calculated from the relative location of the wells and assumes a fault trend of $N10^{\circ}W \pm 10^{\circ}$. The computed dip of 67° is shallower than the dip deduced from geophysical modeling and may indicate step faulting.

Temperatures observed in MC1 and MC2 after completion indicate the central part of the Monroe system is near isothermal at 165° between depths of 165 and 820 ft. Significantly higher temperatures may be expected only below the depth where cold water mixing may occur.

Both MC1 and MC2 produce artesian flow. An initially strong artesian flow from MC2 of approximately 200 gpm, which was considerably reduced when the bottom 250 ft of the hole collapsed, was attributed to production from a fracture within the volcanic bedrock. This fracture had been previously delineated by the caliper and natural gamma logs. A residual difference of 5 psi shut-in wellhead pressure between MC1 and MC2 after correcting for wellhead elevation represents a friction head loss caused by water flowing between the two wells which are at an elevation difference of approximately 200 ft.

Water levels of 130 ft in gradient hole MC1, 150 ft in RH3, and between 50 and 200 ft in other domestic wells to the west (valley side) of the hot springs indicates the presence of a very steep hydraulic gradient of approximately 10-12% between the hot springs and the valley ground waters. In addition, the water in the valley wells is cold (with the exception of RH3 which is influenced by apparent leakage from the fault) with dissolved solids contents below 500 ppm compared with 2770 ppm for the geothermal fluid. It was concluded that there is little hydraulic connection between the hot springs and the shallow valley ground waters in the immediate vicinity of the Monroe Mound.

Penetration of the fractures within the fault zone was the principal goal of the production test drilling. The well was designed and located on the basis of the geometry inferred from the test hole drilling to intersect the volcanic bedrock at 900-1100 ft. It was felt that production from the 1100 ft level and below offered the advantages of good artesian flow due to increased driving potential with depth. In addition, it was expected that production from this level would minimize any influence on shallow and surface hydrologic conditions.

5. DRILLING AND TESTING

Well MC-3, as originally envisioned, was to have been completed to a depth of 1500 ft. From the surface to a depth of 1000 ft, the well was to have been completed with a 16-in. diameter cemented casing. From 1000 ft to total depth, the well was to have been left open hole; with the diameter at the option of the driller. The formation lithology expected before drilling was silicified alluvium (semi-consolidated) from the surface to 900 ft and brecciated volcanics (consolidated rock) from 900 to 1500 ft.

During actual drilling, an unanticipated hard formation was intersected at a depth of 687 ft. The chips from this zone consisted of limestone with some quartz distributed within the matrix. Upon encountering the hard formation, it was decided to continue drilling with the 9-7/8-in. diameter bit in an attempt to intersect the originally targeted volcanics interface. Drilling with this bit was terminated at 1313 ft.

In view of the difficult drilling and the high cost of 14-3/4-in. and 20-in. diameter button reamers, it was decided to run the 16-in. diameter casing to only 690 ft. From 645 to 1313 ft (45 ft overlap), the well was completed with 7-5/8-in. diameter liner, with the interval from 943 to 1313 ft slotted. Although not originally specified, slotted liner was used in the lower regions of the well to avoid sloughing and sedimentation due to the uncertainty of the lithology in this region.

The well was completed to a depth of 1500 ft using a 7-7/8-in. diameter bit. From 1313 to 1500 ft, the well was completed open hole. The well is capable of producing 600 gpm of geothermal fluid at 164°F. The well lithology is shown in Figure 16.3.

Fig. 16.3 Well MC-3 Lithology.

The original fixed price amount of the drilling contract was \$156,800. Due to the unexpected hard drilling which was encountered and due to changes in the scope of work resulting from these conditions, Sweetwater Drilling Co., Inc. was paid \$197,266.76 following completion of the drilling program.

Following well completion and testing, compressed air development treatment of the well was conducted.

Considerable improvement in the yield of the well was observed following the stimulation treatments. The artesian flow rate from the well after stimulation was 260 gpm; the flow before testing was 160 gpm.

After compressed air treatment and further well flow testing, a small workover rig was brought in for further well development. The lower portion of the well was swabbed for approximately 4 h. A further improvement in the artesian flow from the well to 280 gpm was observed following the swabbing treatment.

The following logs were obtained during the course of the drilling program: temperature, drilling penetration rate, lithology, caliper, natural gamma, and self potential. Penetration rates and temperature logs are shown in Figure 16.4.

A series of artesian and pumped flow tests were performed to assess the production characteristics of Well MC-3. Testing was conducted prior to and following development treatment of the well.

For each group of tests, the long-term pumped flow testing was of primary interest. Preliminary testing prior to the long-term tests was conducted primarily to enable selection of appropriate production rates for the long-term tests.

Fig. 16.4 Penetration Rates and Temperature Logs

The carbon dioxide concentration in the geothermal fluid was determined since it is necessary to maintain system pressures above the saturation pressure of carbon dioxide in the fluid to prevent calcite deposition. A chemical analysis of the fluid was also performed, and corrosion tests using several different metals were conducted.

6. PRODUCTION SYSTEM

The design of the production well is depicted in Figure 16.5. A 16-in. diameter casing is cemented from the surface to a depth of 690 ft. A 7-5/8-in. diameter liner is in place from 645 to 1313 ft, with the interval from 943 to 1313 ft being slotted. From 1313 to 1500 ft, the well was completed open hole in competent volcanic rock.

At the surface, the 16-in. casing is completed with a 125 lb, slip-on flange, located approximately 3 ft above ground level. Presently, the well is capped with a 16-in., 125-lb blind flange. An 8-in. diameter horizontal branch line with an 8-in., 125-lb gate valve, is attached to the 16-in. casing.

Estimated drawdowns and noncondensable gas considerations dictate the need to set the production pump to a depth of 600 ft. Due to the range of required production rates, two deep well pump options were considered:

1. A single variable-speed shaft pump, and
2. Two or three identical submersible pumps.

Final selection of a pumping system and specific equipment was not made due to project cancellation. However, preliminary studies indicated that the multipump option was probably the better alternative due to reduced power consumption, backup capacity, and comparable costs.

Fig. 16.5 Well MC-3 Profile

7. DISPOSAL SYSTEM DESIGN

The disposal portion of the proposed Monroe District Heating System would consist of 3200 ft of 10-in. diameter pipe, an injection pump, and an injection well. At the time of project cancellation, only the piping design had been finalized. A tentative location for the injection well, near gradient test hole RH-5, had been chosen. However, design of the injection well and selection of an injection pump was not completed.

Buried, uninsulated fiber glass reinforced pipe (Bondstrand 2000) was selected for the disposal line. This pipe was selected due to ease of installation, mechanical strength characteristics, and corrosion resistance. In addition, it would be possible to clean the pipe with an acid flush should calcite deposition occur. The pipeline was sized to accommodate future system expansion.

8. TRANSMISSION SYSTEM DESIGN

Presented in Figure 16.6 is a schematic drawing of the proposed but not installed Monroe district heating system. The transmission portion of this system consists of 2000 ft of buried 6-in. diameter pipe running from the production well to the heating plant.

A Bondstrand 2000 series fiberglass reinforced plastic pipe preinsulated with PVC jacketed urethane foam by Rouanco was selected for the transmission piping.

The system would have encompassed an intermediate heat exchanger installation, a primary fluid 316 stainless steel plate-type heat exchanger recirculation loop, secondary supply and return mains, and secondary circulation pumps.

It was determined to be necessary to incorporate the existing high school heating system into the distribution system to minimize retrofit costs. To do this, it would be necessary to operate the secondary system at a constant flow rate of approximately 600 gpm. In addition, it would be necessary to place the high school in series with the remainder of the Monroe City loads to maximize the temperature of secondary water entering the high school.

A maximum secondary system supply temperature of 156°F is based upon production well characteristics, secondary system flow, and the selected heat exchange equipment. The secondary supply temperature could be altered downward from 156°F according to a reset schedule controlled by ambient air temperature.

To reduce the potential for fouling of the primary heat exchange surface and to minimize the flow rate from the production well, flow of the geothermal fluid through the exchanger would be maintained constant at a rate of approximately 600 gpm by a recirculation loop. The relative

Fig. 16.6 Proposed System Schematic

proportion of recirculated water to fluid supply from the production well would be regulated as required to maintain the secondary system delivery temperature at the required level.

The existing high school space and hot water system was to be utilized with only minor piping modifications required. The entire 600 gpm flow of the secondary system would be directed through the high school system before servicing the loads in Monroe City. An additional three-way temperature control valve would be added to the high school system to enable augmentation by the existing high school boilers, if required.

A typical individual user system would consist of a 50,000 Btu/h unit heater with a thermostatically controlled fan, an operating-time meter for the fan, and required 1-in. piping components. Connections to individual residences would be arranged to provide a constant water flow through building laterals.

The energy usage monitoring system for the high school would consist of a device to record the water temperature drop through the high school versus time. For determining charges for residences, cumulative cabinet heater fan usage was to be recorded by an hour meter. Specific equipment had not been selected at the time of project cancellation.

9. ALTERNATE CONSIDERATIONS

Upon completion of field development, assessment, and preliminary design for the district heating system, it was determined that the project as proposed was not economically viable due to estimated high capital equipment costs, a more remote disposal site than planned, predicted high pumping and operating costs, and the large area/low population density in Monroe. A thorough investigation of economic alternatives for utilizing the resource was not productive and further project activities were cancelled. Possible alternative uses included: greenhouse heating, mushroom farming, milk pasteurization, prawn farming, poultry production, heating of a local church, and electric power generation (binary system) coupled with space heating of a recreational facility. Large aerial space heating applications, such as mushroom farming and greenhousing, were found to have the potential of most effectively utilizing the geothermal resource. Savings in fuel costs (compared with coal) using the existing production well approaching \$250,000 per year (1980 dollars) could be possible with a large facility.

Nonreinforced plastic pipe systems were considered but rejected on the basis of the lack of adequate data on long-term stability at high operating temperatures and pressures. Asbestos cement piping was rejected due to the inability of using acids for cleaning purposes and due to concerns regarding thermal stresses in the event of large variations in temperature (e.g. system startup). Bandstrand 2000 series fiberglass reinforced plastic pipe preinsulated with PVC jacketed urethane foam was selected because of its ability to transmit 164°F fluids at pressures exceeding 100 psi. This piping is corrosion resistant, is economical to install, and can be cleaned by an acid flush should calcite deposition occur.

10. SYSTEM COSTS, SCHEDULE, AND ORGANIZATION

10.1 System Costs

The estimated cost for the total project, based on the preliminary design, was almost twice the initial proposal cost estimate, increasing from \$994,000 to \$1,944,500. Because realistic near-term system loading would not be sufficient to generate enough revenue to cover system operating costs, the project as originally envisioned was not considered to be economically viable. In addition, residential connection and conversion costs were high in comparison to the per capita income for Monroe City. Thus, it was felt that it would be difficult to attract customers to the system unless a significant cost advantage over existing systems could be demonstrated.

In view of the projected negative yearly cash flows, further economic analysis was not completed.

A total of \$1,135,000 was spent on the project, primarily for the production well development and design costs. The DOE share was about \$487,000, and the city spent \$648,000.

10.2 Schedule

The project schedule is shown in Figure 16.7 and described in Figure 16.8.

10.3 Organization

The City of Monroe, Utah was the prime contractor for the program. Terra Tek, Inc., Caldwell, Richards, and Sorensen, Inc., and Sweetwater Drilling were subcontractors to Monroe City in conducting the project. The program manager was Mr. Duane Nay, Mayor of Monroe City. Dr. Arfon Jones

WORK SCHEDULE

Fig. 16.7 Project Schedule

TASK	DESCRIPTION OF ACTIVITY
<u>Phase I - Field Development</u>	
Task 1.1 - Environmental Report	A report addressing major environmental considerations was prepared.
Task 1.2 - Production Well	Necessary leases and permits for drilling a production well were obtained. A well was designed by Terra Tek, Inc. and drilled by a licensed drilling contractor.
Task 1.3 - Well Test	A comprehensive testing program was completed to determine the production characteristics of the production well and the Monroe Resource.
Task 1.4 - Evaluation	Data from the well testing program were evaluated to enable prediction of long-term resource production characteristics.
<u>Phase II - Commission Central Plant</u>	
Task 2.1 - Injection Well	A site for an injection well was selected. Appropriate drilling and disposal permits were obtained. An injection well was to have been designed, drilled, and tested.
Task 2.2 - Flood Protection	A flood protection barrier was to be installed to the east of the production well.
Task 2.3 - Central Plant	The design of the district heating system, including the production system, transmission system, disposal system, distribution system, and application system was to be completed. The system, excluding distribution mains, was to be constructed.
Task 2.4 - School Heating	Distribution mains to South Sevier High School were to be installed. The school's heating system was to be retrofitted and connected.
Task 2.5 - Commissioning	Procedures for system operation and maintenance were to be developed. System operation was to be initiated and then monitored for a period of time.
<u>Phase III - Mains Network</u>	
Task 3.1 - Mains Network	The distribution mains network beyond the school were to be installed. Branch piping and individual hookups were to be completed.
Task 3.2 - Retrofit Existing Buildings	City Hall and the fire station were to be retrofitted and then connected to the system.
Task 3.3 - Commissioning	The total system was to be put into operation and then monitored over a four month period.

Fig. 16.8 Task Descriptions

of Terra Tek, Inc. was responsible for overall project management. Caldwell, Richards, and Sorensen, Inc., Consulting Engineers, were responsible for system design and construction management. The University of Utah Geology and Geophysics Department acted as an advisor to the project under contract with the Department of Energy. An organization chart for the project is included as Figure 16.9.

Fig. 16.9 Project Organization

11. LEGAL AND INSTITUTIONAL CONSIDERATIONS

An environmental report, concluding that impacts are minimal, was prepared for the U.S. Department of Energy for test drilling two holes. An environmental report was also prepared for all other drilling and construction required in support of facility development.

The Monroe Hot Springs are located on private land. A geothermal lease was negotiated between Monroe Hot Springs Resort (property owner) and Monroe City.

There were no established city or county regulations to abide by during the drilling and testing phase. Building permits might have been required during the construction phase.

The Division of Water Rights of the State of Utah has jurisdiction and authority to require that all wells for the discovery and production of water to be used for geothermal energy production in the State of Utah be drilled, operated, maintained, and abandoned in such a manner as to safeguard life, health, property, the public welfare, and to encourage maximum economic recovery (73-1-20 UCA). Approval was received from the Division to drill a production and an injection well. Application was made to appropriate the water, and disposal of spent fluids was also under their jurisdiction.

It would have been necessary to obtain permission from the Bureau of Land Management to construct the pipeline across portions of their land.

Air quality regulations to be met during construction and facility operation would have been those set by the U.S. Environmental Protection Agency.

12. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and the figures contained in this report are excerpted from the project final report prepared by Terra Tek, Inc., and appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. Terra Tek, Inc., Direct Utilization of Geothermal Resources at Monroe, Utah, Final Report, July 14, 1978 - July 31, 1981, Report No. DOE/ET/27054-6, Cooperative Agreement No. DE-FC07-ET 17054, December 1982.
- *2. D. H. Crockett, Environmental Report for Direct Utilization of Geothermal Resources Field Experiments at Monroe, Utah, Report No. DOE/ET/27054-1, for Cooperative Agreement No. DE-FC07-78ET27054 (formerly ET-78-F-07-1730), September 16, 1978 (77 pages).
3. R. F. Harrison, Direct Utilization of Geothermal Resources Field Experiments at Monroe, Utah, Technical Progress Report, Report No. DOE/ET/27054-2 (formerly IDO-1730-1), for Cooperative Agreement No. DE-FC07-78ET27054 (formerly ET-78-F-07-1730), December 1978 (15 pages).
4. Ibid, Report No. DOE/ET-17054-3 (formerly IDO-1730-2), for Cooperative Agreement No. DE-FC07-78ET27054 (formerly ET-78-F-07-1730), February 1979 (9 pages).
5. Ibid, Report No. DOE/ET/27054-4 (formerly IDO-1730-3), for Cooperative Agreement No. DE-FC07-78ET27054 (formerly ET-78-F-07-1730), September 1979 (25 pages).
- *6. R. F. Harrison, Direct Utilization of Geothermal Resources Field Experiments at Monroe, Utah, Phase I Report, Report No. DOE/ET/27054-5, for Cooperative Agreement No. DE-FC07-78ET27054, February 1980 (144 pages).

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

- *7. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract No's. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *8. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

17. AGRIBUSINESS PROJECTS - INTRODUCTION

Two agribusiness projects were developed. The Utah Roses project in Sandy, Utah demonstrates the feasibility of using a 123°F geothermal resource to heat a large greenhouse complex. This project lead to the development of another Utah Roses greenhouse facility using geothermal fluid from a well located close to the Utah State Prison project. An existing well at the Diamond Ring Ranch in central South Dakota was used to provide heat for six structures, a grain dryer, stock watering, and irrigation. The heating circulating loop was freeze-protected with antifreeze. The antifreeze was lost due to leakage, and has not been replaced by the operators who continue to use the geothermal fluid for stock watering and irrigation.

This section of the report provides summary data, project history and development, resource and drilling information, how the geothermal fluid was used, alternate considerations, legal and institutional considerations, and cost, schedule, and operational data. Significant observations and conclusions relative to each project are also given.

UTAH ROSES PROJECT

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1. PON PROJECT SUMMARY

Project Title: Utah Roses Floral Greenhouse Geothermal Heating

Project Data:

Project Description: The project demonstrates the feasibility of utilizing a moderate temperature (123°F) resource to supply heating for an existing seven-acre greenhouse facility.

Location: Sandy, UT, about 10 mi south of Salt Lake City airport, and two blocks west of the 90th South Street interchange on Interstate 15.

Peak Heat Load: 2.9 million Btu/h

Annual Heat Load: 45 billion Btu/yr (Total required is 11 million Btu/h at 10°F outdoor temperature)

Simple Payback: 8.7 yr

Status: The project continues to operate satisfactorily

Cooperative Agreement Data:

Number: DE-AC07-79ET27056, formerly ET-78-N-03-2047

Period: February 1979 to September 1982

DOE Share: \$461,000 (66%)

Participant Share: \$237,500 (34%)

Total Cost: \$698,500

Principal Investigator:

Ralph M. Wright
Chairman of the Board
Utah Roses, Inc.
567 W. 90th South
Sandy, UT 84070
801/561-4264

Other Participants:

Project and Drilling Engineer, Mechanical Design and Retrofit, Geology
and Hydrology

Dr. Jay F. Kunze
Energy Services, Inc.
Two Airport Plaza
Skyline Drive
Idaho Falls, ID 83402
208/529-3064

Drilling Contractor
Hershel Pelcher
CRC Colorado Well, Inc.
2603 E. Main
Rangely, CO 81648
303/675-8281

2. PROJECT HISTORY AND DESCRIPTION

Utah Roses, Inc., at project inception, was an established floral and potted-plant company having operated in Sandy, Salt Lake County, Utah for 8 yr. Their principal business location is 10 mi south of Salt Lake International Airport and the State Capitol building (Figures 18.1 and 18.2), and located within the Salt Lake City area.

Ralph M. Wright is chairman of the board and C. Richard Wright is president. In 1978, the organization employed approximately 50 people and had annual gross receipts of approximately \$850,000. The heating bill, using interruptible natural gas normally, and fuel oil (both in the same boilers) during times of gas curtailment, was \$85,000 in 1978, at an average cost of \$1.30 per million Btu. At that time, Ralph Wright was president of the Society of American Florists, an organization having 15,000 members. Many of those members experienced much higher fractional heat costs (of their gross expenses), and were less than profitable because of these high heat bills. At that time (and still true in 1982), Utah (served by Mountain Fuel Supply Company) had natural gas costs about one-half of the national average.

Utah Roses initiated a study of floral greenhouse heat with geothermal energy in 1976. Their intent was to encourage geothermal energy use in the floral industry throughout the nation. In 1978, they contracted with Energy Services of Idaho Falls to assist them in the study of the geothermal potential of their area. Three warm water wells were identified within 3 mi of the greenhouse. The area's geothermal potential extended north and south along the Wasatch Mountain Front. Although the greenhouse is about 4 mi from the Wasatch Fault, another perpendicular fault had been inferred as cutting directly through the property.

With the ultimate goal of an operating geothermal heating system for their business in July 1978, Utah Roses applied to participate in a cost share cooperative agreement with the Department of Energy (PON ET-78-N-03-2047), which agreement became effective on January 24, 1979.

Fig. 18.1 Location Map

Fig. 18.2 Site Plan

The environmental report was completed during the next two months. After receiving approval on the environmental aspects, the project team then investigated further the geographical distribution of the faults and any other hydrogeological indications of geothermal energy in the area. It was concluded, by the project team and by the Department of Energy's advisors, that the Utah Roses seven-acre property was as promising a location for finding geothermal energy as any other location within about 2 mi. It appeared that there was a buried east-west trending fault running directly under the property.

Work proceeded on contracting for a large drilling rig capable of reaching a minimum of 5000 ft, i.e., an adequate contingency capability for the target depth of 3000 ft. Drilling of the well began just after Thanksgiving in 1979, and was completed to a depth of 4994 ft from ground level on December 12. The well proved to have temperatures only slightly above the nominal minimum target of 120°F, and the productivity was much less than was sought, but still adequate to supply a significant portion of the heat for the facility.

Many attempts were made to enhance the productivity and temperature from the well, all with little or no additional success. The well appeared to be producing from the 2800 to 3800 ft depths, and pump testing indicated enough warm water (220 gpm) to supply between 50 and 60% of the annual heat needs of the greenhouse facility. On this basis, the greenhouse owner decided to proceed with retrofitting the greenhouse to extract heat from the water at 123°F.

The well is located only 100 ft from the greenhouse facility. A 100-hp submersible pump is set at the 1229 ft level, and the wellhead has a slow-closure bypass valve and a pressure relief valve to prevent the pump from overpressurizing the greenhouse lines during startup. The well does have a small free (artesian) flow of about 5 gal per min when fully recovered. PVC pipelines carry the flow to the greenhouse and distribute it inside the greenhouse to 46 finned tube heaters, each with fan-forced air. At the inlet to the first of the heaters, the water temperature is

121°F (about 2°F is lost between the wellhead and the first heaters). All the discharge water is collected in a common discharge line and then discharged to a small waste water canal that flows parallel to and about 20 ft from the north wall of the greenhouse. The discharge water is about 90°F, containing 2800 ppm dissolved solids. The waste water canal empties into the Jordan River about 500 yd downstream, and the Jordan flows for about an additional 12 mi before emptying into the Great Salt Lake.

Construction of the distribution system and the installation of the wellhead equipment and the heat exchangers inside the greenhouse began in July, 1981 and was completed at the end of October 1981. The system was first put into continuous operation on November 4, 1981.

3. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

The major technical uncertainty, whose overall effect cannot be evaluated for several years, concerns the long range performance of the heat exchangers (finned copper tubes), which are in direct contact with the geothermal water. This decision involved both economic and technical considerations. It was eventually decided to use finned copper tubes to gain substantial economic benefits (much lower installed costs) by purchasing off-the-shelf heat exchangers. Should these serve reasonably well for a period of at least 5 yr, the economic gamble will have been justified.

Other technical decisions were less critical or significant, and the project ran smoothly from the standpoint of technical considerations within the constraints of the limited resource provided by nature. The drilling of the nearly one mile deep well was accomplished in two weeks of actual on-site drilling operation time. The expensive rig was dismissed, and the well evaluated and reworked with a less expensive workover rig at a later date. Despite the fact that a small bridge developed in the well in the open hole section shortly after dismissing the large rig, it is concluded that this approach and scheduling of rigs was very cost effective.

The only minor delay experienced during the drilling was to recover the cones and bearings from a mill-tooth bit that was completely worn out and came apart after only 12 h during 300 ft of drilling. The drilling, however, was in a very abrasive sandstone, that cut rather easily. There was no warning that the bit was worn out before it came apart. Awareness and appropriate care during the drilling of similar formations on future projects would be appropriate.

The automatic valve equipment on the wellhead, used to protect the distribution lines from water hammer and excessive pressure during pump startup, may have been overdesigned. Apparently the submersible pump, set at the 1229-ft level, is slower acting on startup than had been

anticipated. A single fast-acting, automatic-resetting relief valve might have provided all the protection required from this pump which is capable of generating 1700 ft head.

Issuance of the drilling permit and consumptive water right was accomplished in a timely fashion, and the State of Utah cooperated well. Free, open discussion and dialogue with the state regulators in efforts to obtain permits for such geothermal projects is recommended.

Obtaining the discharge permit was a major issue and one of considerable delay in the project. The State of Utah's Pollution Control Board did act reasonably promptly and gave appropriate but contingent approvals. However, project personnel experienced considerable confusion and delay in interfacing the regulatory responsibilities between the state and the EPA. Future projects should experience less delay, for in 1982 the state became the sole regulator through agreement with the EPA.

Overall, the greenhouse owner considers the project marginally successful, primarily because the geothermal system is unable to meet the desired replacement of all the fossil fuel needed for heat. However, the greenhouse owner must consider that his investment (one-third of the total investment) was successful, for the simple payback period is only 3 yr, even in the depressed natural gas price structure of Utah. When taken as a whole, however, the project has only been marginally successful economically in the climate of the high interest rates that existed throughout most of the project period and the low natural gas prices in Utah. In the current (January 1983) climate of much lower interest rates, plus the prospect of deregulation of natural gas prices, the economic benefit of the project appears to become very significant.

The major economic decision was required after the completion of the well and prior to committing approximately \$200,000 to \$300,000 investment into the heating system. The disposal permits had been issued at that time, so additional expense for an injection well was then known not to be necessary. The U.S. Department of Energy had no remaining obligated funds

to assist in drilling an injection well, and the entire cost of such would have had to have been borne by the greenhouse owner. (The Department of Energy had paid for the bulk of the costs of the production well, but the investment in the pump and heating system was entirely the responsibility of the owner.) Even if the involvement of the Department of Energy had been less for the production well drilling phase of the project, it is doubtful if the decision to proceed with completion of the project would have been any different.

With the lower well flow than had been targeted, it was decided to reduce control costs for the system and its pumping operation to a minimum, and to operate the system for maximum utilization. This has been done to date. Through most of the winter months, the system is operated at a steady pumping rate of 24 h a day. In the spring and fall, the system is usually shut off during the daylight hours if there is sunshine and normal movement of air from the ventilation fans. In order to extract as much heat as possible from this 123°F water, it was decided to use the fan-coil type of heat exchangers, all overhead.

If heat exchangers would be installed to heat outside air being used for interior ventilation, daytime winter operation could probably reduce the discharge geothermal temperature to as low as 70°F, and extract much more energy from the system. However, it is not clear that the occasional daytime winter usage of these additional heat exchangers would justify the investment.

The 4-in. PVC pipeline from the well to the greenhouse, approximately 100 ft long, is not insulated. Temperature measurements indicate a nominal 2°F loss in temperature along this pipeline. If indeed, this is the amount of temperature loss, then it would have been cost effective to insulate the line with a coating of urethane foam. Each degree loss in temperature is costly, on a yearly basis, resulting in approximately \$3,000 of heat that is never delivered to the facility (about 1000 MCF of natural gas).

As a result of the initial encouragement by the U.S. Department of Energy, Utah Roses, Inc. concurrently pursued expanding its production capability by building a new facility at a site that had significant geothermal potential. Crystal Hot Springs, 10 mi south of the main Utah Roses facility, was selected because of location and the reasonable purchase price. In the fall of 1979, a well was drilled successfully at this location to a depth of only 410 ft. Flows of 400 gpm of 190°F geothermal water were pumped with a 30-hp pump.

Three acres of new greenhouses were put into operation in the summer of 1980, and a reinjection well drilled. The units were operating on geothermal heat by September and were the sole source of heat for the facility. The additional cost for the geothermal system, compared to a natural gas heating system was about \$70,000.

This new greenhouse and geothermal heating system is replacing approximately \$110,000 of natural gas annually. Electricity charges for operating the geothermal well pump are only about \$5000 per year. Because of the higher quality and availability of the geothermal resource at Crystal Hot Springs, the simple payback for the geothermal system there was less than 1 yr compared to about 8 yr with the resource at the Sandy, Utah facility.

4. THE RESOURCE

4.1 General

Utah Roses is located within four miles of the major system of north-south faults known as the Wasatch Fault that extends from St. George northward through Salt Lake City, Ogden, and on into Yellowstone Park. Thermal springs are common all along this fault system. A less well-defined east-west cross fault cuts through Sandy apparently directly across the Utah Roses property. Within a radius of two miles of the property, there are three thermal wells. Many thermal wells and springs exist in the metropolitan Salt Lake area. Geothermometric calculations, based on geochemical properties of spring and well water, indicate likely source temperatures from about 170 to 350°F. A slightly warm (80°F) well, 800 ft deep, is within 700 ft of the Utah Roses well. The fault that passes east-west through the Utah Roses property and intersects the Wasatch Fault was identified by aeromagnetic data made in the 1950s by a private oil company. (Reference USGS Circular 75-616.) This latter fault was encouraging, not merely as a conduit for hot water from depth, but as an indication that fracturing and good permeability should exist at depth.

Crystal Hot Springs, 10 mi to the south, is a known resource of at least 135°F, and was confirmed to be able to produce 190°F water by drilling that took place one month before the well was drilled at the Utah Roses greenhouse. (The drilling at Crystal Hot Springs has since resulted in a major geothermal development for three additional acres of greenhouse, built by Utah Roses in 1980, and entirely heated by geothermal water.)

Additional geophysical investigations were considered, but it was decided that neither resistivity nor reflection/refraction active seismic work would give practical results in the heavily industrialized area adjacent to Interstate 15. Furthermore, the cost of effective geophysical surveys of this type would be half the cost of the proposed production well. Finally, it was recognized that there was virtually no geographical

option for the intended application. Pipelines to transport geothermal waters in this area of metropolitan Salt Lake City would be extremely expensive, virtually limiting the location of the well to or very near to the seven acres owned by Utah Roses, Inc.

The likelihood of geothermal waters being present in this area was high. Indications from the geothermal seeps in the area were such that the quality of these waters was likely to be good--less than 5000 ppm dissolved solids.

4.2 Well Drilling

The site was selected on the seven-acre Utah Roses property because of convenience and because no scientific case could be established for a more geologically desirable drill site within two miles.

There was only one location on the property large enough to accommodate a medium sized oil-drilling rig. That location was on the west side of the greenhouse, adjacent to the Galena Canal. A reserve pit approximately 50 by 30 ft by 8 ft deep was dug, and the remainder of the site prepared with a heavy gravel base.

The well drilling was performed under a standard contract of the International Association of Drilling Contractors. CRC Colorado Well Service performed the drilling, and the workover and completion of the Utah Roses well was under the engineering direction of Energy Services, Inc. of Idaho Falls, Idaho. Energy Services also served as the overall engineering subcontractor on the geothermal demonstration project.

The completed well profile is shown in Figure 18.3. The drilling began on November 25, 1979 and was concluded on December 9 at a depth of 5008 ft (kelly bushing), 4994 ft from ground level. Water samples, formation samples, and temperature logs were taken periodically

Fig. 18.3 Well Profile and Lithology

during the drilling. Chemical and radioactive analyses were run on the drilling fluid return samples and on the geothermal fluid samples taken later from artesian flow in the well. Graphic depiction of drilling activity is shown in Figure 18.4.

The suspected east-west fault, identified from aeromagnetic and gravity data, was not positively confirmed by the drilling. Virtually all of the drilling below the 500 ft level was in sandstone formations, fairly well cemented, and apparently with relatively poor permeability. There was no evidence that a better well would have been obtained if the well had been located anywhere else within easy piping distance (a city block or so).

Apparently, no fluid is being produced below the 3800-ft level, and the temperatures only meet minimum expectations. The geothermal gradient is about 2.3°F per 100 ft, higher than the worldwide average, but slightly less than typical conditions for the basin and range area.

4.3 Well Testing

Since the well was only slightly artesian in flow (about 7 gpm maximum), the only meaningful resource testing required the use of a pump. Both stepped drawdown tests (for short periods at each flow step) and long term drawdown tests (nearly to the bowls of the pump) were conducted. In general, all tests were run so as to apply the Jacobs approximation to the Theis Equation solution for two-dimensional radial flow in a porous medium. This required constant flow while accurately measuring the change in drawdown.

Extrapolation of the results of the Theis Equation lead to the conclusion that there was little well bore damage, i.e., that the restricted production from the well was primarily the result of tight formation. After 12 h of drawdown testing, there was no obvious deviations from a constant semilog slope. Extrapolation of the data led to the

Fig. 18.4 Drilling Profile

conclusion that the productivity index was approximately 5 ft of drawdown per gallon per minute production, over the long term (five years of winter operation only).

It was also concluded that to maintain a 190 gpm rate indefinitely, for nighttime usage only, the well would have to be allowed to recover for at least eight hours each day, at least for the long term of more than two months operation. Subsequent actual operating experience for the first six months, the last five of which were continuous, showed that the above conclusion was conservative. The well was capable of sustained operation at about 180 gpm without drawing down close to the pump bowls (within 100 ft). Current detection safety equipment in the pump circuit would automatically shut the pump off if pumping conditions allowed the suction head to be less than approximately 100 ft of water.

5. THE ENERGY EXTRACTION AND USE SYSTEM

5.1 General

A 42-stage Centrifugal submersible 100-hp pump was installed with the motor set at a depth of 1270 ft (Figure 18.5). The optimum long term flow rate for a nominal 1000-ft drawdown was calculated to be 180 gpm. The relatively low temperature of the geothermal fluids made it possible to use PVC pipe for distribution through 4-in. main headers. Service was provided to fan-forced heaters in overhead locations as shown in Figure 18.6. As-built, 35 Coil Company heaters were installed in the east greenhouse, and 20 Modine heat exchangers that had been in steam service were converted to geothermal service. Later, three were converted back to steam use. The discharged geothermal water, cooled to a nominal 90°F, leaves the greenhouse at its northeast corner and discharges into a waste water ditch (known as the Aarnall ditch) which runs along the north side of the greenhouse. The water then discharges underground to a storm sewer, for a distance of about one-half mile, where it discharges into the Jordan River. The only special provisions required were the construction of an aqueduct over a "fresh water" canal (Galena Canal) owned by a mining company, and occasionally used in a milling operation that is located two miles north of the greenhouse.

The Aarnall ditch normally carries flow of 600 to 2000 gpm of waste water, usually at temperatures nominally equal to the daily average ambient air temperature. The geothermal heating system discharges about 180 gallons per minute of 90°F water into the ditch.

5.2 Controls

A 12-in. master gate valve controls the wellhead flow. Wellhead pressure control is provided by a surge control valve and a pressure relief valve, both made by Bailey. A minimum pressure of 25 psi is maintained to minimize corrosion and deposition from sulfide, bicarbonate, calcium, and chloride ions in the geothermal fluid. Control of the system is manual with

Fig. 18.5 Final Wellhead/Pump Assembly

Fig. 18.6 System Schematic

safety overrides to maintain pressure. There is no temperature control for the geothermal system. If the geothermal system cannot meet load requirements, the backup steam system comes on, providing heat to the peripheral piping radiators, plant basepipe radiators and existing fan-forced steam heat exchangers. If the temperature gets too high, modulating is achieved with exhaust/ventilation fans that are thermostatically controlled to maintain 70°F during the day and 60°F at night.

The primary form of routine monitoring of the energy derived from the geothermal system is to record the periods that the geothermal deep well pump is operating. Annual energy savings are determined by comparison of fossil fuel bills from year to year, corrected for differences in outside temperature.

Thermometers monitor the inlet temperature of the geothermal water to the greenhouse, and the discharge temperature from the greenhouse. A "turbine-type" flow meter monitors the flow rate.

Effluent discharge is monitored weekly for conductivity of the water, and quarterly for major chemical and radioactive contaminants. Total flow is obtained on a weekly basis.

6. ALTERNATE CONSIDERATIONS

Modification of the primary scope occurred only with respect to the depth of the well. A decision to continue drilling beyond the 3000-ft level was made during drilling. The decision stemmed from the fact that temperatures and flow at the 3000-ft level were below expectations and deeper drilling could be accommodated by the drilling budget. Drilling continued in an open hole until terminated at the 4994-ft level, due to budget limitations. The 2000-ft of additional depth achieved both higher water temperatures and increased production.

Bids were received on heat exchangers made with copper tubes (\$800), admiralty brass (\$2,800) and stainless steel (\$7,000). Based on limited coupon and tubing sample arrays subjected to geothermal fluids and the atmosphere at the project and long-term controlled test data obtained from the Raft River geothermal project, it was concluded that the advantage of admiralty brass over copper was not significant enough to warrant paying the increased price. There was also concern that stress-corrosion cracking might occur on the stainless steel tubes as a result of the high chloride content in the water, and that the order of magnitude higher price for these units was not an economical cost benefit ratio.

Consideration was given to installing a plate-type heat exchanger, at a cost of approximately \$10,000, to isolate the geothermal fluid from the copper coils of the fan-coil units. It was calculated that this unit would have a temperature difference between the primary (geothermal) and secondary (treated water circuit to heat exchangers) fluids at no less than 5°F. This amount of temperature loss, before even reaching the main heat exchangers, would result in less heat transferred to the facility space, lowering the geothermal displacement of fossil fuel by \$18,000 per year (at the then current Utah natural gas prices). After considering these estimates, it was determined that if the standard copper-tube heat exchangers were to be used and lasted approximately five years before all needed to be replaced, that this alternative for the design would have a

substantial overall economic advantage compared with the other alternatives. This was true even if the use of intermediate plate heat exchanger would allow the copper-tube heat exchangers to last indefinitely.

The automatic valve equipment on the wellhead that protects the distribution lines from water hammer and excessive pressure during pump startup, may have been overdesigned. Apparently the submersible pump, set at the 1229-ft level, is slower acting on startup than had been anticipated. A single fast-acting, automatic-resetting relief valve might have provided all the protection required from this pump, which is capable of generating a 1700-ft head.

7. SYSTEM OPERATION

The well and the pump have delivered the quantities of fluid that were expected from long-term operation, within the measurement accuracy of $\pm 10\%$. Actually, the well has performed better than had been planned. With the pump setting depth selected, it was felt that it would be unlikely that the well could be run continuously at flows of about 180 gpm without drawing the water level down to the bowls. After the first six weeks of operation, with the planned 16 h on, eight h off schedule, the well showed no signs of drawing down to the level that would cause sufficient current underload on the pump, indicative of a low suction head. It was therefore decided to attempt to operate the pump around the clock throughout the cold months, and this was done from mid-December until mid-April.

The system has been largely maintenance free. It was shut down for brief periods twice. One shutdown occurred because the output of the pump appeared to be well below the 190 gpm predicted; actually, the flow meter had failed, which was verified by measuring the discharge with a bucket. A second failure occurred to part of the system when the surge control valve failed to operate as it should. The fault was eventually isolated to a stuck four-way solenoid valve, which had to be replaced.

There have been no postconstruction modifications (as of October 1982) to the production system. Owner satisfaction has been mixed; the well has not performed as was hoped before drilling and completion, but the well has performed slightly better than the pump testing and design conditions had indicated. It has been possible to run the well pump continuously without drawing down to the bowls.

The distribution system, consisting of PVC pipe inside the greenhouse, has performed well, with virtually no problems. An occasional glue joint has come loose.

The heat exchangers performed well over their first 15 months of service, four of those months with no operation, but filled with geothermal

water (corrosion inhibitor was not used during the first summer shutdown). One heat exchanger developed a leak, but careful examination revealed that the leak was not a result of corrosion, but a manufacturing defect (a bad solder joint).

Data on overall system performance have been limited to occasional monitoring of greenhouse inlet and outlet geothermal water temperatures and flow. This has revealed that the performance of these heat exchangers is 20 to 25% less effective than had been predicted from extrapolating, to lower temperatures, the manufacturer's performance data for 160°F inlet water temperatures. Such extrapolations can be expected to be somewhat inaccurate, but the difference was a bit larger than would normally be expected.

The only postconstruction modification to the distribution system was to switch three of the old Modine heat exchangers in the west greenhouse back to steam service, leaving nine geothermal water heat exchangers in the west greenhouse.

There has been no significant variation in the chemical or radioactive content of the well water (and hence the discharge water). The concern over potential localized fog conditions upon a nearby roadway arising from the discharge waters proved to be minimal.

8. SYSTEM, COSTS, SCHEDULE, AND ORGANIZATION

8.1 Costs

Table 18.1 is a summary of the costs incurred in 1979-81 for the development of the Utah Roses PON project.

Based on an estimated annual net fuel cost savings of \$83,510 and annual maintenance costs estimated at \$2,000, the simple payback period for the total project cost would be 8.7 years. However, actual savings the first year of operation were only \$40,000. This savings does not reflect any additional economic benefit to the investor from tax benefits, such as investment tax credits and various expenses for operations, intangible drilling costs, and depreciation. Without these, it is likely that this particular project, in the particular time period that it was undertaken (extremely high interest rate costs), would not have been economically satisfactory to Utah Roses.

8.2 Schedule

The cooperative agreement for the project was set in place January 24, 1979. Drilling activity started in September, and the well was spudded in November and completed in December. However, well workover was not completed until May, 1980. Construction work occurred between July and October 1981, and initial plant operation started November 4, 1981.

8.3 Organization

The project was initiated by Utah Roses, Inc. under the direction of Mr. Ralph Wright, Chairman of the Board. In May 1979, he contracted with Energy Services of Idaho Falls, ID, a subsidiary of Forsgren-Perkins Engineering, to have a proposal prepared for submission to the Department of Energy. The proposal preparation and all subsequent technical work was under the direction of Dr. Jay F. Kunze, manager of Energy Services of

TABLE 18.1. UTAH ROSES PON PROJECT CONSTRUCTION COSTS

<u>Intangible Costs</u>	<u>DOE (\$)</u>	<u>Utah Roses (\$)</u>	<u>Total (\$)</u>
Proposal preparation	--	11,500	11,500
Environmental, geological	17,700	2,300	20,000
Well drilling	190,000	--	190,000 ^a
Remedial work on well	68,000	--	68,000
Permits, other legal	--	4,200	4,200
Reports, technical papers	21,300	--	21,300
Project management	--	20,500	20,500
<u>Tangible Costs</u>			
Well drilling	140,000	--	140,000
Remedial work on well	18,000	--	18,000
Pump and well head	--	89,000	89,000
Heat exchangers, piping	<u>--</u>	<u>116,000</u>	<u>116,000</u>
Totals	455,000	243,500	698,500

a. Does not include geophysical logging provided by the U.S. DOE Grand Junction office, and a master gate valve, with a combined value of \$5,000.

Idaho Falls and an engineer licensed in the State of Utah. Supervision of the drilling operation was under the direction of Ray W. Gould of Energy Services.

Several professional consultants participated during the formative stages of the project, and in the environmental and resource assessment efforts. These were Mr. Jack A. Barnett, Professional Geologist and water right expert and then the Director of the Western States Water Council; Mr. Wayne S. Ursenbach, Environmental Specialist and Assistant Director of the University of Utah Research Institute; and Dr. Charles Pitt, Professor of Metallurgy at the University of Utah.

The Federal Land Bank was the financing organization, and legal counsel was provided by W. Robert Wright, Salt Lake City, Utah.

9. LEGAL AND INSTITUTIONAL CONSIDERATIONS

An environmental report was prepared as the first phase of the project. This report formed the basis for an environmental review by the U.S. Department of Energy. Since there were no significant environmental problems and the project was to result in benefit to be realized in reduced consumption of depletable fossil fuels, the environmental assessment was favorable toward proceeding with the project. The project resulted in no significant environmental impact.

Utah Roses, Inc. owns the land and all mineral and water rights on which the well was drilled. This made the acquisition of drilling rights, access to the land, and permission to modify the surface, all issues of little consequence. Permits were much easier to obtain than in the conventional buyer-seller arrangements. There was no need for leases or obtaining rights-of-way.

A construction permit for the well and heating system was obtained from the City of Sandy prior to receiving the Department of Energy grant.

Issuance of the drilling permit and consumptive water right was accomplished in a timely fashion, and the State of Utah cooperated well. Free, open discussion and dialogue with the state regulators in efforts to obtain permits for such geothermal project proved to be successful.

Obtaining the discharge permit was a major issue and one of considerable delay (one heating season) in the project. The State of Utah's Pollution Control Board did act reasonably promptly and gave appropriate but contingent approvals. However, project personnel experienced considerable confusion and delay in interfacing the regulatory responsibilities between the State and the EPA. Future projects should experience less delay, for in 1982 the state became the sole regulator through agreement with the EPA.

10. REFERENCES

Numerous documents were prepared to cover various aspects of this project. Much of the information contained in this report is excerpted from the project final report prepared by Energy Services, Inc., Idaho Falls, Idaho, and appreciation and thanks are extended to them and Utah Roses, Inc. for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. Energy Services, Inc., Final Report, Floral Greenhouse Geothermal Heating Demonstration, Report No. DOE/ET/27056-5, Contract DE-AC07-79ET 27056, October 1982.
2. Energy Services, Inc., Utah Roses, Inc., Technical Proposal, UR-G-78, July 1978.
3. Energy Services, Inc., Utah Roses, Inc., Business Proposal, UR-G-78, July 1978.
- *4. Energy Services, Inc., Environmental Report for Geothermal Space/Process Heating Project, Report No. DOE/ET/27056-1, Contract DE-AC07-79-ET-27056, March 1979.
- *5. Energy Services, Inc., Semi-Annual Report, Floral Greenhouse Heating, Report No. DOE/ET/27056-2, Contract DE-AC07-79-ET-27056, October 1979.
6. Energy Services, Inc., Technical Specifications for Geothermal Well Drilling, Application No. 50289 (57-8337), July 9, 1979 (Revised August 14, 1979).
7. Energy Services, Inc., Utah Roses Floral Greenhouse Geothermal Project Semiannual Technical Report, August 1979 to April 1979, Report No. DOE/ET/27056-3, Contract DE-AC07-79ET-27056, April 1980.
8. Energy Services, Inc., Environmental Supplementary Analysis Pertaining to Discharge of Geothermal Fluids, Report No. DOE/ET/27056-4, Contract No. DE-AC07-79-ET-27056, October 1980.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

9. Kunze, Gould, Hyndman, Wright, Low Temperature Geothermal Heating System at Two Utah Roses Facilities, ASHRAE Report, January 1982, Presented at Annual Meeting, June 1982, Toronto. ASHRAE Paper TO-82-4, No. 2 (Included in ASHRAE Transactions, Vol. 88, Part 2).
- *10. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *11. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

DIAMOND RING RANCH PROJECT

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1. PON PROJECT SUMMARY DATA

Project Title: Diamond Ring Ranch Heating and Processing

Project Data:

Project Description: Geothermal fluid at 152°F with 170 gpm artesian flow is used to heat six structures, provide heat for a 700 bushel/h grain dryer, and for stock watering.

Location: 50 miles west of Pierre, South Dakota in Haakon County, central South Dakota

Peak Heat Load: 2.26 million Btu/h

Annual Heat Load: 4.74 billion Btu/yr (23.9% load factor)

Simple Payback: 8 yr

Status: The system was installed and operated satisfactorily. However, ranching activities were halted and use of the system stopped accordingly.

Cooperative Agreement Data:

Number: DE-FC07-78ET28419, formerly ET-78-F-07-1729

Period: June 30, 1978 to September 30, 1982

DOE Share: \$249,900 (62%)

Participant Share: \$153,200 (38%)

Total Cost: \$403,100

Principal Investigator:

Dr. Stanley M. Howard
South Dakota School of Mines and Technology
500 East St. Joseph Street
Rapid City, SD 57701
605/394-2341

Other Participants:

Design, Construction Supervision:

Thomas Zeller
RE/SPEC, Inc.
Box 725
Rapid City, SD 57709
605/343-7868

Construction:

C. K. Gerlach
Gerlach & Ebert Plumbing and Heating
1104 Jackson Blvd.
Rapid City, SD 57701
605/342-0674

Resource and Applications Owner:

Joe Verlin
Kalispell, MT
406/883-2859

2. PROJECT HISTORY AND DESCRIPTION

The Diamond Ring Ranch completed in 1959 a 4112 ft geothermal well into the Madison aquifer for the purpose of providing domestic livestock and irrigation water. The well has 8-in. casing at the surface and flows artesian at the rate of 170 gpm and at a temperature of 152°F. The ranch operator had considered utilizing the resource for more than watering, but it took the implementation of the PON project to establish the scope of the work that could be done. The project activity started in June 1978, and construction occurred during the spring and summer of 1979.

The completed geothermal project provided space heating for a shop, an insulated hospital barn, and four residences for the ranch that is located about 50 mi west of Pierre, South Dakota (Figures 19.1 and 19.2). Heat was also provided for a grain dryer.

The geothermal system includes a number of components. A new air separator is installed on an existing geothermal production well. The fluid is transported in buried PVC piping a total of 4000 ft to the grain dryer building where a plate-type heat exchanger isolates the fluid from a closed hydronic loop. A second heat exchanger was also installed at the dryer building to provide closed loop hydronic service to the remaining ranch buildings. Service was not provided to the feedlot sheds as originally planned because the cost exceeded the expected benefit. A significant amount of the geothermal fluid leaving the heat exchangers is pumped to livestock watering systems, and a small amount is used for domestic use. The remainder is discharged into reservoirs on the ranch property.

Fig. 19.1 Location Map

Fig. 19.2 Site Plan

3. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

This project demonstrated the feasibility of utilizing a moderate temperature geothermal resource for space heating and agricultural purposes. A number of significant findings from the project are listed below:

- o Geothermal heating systems in remote locations must be passively protected against freezing in the event of power or other equipment failure. This is most effectively done by requiring antifreeze in all recirculating lines exposed to freezing conditions and providing for automatic drainage of geothermal fluid transmission lines which may be subjected to freezing conditions. In addition, every effort should be made to prevent leakage of the antifreeze.
- o Each space heating application should have shut-off valves on both the return and supply lines located immediately outside each application structure so as to allow servicing of geothermal exchangers and interior distribution lines without danger of flooding the structure.
- o Filtering screens should be placed before each positive displacement flowmeter.
- o No special insulation should be required in transmission or distribution lines buried in dry, low-conductivity soils such as the Pierre Shale.
- o Stainless steel 304 is normally a suitable corrosion resistant material for contact with Madison aquifer geothermal fluid.
- o Air vents should be installed in the high points of gravity flow transmission lines.

- o Pipe thread joints between bronze circuit setters and PVC pipe threads should be inspected before installation to ensure compatibility. It was found that the PVC male threads did not seal with the circuit setter threads because the circuit setter threads were too short.
- o To minimize the institutional and regulatory barriers to private site geothermal development, plans should be made for the cascaded use of the geothermal fluid. This is easily done in agribusiness by using the fluid for irrigation or stock watering.

The economic feasibility of a geothermal system is highly dependent upon a number of factors, some of which are:

- o The size of the thermal demand
- o The transmission distance for the geothermal fluid
- o The assignment of well cost to water development
- o The distance between individual application sites within one system
- o The development of year-round applications for the resource.

The following recommendations are made as having a major favorable impact on the economic impact on geothermal systems in agribusiness:

- o Develop the geothermal resource in concert with water development so that well costs may be shared or assigned to water development.
- o Drill production wells near the application site. This is relatively easily done in the Madison aquifer.
- o Develop grain drying and other such nonheating season applications so as to increase use efficiency.

4. THE RESOURCE

4.1 General

The Madison aquifer, or as it is locally known in the Black Hills, the Pahasapa Formation, is generally referred to as a limestone, although much of the formation is actually a clean, crystalline dolomite. The Madison carbonates, and their time equivalents elsewhere in the Rocky Mountain region, were deposited in a broad seaway which covered much of the area now occupied by the Rocky Mountains of the United States and Canada. South Dakota lies on the eastern edge of that former seaway. The formation thickens from zero along the eastern edge of the subcrop to over 1300 ft in northwestern Harding County. Further to the north and northwest, it thickens to about 2700 ft in the center of the Williston Basin in North Dakota, and to over 2800 ft in the Central Montana trough.

The Madison is divisible into three lithologic units, which are in ascending order: the Lodgepole Member, the Mission Canyon Member, and the Charles Member. In the deeper parts of the Williston Basin, and extending into northwestern South Dakota, the Charles contains evaporite units which profoundly affect the quality of the Madison water.

Porosity in the Madison aquifer is a combination of three types: (a) normal intergranular porosity, particularly in the dolomites, (b) joint and fracture porosity, and (c) solution openings ranging in size from slightly enlarged joints to caverns in which the drill bit may drop several feet. Permeability is affected also by the types of openings present in the aquifer. It is not surprising that well yields vary widely.

The Madison limestone is noted throughout its areal extent for large flows of water under high artesian pressures, and for the attendant drilling problems of well control and lost circulation.

Because water now entering the limestone cannot all be accepted by the hydrologic system, some of it breaks back to the surface to form artesian or resurgent springs. Although the position of these springs has shifted somewhat as erosion progressed, the present-day sinkholes and springs are descendants of the earlier system.

Very little is known about the movement of the water once it enters the Madison artesian system. Except close to the outcrop area, the potentiometric surface becomes nearly flat, and no definite directions of movement can be inferred. Very little information is available on transmissivities, storage coefficients, or specific capacities of Madison wells in South Dakota. The question of interference between closely spaced limestone wells has not been adequately studied.

Recorded well yields in the Black Hills area range from 80 gpm using a pump to over 1000 gpm free flow. It would appear from study of the randomly distributed wells in South Dakota that a discharge of 500 gpm, either natural flow or pumping, can be considered an average for a properly constructed and developed Madison well. Some wells would require acid fracturing to reach this rate of production.

A distinction has been made between temperatures obtained directly from flowing or pumping wells, and data from bottom-hole temperature recorders. Surface water temperature is slightly lower than formation temperature if the water movement to the surface is slow, and wells in long service frequently yield water a few degrees warmer than the figures obtained on the initial production tests.

The highest temperatures occur in the northwestern part of the state, where the Madison lies at depths of over 7000 ft with temperatures of 170°F.

The large warm-water area in the west-central part of South Dakota is an anomaly for which there is no satisfactory explanation at present. Carda has noted that the Philip, Midland, and Bar-N Ranch wells in Haakon County are the only three Madison wells within the state in which he detected Radium 226, and all three lie within the warm-water anomaly.

Madison wells are sometimes difficult to complete properly. If the red shale cap which generally overlies the Madison karst surface were always underlain by relatively solid limestone, it would be relatively simple to drill a few feet into the top of the limestone to set and cement casing. But in karst topography, mud-filled fractures and caverns may be encountered several feet or even several tens of feet below the first apparently solid limestone. These red zones may cause trouble by permitting the well to throw out chunks of red shale. The chunks may wedge in the casing, where they restrict flow and usually cause the well to yield water with a reddish cast. Generally, setting a perforated liner after determining the extent of the cavernous area will solve the problem.

Because drillers anticipate a large flow when the first cavernous porosity is encountered, they are prone to set casing at the first sign of Madison limestone, and to take their chances on later cavern fillings.

Fortunately, limestone wells respond to acid stimulation. Acid injected under high pressures not only fractures the rock hydraulically, but enlarges the fractures as the acid is held in the rock under hydrostatic pressure. Acidizing at selected intervals, after examination of porosity logs (gamma ray and bulk density), permits placing the acid in relatively tight areas rather than having it all pass into the most open passages. Successive injections of small amounts of acid (3000-5000 gal) in carefully selected intervals is generally more effective than one large "shotgun" treatment.

4.2 Well Development and Testing

The well used for this project was drilled in 1959 and had an artesian flow of 173 gpm at 153°F. No reservoir studies or assessment were conducted as a part of this investigation. However, a comprehensive review of the Madison was completed under a previous geothermal investigation. The only site-specific analysis performed at the Diamond Ring Ranch involved corrosion analysis.

Previously analyzed and compiled data on the Madison show water quality varies widely within the Madison aquifer. It can generally be said that the water quality is best close to the Black Hills perimeter and decreases radially outward, with the lowest quality occurring to the north of the Black Hills. The northernmost counties in South Dakota have the worst quality, at the greatest depths and some of the highest temperatures, but have the lowest population. This water in most cases exceeds recommended EPA levels for human consumption in several parameters; however, people have been known to drink it with few ill effects, notably in Midland and Edgemont.

The Madison waters observed, when permitted to cool and evaporate in the atmosphere, will produce a heavy white deposit composed primarily of gypsum and amorphous silica. However, this deposit does not seem to occur in the transmitting pipelines. Madison water is far superior to most water from the shallower Inyan Kara group and is highly prized by the ranchers.

The gas contained within the water is composed largely of nitrogen, carbon dioxide, traces of oxygen, and hydrogen sulfide. The sulfide concentration has been determined on-site by the methylene blue colorimetric method and measured spectrophotometrically. The hydrogen sulfide is apparently the cause of much corrosion.

Because of the complexity of Madison waters and the difficulties encountered in using scaling indices to predict corrosion and scaling tendencies, an experimental program was undertaken under a previous grant and continued under this project to provide reliable information on (a) the corrosion behavior of commonly used heat exchanger metals and alloys and (b) the probability of scaling. A corrosion test rack was installed at the ranch on August 16, 1977. Inspection of the specimens after three weeks' exposure showed the familiar black copper sulfide deposit throughout the assembly. Aluminum 3003 was corroded with large deposits of a white amorphous material covering severe pits. Carbon steel was also severely

etched. This rapid attack on aluminum and carbon steel was attributed to high chloride concentrations. Disks of 304 and 316 stainless steel appeared least affected by exposure.

5. THE ENERGY EXTRACTION AND USE SYSTEM

The geothermal well drilled in 1959 is at a higher elevation than the geothermal use locations; the flow is artesian and no pumping equipment is required at the well site. A 6-in. diameter flanged tangential type air separator was installed at the wellhead to remove gases evolving from the geothermal fluid. The exit from the degasser consists of 6-in. PVC pipe, which is buried at a depth of approximately 4 to 5 ft. The distance from the well to the grain dryer is approximately 4000 ft. Due to the moderately undulating terrain between the wellhead and the grain dryer, two low spots in the line were unavoidable. Both of these low spots were fitted with a manhole with a valve and a tee to allow periodic flushing of the distribution line. From a point several hundred yards from the grain dryer, the 6-in. line branches into two 4-in. lines; one running to the grain dryer and the other continuing approximately another 1000 ft to the shop plate-type heat exchanger. One additional cleanout was required on the section of the line from the tee to the shop. Figure 19.2 shows the route and layout of the transmission line and Figure 19.3 is a schematic layout of the system.

The transmission system consists of two closed hydronic loops: one supplying the shop, hospital barn, and the two trailer homes, and the other supplying the owner's home and the employee's home. All of the lines are 4-in. PVC pipe buried approximately 4 ft deep except inside each space heating application where the lines are reduced to 1-in. diameter and located above ground. Flow balance to each application is achieved through the use of conventional bronze circuit setter valves.

Initially, protection from freezing was provided by an ancillary electrical generating plant. However, this proved unreliable and passive protection was eventually provided by using a water-ethylene glycol mixture in the recirculating lines.

The distribution system at the grain dryer was very simple owing to the close proximity of the isolation plate-type heat exchanger to the water-to-air radiators. The short aboveground recirculating lines were

Fig. 19.3 System Schematic

filled with a water-ethylene glycol mixture at the onset of the project to provide for freezing protection. The geothermal water side of the isolation exchanger was protected from freezing during off periods by a small hole in the shutoff gate valve feeding geothermal water to the exchanger. This provides a small, constant flow through the exchanger. The same type of heat exchanger is used for the system providing heat to the farm buildings. The spent geothermal fluid discharge from the shop runs to a tee where it can either be discharged into a ravine leading to a collection reservoir or allowed to flow through a looped 2-in. PVC line cemented into the floor of a guest house and garage which are adjacent to the owner's home.

Fan coil units are used in the hospital barn and shop, and water to air heat exchangers were installed in existing plenums of the forced air heating systems of the ranch homes.

6. INSTRUMENTATION AND CONTROLS

The electric control system for the pumps is centralized in the pump-heat exchanger room in the shop. This minimized the electrical modification to the homes, shop, and hospital barn. It also facilitated manual control of the pump when setting the flow rates and also in emergencies when the pumps must be cross-linked. Installation and service was also made easier. Thermostatic controls are used for the homes. The shop and hospital barn did not have to be linked into existing systems. An underground control line was installed to link the various components. The controls are designed to ensure adequate heating in the homes plus freeze protection for the heat exchangers.

Energy delivered by the geothermal system is monitored using Btu meters located at the hospital barn, the shop, the two mobile homes, the employee's home, and the owner's home.

Energy monitoring at the grain dryer consists of measuring the increase in air temperature through the grain dryer. This information, combined with the volumetric flow rate of air through the dryer, allows for the calculation of energy delivered by the geothermal system. The only environmental monitoring required for this project involves the periodic sampling of reservoirs receiving the discharge water from the geothermal system. The discharge from the geothermal system runs to Reservoir 1, which flows into Reservoir 2, and ultimately into Reservoir 3, approximately 6 mi downstream. Water samples are drawn from these reservoirs on a periodic basis before and after geothermal system operation.

7. ALTERNATE CONSIDERATIONS

Consideration was given to using the geothermal fluid directly or having isolated recirculation loop systems. The direct delivery system would have supplied raw geothermal water to each application. This would have necessitated corrosion resistant exchangers (Type 316 stainless steel) at each application and a substantially more complicated flow control system. The isolation loop system was selected because it had lower cost, confined all corrosion and scaling problems to central isolation exchangers, and allowed less complicated flow control for each application. At the grain dryer, a direct geothermal fluid-to-air approach had obvious advantages with respect to freezing protection, but was rejected because of the eventual prospect of corrosion failure resulting in very costly water damage to grain in the dryer. Also, the time required to replace failed coils could result in the loss of undried grain.

The location of the central, isolation exchanger was always presumed to be at the shop since it was centrally located with respect to all of the applications. However, recirculating piping and pumping costs to the grain dryer were very high. Therefore, to reduce the construction cost, a second isolation heat exchanger was placed at the grain dryer. This also permitted a smaller supply line from where the grain dryer tap was made to the shop. This arrangement reduced the construction cost by approximately \$10,000.

A major design consideration was simplicity since the Diamond Ring Ranch is 50 mi from the nearest city where competent maintenance and repair service personnel might be found for sophisticated control systems. A second major objective was to build a system that could withstand prolonged electrical power outages, which are common during severe winter storms.

8. SYSTEM OPERATION

The geothermal well continued to flow as expected after being fitted with a degasser connected to the geothermal transmission line. The only problem arising after the construction was completed was a leak near the casing as it exited at the ground. This leak continued to increase and was repaired by exterior cementing.

Shortly after the degasser was placed in operation at the wellhead, an air lift problem in the degasser vent became apparent. Several gpm of fluid were being air lifted through the vent, falling on the ground and creating a mess. This problem was rectified during the operation by installing a 3-in. diameter PVC pipe approximately 20 ft long vertically from the degasser. This diameter was large enough to disrupt air lift of the water from the degasser. No additional loss of water from the degasser vent was observed after this modification.

No significant change in surface water quality was observed as a result of this project. The pipeline delivered 170 gpm of geothermal fluid as designed. However, during the first several weeks of operation it was observed that flow diminished with time. Repeated flushing of the line at the cleanouts along the low points of the lines improved the flow rate to some extent, but lower-than-design flow rates were achieved. This was found to be the result of air pocket accumulation in the high points along the line. This was corrected by providing air purge devices at two high points along the transmission line.

The transmission system is far superior to the transmission system previously used by the Diamond Ring Ranch personnel for stock watering. The transmission system is reliable and is not subject to plugging as was the smaller line previously used. The only difficulty in the transmission system exists at the discharge points for the transmission line. Both discharge points are fitted with large gate valves to control flow rates.

These large gate valves have a propensity for corroding and becoming very difficult to operate. This requires either very frequent maintenance or, as is the normal case, heating of the thread rod on the gate to free the valves.

A small amount of iron pyrite sediment was found to collect in low points of previously constructed lines. The accumulation of this deposit required periodic cleaning of the lines. Consequently, all low points in the new transmission lines are designed with flushing cleanouts.

The pipeline carrying geothermal fluid requires no maintenance with the exception of biweekly flushing of the low points along the line. This requires only several minutes of an operator's time.

The distribution system, consisting of two closed hydronic loops, was initially charged with water. The original design concept included auxiliary power for recirculating the water through the distribution system to protect it from freezing in the case of power failure. During the first winter of operation (1978-80), there was no power failure and the system operated normally. However, during the second winter, there were numerous power failures and considerable periods of inoperation leading to freezing of the lines. As a consequence, many of the aboveground lines had to be replaced during the summer of 1981. This experience made it apparent that more than auxiliary power supplies would be required to protect the system from freezing. It was determined that a passive protection system was far superior to an active protection system requiring the presence of an operator. Consequently, it was determined that antifreeze be placed in the distribution lines to ensure the protection of the lines from freezing. This was installed in September of 1981 and no problem with freezing occurred thereafter. However, leakage in the piping in the winter of 1984 caused the loss of the antifreeze, which was never replaced, making the system inoperable.

Leakage occurred between PVC pipe threads and the bronze circuit center. Although each joint received pipe compound, any twisting of the

thread caused leakage. It was determined that the PVC pipe threads bottomed out in the circuit center. The problem was cured by cutting off about 1/2 in. of the PVC thread and adding Teflon tape.

Service or modification of heat exchange equipment and monitoring equipment in each space heating location requires shutting the geothermal circulation for access. It became apparent from such experiences that it should be specified in each such geothermal system that there be a main shutoff in both supply and return lines to each home or other space heated structure at the exterior of the building. All of the exchangers performed as expected when the system was first operated. However, two major problems did appear in the system after initial operation. The first problem that arose was water freezing in the recirculating space heating system during periods of power failure. This freezing caused rupture of both exchangers in the mobile homes. These were removed and repaired with substantial difficulty. This problem was rectified by adding approximately 1000 gal of ethylene glycol (30%) to the system.

Another problem was the plugging of the flowmeters by particles in the recirculating lines. Most of these particles were introduced when a line was inadvertently broken during excavation unrelated to this project. This plugging was eliminated by placing in-line screens before each flowmeter.

The Btu meters performed satisfactorily until blockages or freezing occurred in the lines. At that point, ranch personnel applied heat to some of the flow meters, which melted the plastic rotors.

The system is presently inoperative because the antifreeze contained in the circulating loops leaked out. The ranch operators have chosen not to replace the large quantity of antifreeze, but are using the geothermal fluid for domestic purposes and irrigation.

9. SYSTEM COSTS, SCHEDULE AND ORGANIZATION

9.1 System Costs

The total project cost \$403,100. However, this includes \$90,000 for the value of the existing well. Diamond Ring Ranch provided 38% of the funding (\$153,000) and DOE provided 62%. The general costs are shown in Table 19.1.

TABLE 19.1. SYSTEM COSTS

<u>Item</u>	<u>Cost (\$)</u>
Design	33,700
Construction	327,200
Operation and monitoring	23,600
Technology transfer	<u>18,500</u>
Total	403,000

Monitoring data obtained show the space heating system capable of saving up to \$26,543 per year and the grain dryer substantially more than that, depending on usage. A typical two month per/year usage would result in fuel savings of \$20,784. Payback times under most assumptions for the system were generally less than 10 yr.

9.2 Schedule

The schedule for the Diamond Ring Ranch PON project is shown in Figure 19.4.

9.3 Organization

The principal investigator for the project was Dr. Stanley Howard of the South Dakota School of Mines and Technology, Rapid City. Design and

Fig. 19.4 Project Schedule

construction management services were provided by Thomas Zeller, RE/SPEC, Inc., Rapid City, South Dakota. Construction was under the supervision of C. K. Gerlach, Gerlach & Ebert Plumbing and Heating, Rapid City. Gene Armstrong and Joe Verlin represented the Diamond Ring Ranch.

10. LEGAL AND INSTITUTIONAL CONSIDERATIONS

Since this project used an existing well with little or no change in either production or discharge practices, no additional governmental permits were required. The Environmental Protection Agency office ruled that an Environmental Impact Statement was not required for this project. However, an Environmental Impact Review was submitted. That review indicated only minimal environmental impact.

The only private consideration that was necessary to resolve involved mineral rights. Since some question existed as to whether the geothermal heat constituted a mineral right, the holders of the mineral rights to the land were asked to furnish a waiver to any such claim.

11. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and the figures contained in this report are excerpted from the project final report prepared by Dr. Stanley Howard, Department of Metallurgical Engineering, South Dakota School of Mines and Technology, and appreciation and thanks are extended to him for his construction. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. Dr. S. M. Howard, Direct Utilization of Geothermal Energy in Western South Dakota Agribusiness, Final Report, Report No. DOE/ET/27158-7, Cooperative Agreement No. DE-FC07-78ET27158, September 1983.
- *2. Ibid, Fifth Quarterly Report, July 1, 1979 - September 30, 1979, Report No. DOE/ET/27158-6, October 1979.
- *3. Ibid, Fourth Quarterly Report, April 1, 1979 - June 30, 1979 Report No. DOE/ET/27158-5, July 1979.
- *4. Ibid, Third Quarterly Report, January 1, 1979 - March 31, 1979, Report No. DOE/ET/27158-4, April 1979.
- *5. Ibid, Second Quarterly Report, October 1, 1978 - December 31, 1978, Report No. DOE/ET/27158-3, January 1979.
- *6. Dr. S. M. Howard, Direct Utilization of Geothermal Energy in Western South Dakota Agribusiness, First Quarterly Report, June 30, 1978 - September 30, 1978, Report No. DOE/ET/27158-2, Cooperative Agreement No. DE-FC07-78ET27158 (Formerly No. ET-78-F-07-1729), October 1978.
- *7. Dr. S. M. Howard, Environmental Report, Demonstration for Non-Electric Applications of Geothermal Energy, Report No. DOE/ET/27158-1, Cooperative Agreement No. DE-FC07-78ET27158 (Formerly No. ET-78-F-07-1729), August 10, 1978.
- *8. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Reports are available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Regal Road, Springfield, VA 22161.

- *11. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Reports are available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Regal Road, Springfield, VA 22161.

20. INDUSTRIAL PROJECT - INTRODUCTION

ORE-IDA Foods, Inc. planned to use geothermal energy for potato processing and space and domestic water heating at their Ontario, Oregon potato processing plant. The well was drilled over 10,000 ft deep and encountered 380°F temperatures. The flow was inadequate, and the project was halted after provisions were made for possible reworking of the well at a later date.

This section of the report provides summary data, project history and development, resource and drilling information, alternate considerations, legal and institutional items, cost and schedule data, and significant observations and conclusions about the project.

ORE-IDA FOODS PROJECT

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1. PON PROJECT SUMMARY DATA

Project Data:

Project Description: The project planned to use geothermal fluid for potato processing (blanch, peel, cleanup) and space and domestic water heating in the ORE-IDA potato processing plant.

Location: Ontario, Oregon

Peak Heat Load: 63 million Btu/h

Annual Heat Load: 331 billion Btu/yr (60% Load Factor)

Simple Payback: 5.6 years

Status: The bottom hole temperature is 380°F in the production well that was drilled to 10,054 ft. The flow was inadequate and the project was stopped.

Cooperative Agreement Data:

Number: DE-AC07-78ET28424, Formerly ET-78-C-07-1725

Period: May 17, 1978 to May 31, 1982

	<u>Planned</u> <u>(\$)</u>	<u>Actual</u> <u>(\$)</u>
<u>DOE Share</u>	2,256,000 (45.5%)	2,529,910 (90.5%)
<u>Participant Share</u>	2,593,500 (53.5%)	242,000 (9.5%)
<u>Total Cost</u>	\$4,849,500	2,529,910

Principal Investigator:

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2. PROJECT HISTORY

The Ore-Ida project was initiated to demonstrate the feasibility of exploring, testing, and developing a potential source of geothermal energy; retrofitting an existing gas/oil-fired steam system; and converting the system to accommodate food processing and space heating.

The existing ORE-IDA facility processes potatoes, corn, and onions into frozen food products, which are shipped and marketed throughout the United States. The plant is located on a 200-acre site near the northeast edge of the City of Ontario, Oregon, immediately over the Oregon-Idaho border in Malheur County (see Figure 21-1).

Ontario is uniquely situated in an area of known geothermal activity. To the southwest, hot springs near Vale, Oregon, emerge at temperatures of 210°F. To the north, the Weiser, Idaho area shows considerable surface expression of geothermal activity.

In 1975, ORE-IDA began investigating the use of geothermal energy to provide heat for potato processing, water heating, and space heating at the company's Ontario plant. ORE-IDA's engineering staff and personnel from the Oregon Institute of Technology conducted extensive studies to determine the economic and technical feasibility of retrofitting the facility's natural gas and oil-fired processing equipment and utilizing geothermal heat as an alternative energy source. They concluded that the presence of a local geothermal resource was likely and that the economics of a retrofit were favorable.

This evaluation was followed in 1977 by the preparation of a proposal which was submitted to the DOE to obtain partial funding for the project under PON EG-77-N-03-1553. After a competitive evaluation, funding was granted in early 1978, and a seismic survey was undertaken to investigate the presence of the geothermal resource and determine well locations.

Fig. 21.1 Location Map

Ore-Ida No. 1, a deep geothermal production test well, was spudded at the company's food processing plant site on August 19, 1979, and drilled to a total depth of 10,054 ft by November 7, 1979. A temperature of 380°F was recorded at total depth--more than adequate to meet ORE-IDA's processing requirements. However, sufficient flow could not be obtained from the production well.

Although a thick section of basalt was penetrated, no significant zones of high permeability were demonstrated. Having found inadequate water inflow from the basalt intervals behind the slotted liner, the casing was jet-perforated over several intervals from 6000 to 7900 ft. After unloading the hole with nitrogen to 6800 ft, a water inflow of only 13 gal per min was measured. When the hole had self-filled, an artesian flow of 1 to 2 gpm was measured. The shut-in pressure was 120 psi.

Testing and logging activities continued to November 27, 1979, after which the hole was capped with a pressure-tight flange, valve, and pressure recorder.

Attempts were made to increase the flow at the production test well--all with minimal success. The last attempt was made in May 1981, when fluid injection pump tests were conducted on the well. Following the loss of pressurizing fluids at the 5900 to 6000-ft level, the test was abandoned on May 20.

Due to a lack of funds to conduct further testing and flow stimulation techniques, plug and abandon procedures were outlined to seal the well.

3. PROJECT DESCRIPTION

Preliminary plans were to establish two production wells and one injection/disposal well on the 200-acre site owned by ORE-IDA. Downhole pumps were to pump geothermal water into a buried insulated steel pipeline, which was to carry the water to three large plate heat exchangers located in a boilerhouse on the site. Heat was to be transferred from the geothermal fluid to closed intermediate water loops and an open washwater loop. The geothermal fluid was to then go to the injection well to be pumped back into the underground aquifer.

The heated water in the intermediate loop was to be circulated through the potato processing area to smaller secondary plate heat exchangers located by each piece of process equipment requiring heat. Process water was to be pumped from the process equipment through the heat exchanger, where it would be heated by the intermediate loop water, and then back to the process equipment. Most of the intermediate loop water was to return to the boilerhouse for reheating, but some could be bled off to provide makeup water for the process equipment.

Heated water in the open washwater loop was to be distributed to a series of hose stations in the process area for plant washdown.

4. SIGNIFICANT OBSERVATIONS AND CONCLUSIONS

Due to economic considerations, Ore-Ida No. 1 was not drilled at the primary site, which was selected because of its location over a predicted fault. It is believed that, had the primary site been drilled, adequate flow could have been obtained.

Attempts to improve the flow characteristics of Ore-Ida No. 1 well met with little success. Los Alamos National Laboratory (LANL) ran a temperature log of the hole and participated in a fluid injection pump test on May 19, 1981. The well was pressured to 1400 psi at the wellhead and approximately 350 gpm pumped into the well in an effort to produce a mini-hydrofrac in the lower zones below 7000 ft. However, all of the pressurizing fluids were lost at the 5900 to 6000 ft interval. An unsuccessful attempt to temporarily seal these perforations with frac balls was made before abandoning the test on May 20.

A reevaluation of the original test well logs was also conducted during the summer of 1981. This analysis did not reveal any reasons to embark on a major reworking program for the well for the following reasons:

1. All potential fracture zones are either behind uncemented slotted liner, or if cased and cemented, the casing is perforated and, presumably, the cement and the well wall are penetrated.
2. Initial and subsequent well tests by nitrogen stimulation did not yield significant flow, possibly because of suspected mud damage to potentially productive zones. Stimulation of the well by chemical means or hydraulic fracturing to remove mud damage is expensive (several hundred thousand dollars). Without any positive evidence of mud damage or the presence of a significant resource around this well, such expenditure was not considered to be justified. While the well temperatures are adequate, little positive evidence exists of the presence of significant fluid reserves.
3. Equilibrium temperature profile does not indicate any evidence of a convective gradient; hence, major communicating fracture zones are not present in this well.

Plug and abandon procedures were outlined to seal the well. Additional funds required to set deep packers and conduct a second hydrofrac test do not appear to be available in the near future. It is recommended, however, that actual plug and abandon not be performed for several years in anticipation of additional funding and interest for stimulation of Ore-Ida No. 1 well.

5. THE RESOURCE

Ontario, Oregon, is located near the axis of the northwestern part of the Snake River depression. The western segment is the Snake River Basin. The basin is considered to be a rift zone graben in the North American continent, along which crustal spreading has occurred during the last 30 million years. Extension of the crust has caused the upper crust to thin. The result is nearer-surface intermediate and lower crust and mantle material, all of which are hotter than the upper crust. In this region, the following tectonic conditions are exhibited:

1. Youthful basaltic volcanism.
2. High heat flow.
3. High temperature gradients in shallow wells.
4. Widespread distribution of thermal water.
5. Chemical indicators of high temperatures at depths of about 1.2 miles.
6. Geophysical indicators of parallel, northwest-trending, intra-Basin fault systems which may be two-way water circulation conduits.
7. A thickness of more than 1.8 mi of basalt flows and interbedded clastic sedimentary rocks, with a potential for a thermal reservoir in fractured volcanic rocks below an 0.6-mi-thick thermal and hydrologic insulator of clay, silt, and sand.

The Snake River Basin has been an attractive area for exploration for geothermal resources during the last 10 yr. It was expected that the Ontario area would likely produce a mixture of hot water and steam from a

zone at depths between 1 and 2 mi. Temperatures at these depths were expected to range from 300 to 400°F. The critical factor was anticipated to be the production capacity of the wells.

Evidence supporting the potential for geothermal resource development in the Snake River Basin included structural geology analyses, gravity survey analyses, aeromagnetic survey analyses, geochemical base temperature calculations, temperature gradient measurements in wells, gradient holes and deep oil and gas exploration holes, heat flow calculations, reflective seismic surveys, and extrapolation of subsurface geology from deep drill hole logs.

From the foregoing evidence and interpretations, it appeared probable that a hole drilled in the vicinity of the ORE-IDA facility at Ontario would encounter formation and fluid temperatures of at least 300°F at depths between 6000 and 7000 ft. Furthermore, it was expected that a thick section of tuffaceous clays and silts with low thermal conductivity would serve as a partial thermal and hydraulic barrier above the geothermal reservoir. Evidence indicated that the reservoir was in basalts with fracture permeability. Recharge was expected to be afforded near the margins of the Snake River Basin where the basalts crop out, as well as directly through high-angle fractures near the basin margins. Therefore, storage and recharge, although requiring tests, were anticipated to be adequate to support production designs, including partial or total artificial recharge of waste fluid, but not directly into the production zone.

As part of the Phase I determination of whether to proceed with drilling, seismic and hydrogeochemical studies were conducted by GeothermEx, Inc. The positive indicators evolving from these studies and data analyses strongly encouraged a decision to proceed to the drilling phase.

With verification of the presence of a geothermal resource, particularly evidence of one likely and one possible fault zone indicated by the seismic survey, it was possible to select a primary and a secondary site for drilling the initial exploratory production holes.

The primary site, located southeast of Ontario, is within an area bordered by Interstate 80N to the east-southeast, Treasure Valley Community College to the west-southwest, 9th Avenue on the south, and 7th Avenue on the north. The site is 1.1 mi from the ORE-IDA plant and the planned heat exchanger facilities. The secondary site, located northeast of Ontario between the Interstate and the Snake River, is on ORE-IDA property.

In the immediate vicinity of the secondary well site are a sand and gravel operation, a motel complex, three residences, the Ore-Ida sludge lagoons and sewage treatment facilities, and seven municipal wells for the City of Ontario.

The primary site was chosen to take advantage of the projection at depth of the near-certain fault and therefore was more favorable technically, as this enhanced the probability of drilling into rocks with high permeability in the potential thermal zone. It was expected that the fault would provide a channel along which the deep, high-temperature water could be raised to the surface. It was anticipated that these two factors would permit a shallower hole with a shorter length of completion zone necessary to produce thermal fluid.

The secondary site was selected as an alternative because of its proximity to the plant, its location on property owned by ORE-IDA and minimal environmental impacts.

It was planned to drill the secondary site to make the all-important first test of the resource. If the secondary site proved to contain sufficient producible fluid at temperatures above 300°F, the roles of the

two holes were to be switched so that a less expensive pipe could be constructed. It was agreed before drilling commenced that if the secondary site did not produce the needed fluid, the primary site, some 1.1 mi southeast, would be drilled. The secondary site well would then be used for injection.

The logic of this decision was that if the secondary site proved successful, 1.1 mi of pipeline and the associated costs (an estimated \$1 million) would be saved. The injection well could then be located closer to the facility, or possibly discharge to the Snake River if adequate geothermal water quality existed.

Given the information gained during the initial drilling, a post-drilling assessment of the drilling operation revealed only minor changes in program approach. The drilling procedure and method contributed to a smoothly operated drilling program. Little would be changed in the overall drilling approach from a technology standpoint.

The uncertainty that may have had the largest impact upon the drilling project was the depth to the target basalt. As detailed in Section 8, the target basalts occurred at approximately 8000 ft below ground surface. This was some 1000 to 1200 ft deeper than preliminary investigations had indicated. Second, the drilling site for Ore-Ida No. 1 was not the primary geologic choice. Although it was initially agreed that if the secondary site failed to produce the required flow, the primary site would be drilled. This decision was subsequently changed due to a lack of funds. In retrospect, it could have been well-advised to drill the primary site, located a mile southeast of the plant facility. However, the site of Ore-Ida No. 1 was selected because of its proximity to the facility and because it was interpreted as being an excellent secondary site location.

6. DRILLING AND TESTING

Ore-Ida No. 1, a deep geothermal test hole, was spudded at Ontario, Malheur County, Oregon, on August 19, 1979. The hole was drilled to a total depth of 10,054 ft (Figure 21.2) by November 7, 1979. Temperatures below 7100-ft depth are greater than 310°F. Flow measurements during testing indicated a water inflow rate of 13 gpm at 6500 ft. The hole self-filled until an artesian flow of 1 to 2 gpm was measured. Later, a shut-in pressure of 120 psi was recorded. Massive basalts were not encountered until the 8135 ft depth. Testing and logging activities continued to November 27, 1979, after which the rig was moved from the site and the hole capped with a pressure-tight flange, valve, and pressure recorder.

The well was drilled using standard rotary drilling techniques for a deep geothermal test hole. A rig with capability to drill beyond 11,000 ft was used. Gel-water mud was used during initial drilling. Buttressed 13-3/8-in. casing was landed to 925 ft depth and cemented bottom to top. Drilling proceeded using lignosulfonate muds. Weights, viscosities, and acidities of the mud were altered for maximum penetration, hole stability, and water loss control to a depth of 8216 ft, inclusive of a core from 8188 to 8216 ft depths. An intermediate string of 9-5/8 in. casing was landed and cemented bottom to top at 8183 ft depth. Drilling was attempted with water, but connections were difficult and the drilling string was stuck on several occasions because of slough in an unstable hole. After experimenting with the mud weight, a full-weight (83 lb per cubic foot) lignosulfonate program was reinstituted. The hole was stabilized and drilled to total depth. After a 7-in. perforated liner was hung from 8142 to 10038 ft depth, fresh water was circulated to remove all possible residual mud.

Initial liquid nitrogen stimulation tests did not produce fluid. Water infill appeared to be restricted to about 15 gpm. The well filled in about 2 weeks. At 3 weeks, a shut-in pressure of 64 psi was recorded prior to an artesian flow of about 1 gpm at about 80°F. A wellhead pressure of about 80 psi was developed by February 1980.

Fig. 21.2 Ore-Ida No. 1 Well Profile

Geophysical logs were run in the hole. Except for intervals from surface to 925 ft depth, and 7952 to 8182 ft depth, there is complete log coverage, including overlap in an interval between about 6800 and 7160 ft.

In May 1981 (almost 18 months after the completion of drilling), Los Alamos National Laboratory conducted several tests on Ore-Ida No. 1 well, including a series of temperature surveys, spinner calibration runs, and injection flow tests. LANL's data indicated an equilibrium temperature of approximately 380°F at total depth (10,054 ft). Of note was a slightly depressed temperature in the 6000 to 6400 ft region (probably due to a small formation flow) and a marked increase in gradient above 4000 ft.

While "rabbiting" the well with a special tool to determine whether the hole was open to at least 5 in. in diameter to total depth, LANL encountered a heavy, dark grey, jellied substance. The material was eventually identified as the bentonite-weighted lignosulfonate drilling mud used to drill the lower portions of Ore-Ida No. 1.

Following the background temperature log, the spinner tool was velocity-calibrated in the lower part of the hole, near 8100 ft. Spinner speeds ranged from 2.8 to 4.1 Hz until a depth of 8220 ft, where the velocity dropped by about 60% and became very erratic. The spinner stopped turning altogether at 8272 ft. The erratic spinner behavior was repeated in subsequent calibration runs, and LANL concluded that the slotted liner section of the hole was filled with a highly viscous fluid from a depth of about 8220 to 9900 ft.

During the series of injection and backflow tests on May 19, using Halliburton pumping equipment, the surface injection pressure could not be increased above about 1400 psi at flow rates up to 542 gpm, the capacity of the pump truck. Injection flow spinner logs and shut-in temperature logs showed that almost all of the fluid was exiting the wellbore through the uppermost set of casing perforations in the interval from 5980 to 6000 ft. This conclusion was supported by further temperature surveys.

Major conclusions derived from LANL's temperature surveys, spinner calibration runs, and injection flow tests include:

- o The equilibrium total depth temperature for Ore-Ida No. 1 is 380°F, with a uniform temperature gradient of 2.5°F/100 ft over the lower 5000 ft of this hole.
- o There are some regions within the lower massive basalt flows that may contain open fractures, although they may still be completely sealed with viscous lignosulfonate drilling mud.
- o Residual drilling mud presently fills at least 1680 ft of the slotted liner interval, starting at a depth of about 8200 ft.
- o The presence of this residual drilling mud, which must have flowed into the wellbore subsequent to hole completion, represents a very significant open fracture surface area and portends the possibility of a dry hot rock geothermal reservoir within the deep, hot volcanic flows at Ore-Ida No. 1.
- o To adequately test the geothermal potential of the hotter portions of Ore-Ida No. 1, the following steps would be required:
 1. Remove the residual drilling mud from the hole by chemical treatment, surging, and circulating.
 2. Nitrogen-lift the fluid from the hole so formation pressures can cause outflow of available resource.

All the above could be accomplished in about 10 days with a modest size workover rig with integral pumping capability (about \$5,000 per 24-h day).

7. PRODUCTION SYSTEM

The anticipated geothermal resource at the ORE-IDA facility was to be utilized to heat process water by using heat exchangers and retrofitting the process equipment. The planned geothermal system included two production wells, a transmission main, a complex of plate heat exchangers, pumps, controls, and a deep injection well. The cascade principle was to be employed to extract a maximum amount of usable energy from the geothermal water.

It was expected that geothermal water at 300°F, with flow of about 800 gpm, could provide more than 50% of industrial process energy requirements at the facility. The potato processing line was to utilize the major part of the energy, with approximately 50 million Btu/h required for the peelers, blanchers, sugar drags, and dryers (see Figure 21.3). In addition, 26 million Btu/h is required for heating wash water and process makeup water, and 13 million Btu/h is used in three makeup air heaters operated during the winter months. These requirements total 89 million Btu/h of primary heating. There are several additional areas where the spent, low-temperature geothermal water was to be used for secondary heating before disposal.

Since the Ore-Ida production test well did not produce adequate geothermal flow, final design of the production of transmission systems was never completed. However, preliminary designs were provided in a report prepared in April 1980.

Generally, this study assumed that the two planned production wells would require a pump setting of 2000 ft below the ground surface. The actual setting required was to be determined by well tests and would have affected the choice of pump type. The pumps were initially planned to be 150-hp deep well pumps suitable for operation in geothermal waters at temperatures in excess of 350°F.

Fig. 21.3 Proposed System Schematic

The geothermal transmission system considered for the Ore-Ida project consisted of pump stations and an insulated geothermal water pipeline from the flange of the production well pump to its entrance into the boilerhouse, and from the boilerhouse to the injection well pump and into the injection well.

It was assumed that the injection pump would be a high-pressure, centrifugal type to force the geothermal water back into the rock formation. The injection pump was to be a split case, multistage, horizontal centrifugal type. The pump, electrical gear, and instrumentation were to be housed in a concrete block building with an electrical unit heater, similar to the layout for the production pump.

Geothermal water temperature and pressure at the surface were to be displayed by monitoring devices (flowmeters and thermometers) located in the pumphouses. These sensors would have been used to indicate when and where temperature and flow adjustments were required. Flow control was to be provided through the use of valves at either the pumphouse or boilerhouse. Temperature control was to be maintained by heat exchangers in the boilerhouse. By proper monitoring of these heat exchangers, it would have been possible to determine how much heat was being extracted from the geothermal water and how much heat was being added to the intermediate and wash water loops.

8. ALTERNATE CONSIDERATIONS

Although the initial intent of the Ore-Ida project was to utilize geothermal resources for a food processing application, the flexibility to incorporate secondary uses was developed into the program at an early stage. These alternatives included additional space heating in office buildings, maintaining temperatures in potato storage cellars, stabilizing wastewater temperatures for better treatment, use in byproduct production, greenhouse operations, potable water heating, slab heating, and other uses.

One consideration was whether the transmission pipeline should be above or below grade. A cost analysis indicated there would not be a substantial price difference between the aboveground and belowground installations. The belowground installation, however, was deemed superior from a standpoint of immunity to accidental or intentional damage and, therefore, was chosen as the better alternative.

Several different pipe materials were considered for the geothermal fluid pipeline. Asbestos-cement pipe was ruled out because of low strength, unsuitability of the sealing rings at the 300°F water temperature, and the experience of temperature shock fractures reported by DOE at the Raft River geothermal site. Fiberglass-reinforced plastic pipe was rejected since it is not recommended by the manufacturer for use at +300°F. Welded carbon steel pipe can withstand the pressure and temperature conditions, but drawbacks are susceptibility to corrosion and the need to allow for the thermal expansion of the pipe. It was felt the geothermal fluid would not be unduly corrosive, and proper coating and cathodic protection would protect the pipe from external corrosion. Therefore, it was decided that carbon steel pipe was the best material choice for the pipeline.

An economic analysis of four different insulation alternatives was performed to arrive at a recommendation. No insulation was the most costly approach because of the fossil fuel required to replace heat lost to the environment. The other three insulation alternates considered were; (a) a nonwetttable mineral powder placed in a formed trench around the pipe,

(b) preinsulated pipe with a 1-1/2-in. calcium silicate layer against the pipe, a 1-in. polyurethane layer over the calcium silicate, and a 24-gage galvanized steel jacket, and (c) preinsulated pipe with 1 in. of foamed glass next to the pipe, 1 in. of polyurethane over the foamed glass, and a 40-mil polyvinyl chloride (PVC) jacket.

Although alternative 3 had a slightly greater heat loss than the other two, its initial cost was estimated to be substantially lower, and was recommended.

9. SYSTEM COSTS, SCHEDULE AND ORGANIZATION

9.1 System Costs

The project was jointly funded by ORE-IDA and the DOE under the PON program. The original estimated total project cost of \$4.850 million was proportioned \$2.256 million (46.5%) by DOE and \$2.594 million (53.5%) by ORE-IDA. The ORE-IDA share included the investment of time and personnel (about \$330,000). The DOE cost share would be the greatest in the first two fiscal years during the resource assessment and well drilling phases, diminishing significantly in the latter 2 years. User/developer financing was to have been provided by ORE-IDA. Actual project costs through fiscal 1981 are shown in Table 21.1.

9.2 Schedule

The project was divided into four phases, to occur over a 4 yr period. Phase I covered program startup and resource confirmation, Phase II--design, Phase III--construction, and Phase IV--operation. The schedule is shown in Figure 21.4 and called for a project completion date in the latter part of 1981. Due to the lack of fluid flow from the drilled production test well, development activities were essentially completed on May 20, 1981 after numerous attempts to increase the flow, followed by loss of pressurized fluids during fluid injection pump tests.

9.3 Organization

The project team (Figure 21.5) comprised ORE-IDA Foods, Inc., Boise, Idaho; CH₂M HILL, Boise, Idaho; GeothermEx, Inc., Berkeley, California; and miscellaneous subconsultants. The well drilling contractor, Montgomery Drilling Company of Bakersfield, California, was under the direct supervision of GeothermEx, Inc. This project team formed a complete composite of the technical and management skills required to field-demonstrate the technical, economic, and environmental feasibility of geothermal resource utilization in an industrial application.

TABLE 21.1. PROJECT COSTS

Item	Cost (\$)
Ore-Ida Labor, G&A	123,540
CH ₂ M Hill	462,240
Miscellaneous Costs (leases, insurance, etc.)	31,850
Site Preparation	35,100
Drilling Materials/Services	835,980
Montgomery Drilling Mud Charges	786,830
Diesel Fuel	56,300
Energy Log Charges	50,370
Total	2,529,910
DOE Share	2,287,910 (90.45%)
ORE-IDA Share	242,000 (9.55%)

Fig. 21.4 Project Schedule

Fig. 21.5. Project Organization

10. LEGAL AND INSTITUTIONAL CONSIDERATIONS

An environmental assessment of the Ore-Ida project was undertaken and completed in late 1978. The results of this investigation indicated no significant environmental impacts resulting from implementation of the project. There were no amendments or changes in the environmental assessment of the project following drilling of the test well. Generally, potential impacts identified in the environmental report were found to be accurate. Mitigation measures were taken, as necessary, through the duration of drilling and testing. These included removal and disposal of cuttings and test fluids by locally approved methods.

Because the production, transmission, and disposal systems were located on land entirely owned by ORE-IDA, no purchase or leasing of property for right-of-way was necessary. In addition, mineral rights were conveyed with the property and are owned by ORE-IDA. The transmission main was to cross Interstate-80 through an existing utility tunnel maintained for ORE-IDA's exclusive use.

The company's ownership of all project land and equipment requiring retrofit also served to minimize the number of issues and permits necessary to implement the project. There were no known conflicts with local, state, or regional areas.

A building permit from the City of Ontario was required to drill the initial production test well. The Ontario City Engineering Department was consulted before and after the project was initiated.

A geothermal drilling permit, liability bond, and conditional use permit for rezone were obtained through Malheur County, Oregon. The Malheur County Planning Department and Historical Society were contacted during preparation of the environmental impact report.

Issues and permits through the State of Oregon, Department of Geology and Mineral Industries, included a plan of operation, compliance bond, and geothermal drilling permit. State agencies consulted in regard to the project were the Oregon State Department of Fish and Wildlife, Department of Environmental Quality, and Historic Preservation Office.

The State of Oregon, by statute, treats geothermal resources (essentially the heat in geothermal fluid and steam) as a mineral resource owned by the owner of the surface. The state has no regulations concerning reinjection of spent geothermal fluid used solely for heat extraction.

Federal agencies contacted in relation to the project included the U.S. Soil Conservation Service and the U.S. Bureau of Land Management.

The United States owns geothermal resources underlying lands to which it holds title and in which the land has passed from Federal ownership with a reservation of "minerals." Mineral rights on the project site are owned solely by ORE-IDA.

11. REFERENCES

Numerous documents were prepared covering various aspects of this project. Much of the information and the figures contained in this report are excerpted from the project final report prepared by CH₂M Hill, and appreciation and thanks are extended to them for their contribution. The following listing of documents is provided so that interested readers may investigate additional information sources applicable to their specific areas of interest.

- *1. J. C. Austin, CH₂M Hill, Inc., Direct Utilization of Geothermal Energy Resources in Food Processing, Final Report, May 17, 1978-May 31, 1982, Report No. DOE/ET/28424-6, Cooperative Agreement No. DE-AC07-78ET28424, May 1987.
- *2. CH₂M Hill, Inc., Environmental Report for a Field Experiment: Food Processing Industry--Geothermal Energy, Report No. DOE/ET/28424-1, Subcontract No. ET-78-C-07-1725, October 1, 1978.
- *3. GeothermEx, Inc., Data Analysis and Drilling Site Selection for ORE-IDA Property, Ontario, Oregon, Report No. DOE/ET/28424-2, October 1978.
- *4. CH₂M Hill, Inc., Preliminary Design Report on the Conversion of Process Heat Load to a Geothermal Resource for ORE-IDA Foods, Inc., Ontario, Oregon, Report No. DOE/ET/28424-3, April 1980.
- *5. GeothermEx, Inc., Technical Report, Deep Well Test and Exploration Program for Ore-Ida No. 1, Ontario, Oregon, Volumes I, II, and III, Report No. DOE/ET/28424-4, Subcontract No. ET-78-C-07-1725-GTX, May 1980.
- 6. GeothermEx, Inc., Well Log Analysis on Ore-Ida No. 1 Well, Ontario, Oregon, Informal EG&G Idaho, Inc., Report Performed Under DOE-ID Contract No. DE-AC07-78-ET/28426, June 1981.
- *7. ICF Incorporated, Resource Assessment for Geothermal Direct Use Applications, Report No. DOE/ET/12099-3, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.
- *8. ICF Incorporated, Resource Development; System Design, Construction, and Operation for Geothermal Direct Use Applications, Report No. DOE/ET/12099-4, Contract Nos. DE-AC07-80ID12099 and DE-AC07-76ID01570, April 1984.

*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.