Small-Scale Appropriate-
Energy-Technology
Grants Program

PACIFIC SOUTHWEST REGION
UNITED STATES DEPARTMENT of ENERGY

Geothermal Heating
for ^aCliente, Nevada

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FINAL REPORT

**GEOHERMAL HEATING FOR
CALIENTE, NEVADA**

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**A. GEOHERMAL HEATING FOR
AGUA CALIENTE TRAILER PARK**

GRANT NO. EM-78-G-03-1975

**B. GEOHERMAL HEATING FOR
GROVER C. DILS MEDICAL CENTER**

GRANT NO. DE-F603-79SF10569

MASTER

**Prepared For: Small-Scale Appropriate Energy
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February 1981

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U.S. DEPARTMENT OF ENERGY

SMALL SCALE APPROPRIATE ENERGY TECHNOLOGY GRANTS PROGRAM

REGION IX

BACKGROUND

In his energy message of 1977, President Carter stated that a balanced energy program should seek out the talents of individual inventors and small businesses and groups. Congress subsequently authorized the Energy Research and Development Administration (now the Department of Energy, DOE) to undertake a grants program in small-scale, energy-related technologies referred to as appropriate technologies because they are "appropriate" to local needs and skills. This small grants program has come to be known as the Appropriate Energy Technology (AET) Program.

WHAT

A regional pilot program in appropriate energy technology was implemented to provide monetary grants for small-scale, energy related projects for:

- o Idea development, for concepts demonstrating potential;
- o Concepts testing, for projects that have gone beyond the idea-development phase and are ready for testing;
- o Demonstration, to develop projects which, having been tested, now must be proven through actual use.

In terms of resources, Appropriate Energy Technology ...

- o makes best use of available renewable energy sources
- o conserves nonrenewable resources
- o depends largely on human labor
- o emphasizes the use of local materials and labor skills

The scale and efficiency, Appropriate Energy Technology ...

- o is efficient in its use of energy and other resources
- o is simple to install, operate and maintain
- o may employ scaled-down industrial technology
- o employs novel application of existing technologies
- o emphasizes decentralized technologies

In relation to the end-user, Appropriate Energy Technology ...

- o satisfies local needs
- o increases community energy understanding and self-reliance
- o is environmentally sound
- o results in durable recyclable systems and/or products

WHERE

The Region IX program covers the states of Arizona, California, Hawaii, and Nevada, as well as American Samoa, Guam, and the Pacific Trust Territories. This program is managed by the Office of the Regional Representative, Region IX, of the U.S. Department of Energy. Similar programs are being managed through the other nine regional offices around the country.

WHO

Eligible projects can come from

- o individuals
- o local nonprofit organizations and institutions
- o state and local agencies
- o American Indian tribes
- o Small businesses

WHEN

Contact the regional DOE offices for the annual awards cycle.

RESULTS

Over one hundred and eighty applicants in Region IX have been granted funds with which to start or continue their projects during the first three years of the Appropriate Energy Technology Program.

For additional information on this program, please contact:

Small Scale Appropriate Energy Technology
U.S. Department of Energy
333 Market Street, 7th Floor
San Francisco, California 94105

Nationally, the Small-Scale Appropriate Energy Technology Grants Program is directed by the Office of Small-Scale Technology, U.S. Department of Energy, Washington, D.C.

SMALL-SCALE APPROPRIATE ENERGY TECHNOLOGY
GRANTS PROGRAM - REGION IX
U.S. DEPARTMENT OF ENERGY

PROJECT FACT SHEET

PROJECT # : NV-79-45

GRANT # : FG-03-79SF10569

PROJECT TITLE : Geothermal Heating For Grover C. Dils
Medical Center
(Published In: Geothermal Heating For Caliente,
Nevada)

GRANTEE : John Schaper
Grover C. Dils Medical Center
P.O. Box 38
Caliente, NV 89008

AWARD AMOUNT : \$9,772

DESCRIPTION
and RESULTS : Under this grant, the Grover C. Dils Medical
Center in Caliente, Nevada drilled a geothermal well
and piped the hot water (through a heat exchanger)
to preheat air for space heating. This geothermal
"preheater" served to convert the existing forced
air electric furnace to a booster system. It is
estimated that the hospital will save an average
of \$5,300 in electric bills per year, at the current
rate of \$.0275/kwh. this represents a payback of
approximately two years.

DATE REPORT
SUBMITTED: September, 1980

SMALL-SCALE APPROPRIATE ENERGY TECHNOLOGY
GRANTS PROGRAM - REGION IX
U.S. DEPARTMENT OF ENERGY

PROJECT FACT SHEET

PROJECT # : NV-78-64

GRANT # : FG-03-78SF01975

PROJECT TITLE : Geothermal Heating For Agua Caliente
Trailer Park
(Published In: Geothermal Heating For
Caliente, Nevada)

GRANTEE : Ferg Wallis
Agua Caliente Trailer Park
P.O. Box 38
Caliente, Nevada 89008

AWARD AMOUNT : \$30,000

DESCRIPTION
and RESULTS : Under this grant, Ferg Wallis, part-owner and
operator of the Agua Caliente Trailer Park,
assessed the potential of hot geothermal water
for heating the 53 trailers in his park. The
results of the test wells indicated sustainable
temperatures of 140°-160° F. Three wells were
drilled to supply all 53 trailers with domestic
hot water heating, 11 trailers with space heating
and hot water for the laundry from the geothermal
resource. System payback in terms of energy cost-
savings is estimated at less than two years.

DATE REPORT
SUBMITTED : July, 1979

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I. INTRODUCTION

Utilization of geothermal resources in the town of Caliente, Nevada (population 600) has been the objective of two grants under DOE's Small-Scale Appropriate Energy Technology Grants Program. The first grant was awarded to Ferg Wallis, part-owner and operator of the Agua Caliente Trailer Park, to assess the potential of hot geothermal water for heating the 53 trailers in his park. The results from test wells indicate sustainable temperatures of 140° - 160°F. Three wells were drilled to supply all 53 trailers with domestic hot water heating, 11 trailers with space heating and hot water for the laundry from the geothermal resource. System payback in terms of energy cost-savings is estimated at less than two years.

The second grant was awarded to Grover C. Dils Medical Center in Caliente to drill a geothermal well and pipe the hot water through a heat exchanger to preheat air for space heating. This geothermal "preheater" served to convert the existing forced air electric furnace to a booster system. It is estimated that the hospital will save an average of \$5,300 in electric bills per year, at the current rate of \$.0275/KWH. This represents a payback of approximately two years.

The results of these projects have led to a growing interest in the potential for geothermal heating throughout Caliente. Subsequent studies on the geothermal resource base in Caliente and on the economics of district heating indicate that geothermal may represent the most effective supply of energy for Caliente. Two of these studies are included as appendices to this report.

II. GEOHERMAL HEATING FOR AGUA CALIENTE TRAILER PARK

Final Report: Grant No. EM-78-G-03-1975
Agua Caliente Trailer Park

Principal Investigator: Ferg Wallis

1. Project Summary

Agua Caliente, a Nevada corporation, is the owner of some 30 acres of land lying within the city limits of Caliente, Nevada. Under this land there are undetermined reserves of hot water which approximate 160 degrees fahrenheit. This hot water can serve as a very potential source of energy for both residential and commercial purposes.

On this property Agua Caliente developed a small trailer park with a laundry and bath-house. Most of the trailers in this park are occupied by senior citizens and other of modest income and financial means. Energy costs (for heating water as well as environmental space heating) are a great concern to these people. In Caliente, there is no source of natural gas. Alternate sources of energy (electricity, oil, etc.) are available only at prohibitive costs.

It was the purpose of the Agua Caliente grant application to fund a study and subsequent installation of a hot water system utilizing the hot water under the ground for heating both water for bathing and culinary purposes as well as environment space heating.

The first priority was to determine the extent of the hot water under the ground. Up to the point in time when this application was submitted to the Department of Energy, the funds available to Agua Caliente were so limited as to make such a determination impossible.

Funds gained from the grant were to be used to drill test wells, determine the extent and locations of the hottest water, pump the water through a pipeline system to trailers, and provide economical heat by the use of this water.

Subsequent to this accomplishment, economic opportunities would be made available to residents to explore other uses for this hot water in commercial and industrial applications.

2. Test Results

Upon receipt of the Appropriate Technology grant, Agua Caliente contracted to have several wells drilled for exploratory purposes and actual use in supplying hot water for the project. A summary of the wells drilled follows.

- o Well #1 - Located in the Northwest corner of Agua Caliente property.

Depth: 300 feet

Size: 5" diameter

Drilled by: Southwest Drilling

Temperature of water: 130° fahrenheit @ 60 feet deep.

Results: This well was too low in temperature to provide an adequate source of energy. Interestingly enough, this well was the deepest drilled and provided the lowest temperature. At the deepest part of the well (300 ft.) the temperature of the water was only 104° fahrenheit. Well was not test-pumped.

- o Well #2 - Located Southwest of the Well #1 above.

Depth: 60 feet

Size: 5" diameter

Drilled by: Southwest Drilling

Temperature of water: 130° fahrenheit

Results: This well was too low in temperature to provide an adequate source of energy. Therefore, it was not test-pumped.

- o Well #3 - Located centrally on Agua Caliente property.

Depth: 86 feet

Size: 8" diameter

Drilled by: Southwest Drilling

Temperature of water: 158° fahrenheit

Results: This well was very good and test-pumped at 450 GPM for a period of 24 hours. We are presently using this well with a small pump as a back-up for Well #4.

- o Well #4 - Located centrally on Agua Caliente property.

Depth: 83 feet

Size: 16" diameter

Drilled by: Vic's Drilling

Temperature of water: 160° fahrenheit

Results: This well was the best of the four and test-pumped at some 850 GPM for a period of 24 hours. We are using this well as our primary source of hot water and have installed a five horsepower pump.

3. Installation

Upon completion of the test drilling of the four wells, Agua Caliente contracted with B&W Equipment Company to install a Johnson 4 HP Turbine Pump (3 Ph. 1800 RPM). This pump has been supplying water at a rate of 100 GPM, although the capacity is 150 GPM which could be accomplished with no alterations to the system. At present, 100 GPM is adequate for the park's needs.

The following PVC Schedule 40 piping has been installed to carry hot water from the pump to the trailers, etc.:

400' - From Pump to Trailers - location 1.

300' - From Trailers to Bath-house and Laundry.

360' - From Pump to Trailers - location 2.

200' - From Pump to Trailers - location 3.

1200' - From Pump to Trailers - location 4.

From the main 2" supply lines, a 1" PVC line has been run to each of the trailers supplied by the hot water.

Hose bibbs, etc. have been installed for each trailer to take water from the system to the individual trailer. Each owner the pipes the water from the hose bibbs to his own trailer.

Some 11 trailers and the manager's residence have been equipped with a hot water coil which provided space heating in the residence. In each case, this hot water space heating has proved both satisfactory and extremely economical.

All trailers and the manager's residence have been equipped with a hot water coil which provided space heating in the residence. In each case, this hot water space heating has proved both satisfactory and extremely economical.

All trailers and the manager's home have hot water for culinary and hot water uses piped for use as desired. Hot water is also provided for the laundry.

The temperature drop in the water from the source of supply to the trailers and home is insignificant.

4. Results

The geothermal hot water meets the total hot water and space heating requirements of each trailer connected to the system. By using F-Chart

GEOTHERMAL WELL AT AGUA CALIENTE

calculations and assuming an average trailer size of 550 square feet, R-12 insulation in the ceiling and 15% glazing, the annual energy savings is estimated at 2,662 million Btu's. This represents a system payback of less than two years.*

As a result of this project, the City of Caliente is considering other applications of geothermal heating, including a community district heating system.

* See: F.B. Lucarelli, et.al., The Energy Savings Potential of the Region IX Appropriate Energy Technology Grants Program, (Lawrence Berkeley Laboratory; October, 1979, LBL-9715 UC-95d), p. E-2.

III. GEOHERMAL HEATING FOR GROVER C. DILS MEDICAL CENTER

Final Report: Grant No. DE-F603-79SF10569
Grover C. Dils Medical Center

Principal Investigator: John Schaper

1. Project Summary

The plan for the project consisted of utilizing hot geothermal water to either eliminate or augment the central electrical radiant heat in heating the hospital. The unmodified heating system consists of one central, electrical resistance heating coil with a Btu capacity of 330,000 which heats outside ambient air as it passes over the coils into the hospital. The heart of the geothermal heating system is a hot water coil located in the supply air system. In operation, outside air is pre-heated by an electric duct heater before being forced through the hot water coil which is supplied with hot water from the geothermal well. It was planned that by integrating a heat exchanger near the fresh air intake and near the radiant coil and then circulating geothermal water through the heat exchanger, the energy consumed in heating the hospital would be greatly reduced.

The first step of the project involved drilling two wells; one well was drilled to a depth of 80 feet where the maximum water temperature of 102° fahrenheit was reached. This well was to be the source of the hot water to be pumped through the heat exchanger. A second, cooler well was drilled to a depth of 32 feet. This well was to be used for discharging water from the first well after it had passed through the heat exchanger. A five horse-power submersible pump capable of withstanding temperatures in excess of 200° was placed in the deep well; it was then wired with electricity. However, two step-down transformers were installed to drop the pump voltage from 230 volts to the hospital's voltage of 208 volts.

Once the wells were drilled and the hot water temperature determined, a heat exchanger was ordered and integrated into the ducting approximately 5 feet from the fresh air intake and 1 foot below the radiant coil. Minimal sheet metal modifications were made. Plumbing was connected from the hot well to the heat exchanger and from the heat exchanger to the shallow return well. When the system was installed, there was no control on the geothermal coil to regulate the amount of heat added to the air by the geothermal system; consequently, the air tended to be overheated by the geothermal coil. The system modification recommended to solve this problem involves the addition of a thermostatically controlled three-way blending valve across the geothermal coil. The blending valve controls the flow of hot geothermal water through the coil to maintain air temperatures at the thermostat setting.

Figure 1
**GROVER DILS MED CENTER
 GEOTHERMAL HEATING SYSTEM**

JAN 23, 1981

2. Installation

The hot water well was drilled to a depth of 80 feet using 6 inch casings. The casing was then packed with cement. Eight inch casing was also used in the 32 foot well which was not packed with cement.

A modified, 5 horsepower, 3 phase, 230 volt submersible pump motor was placed in the well. The pump was manufactured by Mitsubishi Electrical Corporation and cost \$1,638.56. The pump was modified to withstand high ambient temperatures by Aeromotor Co., Conway, Arkansas. With the pump installed, it was then wired with electricity. However, since the pump was designed for 230 volts and the hospital's voltage is 208 volts, two step-down transformers were installed. These transformers were purchased from Acme Electric Corp., Catalog Number T-1-81051, for \$36.80 each. The hospital's maintenance personnel installed these transformers and wired the pump with electricity. The pump was also wired to the emergency electrical system to provide continuous heating in the case of a general power failure.

The heat exchanger coil has a Btu capacity of 460,000. Additional specifications of this coil are that it has 4 rows of tubes and 24 tubes per row. Outside dimensions of the coil are 39 inches by 66 inches. The brand name of the coil is Wave Fin, manufactured by Dunham-Bush, Inc. of Harrisburg, Pennsylvania.

Plumbing from the hot well to the coil and then to the return well uses 2-1/4 inch outside diameter steel pipe. The pipe from the hot well to the coil is insulated with a plastic shroud.

An electric heater control temperature sensor was installed between the electric heater and the hot water coil, with the sensor bulb as close as possible to the hot water coil. The electric heater control thermostat was adjusted so that the air leaves the electric heater at 32-35°F when outside air is below freezing. Hence, the electric heater acts only as a preheater for air going to the geothermal coil.

A mixing valve was installed on the outlet side of the hot water coil with pipe unions, so that it could be removed easily for future servicing. A valve control thermostat was installed on the duct surface, downstream of the hot water coil, with the sensor probe extending into the duct. The mixing valve required 120 volts A.C. for its circuits. The valve thermostat was set to provide a maximum delivered air temperature of 75-80°F. The freeze thermostat was set at 40°F.

A freeze thermostat was attached to the geothermal pump motor so as to start the pump when outside temperatures fall below 75°F. The thermostat sensor bulb was installed in the inlet air plenum, upstream from the electric heater and inlet dampers.

3. System Costs

Equipment and labor costs for project are summarized below:

Well drilling and casing	\$ 1,735.00
Submersible pump and installation	1,845.81
Field Survey and map preparation for water appropriation permit	266.00
Two step-down transformers	73.60
Fee for water appropriation permit	35.00
C.O.D. on transformers	4.53
Electrical supplies	10.64
Electrical supplies	99.14
Electrical supplies	56.00
Water analysis	210.00
Lump sum payment for project completion ¹	6,000.00
Labor (Hospital Personnel)	<u>388.27</u>

Subtotal \$10,673.99

Modifications to Controls ²	
Three-way valve assembly	563.00
Thermostat	63.00
Sensor	24.00
Misc. Wiring and Conduit	30.00
Labor	<u>1,270.00</u>

Subtotal \$ 1,950.00

TOTAL PROJECT COST \$12,623.99

4. Results

The heating system, prior to installation of the coil, consisted of one central radiant heat coil which supplied approximately 70% of the building's heating requirements and individual room radiant heaters which supplied the remaining heating requirements.

Measurements taken while the geothermal heating system was in operation showed an air flow rate of 4200 CFM (corrected to sea-level) and an air temperature rise across the geothermal heating coil of 43°F. Air supplied to the building was thermostatically controlled at 72°F.

¹ This amount includes coil costs, installation, plumbing, electrical sensors and labor to integrate heat exchanger into heating system and make system operational. Contractor did not itemize these expenses.

² This work was done to eliminate the overheating problem described above. The grantee paid for these modifications.

Because of a lack of detailed climate data for Caliente, values were interpolated from existing Las Vegas and Reno data and corrected for the proper number of degree-days (5,113 in Caliente). This data is shown in the first two columns of Table 1 in terms of 5°F "bins" and hours at each bin. An energy summary is shown at the bottom of Table 1 and indicates that the geothermal heating system should be able to save 192,000 kilowatt-hours of electrical energy in a typical year. Although the actual savings depends on a number of factors (especially climate) and can vary significantly from year to year, the hospital should realize an average annual energy cost savings of \$5,300 at the current rate of \$.0275/KWH.

Table 1
Calculation of Energy Savings

Outside Temp. (T _O)	Hours	(72-T _O)	BTU's Req'd. (X10 ⁶)	Geothermal BTU's (X10 ⁶)	Electric BTU's (X10 ⁶)
67°F	618	5	14	14	—
62	701	10	32	32	—
57	813	15	55	55	—
52	889	20	81	81	—
47	896	25	102	102	—
42	816	30	111	111	—
37	675	35	107	107	—
32	511	40	93	93	—
27	316	45	65	62	3
22	217	50	49	42	7
17	126	55	31	25	6
12	55	60	15	11	4
7	19	65	6	4	2
2	8	70	3	2	1
			764	741	23

Total Supply Air Heating Required = 764 X 10⁶ BTU
 Portion Supplied by Geothermal = 741 X 10⁶ BTU
 Portion Supplied by Electric Coil = 23 X 10⁶ BTU

Equivalent Electric Energy Savings = 217 X 10³ KWH
 Energy Required by Geothermal Pump = 25 X 10³ KWH
 Net Annual Energy Savings = 192 X 10³ KWH

IV. APPENDICES

- A. DISTRICT HEATING SYSTEM IN CALIENTE
- B. ASSESSMENT OF GEOTHERMAL RESOURCES
OF CALIENTE

GEO-HEAT UTILIZATION CENTER

DISTRICT HEATING SYSTEM

City of Caliente, Nevada

2-80

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DISTRICT HEATING SYSTEM

City of Caliente, Nevada

The following study is the result of a request to the Geo-Heat Utilization Center for Technical Assistance.

Introduction

The Geo-Heat Utilization Center and the Nevada Bureau of Mines and Technology, have agreed to assist the Nevada Department of Energy in assessing the geothermal resource in Caliente and its potential application. As our part in the effort, the Center performed this engineering economic study of the feasibility of installing a district heating system.

Considerable preliminary information has been gathered on the heating requirements of Caliente by Center personnel and others.⁽¹⁾ It is reported that the City consists of 320 residential buildings, 90 commercial buildings, and two industries, a total of 412. Heating is predominantly by fuel oil or LPG. Only 113 of the residential, 17 of the commercial, and 1 of the industrial buildings are heated electrically. It is also reported that the average electrically heated home consumed 13,600 KWH in the year 1978, and the average all-electric commercial building 53,100 KWH. These buildings and usages are the basis for this evaluation.

Summary of Conclusion

A geothermal district heating system for the city of Caliente, Nevada is economically feasible. This assumes that a 160°F geothermal source capable of delivering a peak load of 850 gallons per minute from a relatively shallow depth can be located within, or near, the City boundaries. Total volume needed from the geothermal reservoir during the 20 year project life is 5400 acre-feet.

Based on 8% bond financing of a capital investment for equipment of \$2,500,000, a present worth of about \$5,400,000 is generated over the project life.

Total energy saved during the project life is 63 million KWH of electricity, and 7.5 millions therms of fuel.

Method of funding the project is an important consideration. Some additional money for working capital may be required.

District Heating System Operating Demand

Total of residential, commercial, and industrial buildings at the present time is 412. The proposed system must provide the needed heat for these buildings, plus the buildings to be built over the 20 year project life used in this evaluation. At start-up demand on the system is assumed to be 50% of that required for

(1) Energy Used for Space Heating in Caliente, 1978, David M. Chambers

the 412 buildings (100%). After three years all the buildings in town are considered to be on line. This included the added buildings built during the three year period. Over the 20 year projected life a growth in energy demand of 1% per year is assumed. Figure #1, District Heating System Operating Demand shows this growth rate. During the 20th year the operating demand is about 122% of that required for the 412 buildings. The system is designed to meet this requirement.

Design Capacity

Table 1, Design Capacity, summarizes the development of the design energy to be supplied by the geothermal system. This amounts to 23.66 million BTU per hour to be furnished by 850 gallons per minute of 160°F geothermal water.

Description of District Heating System

Figure #2, Flow Diagram of District Heating System, shows the key elements of the proposed system. Basic assumption is that the geothermal water is potable without chlorination. This allows hot water to be furnished directly from the geothermal system without heat exchange. The city water is not chlorinated at the present time. If chlorination is found to be necessary then a heat exchanger between geothermal and city water would be necessary at each of the hot water users. Cost of a small heat exchanger would increase retrofit cost by about 15%. Also, the amount of geothermal water injected would be 850 gpm, the same as the amount produced.

The commercial segment uses the largest portion of geothermal water, 441 gpm out of 850 gpm, and most of this for space heaters (410 gpm).

Water is supplied from two wells, with 14" bore and 12" steel casing. The wells are 300 feet deep with the water pumping level at 50 feet. Each well is equipped with a turbine pump with variable speed drive. A 20 hp electric motor is needed to develop the 78 psi discharge pressure at 850 gpm to the system. During this peak period each of the pumps will be operating. Each pump has a capacity of 600 gpm. One pump delivers sufficient volume to supply the system except in the three coldest months when both pumps will operate.

Space heating will be accomplished by finned tube coils in existing forced air ducting where possible. Other areas will require unit forced air convectors

Injection pumps will not be required, as the small injection pressure will be supplied by the production pumps. The one injection well is identical to the production wells.

The tentative location for the production wells and the injection well is shown on Drawing #1, Piping Layout for District Heating System. The drawing also shows the routing of the geothermal piping. Supply piping is insulated fiberglass reinforced plastic pipe. Size varies from 8" to 2". Return piping is within the same pipe size range, but is uninsulated PVC, normal impact grade. Small piping is not shown, but the bulk of the pipe will be 1/2" for the domestic users and 3/4" for the commercial users. Supply piping is insulated steel, and return piping is uninsulated PVC. All piping is buried about 3 feet deep. Estimated annual water usage by the system when operated at design (during the 20th year) is 307 acre-feet, with 267 acre-feet injected. Total geothermal water usage during the project life is estimated to be 5400 acre-feet.

DISTRICT HEATING SYSTEM OPERATING DEMAND
CALIENTE, NEVADA
FIGURE #1

DESIGN CAPACITY

District Heating System, Caliente, Nevada

TABLE #1

								Existing (100%)			
Domestic								Commercial			
No. Bldgs.	Space Heat		Hot Water		Total		No. Bldgs.	Space Heat		Hot Water	
	Annual BTU/YR 10 ⁶	Peak BTU/HR 10 ⁶	Annual BTU/YR 10 ⁶	Peak BTU/HR 10 ⁶	Annual BTU/YR 10 ⁶	Peak BTU/HR 10 ⁶		Annual BTU/YR 10 ⁶	Peak BTU/HR 10 ⁶	Annual BTU/YR 10 ⁶	Peak BTU/HR 10 ⁶
All Electric	113	3,130	-	1,749	-	4,879	17	3,085	-	383	-
Fuel Heated	207	5,734	-	3,204	-	8,938	73	13,247	-	1,644	-
Total Annual	-	8,864	-	4,953	-	13,817	-	16,332	-	2,027	-
Existing Peak (100%)	-	-	4.56	-	2.83	-	-	-	8.41	-	1.1
Design Peak (122.06%)	-	-	5.57	-	3.45	-	-	-	10.26	-	1.4

											Design (122.02%)	
Industrial										Total Existing (100%)		
Total		No. Bldgs.	Space Heat		Hot Water		Total					
Annual BTU/YR 106	Peak BTU/HR 106		Annual BTU/YR 106	Peak BTU/HR 106	Annual BTU/HR 106	Peak BTU/HR 106	Annual BTU/YR 106	Peak BTU/HR 106	Annual BTU/YR 106	Peak BTU/HR 106	Annual BTU/YR 106	Peak BTU/HR 106
3,468	-	1	1,936	-	387	-	2,323	-	10,670	-	13,019	-
14,891	-	1	1,936	-	387	-	2,323	-	26,152	-	31,911	-
18,359	-	-	3,872	-	774	-	4,646	-	36,822	-	44,930	-
-	9.57	-	-	1.99	-	.44	-	2.43	-	19.39	-	-
-	11.68	-	-	2.42	-	.54	-	2.96	-	-	-	23.6

FLOW DIAGRAM OF DISTRICT HEATING SYSTEM

CALIENTE, NEVADA

FIGURE #2

TURBINE PUMPS (2)
W/ VARIABLE SPEED DRIVER
600 GPM / EA, 20 HP MOTOR

GPR 1/25/80

Capital and Operating Costs

Table #2 summarizes the capital and operating costs. Total capital cost is estimated to be 2.5 million dollars. This includes a cost of \$500,000 to retrofit the existing 412 buildings. Buildings that connect later will pay their own connecting costs.

Operating cost for the first year is estimated to be \$62,550. As previously indicated, this assumes that 50% of the existing 412 buildings are on line at the start-up. Operating costs will increase over the years as load on the system increases, and costs escalate. Table #5, shows the yearly operating costs over the 20 year project life. These costs take into consideration the initial 3 year period of reduced operation, and the 1% growth in energy demand. Also, electricity is escalated at 9.5% annually through 1986 and 8.58% annually thereafter. Maintenance costs are inflated at 7% per year, which is assumed to be the economic inflation rate over the life of the project. Insurance for the geothermal system, which excludes well and reservoir insurance, is increased at 2% per year.

Cost Analysis

Table #3, Energy Savings at Start-Up, shows how first year dollar savings for electricity and fuel were developed. The savings per year at start-up is \$141,872. Cost of electricity for pumping the geothermal water is not considered in this amount, but is included as an annual operating cost. Pumping electricity consumption is small, varying from 4.9% of electricity saved during the start up year, to 5.7% during the 20th year.

First year cost for fuel was set at \$.655 per therm. This is equivalent to fuel oil at \$.91 per gallon, and LPG at \$.60 per gallon.

Conventional fuel costs for propane and oil are combined. The inflation rates for these fuels is assumed to be 8.5% over the 20 year life of the project. The city growth rate is assumed to be 1% per year over the life of the project. Refer to Table #4, Conventional System - Energy Usage Over 20 Year Time Period. The first column shows the number of therms to heat the city based on current consumption figures and the projected inflation rates for growth. The second column shows the current rate for oil and propane of \$0.655 per therm and indicates the projected 20 year costs for this energy based on an inflation rate of 8.5%. Column 3 shows total cost for propane and fuel oil based on both growth rates and inflation rates. Column 4 shows the current electrical consumption for the city in kilowatt hours (kwh) and projects and kwh of usage over the next 20 years based on the assumed growth rate of 1% per year. Electricity used for lighting is excluded. Column 5 shows the current averaged rate for electricity of 0.0177 per kwh and indicates the projected 20 year cost for this energy based on assumed inflation rates which are 9.5% annually through 1986 and 8.58% annually thereafter. Column 6 multiplies the kwh rate times the kwh usage taking into consideration both the inflation rates and the growth rates of the city and shows annual cash flows for this energy for the next 20 years. Column 7 combines the cost for propane, heating oil, and electricity for the city. It shows the total annual cash flow for a 20 year period to heat the city with the assumed inflation rates and a growth rate of 1% annually. Table #5 shows the geothermal system costs. The growth rate for the pump costs varies from the normal growth rate due to the fact that pumping costs are not a linear function. Therefore, as the amount of geothermal water is increased, the amount of power needed for

SUMMARY OF CAPITAL AND OPERATING COSTS

District Heating System
Caliente, Nevada

TABLE #2

Capital Costs

Geothermal (2) & injection (1) wells	30,000
Turbine pumps (2)	86,000
Geothermal supply & return piping	1,400,000
Well head buildings	6,000
Retrofit existing building (412)	500,000
Miscellaneous electrical & mechanical	78,000
Engineering @ 10%	<u>210,000</u>
Subtotal	2,310,000
Contingency	<u>190,000</u>
(1) Total capital cost	\$2,500,000

Operating Costs

Maintenance:	
Piping	8,333
Turbine pump, buildings & electrical	38,214
Insurance	14,702
Electricity:	
Pumping	190
Convactor fans	<u>1,111</u>
Total annual operating cost (1st year)	\$62,550

(1) Excludes permits or licenses, and cost escalation.

ENERGY SAVINGS AT START UP

District Heating System, Caliente, Nevada

TABLE #3

	Electricity				Fuel				Total
	<u>KWH/YR</u>	<u>Equivalent BTU/YR 10⁶</u>	<u>\$/KWH</u>	<u>\$/YR</u>	<u>Output BTU/YR 10⁶</u>	<u>Purchase (@75% Eff.) Therms/yr</u>	<u>\$/THERM</u>	<u>\$/YR</u>	<u>\$/YR</u>
Domestic	1,429,676	4,879	.01842	26,335	8,938	119,173	.655	78,058	104,393
Commercial	1,016,065	3,468	.01710	17,375	14,891	198,547	.655	130,048	147,423
Industrial	680,692	2,323	.01710	11,640	2,323	30,973	.655	20,287	31,927
Total existing (100%)	3,126,433	10,670		55,350	26,152	348,693		228,393	283,743
Savings Per Year at Start Up (50%)	1,563,217	5,335		27,675	13,076	174,347		114,197	141,872

District Heating System, Caliente, Nevada

YEAR	NUMBER	OIL AND	TOTAL	NUMBER	ELECTRICAL	TOTAL	TOTAL
	OF	COST	OIL AND	OF	COST PER	ELECTRICAL	CONVENTIONAL
	THERMS	PER	PROPANE	KWH	KWH	COST	ENERGY
	1	THERM	COST	4	5	6	COST
		2	3				7
Present Year	348693	0.655	228394	3126433	0177	55338	
1	352180	0.711	250295	3157697	94	61201	311486
2	355702	0.771	274275	3189274	.0212	67685	341960
3	359259	0.837	300565	3221167	.0232	74856	375421
4	362851	0.908	329374	3253379	.0254	82727	412161
5	366480	0.985	360344	3285913	.0279	91559	452503
6	370145	1.069	395541	3318772	.0305	101259	496800
7	373846	1.159	433453	3351959	.0331	111047	544500
8	377585	1.258	475000	3385479	.0360	121781	596780
9	381360	1.365	520529	3419334	.0391	133552	654080
10	385174	1.431	570421	3453527	.0424	146460	716882
11	389026	1.607	625096	3488062	.0460	160617	785713
12	392916	1.743	685012	3522943	.0500	176142	861153
13	396845	1.892	750670	3558172	.0543	193167	943837
14	400814	2.052	822622	3593754	.0589	211839	1034460
15	404822	2.227	901470	3629692	.0640	232314	1133784
16	408870	2.416	987876	3665989	.0695	254770	1242645
17	412959	2.621	1082564	3702643	.0755	279395	1361959
18	417033	2.844	1186327	3739675	.0819	306401	1492728
19	421259	3.086	1300037	3777072	.0890	336017	1636054
20	425472	3.343	1424645	3814842	.0966	368496	1793141
						TOTAL	17188049

GEOHERMAL SYSTEM
ENERGY USAGE AND SAVINGS OVER 20 YEAR PROJECT LIFE

District Heating System, Caliente, Nevada

TABLE #5

YEAR	PUMPING COSTS FOR THE GEOHERMAL SYSTEM	ELECTRICAL COSTS FOR FAN COIL UNITS	MAINTENANCE COSTS FOR GEOHERMAL SYSTEM	INSURANCE COSTS FOR GEOHERMAL SYSTEM	CONVENTIONAL FUEL THAT HAS TO BE PURCHASED WITH THE GEOHERMAL SYSTEM	SAVINGS PER YEAR OF THE GEOHERMAL SYSTEM OVER THE CONVENTIONAL SYSTEM	PRESENT WORTH AT 8%
	1	2	3	4	5	6	7
Present Cost	190	1111	46547	14702	141866		
1	309	1548	49805	14996	116415	128413	118901
2	503	2157	53292	15296	71964	198749	170395
3	818	3096	57022	15602		298973	237335
4	912	3324	61014	15914		330998	243293
5	1017	3676	65285	16232		366293	249293
6	1134	4066	69854	16557		405189	255338
7	1253	4459	74744	16988		447156	260911
8	1385	4890	79976	17226		493303	266516
9	1532	5363	85575	17570		544041	272156
10	1693	5881	91565	17922		599821	277833
11	1872	6449	97975	18280		661137	283550
12	2069	7073	104833	18646		728533	289310
13	2288	7756	112171	19019		802604	295116
14	2529	8506	120023	19399		884003	300969
15	2796	9323	128425	19787		973449	306872
16	3091	10230	137414	20183		1071727	312827
17	3417	11219	147033	20586		1179703	318837
18	3778	12303	157326	20993		1298324	324904
19	4176	13492	168339	21413		1428629	331031
20	4617	14796	180122	21846		1571759	337218
					TOTALS	14412805	5452605

the geothermal system increases by 48.5% through the first 3 years as the system comes on line and at approximately 2% per year thereafter. The geothermal system is assumed to start-up satisfying 50% of the heat load which leaves 50% of the heat load to be satisfied by propane, oil and electricity. At the end of the first year this geothermal system is supplying 63% of the needs. At the end of the second year the geothermal system provides over 80% and at the end of the third year the geothermal system has picked up 100% of the heating district.

It must be considered that while the geothermal system is picking up the heat load over the first 3 years, the heat load itself is increasing due to the growth of the town at 1% per year. Therefore, at the end of the third year, the geothermal heating system has picked up 103% of the original heat load at start time zero. Geothermal pumping costs (column 1) are, therefore, inflated, not only from a growth point of view, but also from a cost per kilowatt inflation rate point of view, which is the same rate as is used for the electrical costs. The electrical usage for the fans associated with the geothermal system are inflated at 27.25% for the first 3 years until the 100% heat load is picked up and then at 1% per year thereafter for the remaining 20 years of the project. Maintenance costs (column 3) were considered to be the same over the 20 year life of the project. In other words, maintenance costs were not a function of the number of customers on line, and the maintenance costs were inflated at 7% per year, which is assumed to be the economic inflation rate over the life of the project. Insurance costs (column 4) for the geothermal system excludes well and reservoir insurance, and is assumed to increase at 2% per year over the life of the project. Column 6 shows the savings per year resulting from converting to geothermal energy. This forecast of cash flows was completed by evaluating the costs of a conventional system over a 20 year life, evaluating the cost of the geothermal system over a 20 year life, and subtracting those costs of the geothermal system from the costs of the conventional system. The last column shows the present worth of these costs and savings over a 20 year period. It assumes that the city could finance the project at 8% annual rate of interest. The total figure at the bottom of this column shows that the city could afford to spend \$5,452,605 to install the geothermal system, and that the project would pay for itself based on conventional fuel rates in 20 years.

It is estimated, however, that the cost to install the geothermal system will be about 2.5 million dollars and this indicates a 16% return on investment if the project were totally financed by equity. The pay-back at zero interest is slightly less than 8 years. If we consider the amortization of the 2.5 million dollar loan at 8%, the annual payment on that loan would be \$254,631. With such an annual payment, the project indicates that it would pay itself back in less than 5 years. All these cost figures are based on charging all the geothermal users the same price as they would have to pay for conventional fuel.

The installation of a geothermal system should offer some incentive for the consumers to switch from conventional fuel to the geothermal system. With a present worth of \$5,453,000 as opposed to the \$2,500,000 capital investment required, it is obvious that the cost of energy over the 20-year period could be significantly reduced in the long run. Presently, home owners using oil or propane are paying \$6.55 per MBTu, (million BTU) and those customers utilizing electric heat are paying \$4.98 per MBTu. An incentive to convert to geothermal heat might be to charge the consumers the current electric rate and allow this rate to increase at 8% per annum, rather than at the projected inflation rate for electrical energy. Table #6 indicates the revenues that would be received annually if such a rate were charged. The last column indicates the total cash flow by year for the geothermal system starting at a rate of \$4.98 per MBTu.

At the end of 20 years, total revenues would exceed the costs of operating and maintaining the geothermal system and paying interest on a 8% 20-year bond. Interest payments would amount to \$200,000 per year with a balloon payment at the end of the 20th year. Note that the project operates at a loss for the first 5 years. Therefore, working capital of \$400,000 would be required to sustain the project through this 5-year period. Another alternative might be to postpone interest payments for the first 5 years and make increased interest payments to compensate over the last 15 years of the project.

A METHOD FOR CUSTOMER ENERGY CHARGES
District Heating System, Caliente, Nevada

TABLE #6

<u>YEAR</u>	<u>GEOTHERMAL REVENUE AT \$4.98 PER MBtu INFLATING AT 8% PER YEAR</u>	<u>20-YEAR CASH FLOW FOR THE GEOTHERMAL SYSTEM</u>
Present Year	183374	
1	200024	-183049
2	218186	-125026
3	237997	-38450
4	259607	-21556
5	283180	-3030
6	308893	17282
7	336940	39596
8	367534	64057
9	400906	90867
10	437309	120248
11	477016	152440
12	520329	187709
13	567575	226342
14	619111	268654
15	675326	314991
16	736646	365728
17	803533	421278
18	876494	482090
19	956080	548655
20	1042892	-1878490
	TOTAL	1050334

Assessment of Geothermal Resources of Caliente, Nevada

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NEVADA BUREAU OF MINES AND GEOLOGY
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ASSESSMENT OF GEOTHERMAL
RESOURCES OF CALIENTE, NEVADA

MARCH, 1980

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ABSTRACT

An assessment of the geothermal resources of Caliente, Nevada was made to provide information on resource characteristics and to site 2 (two) 500 ft (152 m) test wells to confirm the resource. This report considers only the physical aspects of the resource and is part of a concerted effort to determine the feasibility of geothermal space heating on a city-wide basis.

The strategy used in the resource assessment employed a logical sequence of work elements that included 1) baseline data collection, 2) field investigations, 3) laboratory analyses and 4) data interpretation and synthesis. Airphoto interpretation indicated that a series of normal faults produced a stepped arrangement in the canyon walls on the west side of Meadow Valley Wash north of downtown Caliente. This area coincides with the area of known geothermal occurrences. Temperature measurements in existing wells indicate a rapid cooling of the geothermal waters as they mix with cold groundwater flows in Meadow Valley Wash. Soil mercury analyses range from 15 ppb to as high as 120 ppb. Trends in soil mercury content may indicate the presence of buried faults. Temperatures measured in 2-meter deep auger holes indicated temperatures as high as 40°C in an area north of the Lincoln County Medical Facility. Interpretation of chemical analyses, both major and minor, of waters collected from wells and streams in the area failed to conclusively show any mechanisms for the mixing of thermal and nonthermal waters.

The selection of sites for the 2 (two) 500 ft (152 m) reservoir confirmation wells was made using the results of temperature surveys, geologic structure and historic observations.

ACKNOWLEDGMENTS

The success of this investigation is due largely to the cooperation of the residents of Caliente. For their assistance in providing access to wells for measuring and sampling, the authors would like to thank Mr. Glen White, Mr. R. S. Van Kirk, Mr. and Mrs. Lloyd Van Kirk, Mr. and Mrs. Kevin Phillips, Mr. and Mrs. William Miller, and Mr. John Schaffer. In addition, Mr. Neldon Mathew, Superintendent of the Lincoln County School District, provided his personal services as a pilot, and the resulting photographs from the Air-survey help to put the study into perspective. The authors wish to especially acknowledge Mr. Fergus Wallis and Major Keith Larson. This investigation was initiated by the efforts of these men, and the authors are extremely grateful for their support.

INTRODUCTION

In November, 1979 the Nevada Resource Assessment Team was asked to perform a preliminary geothermal resource assessment of Caliente, Nevada. The purpose of this investigation is to provide information on the resource extent and to site two (2) 500 foot (152 m) test wells to confirm the resource characteristics. This report considers only the physical aspects of the resources and is part of a concerted effort to determine the feasibility of geothermal space heating on a city-wide basis. Other agencies participating in the feasibility study are the Nevada Department of Energy and the Geoheat Utilization Center of the Oregon Institute of Technology.

The strategy used in the resource assessment employed a logical sequence of work elements that included; 1) baseline data collection, 2) field investigations, 3) laboratory analyses, and 4) data interpretation and synthesis. The individual tasks employed in the resource assessment included:

- 1) Collection of existing geologic and hydrologic data.
- 2) Airphoto interpretation to define structural controls.
- 3) Reconnaissance geologic observations.
- 4) Temperature measurements of existing water wells.
- 5) Collection and analyses of water samples from existing wells and surface waters and springs.
- 6) Two-meter temperature probe survey.
- 7) Collection of soil samples for mercury analysis.

Prior to the initiation of the field work phase of the program, existing airphotos of Caliente were examined. The photos included both black and white (scale 1:15,840) and color (scale 1:24,000) stereo pairs. Initial interpretation of the aerial photography indicated the presence of numerous normal faults which produce a stepped arrangement along the western side of Meadow Valley Wash north of the main part of town.

Field work in the Caliente area was performed during the period December 3 to December 8, 1979. A total of 12 man-days were expended during this phase of the program. Results of the major-minor element analyses were not available for interpretation until mid-February, and the results of samples submitted for isotopic analyses have not as yet been received. We will provide this information if it should in any way alter the conclusions and recommendations of this report.

Collection of Existing Geologic and Hydrologic Data and Airphoto Interpretation

Existing geologic information consisted of the Lincoln County Report: Nevada Bureau of Mines and Geology Bulletin 73 (Tschanz and Pampeyan, 1970). The geologic map that accompanies this report is at a scale of 1:250,000 (1 in. equals 4 miles) and unfortunately provided only a gross indication of the major lithologies and structural features.

More detailed information on the geologic structure was obtained from interpretation of stereographic airphoto coverage of the study area. Preliminary interpretation of both B&W and color Ektachrome airphotos revealed many normal faults offsetting younger volcanic rocks (Tertiary) from older carbonates (Paleozoic) and Prospect Mountain quartzite. A small outlier of younger carbonate rocks rest in thrust contact with the quartzite in the Antelope Canyon area. The eastern contact of this thrust plate is a normal fault which juxtaposes the carbonates above the thrust fault with the Tertiary volcanic rocks. The thrust plate is dragged downward along the westernmost normal fault and produces a prominent (resistant) breccia zone on both the north and south sides of Antelope Canyon.

In addition to interpretation of existing airphotos the field geologists (Mr. Trexler and Mr. Flynn) flew an aerial reconnaissance over the area with Mr. Neldon Mathew, Superintendent of Lincoln County Schools on the morning of

December 6. This overflight provided information that supported earlier air-photo interpretations and substantiated observations made on the ground during the previous 2 1/2 days of field work.

Existing water well data from cold wells were collected from the files of the State Engineer. Information on geothermal wells and springs in the area were available from previous work funded by U.S. DOE (Trexler and others, 1979) and the Nevada Bureau of Mines and Geology Bulletin 91 (Garside and Schilling, 1979).

Reconnaissance Geologic Observations

A geologic field reconnaissance was performed along the western edge of Meadow Valley Wash from Antelope Canyon, on the north, to the prominent bluff west of the confluence of Meadow Valley Wash and Clover Creek (figure 1). This reconnaissance was undertaken to locate slickensides along fault planes. Orientation of slickensides can be used to determine the relative direction of movement of the rock units on either side of the fault plane.

During this reconnaissance several orifaces in outcrops were noted to have warm air emanating from them. The orifaces, from which air was issuing had dark halos of moss growing around the opening due to condensation of moisture on the cold rock surfaces. Figure 2 shows an outcrop 200 meters (200 yds.) north of the County Hospital along the western edge of Meadow Valley Wash. The dark crevices to the right of the power pole (arrow) are those from which warm air with temperatures as high as 32°C (90°F) is emanating. The white blotches of the rock face are caliche (CaCO_3) deposits. Figure 3 is a closer view of one of the fissures which has hot air evolving from it. Note the dark halo caused by moss around the opening and geologic hammer for scale.

Although some slickensides were located, no measurements were taken because it appeared the rocks were not in place.

Figure 1. Oblique Air Photo of Caliente, Nevada Looking North-northeast.
A = Antelope Valley B = County Hospital C = Meadow Valley Wash
D = Clover Creek

Figure 2. Photograph of the West Side of Meadow Valley Wash Showing Outcrop that Contains Fissures (arrow).

Figure 3. Close-up View of Fissure Which Eminates Warm Air. Note Geologic Pick for Scale.

Temperature Measurements of Existing Wells and Springs

Temperature measurements were made by two methods. In accessible wells, a down hole temperature was recorded using a cable and digital readout. In wells that were being used, and inaccessible for down hole measurements, the well was pumped for a period of time to insure that water from the bottom was circulated to the outflow which was measured. Results of the temperature measurements are given in Table 1 and the location of measurement sites is presented in Figure 4.

The warmest temperature recorded in the Caliente area was from location No. 2, figure 1, Agua Caliente Trailer Park. The temperature measured at this site was 67°C (153°F). Water from this well is used to heat mobile homes and trailers. As the geothermal fluids migrate southward (following the direction of groundwater flow in Meadow Valley Wash) they become cooler, probably by dilution with shallow groundwater. At the Lincoln County Medical Facility (location No. 3c), the maximum recorded temperature is 48.6°C (120°F). As the geothermal water travels further south, temperatures of only 42.8°C (109°F) are recorded in shallow wells (less than 150 ft) in the vicinity of locations 5-8 and 10, figure 4.

The Hot Springs Motel well (location No. 4) is located along an escarpment which may represent a fault, and has temperatures of 45°C (113°F). This well is shallow (16 ft) and may represent water that has risen by convection along a fault at the base of the bluff on the east of Meadow Valley Wash. An alternative explanation for temperatures that are slightly higher at the motel vs. locations No. 5-8 and 10 is that the amount of mixing with cold groundwater is less because the well at the Hot Spring Motel (location No. 4) is peripheral to the main groundwater flow in Meadow Valley Wash.

Table 1. Measured Temperatures of Wells and Springs

Map Location Number		Temperature °C	Sample Number
1	Cane Spring (Indian Cove)	12.0	CW-1X
2	Agua Caliente Trailer Park	67.0	CW-2X
3	Lincoln County Medical Facility		
	a. production well		
	b. reinjection well	29.2	CW-3X
	c. abandoned well	48.6	CW-4X
4	Hot Spring Motel Well	45.0	CW-5X
5	L. Van Kirk Well (a)	42.8	CW-8X
6	L. Van Kirk Well (b)	42.8	
7	R. S. Van Kirk Well	42.8	
8	K. Phillips Well	42.0	CW-10X
9	Church of Latter Day Saints Well	24.0	CW-11X
10	Miller Well	39.7	CW-12X
11	City well at park	15.0	CW-9X

FIGURE 4
LOCATION OF MEASURED WELLS

⑧ WELL AND NUMBER

CALIENTE
LINCOLN COUNTY
NEVADA
1978

PREPARED BY
NEVADA STATE HIGHWAY DEPARTMENT
PLANNING SURVEY DIVISION
IN COOPERATION WITH THE
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

Two-meter Temperature Probe Survey

To identify near surface temperature anomalies a temperature probe survey was employed. The technique consisted of drilling 3 1/2 inch diameter holes to a depth of 2 meters (6.5 ft) and implanting a thermister probe encased in 3/4 inch PVC tubing. Drilling was performed with a gasoline powered drive and 2 sections of 4-foot long, 3 1/2 inch diameter continuous auger with a fish-tail bit. In areas of difficult drilling, such as Antelope Canyon, where 2-meter depths could not be obtained 1.5 meter probe holes were used. The decrease in depth of penetration was taken into consideration when comparing temperature data from holes that reached the 2 m depth. The locations of the 2-meter probe holes and the resulting isotherms are presented in figure 5.

Temperatures recorded in the 2-meter deep probe holes ranged from 9°C (54°F) at probe site T-17 (located .75 north of T-15, fig. 5) to 40°C (104°F) at probe site T-19. A comparison of the two-meter probe survey with the water well temperature survey reveals three interesting facts; 1) the area containing the highest well temperature (location No. 2, figure 1) is outside of the 30°C contour, 2) the near surface temperatures decrease to the south, much like the well temperature data, 3) minimum temperatures recorded in the two-meter probe survey are found in the southern part of the city.

Temperatures recorded in the two-meter probe survey tend to mimic those measured in wells. The southward shift of isotherms recorded by the 2-meter probe may represent the influence of near surface groundwater. If large quantities of cold groundwater in the near surface are present in Meadow Valley Wash the southward shift would be expected.

Temperature probe holes were placed in Antelope Canyon. Although 2-meter depths were not attained, temperatures of 28°C (82°F) were measured in probe holes of 1.5 meters depth. There are no well data available for Antelope Canyon and inferences about the relationship between near surface temperatures and well

FIGURE 5
2 meter Temperature Probe Survey
Isotherm Configuration.

T-23 ⊙ Measurement site

—25— Contours in °C

temperatures cannot be made. However such high temperatures at depths of 1.5 meters (4 ft) may indicate a high temperature geothermal resource at depth.

Collection and Analyses of Water Samples

Water samples were collected from all sites listed on Table 1, except from location No. 3a, which was obstructed by piping and not capable of being pumped. In addition surface water samples were collected in Meadow Valley Wash opposite antelope Canyon and in Clover Creek, near the Nevada State Girls Training Center. Quantitative chemical analyses were performed for 18 elements, pH and conductivity. Isotopic analyses are being performed to identify the delta values for deuterium and oxygen 18; at the time of preparation of this report the results are not yet available. The results of the chemical analyses are presented in Table 2 and sample locations are shown in Figure 4.

The subsequent discussion of the results of chemical analyses is presented in two parts. The first reports on the analyses for major chemical constituents such as; calcium, magnesium, potassium, sodium, silica, nitrate and nitrite, fluorine, chlorine, sulfate and bicarbonate-carbonate. The next part deals with the interpretation of minor and trace element analyses.

Major Chemical Constituents

The major chemical constituents for both thermal and non-thermal water in the Caliente area do not vary over a wide range. Table 2 lists both physical and chemical data for all waters. Table 3 shows the average chemical composition for thermal and non-thermal waters. These data are also illustrated in Figure 6. With the exception of silica, and to a lesser extent calcium and chloride, the differences in the chemical compositions are not significant.

Figure 7 is a Piper plot for all the water samples collected in Caliente. There is no clear distinction between hot and cold waters. A weak grouping may be apparent for those waters taken from north (II) of Clover Creek and those

Table 2.

Chemical analyses of water from sampled sites: Caliente study area.

Sample Name	Sample Number	T°C	pH	SC umhos	B ppm	Ca ppm	Mg ppm	K ppm	Na ppm	Li ppb	Cl ⁻ ppm	NO ₃ /NO ₂ ppm	SiO ₂ ppm	SO ₄ ppm	CO ₃ /HCO ₃ ppm	F ⁻ ppm	As ⁺⁴ ppb	Ba ppm	Fe ⁺² ppm	Rb ppb	Cs ppb	Sr ppm
Crane Spring	CW1X	12	7.63	732	2.37	55.4	12.5	9.08	69.2	46.3	55.6	7.54	67.8	53.7	228	1.38	22.1	<0.1	<0.01	26.5	7.9	0.11
Wallis well (pumped) 88 ft	CW2X	67	7.71	414	0.321	33.1	4.69	15.4	39.5	187	7.97	7.10	103	33.2	191	1.55	15.4	0.08	<0.01	48	12.8	0.17
Hospital reinjection well 35 ft	CW3X	29.2	7.54	617	0.238	39.7	6.37	35.5	69.7	262	9.31	2.70	151	31.7	323	2.48	<5	0.16	1.29	30.4	6.4	0.09
Hospital old well 50 ft	CW4X	48.6	7.75	476	0.216	37.9	6.59	17.1	45.7	172	15.3	19.7	103	37.2	186	1.38	6.2	0.08	0.034	42	6.1	0.18
Hot Springs Motel well 16 ft	CW5X	45	7.96	504	.311	35.1	6.88	22.1	50.1	191	30.5	3.81	142	29.9	199	1.43	6.9	0.04	<0.01	42.3	5.3	0.06
Clover Valley Wash	CW6X	12	7.74	758	0.180	77.3	13.9	6.36	48.3	41.8	19	2.83	53.7	18.7	371	1.61	87.1	<0.1	<0.01	2.3	7.3	0.14
Meadow Valley Wash	CW7X	5	7.85	990	0.258	58.1	24.9	15.4	94.6	93.6	59.1	0.308	58.6	66.2	387	2.04	85.7	<0.1	<0.01	11	6.4	0.17
Llyod Van Kirk well 115 ft	CW8X	42.8	8.07	462	1.83	25.3	6.41	23	54.1	20.2	13.4	0.447	114	19.1	231	1.74	52.2	<0.1	0.055	8.3	6.5	0.08
Caliente City well Dixon/ McKinely	CW9X	15	7.77	398	0.288	53.3	6.59	4.59	27.6	26.8	12.5	2.26	47.1	5.56	232	1.68	12.4	<0.1	<0.01	3.8	5.1	0.12
K. Phillips well 120 ft	CW10X	42	7.75	482	0.112	29.6	8.02	18.4	49.5	161	17.3	2.66	113	30.8	209	1.43	13.9	<0.1	0.028	12.8	4.9	0.07
LDS well	CW11X	24	7.59	813	0.309	53.2	16.1	20.2	68.7	205	23.2	2.50	94.8	53.7	337	1.43	88.6	<0.1	<0.01	16.8	6.2	0.25
Miller well 120 ft	CW12X	39.7	7.75	554	0.394	45.5	8.25	16.4	46.9	196	19.5	<0.01	113	43.6	254	1.38	18.0	<0.1	0.049	18.1	4.9	0.15

Table 3
Average Composition of Constituents for Thermal and Nonthermal Waters

	Non-thermal waters 4 samples temperatures 5°-15°C	Thermal waters 8 samples temperatures 24°-67°C
Ca	61	37.4
Mg	14.5	7.9
K	8.9	21.0
Na	60	53.0
SiO ₂	57	116.7
NO ₃ /NO ₂	3	4.9
F	1.5	1.6
Cl	36.5	17.1
SO ₄	36	35
HCO ₃ /CO ₃	304.5	241.3

from the south (I). This distinction in chemical similarity may be partially geographical since some samples in Group II are non-thermal.

Table 4 shows the results of two chemical analyses of the water from the Agua Caliente Trailer Park well. The well water samples were taken and analyzed over a year apart by two different laboratories. The fact that the data are nearly identical indicates the geothermal system is geochemically consistent over a period of time.

Table 4
Analyses from Agua Caliente Trailer Park Well, Temperature 67°C

	T°C	pH	SC µmohs	HCO ₃ ⁻ ppm	Cl ⁻ ppm	SO ₄ ⁻ ppm	F ⁻ ppm	Na ppm	K ppm	Ca ppm	Mg ppm	SiO ₂ ppm
Nov. 1978	67	7.2	400	200	8	30	1.4	39.2	14.3	34	4.8	106
Dec. 1979	67	7.7	414	191	7.9	33.2	1.5	39.5	15.4	33.1	4.7	103

Figure 6. Comparison of Average Chemical Composition for Thermal and Non-thermal Waters in Caliente.

Sample
Number

Temperature
°C

Sample
Number

Temperature
°C

1
2
3
4
5
6

12
67
29
48
45
12

7
8
9
10
11
12

5
43
15
42
24
40

Figure 7. Piper Plot of All Water Samples Collected.

Several different mixing models were unsuccessfully attempted for waters in the Caliente area. The chemical composition of waters at location No. 1 which is located several miles north of the town were considered to be background. These chemical constituents were summed with the chemical constituents from two other samples (No. 6 or 9 and 3 or 8). The results of these mixtures of different waters were compared to the composition of thermal waters from location numbers 2 or 10. The method indicated that the hypothesis for mixing was valid for only 50 percent of the major dissolved species.

Thermal waters do show a significantly greater amount of dissolved silica. The use of chemical geothermometers for these waters is considered imprudent, however, because the thermal waters are not significantly different in chemical composition from the non-thermal waters and the probability of mixing is very high, this rules out the use of any geothermometers which are based on the premise of non-mixing of thermal and non-thermal water.

In conclusion, the thermal waters in Caliente 1) appear to be derived from the shallow, non-thermal waters, 2) do not vary chemically over time 3) cannot be used to estimate reservoir temperatures, 4) and will not be used to aid in the drill-site selection process.

Interpretation of Minor and Trace Elements

Minor and trace element analyses for the Caliente waters included boron, arsenic, barium, iron, rubidium, cesium, and strontium. The results of the analyses are listed in Table 2. The values for both barium and iron were too low to plot and will not be given any further consideration.

The values for the remaining elements were plotted against temperature (figures 8A, B, C, D and E). Numbers on figures 8A-E correspond to sample numbers on Table 1. In Figures B, C, and E, no trends can be seen, and the values are consistently low for waters over the entire temperature range. The

Figure 8D and 8E. Plots of Minor Element Compositions as a Function of Temperature.

Figure 8A-8C. Plots of Minor Element Compositions as a Function of Temperature.

one exception is the boron value for sample number one, which was collected 2.2 miles (3.6 km) north of Caliente.

The rubidium values (figure 8A) appear to increase with increasing temperatures, but these values are too variable in the 30-50°C temperature range to be useful in a quantitative temperature estimate. The spread certainly precludes the use of rubidium values as a tool for geochemical exploration.

The final trace element, arsenic, has been used in soil and water geochemical surveys, in conjunction with mercury analyses. In general, a high arsenic value is usually considered a good indicator of high temperature geothermal systems. The results for the Caliente water samples show, contrary to expectation that the non-thermal waters are higher, on the average, in arsenic than the thermal waters. Although this is interesting and ironic, it unfortunately is not a useful tool for this geochemical investigation.

In conclusion, most of the minor and trace elements do not show any trends with respect to temperature and appear to be consistently low for all water samples, regardless of temperatures. None of the plots show any clear trends and these data will not be used to identify potential drill sites.

Soil Mercury Analyses

Analyses of mercury in soils has proved to be an excellent technique in providing information on the location of faults and areas of abnormally high heat flow. The technique is based on the assumptions that high temperatures at depth volatilize mercury, which, in the vapor state, migrates upward along the most convenient routes. The most convenient routes are generally faults. Therefore, anomalously high mercury contents in the near-surface soil are indicative of areas of high heat flow which may be due to geothermal activity or faulting or a combination of both.

The results of 40 soil mercury analyses are presented in Figure 9. The dominant mercury trend is a north-northeasterly trend through Meadow Valley Wash and the center of Caliente. The trend is separated by a region of lower mercury values which may reflect a groundwater inflow from Clover Creek. A similar groundwater caused shift can be used to explain the offset of the mercury anomaly away from the thermal high north of the County Hospital, compare Figure 5 with Figure 9. This may be caused by the groundwater inflow from Meadow Valley Wash.

The extension of the anomaly up Antelope Canyon correlates to the thermal anomaly which exists near the mouth of Antelope Canyon. The extreme southern portion of the north-northeasterly trend can not be related to any known thermal anomaly, but may possibly be explained by a cold groundwater masking of this area.

Selection of Drill Sites

The location of the two sites for the 500 foot (152 m) test wells are north of the main part of town. Figure 10 shows the location of the proposed sites. Site one is located in an open field north of the senior citizen housing near the hospital. The second site is located in Antelope Canyon slightly east of where the breccia zone cuts the canyon.

Site 1 was selected because of the coincidence of a near surface thermal high as shown by the 2 meter temperature probe survey and by slightly higher soil mercury values in the same area. The site is also near the bedrock outcrops which have crevices that emit warm air at a temperature of 32°C (90°F).

The selection of a site for the second resource confirmation hole was based on geologic structure which terminates the eastern edge of a thrust plate that rests on the Prospect Mountain quartzite. Historic reports indicate that a water well was being drilled in this area and hit steam and hot water and the well was

Soil mercury in parts per billion

Figure 9. Map Showing Soil Mercury Concentrations in parts per billion.

Figure 10. Well Site Locations

abandoned. Shallow temperature probe holes in the area are anomalously high with temperatures of 28°C (82°F) at 1.5 meters.

It is anticipated that 500 foot holes in these areas should confirm the extent of the geothermal resource. It is hoped that temperatures in excess of 80°C (175°F) will be encountered in the Antelope Canyon site.

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