OPEN-FILE REPORT NO. 81-3

APPENDICES OF AN APPRAISAL FOR THE USE OF GEOTHERMAL ENERGY IN STATE-OWNED BUILDINGS IN COLORADO

Section A: Alamosa
Section B: Buena Vista
Section C: Burlington
Section D: Durango
Section E: Glenwood Springs
*Section F: Steamboat Springs

by

Richard T. Meyer
Barbara A. Coe
Jay D. Dick

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
DENVER, COLORADO

1981

$1.50

DISCLAIMER

NP--3901250

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FIGURES

STEAMBOAT SPRINGS

The State Highway Department Building at Steamboat Springs has been evaluated in this appraisal for the use of geothermal energy in state-owned buildings. Steamboat Springs is the location of several surface hot springs, including Heart Hot Springs, Steamboat Hot Springs, Sulphur Cave Hot Springs and Routt Hot Springs. The Highway Department Building is favorably located relative to Steamboat Hot Springs but is 6.3 miles from Routt Hot Springs. However, more and better resource assessment information is available for Routt Hot Springs then for Steamboat Hot Springs.

Evaluation of existing resource assessment data for Routt Hot Springs indicates a reservoir temperature of 200°F to 250°F, well depths of 2900 feet, flowrates of 100 gpm per well, and total dissolved solids of 550 mg/l. The data on Steamboat Hot Springs indicates a reservoir temperature of 150°F, well depths uncertain but in the range of 800 to 6000 feet, flowrates of 500 gpm per well, and total dissolved solids of 100 to 6000 mg/l. For purposes of this appraisal, only the resource associated with Steamboat Hot Springs is used and a favorable well depth of 800 feet is assumed.

The State Highway Department Building in Glenwood Springs is a combination office building and maintenance garage. In is presently heated by two suspended natural gas furnaces. Two geothermal options have been evaluated: (1) a heat exchanger coupled to a deep well on the geothermal side and to hot water fan coil heaters on the building side; and (2) water-to-air heat pumps supplied from a shallow warm aquifer. In the first case, space heating can be accomplished using 150°F geothermal water at 30 gpm; in the second case, space heating can be accomplished with 80°F to 100°F warm water at 50 gpm.

The geothermal energy economics are evaluated for both the heat exchanger/deep well and the heat pump/shallow well options. In the former case, the costs of the production well are prorated for the required 30 gpm out of the assumed 500 gpm capacity; it is assumed that other users would use the balance of the production capacity and share the well costs. Both geothermal options are found to be economically competitive with the existing natural gas heating system.

The principal institutional issue for a geothermal heating system for the Highway Department Building is the question of whether or not the State owns the geothermal rights on the State property. A title search is required to make this determination. If the State does not own the geothermal rights, then geothermal leases would have to be acquired. The environmental considerations are minimal, even with the assumption of surface disposal of the small quantity of water used for heating.

Resource Assessment for Steamboat Springs

At Steamboat Springs there are two geothermal resource areas. One is immediately beneath the town of Steamboat Springs. A smaller but hotter geothermal area is found five miles north of town at Routt Hot Springs where there are several small springs with a combined discharge of near 100 gpm and temperatures of 147°F.

There are three main spring areas in the town of Steamboat Springs. On the western edge of town is the Steamboat Hot Springs itself at 79°F and 20 gpm. On the eastern edge of town is Heart Hot Springs at 102°F and 140 gpm, and just south of downtown is the Sulphur Cave Hot Springs at 68°F and 10 gpm.

The geology of the Steamboat Springs area is complex. Cretaceous sediments outcrop through the western and southern portions of the area in southwesterly dipping beds of Mancos Shale and Dakota Sandstone. These sediments truncate against a major high angle reverse fault which trends north-south directly through the town of Steamboat Springs (Figure 38). This fault uplifts Precambrian basement granites and gneisses over 2000 feet into contact with Mesozoic sediments (Snyder, 1977). The Routt Hot Springs are flowing from fractures, while the Steamboat Springs are flowing from outcrops of Dakota Sandstone and the overlying Browns Park Formation.

Geophysical studies within the town of Steamboat Springs itself show the geothermal reservoir appears to be restricted to a northwest-trending normal fault approximately following the Yampa River (Christopherson, 1979). Seismic studies at Steamboat Springs indicate a reservoir would be at depths of at least 6500 feet but the local geology indicates a depth of only 800 feet is possible.

The spring temperatures at Routt Hot Springs, combined with extensive hydrothermal alteration, indicate elevated reservoir temperatures could exist. Although several analyses indicate reservoir temperatures in excess of 250°F at Routt Hot Springs, more realistic, conservative projections seem to be 200°F to 250°F. The geothermal reservoir at Steamboat Springs probably has a lower subsurface temperature, possibly not exceeding 150°F.

The areal extent of each reservoir has been projected by Pearl (1979) and is believed to be restricted to the two controlling fault zones. The geothermal resources at Routt Hot Springs may be confined to a small area only three-quarters of a mile square. The Steamboat Springs reservoir could cover from 0.52 to 1.0 square miles (Christopherson, 1979). The low flow rates at both spring areas, combined with low permeabilities in the Precambrian rocks of Routt Hot Springs, indicate that well production rates may be very low, possibly 100 gpm per well at Routt Hot Springs and up to 500 gpm at Steamboat Springs.

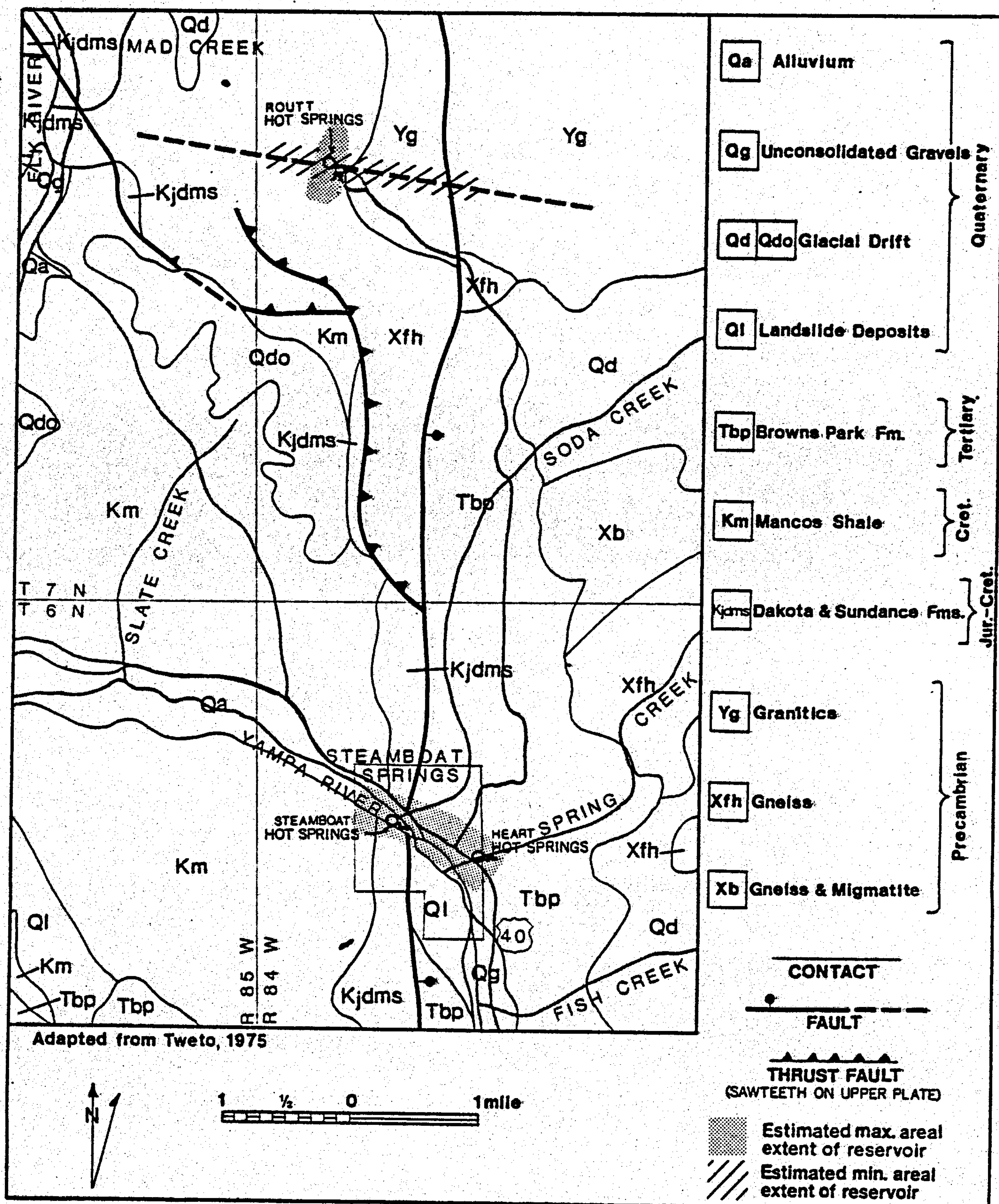


Figure 38: Geology of the Steamboat Springs area and estimated areal extent of geothermal activity (from Pearl, 1979).

The projected geothermal systems at Routt Hot Springs and Steamboat Springs are summarized as:

	Routt	Steamboat Springs
Reservoir temperature:	200°F - 250°F (2)	150°F (2)
Depth:	2900 feet (3)	800-6000 feet (1)*
Production/well:	100 gpm (2)	500 gpm (1)
Areal extent:	0.75 square miles(3)	0.52-1.0 square miles (2)
Formation:	Fractures in p€** (3)	Dakota Sandstone (2)
TDS:	550 mg/l	1000-6000 mg/l
Useable heat:	90×10^{11} Btu (2)	30×10^{11} Btu (1)

* Geology indicates approximately 800' and geophysics indicates approximately 6500'. ** p€ = Precambrian

The geothermal resources at Routt Hot Springs are probably much hotter than those beneath Steamboat Springs. However, the drilling target for a geothermal well at Steamboat Springs would not be as restrictive as at Routt Hot Springs. For purposes of this appraisal, drilling of a production well on the site of the Highway Department Building is assumed.

Building Retrofit Engineering for State Highway Department Building

The retrofit engineering design specifications for the Highway Department Building in Steamboat Springs are presented below. Figure 39 provides a schematic drawing of the heat pump option for the space heating requirements.

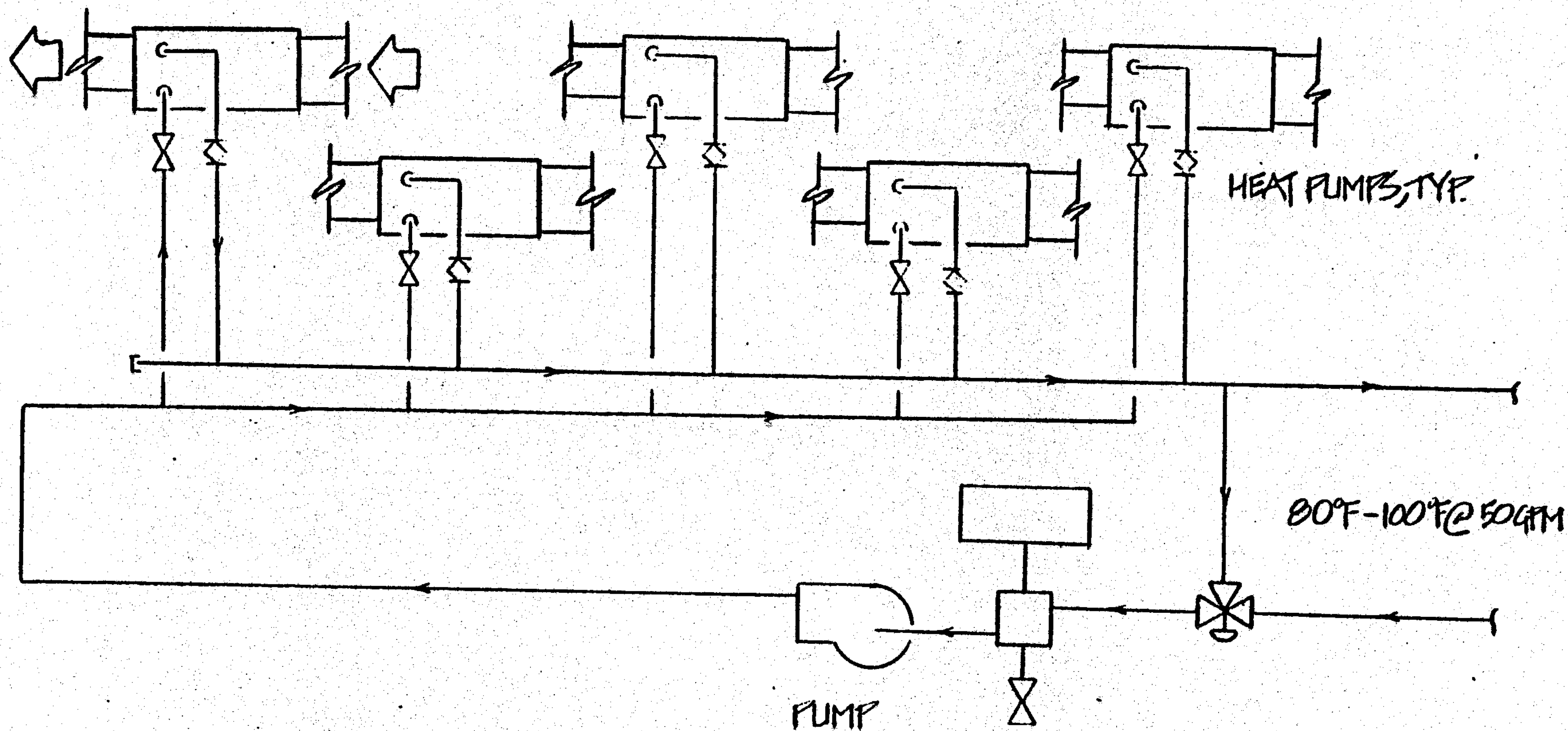
Present Conventional Fuel Heating System

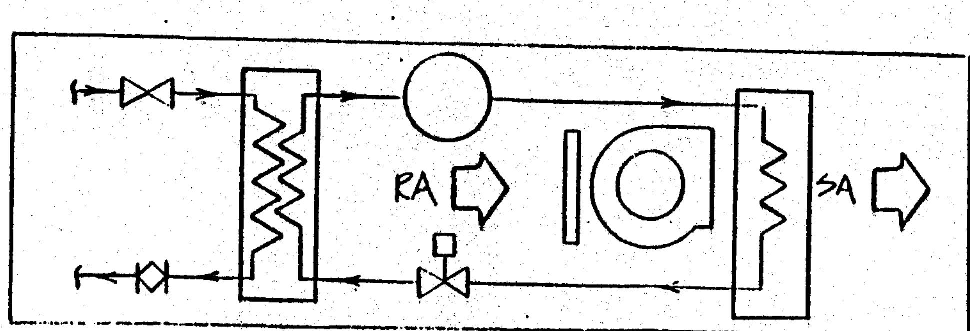
Building	Square Footage	Fuel	Heating Equipment	Peak Heat Load
Office/ Garage	4000	Natural Gas	Furnaces (2)	300,000

Geothermal Heat Exchanger Design Specifications

Proposed System and Modifications:

1. Retrofit to utilize geothermal hot water for space heating.
2. Replace gas fired furnaces with hot water coil H & V units.
3. Existing air distribution to remain.
4. Circulating pump is required.
5. Air separator and expansion tank are required.
6. Distribution piping is required.
7. More sophisticated temperature control is required.





WATER TO AIR HEAT PUMP

Figure 39

STEAMBOAT SPRINGS HIGHWAY DEPT.

Engineering Design:

Design heating can be accomplished using 150°F geothermal water at 30 gpm, ΔT = 20°F and a 10°F approach.

Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Heat Exchanger	30 gpm, 10°approach 150°F-130°F on geothermal side 120°F-140°F on building side	1	$3,000	$3,000
H & V Units	16,000 Btu/hr output 7500 CFM	2	6,000	12,000
Circulating Pump		1	1,000	1,000
Air Separator and Expansion tank		1	1,000	1,200
Piping		200'	16	3,200
Insulation		200'	6	1,200
Temperature Controller		1	1,080	1,080
		SUBTOTAL		$22,680
		Contingency (10%)		2,268
			TOTAL	$24,948

Geothermal Heat Pump Design Specifications

Proposed System and Modifications:

1. Retrofit to utilize geothermal hot water as source for water-to-air heat pumps.
2. Existing air distribtuion to remain; however, additional sheet metal may be required.
3. Replace gas-firedfurnaces with water to air heat pumps.
4. Circulation pump is required.
5. Air separator and expansion tank are required.
6. Distribution piping to heat pumps is required.
7. 3-way diverting valve is required.
8. More sophisticated temperature control is required.

Engineering Design:

Design heating can be accomplished with water-to-air heat pumps (COP =4.0) using an 80°F to 100°F warm water source at 50 gpm and a ΔT of 15°F.

Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Heat Pump	65,000 Btu/hr, COP = 4.0	5	$1,250	$6,250
Sheet Metal				1,000
Circulation Pump	0.9 HP	1	1,000	1,000
Air Separator and Expansion tank		1	1,200	1,200
Piping		200'	16	3,200
Insulation		200'	6	1,200
Temperature Controller		1	695	695
		SUBTOTAL		$14,545
		Contingency (10%)		1,454
			TOTAL	$15,999

Economic Evaluations

On the following pages are presented the itemized geothermal capital improvement costs, the annual operating and maintenance costs for both the geothermal systems and the conventional fuel system, and the results of the calculations of the four economic measures for the heat exchanger and heat pump options evaluated for the Highway Department Building at Glenwood Springs.

The total geothermal capital improvement costs are estimated at $39,232 for the heat exchanger system with a deep well prorated at 30 gpm of the prospective 500 gpm total flow and at $30,674 for the heat pump system and a shallow well. The first year operating and maintenance costs are estimated at $1,399 and $3,535, respectively, for the two geothermal options, as compared to $3,689 for the natural gas fired furnace system.

The calculated economic measures (assuming fuel price escalation of 15% per annum) are summarized as follows:

	Heat Exchanger Prorated Deep Well	Heat Pump Shallow Well
Simple Payback Period	11 years	9 years
Total Annualized Cost:		
Geothermal:	$6,882	$9,870
Conventional:	$11,651	$11,651
Total Undiscounted Savings:	$282,555	$170,900
Total Present Value Savings:	$76,773	$40,537

Both the heat exchanger/prorated deep well and the heat pump/shallow well options are economically competitive with the existing natural gas heating system. The heat exchanger system has a slightly longer simple payback period, but the annualized cost is lower and the "energy" savings are greater than for the heat pump system. However, the economic success of the heat exchanger system is dependent upon other users consuming the balance of the geothermal water produced by the 500 gpm deep well.

CAPITAL COSTS

Location: Steamboat Springs   Facility: Highway Department Building

Geothermal Option: Heat Exchanger with Deep Well on-site

		Costs
A.	Production Well System -Prorated by gpm	
	Exploration	$ 720
	Reservoir Engineering	1,440
	Wells 1 @ $ 120,000 x 30/500	7,200
	Well Pumps (1) 30 gpm, 240 ft-hd, 3.2 HP	1,280
	Valves and Controls	60
	Contingency Funds (10%)	Included
	Subtotal	10,700
	Engineering Design Fee (10%)	Included
	Total	$ 10,700
B.	Transmission Line System	
	Piping (50 ft.) Insulated	1,100
	Pumps ( ) gpm, ft-hd, HP	N.R.
	Contingency (10%)	110
	Subtotal	1,210
	Engineering Design Fee (10%)	121
	Total	$ 1,331

C. Central Distribution System

Heat Exchanger, or	$3,000
Heat Pump	-
Auxillary Building	-
Valves and Controls	1,200
Piping	-
Circulation Pumps ( ) gpm, ft-hd, HP	-
Miscellaneous	-
Contingency (10%)	420
Subtotal	4,620
Engineering Design Fee (10%)	462
Total	$ 5,082

D. Building(s) Retrofit HVAC System

Heating Units	$12,000
Retrofit Plumbing	4,400
Valves and Controls	1,080
Contingency (10%)	1,748
Subtotal	19,228
Engineering Design Fee (10%)	1,923
Total	$ 21,151

E. Reinjection/Disposal System - Surface

Reinjection Well(s): wells @ $	
Piping (100 ft.)	$800
Pumps ( )	N.R.
Controls and Valves	N.R.
Contingency (10%)	80
Subtotal	880
Engineering Design Fee (10%)	88
Total	$ 968

F. Grand Total $ 39,232

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Steamboat Springs   Facility: Highway Department Building

Geothermal Option: Heat Exchanger with Deep Well on-site

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)
A. Production Well System		$ 428 (4%)
Pump electricity 3.2 HP	$ 464	
B. Transmission Line System	-	13 (1%)
C. Central Distribution System		
Heat Pump electricity	-	51 (1%)
Circ. Pump electricity	-	
D. Building(s) Retrofit HVAC System	-	424 (2%)
E. Reinjection/Disposal System	-	19 (2%)
Total	$ 464	$ 935

Conventional Fuel System

Type of System: Natural Gas Fired Unit Heaters

Fuel Cost	
Total Annual Fuel Load	$1,044 \times 10^6$ Btu
1980-81 Estimated Fuel Price	$3.15/$10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 3,289

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	$17,600
Estimated Maintenance Cost	$ 400

Electricity Cost	
1980-81 Estimated Total Annual Electricity Cost	$ 0

ECONOMIC EVALUATIONS

Location: Steamboat Springs Facility: Highway Department Building

Geothermal Option: Heat Exchanger with Deep Well on-site

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$ 3,289
Electricity	0
Maintenance	400
Total	$ 3,689

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 39,232
First Year Operating Cost	464
First Year Maintenance Cost	935
Total	$ 40,631

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 11 years

B. Annual Cost Comparison

(Assume 20-Year Life and 10% per Annum Cost of Capital)

Cost Item	Conventional System Annualized Cost	Geothermal System Annualized Cost
Capital Investment	$ -	$ 4,608
Electricity (9%/yr. escalation)	0	910
Maintenance (10%/yr. escalation)	583	1,364
Conventional Fuel (15%/yr escalation)	11,068	0
Total Annualized Cost	$11,651	$ 6,882

ECONOMIC EVALUATIONS (cont'd)

Location: Steamboat Springs | Facility: Highway Department Building

Geothermal Option: Heat Exchanger with Deep Well on-site

C. Total Savings and Payback Period

	Conventional System			Geothermal System		End of		Present Value
Year	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year	Annual Savings	(i=10%)
1980						0		
1981	$3,289	-0-	$400	$464	$935	1	$2,290	$2,082
1982	3,782		440	506	1,029	2	2,687	2,221
1983	4,350		484	551	1,131	3	3,152	2,368
1984	5,002		532	601	1,244	4	3,689	2,520
1985	5,752		586	655	1,369	5	4,314	2,679
1986	6,615		644	714	1,506	6	5,039	2,845
1987	7,608		709	778	1,656	7	5,883	3,019
1988	8,749		779	848	1,822	8	6,858	3,199
1989	10,061		857	925	2,004	9	7,989	3,388
1990	11,570		943	1,008	2,204	10	9,301	3,586
1991	13,306		1,037	1,098	2,425	11	10,820	3,792
1992	15,302		1,141	1,197	2,668	12	12,578	4,007
1993	17,597		1,255	1,305	2,934	13	14,613	4,233
1994	20,237		1,381	1,423	3,228	14	16,967	4,467
1995	23,272		1,519	1,551	3,551	15	19,689	4,714
1996	26,763		1,671	1,690	3,906	16	22,838	4,970
1997	30,777		1,838	1,842	4,296	17	26,477	5,237
1998	35,394		2,022	2,008	4,726	18	30,682	5,520
1999	40,703		2,224	2,189	5,199	19	35,539	5,811
2000	46,808		2,446	2,386	5,718	20	41,150	6,115
Totals							$ 282,555	$ 76,773

Capital Investment $39,232

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$282,555	$76,773
Payback Period	10 years	14 years

CAPITAL COSTS

Location: Steamboat Springs Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well and Artesian Flow

A. Production Well System	Costs
Exploration	$
Reservoir Engineering	
Wells 1 @ $ 10,000 (500 feet)	10,000
Well Pumps (1) 50 gpm, 140 ft-hd, 3.1 HP	775
Valves and Controls	
Contingency Funds (10%)	Included
Subtotal	10,775
Engineering Design Fee (10%)	Included
Total	$ 10,775

B. Transmission Line System	
Piping (50 ft.) Insulated	1,100
Pumps ( ) gpm, ft-hd, HP	N.R.
Contingency (10%)	110
Subtotal	1,210
Engineering Design Fee (10%)	121
Total	$ 1,331

C. <u>Central Distribution System</u>

Heat Exchanger, or	N.A.
Heat Pump	
Auxillary Building	
Valves and Controls	
Piping	
Circulation Pumps ( ) gpm, ft-hd, HP	
Miscellaneous	
Contingency (10%)	
Subtotal	
Engineering Design Fee (10%)	
Total	$ 0

D. <u>Building(s) Retrofit HVAC System</u>

Heating Units	
5 Heat Pumps @ $1,250	6,250
Retrofit Plumbing	7,600
Valves and Controls	695
Contingency (10%)	1,455
Subtotal	16,000
Engineering Design Fee (10%)	1,600
Total	$ 17,600

E. <u>Reinjection/Disposal System</u> -Surface

Reinjection Well(s): wells @ $	N.R.
Piping (100 ft.)	800
Pumps ( )	N.R.
Controls and Valves	N.R.
Contingency (10%)	80
Subtotal	880
Engineering Design Fee (10%)	88
Total	$ 968

F. <u>Grand Total</u> $ 30,674

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Steamboat Springs Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well and Artesian Flow

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)
A. Production Well System Pump electricity 3.1 HP	 $ 446	$940 (4%)
B. Transmission Line System	-	13 (1%)
C. Central Distribution System Heat Pump electricity Circ. Pump electricity	-	-
D. Building(s) Retrofit HVAC System	1,765*	352 (2%)
E. Reinjection/Disposal System	-	19 (2%)
Total	$ 2,211	$ 1,324

*Heat Pumps

Conventional Fuel System

Type of System: Natural Gas Fired Furnaces

Fuel Cost	
Total Annual Fuel Load	$1,044 \times 10^6$ Btu
1980-81 Estimated Fuel Price	$3.15 10^6 Btu
1980-81 Estimated Total Annual Fuel Cost	$ 3,289

Maintenance Cost	
Percent of Associated Capital Costs	
Estimated Capital Costs	$17,600
Estimated Maintenance Cost	$ 400

Electricity Cost	
1980-81 Estimated Total Annual Electricity Cost	$ 0

ECONOMIC EVALUATIONS

Location: Steamboat Springs   Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well and Artesian Flow

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$ 3,289
Electricity	0
Maintenance	400
Total	$ 3,689

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 30,674
First Year Operating Cost	2,211
First Year Maintenance Cost	1,324
Total	$ 34,209

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 9 years

B. Annual Cost Comparison

(Assume 20-Year Life and 10% per Annum Cost of Capital)

Cost Item	Conventional System Annualized Cost	Geothermal System Annualized Cost
Capital Investment	$ -	$ 3,603
Electricity (9%/yr. escalation)	-	4,336
Maintenance (10%/yr. escalation)	583	1,931
Conventional Fuel (15%/yr. escalation)	11,068	-
Total Annualized Cost	$ 11,651	$ 9,870

ECONOMIC EVALUATIONS (cont'd)

Location: Steamboat Springs

Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well and Artesian Flow

C. Total Savings and Payback Period

	Conventional System			Geothermal System		End of		Present Value
Year	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year	Annual Savings	(i = 10%)
1980						0		
1981	$3,289	-0-	$400	$2,211	$1,324	1	$154	$140
1982	3,782		440	2,410	1,456	2	356	294
1983	4,350		484	2,627	1,602	3	605	455
1984	5,002		532	2,863	1,762	4	909	621
1985	5,752		586	3,121	1,938	5	1,279	794
1986	6,615		644	3,402	2,132	6	1,725	974
1987	7,608		709	3,708	2,346	7	2,263	1,161
1988	8,749		779	4,042	2,580	8	2,906	1,356
1989	10,061		857	4,406	2,838	9	3,674	1,558
1990	11,570		943	4,802	3,122	10	4,589	1,769
1991	13,306		1037	5,234	3,434	11	5,675	1,989
1992	15,302		1141	5,705	3,778	12	6,960	2,217
1993	17,597		1255	6,219	4,155	13	8,478	2,456
1994	20,237		1381	6,778	4,571	14	10,269	2,704
1995	23,272		1519	7,388	5,028	15	12,375	2,963
1996	26,763		1671	8,054	5,531	16	14,849	3,231
1997	30,777		1838	8,778	6,084	17	17,753	3,512
1998	35,394		2022	9,568	6,692	18	21,156	3,806
1999	40,703		2224	10,430	7,361	19	25,136	4,110
2000	46,808		2446	11,368	8,097	20	29,789	4,427
Totals							$170,900	$ 40,537

Capital Investment $30,674

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$170,900	$40,537
Payback Period	12 years	17-18 years

Institutional Requirements

In the Steamboat Springs analysis, two alternative design possibilities are considered: a deep and a shallow well, either to be drilled at the Highway Department site. As with other on-site wells, the drill site is owned by the State, but mineral ownership is unknown pending a title search. Because surface disposal is suggested in the design assumptions, water rights are likely to be required. A State well permit and disposal permits are necessary. The County would require only a mechanical permit to allow retrofitting of the system (Tom Pierce, pers. comm., 1981).

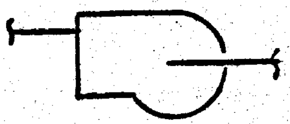
Environmental Considerations

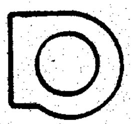
For the Steamboat Springs area, little information is available concerning possible environmental problems from geothermal development. Since on-site wells are suggested for the Highway Department Building, there is little opportunity for pollution to occur. The water quality from the three inventoried geothermal spring areas varies widely, from 903 mg/l TDS at the Heart Hot Springs to 6170 mg/l TDS at Steamboat Hot Springs (Steamboat has high magnesium, boron and chloride concentrations, as well as high alkalinity) (Barrett and Pearl, 1976). For this study, although surface disposal is assumed for the engineering plan, reinjection might be necessary depending upon the water quality obtained by drilling a well.

APPENDIX A

LEGEND FOR ENGINEERING SCHEMATICS

LEGEND

 PUMP

 FAN

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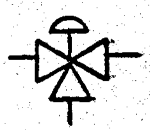
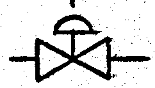
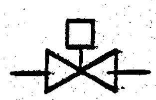
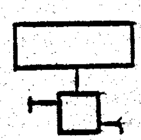
 3-WAY VALVE

 2-WAY VALVE

 EXPANSION VALVE

 SHUT-OFF VALVE

 BALANCING VALVE

 AIR SEPARATOR & EXPANSION TANK

 COIL

RA RETURN AIR

SA SUPPLY AIR