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
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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
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ALAMOSA

Two state-owned building complexes have been evaluated within the city of Alamosa: Adams State College and the State Highway Department Buildings. The locations of these facilities are indicated in Figure 5.

The resource assessment for the Alamosa area is considered generally applicable to the City of Alamosa and the specific sites of the two facilities. For the purposes of this analysis, the drilling locations for the geothermal production wells are placed on-site at Adams State College and at the State Highway Department Buildings. The resource assessment indicates that 150°F may be available at flow rates of 1000 gpm per well, depths of 4000 feet, and possibly under Artesian pressure.

Two building retrofit engineering options are evaluated for Adams State College, both of which assume only partial replacement (approximately 50%) of the existing natural-gas-fired steam-boiler system. Partial replacement rather than total replacement of the steam heating system was chosen in order to provide for a first phase demonstration project and to allow for the on-campus drilling of both the production and reinjection wells. The two retrofit options for geothermal heating include (1) a high performance central heat pump for boosting the circulating heating water to 200°F for space heating and (2) a central heat exchanger for delivery of heating water at 145°F. The first option provides for continued usage of the existing hot water heating units in the campus buildings, with the exception of retrofit of the steam units in College Center. The second option provides for the addition of terminal hot water heating units in all of the buildings in order to adapt to 145°F heating water.

Retrofit engineering for the State Highway Department Buildings provides for the use of a central heat exchanger and the distribution of 140°F heating water to all building areas that are presently heated. The existing system of natural gas furnaces and unit heaters and of propane unit heaters can be retained for a back-up or peaking system.

The geothermal energy economics for Adams State College are evaluated for both the heat pump and the heat exchanger options. In addition, the following variations in parameters are provided: natural gas price escalation of 15 percent per year (through 2000) and of 12 percent/9 percent (through 1984/through 2000); production well pumping and circulation pumping of 8760 hours per year (100% operation) and of 4320 hours per year; and pumping depths of 100 feet and of 300 feet. The same variations are applied to the State Highway Department Buildings, except the operational period was confined to 4320 hours per year.

Results of the life cycle cost analysis for Adams State College strongly favor the geothermal system over the existing natural gas system, with either the heat pump or the heat exchanger option. This result is particularly true for the assumptions of 15% per year escalation on natural gas prices and for an aggregated period of operation of 4320 hours per year. The latter would require the use of an auxiliary heating system for the steam requirements of the cafeteria in College Center.

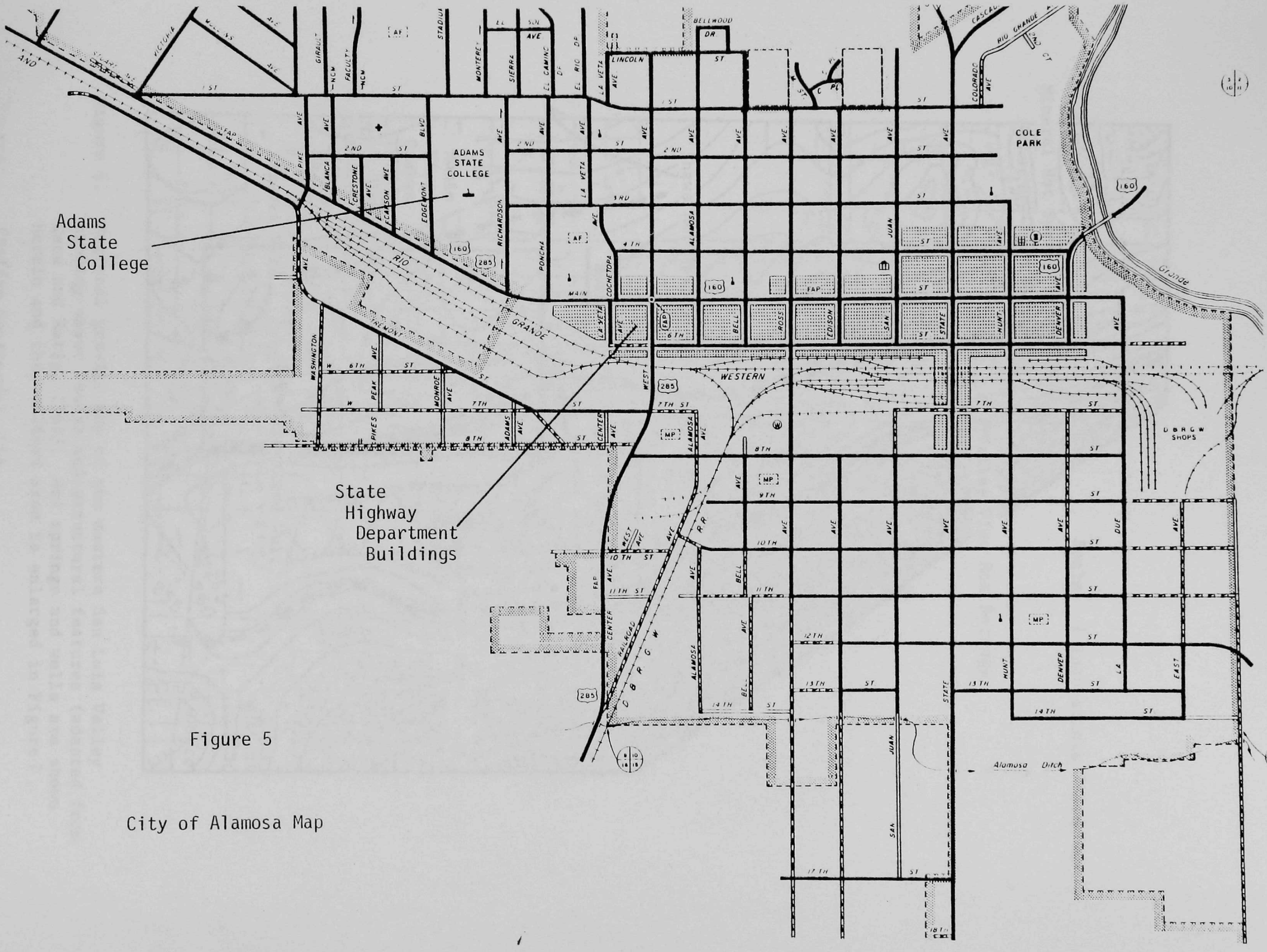


Figure 5

City of Alamosa Map

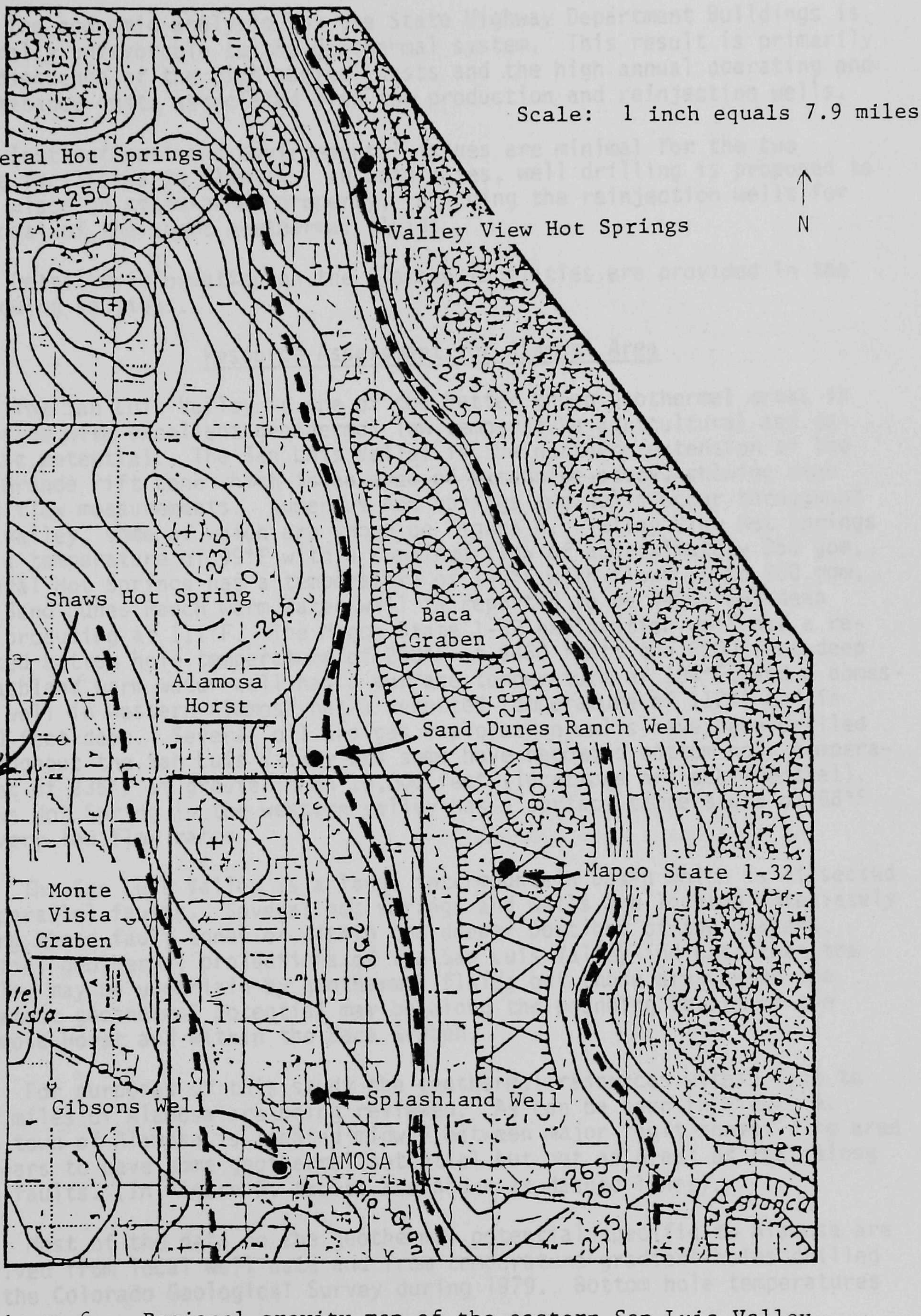


Figure 6. Regional gravity map of the eastern San Luis Valley showing major faults and structural features (adapted from Gaca and Karig, 1965). Hot springs and wells are shown herein and the outlined area is enlarged in Figure 7 .

Source: Chaffee Geothermal, Ltd.

The economic analysis for the State Highway Department Buildings is generally unfavorable to the geothermal system. This result is primarily a consequence of the high capital costs and the high annual operating and maintenance costs associated with the production and reinjection wells.

Institutional and environmental issues are minimal for the two state facilities in Alamosa. In both cases, well drilling is proposed to take place on state-owned property, including the reinjection wells for disposal of the spent geothermal fluids.

Detailed information on the Alamosa facilities are provided in the following sections.

Resource Assessment for Alamosa Area

The San Luis Valley is one of the better known geothermal areas in Colorado with excellent geothermal low temperature agricultural and domestic potential. The San Luis Valley is the northern extension of the Rio Grande rift zone which is an area of extensive study, showing high heat flow measurements. Numerous hot springs and wells occur throughout the valley, some of which are shown on Figure 6. Valley View Hot Springs has a temperature of 99°F with a combined flow of approximately 250 gpm, Mineral Hot Springs has a temperature of 140°F with flows up to 200 gpm, the Sand Dunes Ranch warm water well is reported to be 4400 feet deep and producing at 111°F. The Mapco State 1-32 exploration well has a reported bottom hole temperature of 250°F at 9460 feet; the 2000 foot deep Splashland warm water well has a surface temperature of 104°F; and a domestic well in western Alamosa has a reported temperature of 112°F and is 3000 feet deep. Several oil and gas exploration wells have been drilled throughout the San Luis Valley and some have reported bottom hole temperatures of 235°F at greater than 10,000 feet (locations are confidential). Shaws Hot Spring in the western valley has a surface temperature of 86°F at very low flow rates.

The San Luis Valley is a large intermountain basin which is dissected by parallel faults. Several hot springs and wells are located immediately along these fault zones or within the deeper portions of the grabens. Initial geothermal projections of the San Luis Valley indicate that the valley may be underlain by geothermal fluids but those areas with the greatest geothermal potential may be along the bounding faults of the Alamosa Horst and within the Baca Graben.

For purposes of this study the geothermal resources within five to ten miles of Alamosa are being reviewed. As can be seen in Figure 6, the town of Alamosa is located midway between major fault zones. The area appears to have some geothermal potential but not as great as that along the faults. (In Figure 6, faults are shown as dashed lines).

Most of the data on the geothermal potential specific to Alamosa are derived from local well data and from temperature gradient holes drilled by the Colorado Geological Survey during 1979. Bottom hole temperatures were compared with the temperature recorded at 164 feet (50 meters) and a temperature gradient calculated for each gradient hole (Table16). Data are also available on four warm water wells in the Alamosa vicinity (Table 16). The Splashland well has a temperature of 104°F, municipal wells in town have temperatures of 97°F and 103°F and a domestic well west of town (near the Gibson store) has a surface temperature of 112°F. Temperature gradients were calculated for these wells.

From the temperature gradient contours (Figure 7), the best geothermal areas appear to be west and east of town. If a geothermal well were drilled east of the city, the well depths estimated to be required are 3000 feet for a 150°F reservoir temperature and 4500 feet or more for 200°F reservoir temperature. A well drilled on the western margins of Alamosa would need to be 4000 feet or more for a 150°F temperature and greater than 5500 feet for a 200°F temperature.

Irrigation wells in the San Luis Valley have production rates ranging from several hundred gallons per minute up to 4000 to 5000 gpm. The hot water well near the Gibson store is producing at 600 gpm and several other wells in Alamosa have high flow rates. The geothermal reservoir in the San Luis Valley is within the sediments and valley-fill of the San Luis Basin which generally have very high permeabilities and porosities (those beneath the "Blue Clay" facies) that account for projected high flow rates. Production rates from deep geothermal wells at Alamosa could be 500 to 1000 gpm from each of several wells. The total dissolved solids content in this fluid production is expected to be a low 200 to 311 mg/l based upon chemical analyses of several other wells in the area.

The geothermal reservoir probably lies beneath all of the Alamosa area but the hottest reservoirs are bordering the fault zones. These hotter geothermal systems probably extend two to three miles either side of both fault zones and extend for numerous miles to the north and south. The overall areal extent of the prime geothermal systems near Alamosa is greater than 10 to 15 square miles.

The useable heat content (assuming no recharge) in the geothermal systems near Alamosa is projected by Pearl (1979) to be 93.1 x 10^{11} Btu. Since the reservoir projected herein is a bit larger than that of Pearl's, the estimate of the useable heat for Alamosa may be larger than this figure.

A summary of the projected geothermal resource characteristics (with the associated validity rating) at Alamosa is:

Reservoir temperature:	150°F (2)
Depth:	4000+ feet (2)
Production/well:	500 - 1000 gpm (2)
Areal extent:	10 - 15 square miles (3)
Formation:	Poorly consolidated sediments within volcanic flows
TDS:	300 mg/l
Useable heat:	93 x 10^{11} Btu. (2)

TABLE 16

Well Data and Temperature Gradient Calculations for Select Hot Water Wells and Temperature Gradient Holes Near Alamosa, Colorado.

Well Name	Depth	Bottom Hole Temperature	Temperature at 164'	Calculated Temperature Gradient	Other
GH-1	282'	60°F	55°F	4.24°F*	
GH-2	285'	59°F	55°F	3.31°F	
GH-3	272'	58°F	54°F	3.70°F	
GH-4	276'	55°F	52°F	2.68°F	
GH-5	289'	58°F	54°F	3.48°F	
GH-6	292'	59°F	54°F	3.91°F	
GH-12	276'	56°F	52°F	3.57°F	
GH-13	282'	56°F	52°F	3.39°F	
A-Splashland	2000'	104°F **	54°F	2.72°F	TDS = 311 mg/l
B-12th/River	1768'	103°F	54°F	3.05°F	hotter at 2000'
C-Lot 37	1648'	97°F	54°F	2.90°F	
D-Gibsons	3000'	112°F	54°F	2.05°F	TDS = 200 mg/l, 600 gpm

*°F/100'

** assumed bottom hole temperatures

Raw data on temperature gradient holes GH-1 through GH-13 is from the Colorado Geological Survey (Ringrose, 1980).

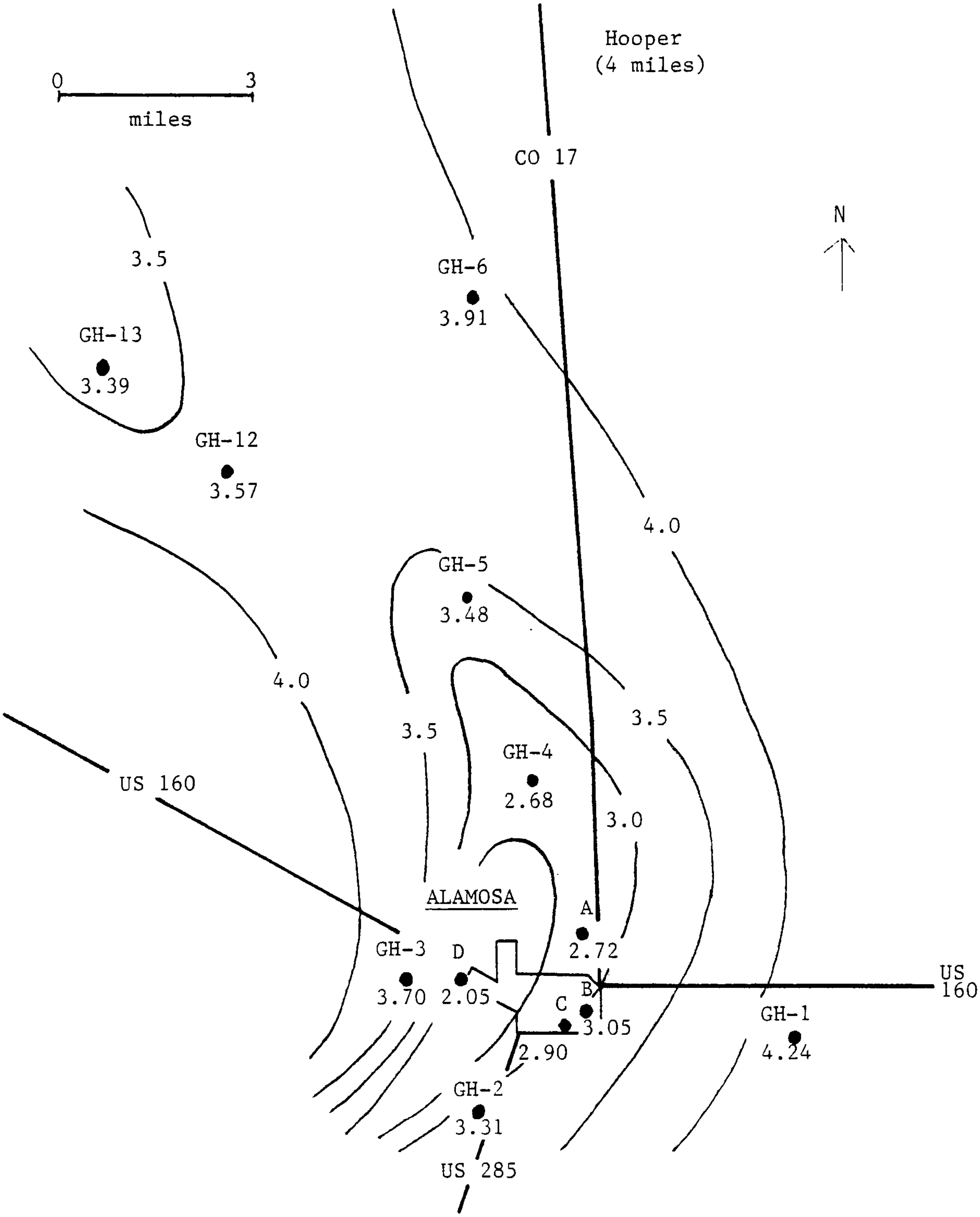


Figure 7. Temperature gradient profiles near Alamosa, Colorado. Contour intervals are in 0.5°F/100 feet isotherms. Well numbers and temperature gradients are shown on Table 1. The bounding faults of the Alamosa Horst are approximately at the borders of this figure.

Well number
●
°F/100'

SOURCE: Chaffee Geothermal, Ltd., 1980

Most of the San Luis Valley has geothermal potential, with the Baca area along the faults having the greatest. At Alamosa drilling would need to be deep to encounter useable geothermal fluids of 150°F but good production rates of 500 to 1000 gpm could be expected. Exploration for the geothermal resource is relatively risky and costly at Alamosa, but if the resource is located the geothermal potential is excellent.

Pipeline Right-of-Way

Geothermal wells to supply Adams State College and the State Highway Department Buildings may be located either on-site or up to 3.5 miles distant with the resource characteristics likely to be those specified above. The vertical relief for this zone is zero feet to ± 20 feet.

Production Well Costs and Well Engineering

Total costs for the drilling of production wells to a depth of 4000 feet are estimated at $265,000 per well. Well engineering design and drilling procedures are basically similar to those described in Chapter VI for Glenwood Springs.

Building Retrofit Engineering for Adams State College

Brief summary descriptions of the present steam heating system, the assumptions made for the design of a geothermal system, the advantages and disadvantages of a geothermal system, and then the design specifications for the central heat exchanger and the central heat pump systems are presented below. A map of the campus of Adams State College is shown in Figure 8.

Present Steam Heating System Description

1. Central steam plant with steam distribution pipelines; natural gas fired boilers; three boilers (40,000 lb/hr, 35,000 lb/hr, and 20,000 lb/hr); maximum supply rate is 60,000 lb/hr (2 boilers only).

2. Most building heating is hot water with some being direct steam.

3. Steam distribution operates at 125 psi.

4. Present hot water operates at 200°F with 20°F ΔT; outdoor reset is used (120°F water @ 60°F outside temperature).

5. Total campus load is 43.11 x 10^6 Btu/hr.

Assumptions for Geothermal System

1. Existing equipment will be used as much as possible in geothermal retrofit.

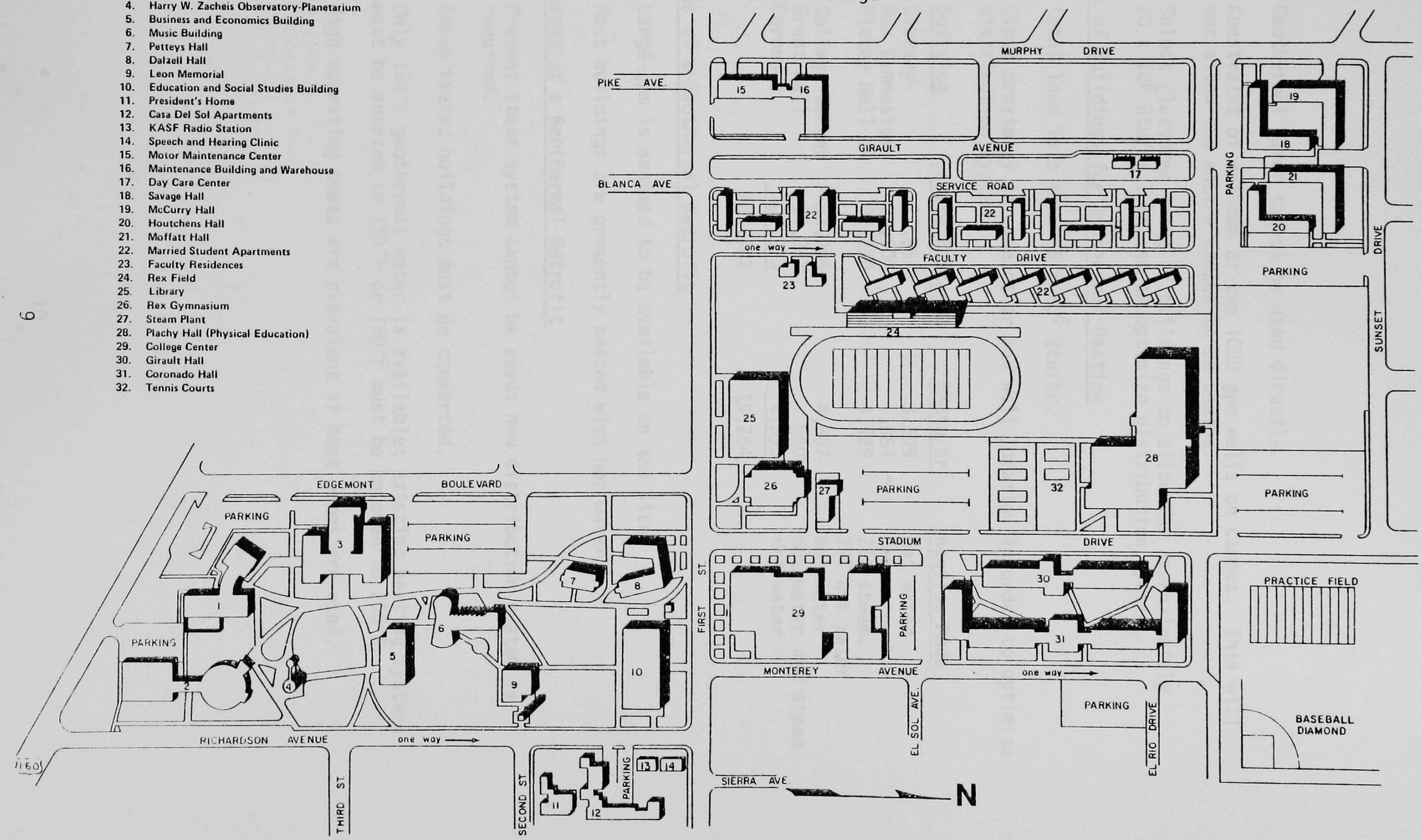
2. 150°F geothermal water is available.

Figure 8

Adams State College

ALAMOSA, COLORADO 81102

SOURCE: Adams State College



1. Art Building
2. Science and Industrial Arts Building
3. Richardson Hall (Administration)
4. Harry W. Zacheis Observatory-Planetarium
5. Business and Economics Building
6. Music Building
7. Petteys Hall
8. Dalzell Hall
9. Leon Memorial
10. Education and Social Studies Building
11. President's Home
12. Casa Del Sol Apartments
13. KASF Radio Station
14. Speech and Hearing Clinic
15. Motor Maintenance Center
16. Maintenance Building and Warehouse
17. Day Care Center
18. Savage Hall
19. McCurry Hall
20. Houtchens Hall
21. Moffatt Hall
22. Married Student Apartments
23. Faculty Residences
24. Rex Field
25. Library
26. Rex Gymnasium
27. Steam Plant
28. Plachy Hall (Physical Education)
29. College Center
30. Girault Hall
31. Coronado Hall
32. Tennis Courts

3. Geothermal water cannot be used directly.

4. Constraint of maximum of two 1000 gpm wells on campus. This will not allow the entire campus to be heated.

5. Select clustered group of buildings to allow for approximately 20×10^6 Btu/hr load and to optimize distribution system.

Selection of Buildings for Geothermal Heating

1. Total load less than 20×10^6 Btu/hr.

2. Close proximity to each other and well location in order to optimize distribution system.

3.

Building	Square Footage	MMBtu/hr	Heating Mode
Library	77,058	3,699	Hot water
Rex Gymnasium	22,600	1,084	Steam
Plachy Hall	92,270	4,429	25% steam, 75% hot water
College Center	93,905	4,507	Hot water
Grant Hall	34,377	650	Hot water and steam
Coronado	101,973	4,895	Hot water
	422,183	19,264	

Advantages of a Geothermal Retrofit

1. Large gpm is assumed to be available on the site.

2. Most buildings are presently heated with hot water.

Disadvantages of a Geothermal Retrofit

1. Present steam system cannot be used; new distribution system is required.

2. Steam heated buildings must be converted.

3. Only 150°F geothermal water is available; existing heating systems must be adapted to 150°F or 150°F must be boosted to 200°F.

4. High operating costs are prevalent if heat pumps are used.

Central Heat Exchanger Design Specifications

Proposed System and Modifications:

1. Heat a closed loop district heating system with 150°F geothermal water using a plate type heat exchanger (loop is 145°F).
2. Install a new hot water heating distribution system around the campus.
3. Replace the steam to water heat exchangers with a three-way valve and secondary pumping bridle.
4. Upgrade and/or add terminal units in the buildings to adapt to 145°F heating water.
5. Replace steam heating systems with water heating systems where necessary.
6. System designed to provide 20 million Btu/hr.
7. Geothermal wells (2-1000 gpm) to be drilled on site.

Engineering Design:

The new hot water distribution system is shown in Figure 9. Figures 10 and 11 provide the specifications for the central heat exchanger and for the retrofit a typical building to the hot water system, respectively.

Equipment Components and Cost Estimates:

	Quantity	Unit Cost	Total Cost
• Hot Water Distribution System			
Underground Pipe (Preinsulated/Prefab)			
8" Single line	460'	$73	$33,580
6" Single line	440'	59	25,960
5" Single line	1620'	57	92,340
4" Double line/1 Conduit	80'	83	6,640
3" Double line/1 Conduit	110'	68	7,480
Heat Exchanger (2000 gpm, 5°F Approach)	1	30,000	30,000
Pumps (1000 gpm @ 130 ft. hd.)	2	8,000	16,000
Air Separator/Expansion Tank	1	5,000	5,000
Miscellaneous Piping & Fitting	L.S.	8,000	8,000
Heat Exchanger/Pump Building	300 S.F.	25	7,500
Subtotal			$232,500
Contingency (10%)			23,250
		Total	$255,750

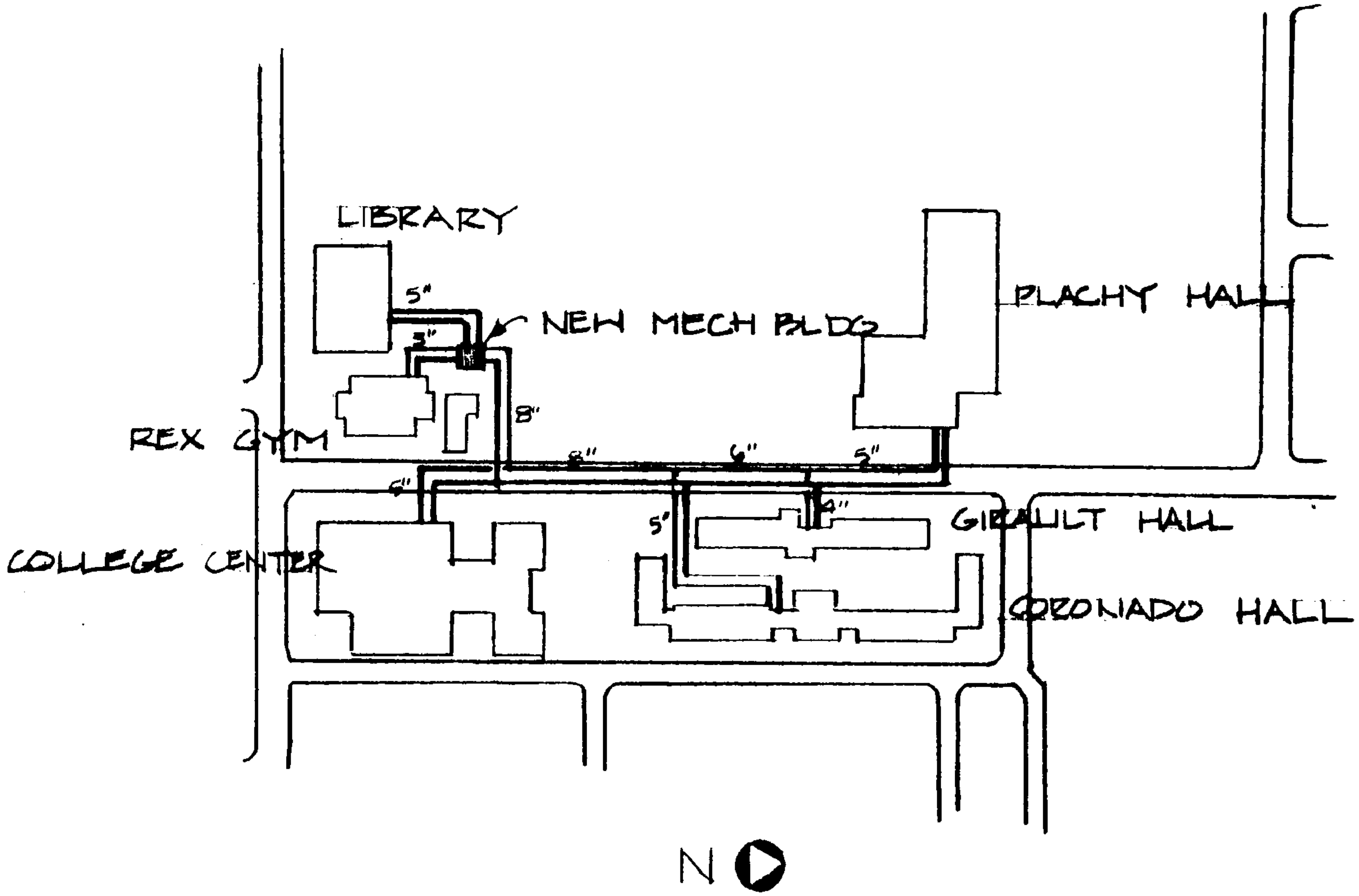


Figure 9

ADAMS STATE DISTRIBUTION SYSTEM

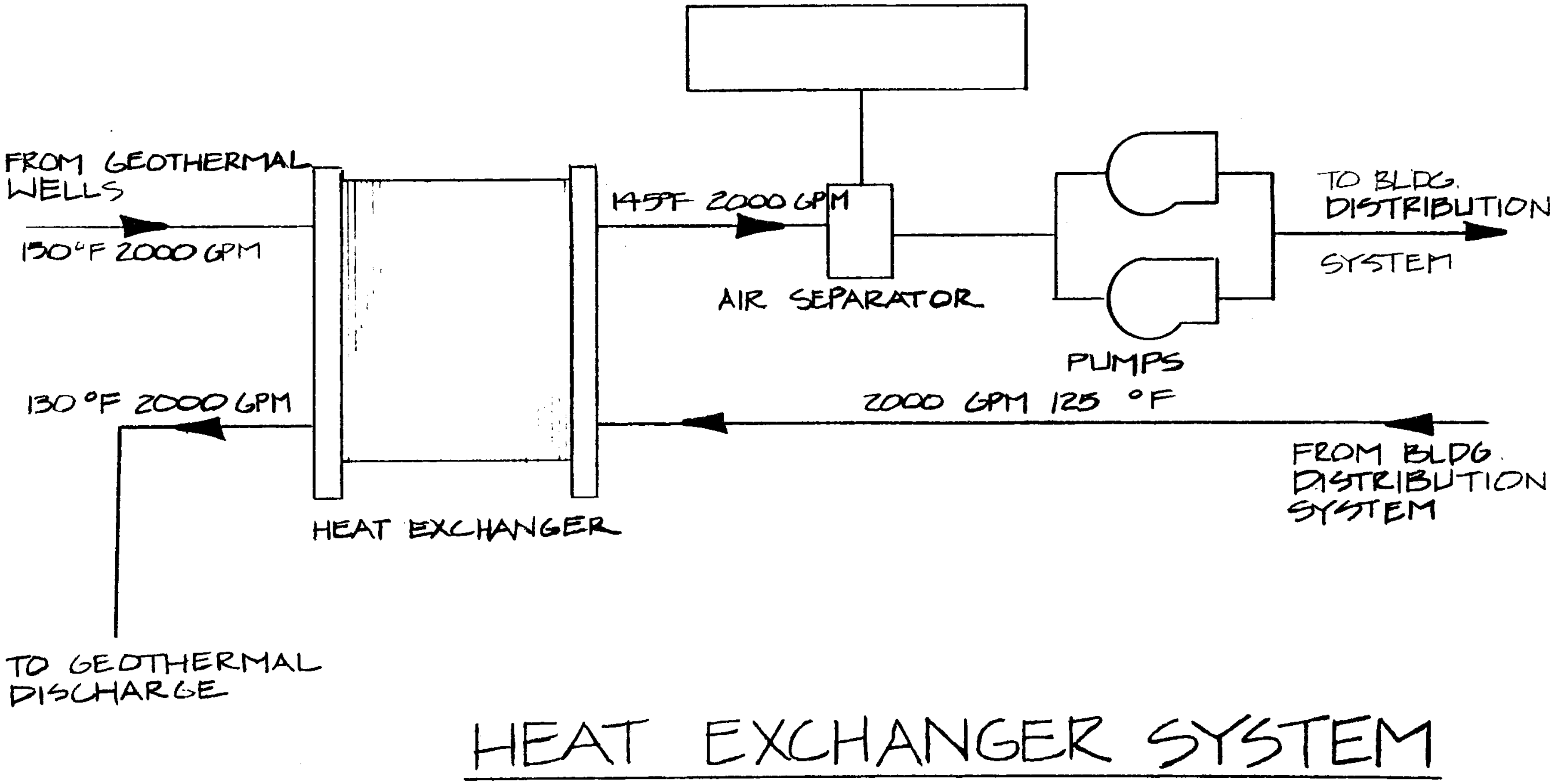

FROM GEOTHERMAL WELLS
130°F 2000 GPM
145°F 2000 GPM
AIR SEPARATOR
PUMPS
TO BLDG. DISTRIBUTION SYSTEM
2000 GPM 125 °F
FROM BLDG. DISTRIBUTION SYSTEM
130 °F 2000 GPM
HEAT EXCHANGER
TO GEOTHERMAL DISCHARGE
HEAT EXCHANGER SYSTEM

FIGURE 10

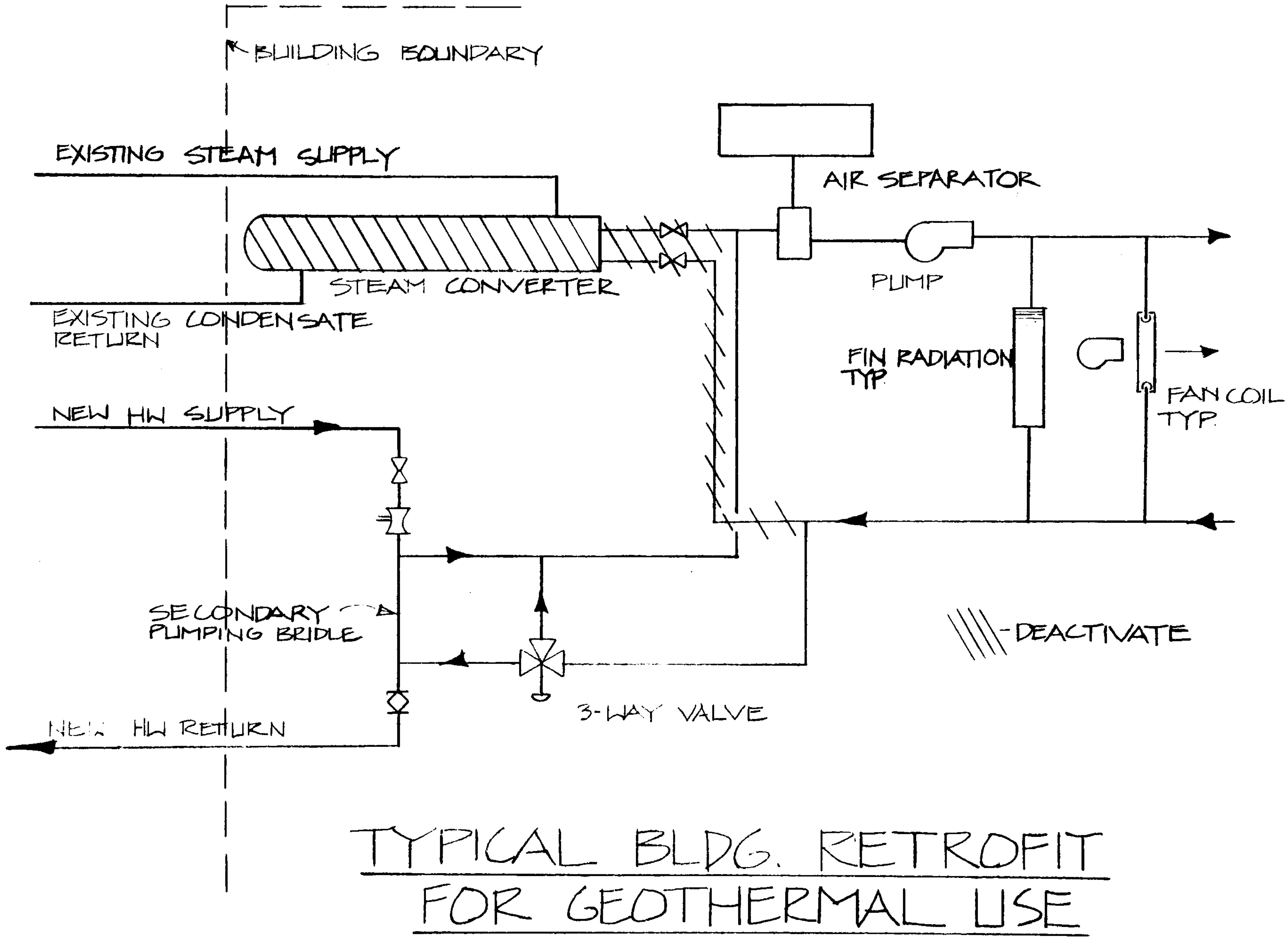

BUILDING BOUNDARY
EXISTING STEAM SUPPLY
STEAM CONVERTER
EXISTING CONDENSATE RETURN
AIR SEPARATOR
PUMP
FIN RADIATION TYP
FAN COIL TYP.
NEW HW SUPPLY
SECONDARY PUMPING BRIDLE
3-WAY VALVE
HW RETURN
-DEACTIVATE
TYPICAL BLDG. RETROFIT FOR GEOTHERMAL USE

FIGURE 11

• Building Heating (145°F water)	S.F. of Bldg.	Cost/ S.F.	Total Cost
Change steam heating to 145°F water system	47,600	$6	$ 285,600
Retrofit existing hot water heated building to handle lower temp water (add supplemental heat to existing equipment)	374,583	4	1,498,332
	Subtotal		1,783.932
	Contingency (10%)		178,393
	Total		$1,962,325

• Geothermal Side (excluding well pumps)		
10" Pipe to 2 wells	Assume 600 ft @ $63/ft	$37,800
	Contingency (10%)	3,780
	Total	$41,580

Central Heat Pump Design Specifications

Proposed System and Modifications:

1. Heat a closed loop district heating system using a heat pump to extract heat from the 150°F geothermal water to heat the circulating water.

2. Install a new hot water distribution system around the campus (200°F).

3. Run the geothermal water directly through the evaporator side of the heat pump.

4. Replace the steam to water heat converter with a three-way valve and secondary pumping bridle.

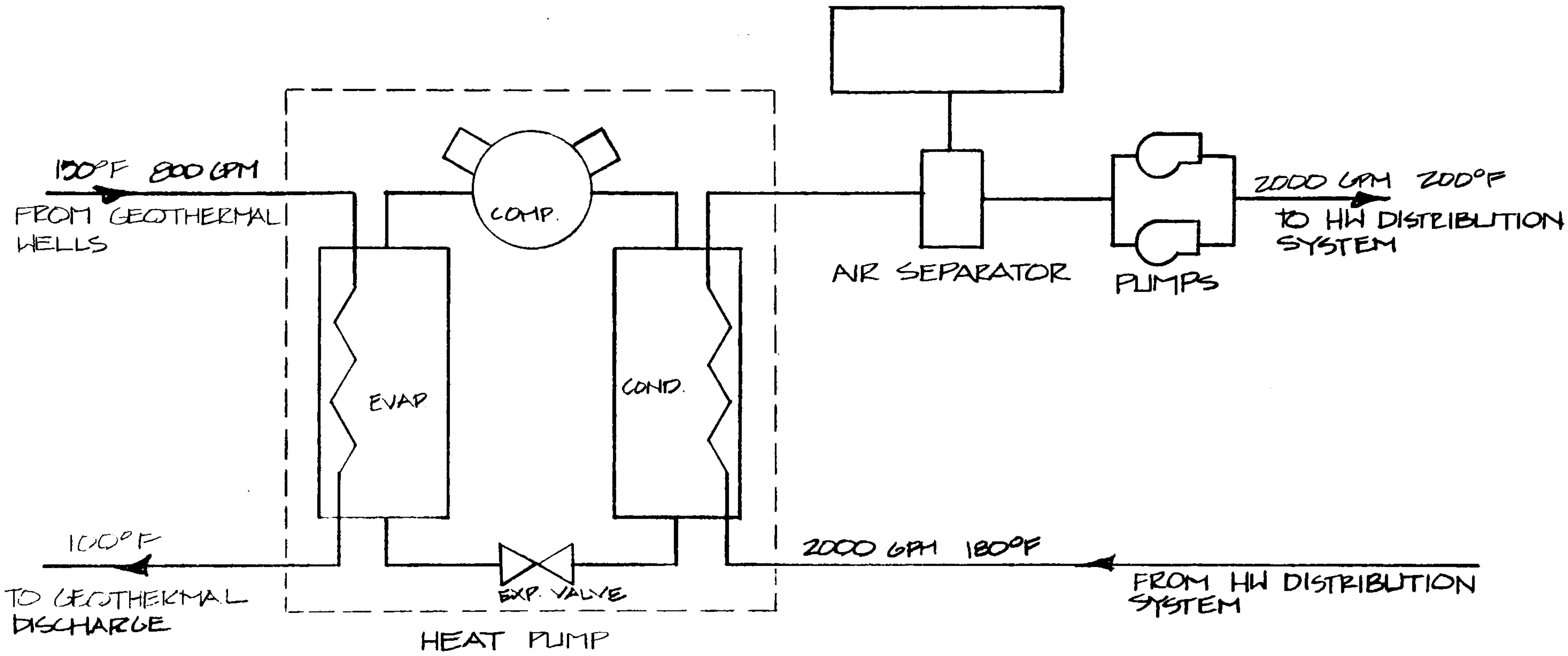
5. Geothermal well is to be drilled on the site.

6. Replace steam heating systems with water heating system where necessary.

7. System to be designed to provide 20 million Btu/hr.

Engineering Design:

The new hot water distribution system is the same as that for the heat exchanger system, as shown in Figure 9. Figures 12 and 11 provide the specifications for the central heat pump and for the retrofit of a typical building to the hot water system, respectively.



HEAT PUMP SYSTEM

FIGURE 12

Equipment Components and Cost Estimates:

	Quantity	Unit Cost	Total Cost
• Hot Water Distribution System			
Underground Pipe (Preinsulated/Prefab)			
8" Single line	460'	$73	$33,580
6" Single line	440'	59	25,960
5" Single line	1620'	57	92,340
4" Double line/1 Conduit	80'	83	6,640
3" Double line/1 Conduit	110'	68	7,480
Heat Pumps (1605 nominal tons, COP=6.0)	1605	400	642,000
Pumps (1000 gpm @ 130 ft. hd.)	2	8000	16,000
Air Separator/Expansion Tank	1	5000	5,000
Miscellaneous Piping & Fitting	L.S.	8000	8,000
Heat Pump/Pump Building	300 S.F.	25	7,500
		Subtotal	844,500
		Contingency (10%)	84,450
		Total	$ 928,950

• Building Heating (200°F Water)	S.F. of Bldg.	Cost/ S.F.	Total Cost
Change steam heating to 200°F water system	47,600	$6	$ 285,600
Tie in secondary/primary pumping bridle and three-way valves to existing system	L.S.		35,000
		Subtotal	320,600
		Contingency (10%)	32,060
		Total	$352,660

• Geothermal Side (excluding well pumps)

6" Pipe to well	Assume 200 ft @ $63/ft	$12,600
	Contingency (10%)	1,260
	Total	$13,860

Building Retrofit Engineering for State Highway Department Buildings

The State Highway Department Complex at Alamosa consists of several buildings on one site. Both natural gas fired boilers for hot water heating and propane fired unit heaters are currently used. The proposed geothermal retrofit is to use a central heat exchanger with hot water distribution to replacement fan coil heaters and unit heaters throughout the complex. The retrofit specifications are outlined below.

Present Conventional Fuel Heating System

Building	Square Footage	Fuel	Heating Equipment	Peak Heat Load (Btu/hr)
Office Building	4,800	Natural gas	Water boiler, fancoils & radiators	1,621,000
Garage	10,260			
North Shed				
Materials Lab	2,400	Natural gas	Water boiler & radiators	217,600
Paint Shop	1,152	Propane	Unit heaters(2)	108,800
South Sheds				
Green Shed	2,400	Propane	Unit heaters(2)	163,200
Work Shed	1,600	Propane	Unit heaters(2)	108,800
Warehouse	4,000	Propane	Unit heaters(3)	326,400
Totals	26,612			2,545,800

Geothermal System Design Specifications

Proposed System and Modifications:

1. Replace existing fan coil units with new units capable of satisfying design loads with low approach temperatures.

2. Replace existing unit heaters with new units capable of satisfying design loads with low approach temperatures.

3. Plate-in-frame heat exchanger is required.

4. Circulation pump is required.

5. Air separator and expansion tank are required.

6. More sophisticated temperature control is required.

7. Use existing two-pipe and add two-pipe where necessary.

8. Assume 150°F geothermal water is available.

Engineering Design:

Building	Design Peak Heat Load(Btu/hr)
Office Building and Garage	1,625,000
North Shed	218,000
South Sheds	780,000
	2,623,000

The design peak load can be accomplished utilizing 150°F geothermal hot water at 500 gpm, a ΔT of 10.5°F and a 2°F approach for the heat exchanger. Figure 13 shows the detailed engineering design for the entire complex.

Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Fan Coils	140°F EWT → 120°F LWT 72°F EAT → 90°F LAT 1200 CFM	4	$750	$3,000
Unit Heaters	140°F EWT → 120°F LWT 72°F EAT → 90°F LAT	21	750	15,750
Heat Exchanger	Plate-in-frame type 500 gpm 150°F → 140°F for geothermal side 250 gpm 140°F → 120°F for building side	1	10,000	10,000
Circulating Pump	250 gpm @ 60 ft. hd.	1	1,000	1,000
Air Separator and Expansion Tank		2	600	1,200
Piping	Twin pipe	1000 L.F.	16	16,000
Pipe Insulation		1000 L.F.	6	6,000
Temperature Controller				2,835
		Subtotal		$55,785
		Contingency (10%)		5,578
		Total		$61,363

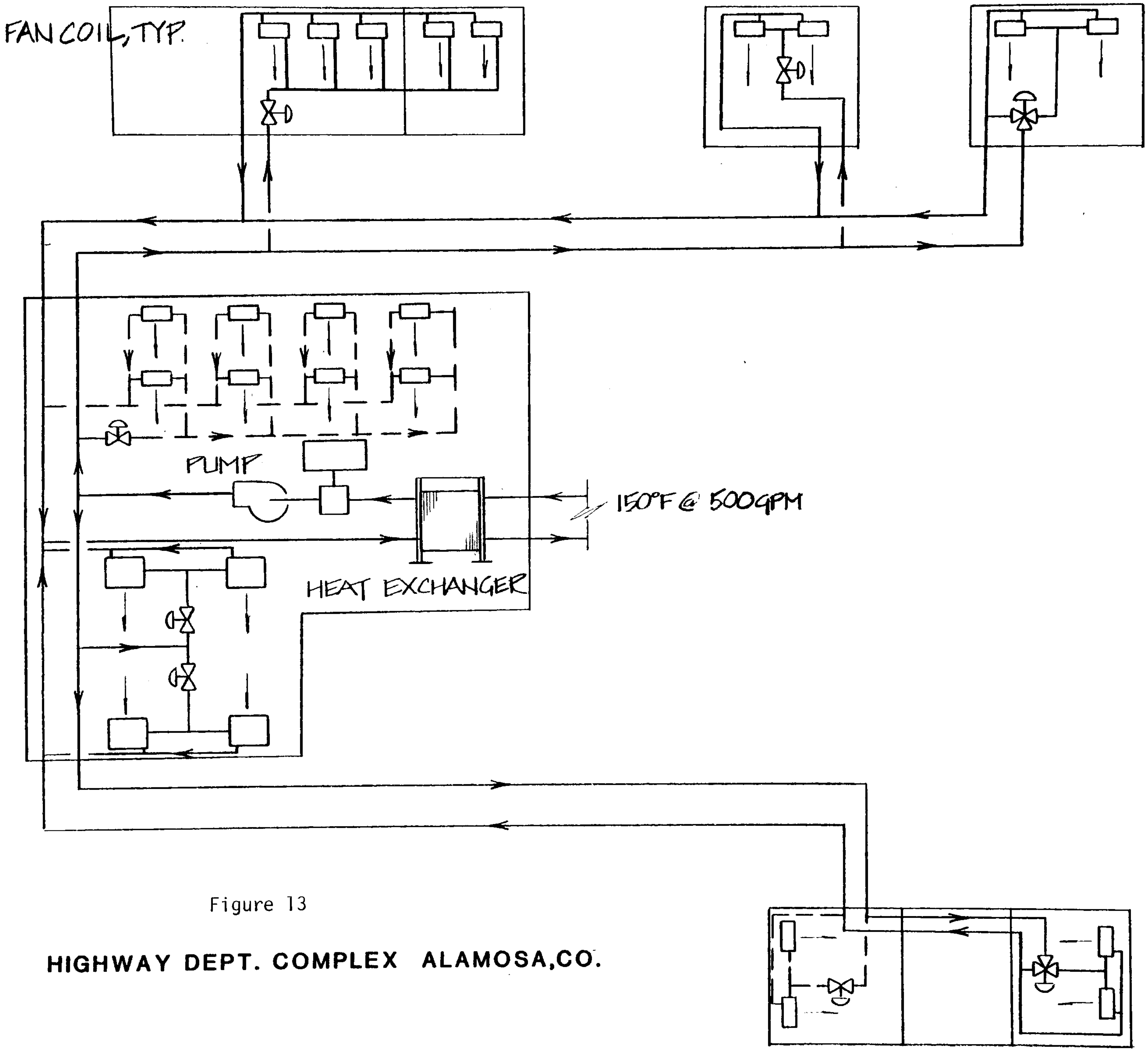


Figure 13

HIGHWAY DEPT. COMPLEX ALAMOSA,CO.

Economic Evaluations

Adams State College

On the following pages are presented the itemized geothermal capital improvements 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 two geothermal options evaluated for Adams State College. Both options apply to only six buildings and about 50 percent of the annual heating load of the campus.

The total capital costs are $3,674,678 for the central heat exchanger with Artesian flow and $2,111,387 for the central heat pump with Artesian flow. The principal capital cost differences reside with the number of geothermal wells required, the high cost of the central heat pump, and the retrofit costs for the campus buildings. The total operating and maintenance costs for the two geothermal options are approximately equal in the first year and are less than the estimated annual costs for the conventional heating system.

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

	Central Heat Exchanger	Central Heat Pump
Simple Payback Period:	16 years	9 years
Total Annualized Cost:		
Geothermal:	$658,049	$476,912
Conventional:	$720,535	$720,535
Total Undiscounted Savings:	$15,336,331	$15,670,359
Total Present Value Savings:	$4,096,455	$4,194,979

Both geothermal options appear economically feasible, with the central heat pump system ranking higher than the central heat exchanger system.

CAPITAL COSTS

Location: Alamosa   Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

A. Production Well System

	Costs
Exploration	$ 53,000
Reservoir Engineering	106,000
Wells 2 @ $265,000	530,000
Well Pumps (2) 2000 gpm, 380 ft-hd, 337 HP	134,800
Valves and Controls	5,000
Contingency Funds (10%)	Included
Subtotal	828,800
Engineering Design Fee (10%)	Included
Total	$828,800

B. Transmission Line System

Piping (600 ft.)	37,800
Pumps ( ) gpm, ft-hd, HP	N.R.
Contingency (10%)	3,780
Subtotal	41,580
Engineering Design Fee (10%)	4,158
Total	$ 45,738

C. Central Distribution System

Heat Exchanger (2000 gpm)	30,000
Heat Pump	N/A
Auxillary Building	7,500
Valves and Controls	5,000
Piping (2710 ft)	166,000
Circulation Pumps (2) 1000 gpm, 130 ft-hd, 575 HP	16,000
Miscellaneous	8,000
Contingency (10%)	23,250
Subtotal	255,750
Engineering Design Fee (10%)	
Total	$ 281,325

D. Building(s) Retrofit HVAC System

Heating Units	1,498,332
Retrofit Plumbing	285,600
Valves and Controls	Included
Contingency (10%)	Included
Subtotal	1,783,932
Engineering Design Fee (10%)	178,393
Total	$1,962,325

E. Reinjection/Disposal System

Reinjection Well(s): 2 wells @ $ 424,000	424,000
Piping (1000 ft.)	30,000
Pumps ( )	N.R.
Controls and Valves	5,000
Contingency (10%)	46,900
Subtotal	505,900
Engineering Design Fee (10%)	50,590
Total	$ 556,490

F. Grand Total $3,674,678

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Alamosa　　　　Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)	
A. Production Well System		$33,152	(4%)
Pump electricity	$ 48,853		
B. Transmission Line System	-	457	(1%)
C. Central Distribution System		2,813	(1%)
Heat Pump electricity	-		
Circ. Pump electricity	16,680		
D. Building(s) Retrofit HVAC System		19,617	(1%)
E. Reinjection/Disposal System	-	11,130	(2%)
Total	$ 65,533	$67,169	

Conventional Fuel System

Type of System: Natural Gas Fired Steam Boiler

Fuel Cost	
Total Annual Fuel Load	$46,234 \times 10^6$ Btu/yr
1980-81 Estimated Fuel Price	$\$4.16/10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 192,238

Maintenance Cost	
Percent of Associated Capital Costs	
Estimated Capital Costs	
Estimated Maintenance Cost	$ 48,000

Electricity Cost	
1980-81 Estimated Total Annual Electricity Cost	$1,825

ECONOMIC EVALUATIONS

Location: Alamosa   Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

A. Simple Payback Calculation

Current Annual Conventional System Cost		Geothermal System Cost	
Natural Gas	$192,238	Capital Cost (1980 Dollars)	$3,674,678
Electricity	1,825	First Year Operating Cost	65,533
Maintenance	48,000	First Year Maintenance Cost	67,169
Total	$242,063	Total	$3,807,380

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 16 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	$ -	$ 431,550
Electricity (9%/yr. escalation)	3,579	128,521
Maintenance (10%/yr. escalation)	70,017	97,978
Conventional Fuel (15%/yr. escalation)	646,939	-
Total Annualized Cost	$ 720,535	$ 658,049

Location: Alamosa　　　　Facility: Adams State College

Geothermal Option: Heat Exchanger with Artesian Flow

C. Total Savings and Payback Period

	Conventional System			Geothermal System		End of		Present Value
Year	Fuel (15%)	Elect. (9%)	Maint. (10%)	Maint. (10%)	Elect. (9%)	Year	Annual Savings	(i = 10%)
1980						0		
1981	192,238	1,825	48,000	67,169	65,533	1	109,361	99,420
1982	221,074	1,989	52,800	71,431	73,886	2	130,546	107,883
1983	254,235	2,168	58,080	77,860	81,274	3	155,349	116,714
1984	292,370	2,363	63,888	84,867	89,402	4	184,352	125,912
1985	336,225	2,576	70,277	92,505	98,342	5	218,231	135,500
1986	386,659	2,808	77,304	100,831	108,176	6	257,764	145,508
1987	444,658	3,061	85,035	109,905	118,994	7	303,855	155,938
1988	511,357	3,336	93,538	119,797	130,893	8	357,541	166,793
1989	588,060	3,636	102,892	130,579	143,983	9	420,026	178,133
1990	676,269	3,964	113,181	142,331	158,381	10	492,702	189,937
1991	777,710	4,320	124,500	155,140	174,219	11	577,171	202,298
1992	894,366	4,709	136,950	169,103	191,641	12	675,281	215,145
1993	1,028,521	5,133	150,645	184,322	210,805	13	789,172	228,623
1994	1,182,799	5,595	165,709	200,911	231,886	14	921,306	242,580
1995	1,360,219	6,099	182,280	218,993	255,074	15	1,074,531	257,243
1996	1,564,252	6,648	200,508	238,703	280,581	16	1,252,124	272,462
1997	1,798,890	7,246	220,559	260,186	308,640	17	1,457,869	288,366
1998	2,068,723	7,898	242,614	283,603	339,504	18	1,696,128	305,133
1999	2,379,031	8,609	266,876	309,127	373,454	19	1,971,935	322,411
2000	2,735,886	9,384	293,564	336,948	410,799	20	2,291,087	340,456
Totals							$15,336,331	$4,096,455

Capital Investment　$3,674,678

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$15,336,331	$4,096,455
Payback Period	11-12 years	18-19 years

CAPITAL COSTS

Location: Alamosa Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

A. Production Well System	**Costs**
Exploration	$ 26,500
Reservoir Engineering	53,000
Wells 1 @ $265,000	265,000
Well Pumps (1) 800 gpm, 300 ft-hd, 106 HP	42,400
Valves and Controls	5,000
Contingency Funds (10%)	Included
Subtotal	391,900
Engineering Design Fee (10%)	Included
Total	$391,900
B. Transmission Line System	
Piping (200 ft.)	12,600
Pumps ( ) gpm, ft-hd, HP	N/A
Contingency (10%)	1,260
Subtotal	13,860
Engineering Design Fee (10%)	1,386
Total	$ 15,246

C. Central Distribution System

Heat Exchanger, or	N/A
Heat Pump (1605 nom. tons)	642,000
Auxillary Building	7,500
Valves and Controls	5,000
Piping	165,950
Circulation Pumps (2) 1000 gpm, 130 ft-hd, 575 HP	16,000
Miscellaneous	8,000
Contingency (10%)	84,450
Subtotal	924,950
Engineering Design Fee (10%)	92,495
Total	$1,017,445

D. Building(s) Retrofit HVAC System

Heating Units	N/A
Retrofit Plumbing	285,600
Valves and Controls	35,000
Contingency (10%)	32,060
Subtotal	352,660
Engineering Design Fee (10%)	35,266
Total	$ 387,926

E. Reinjection/Disposal System

Reinjection Well(s): 1 wells @ $212,000	212,000
Piping (1000 ft.)	30,000
Pumps ( )	N/R
Controls and Valves	5,000
Contingency (10%)	24,700
Subtotal	271,700
Engineering Design Fee (10%)	27,170
Total	$ 298,870

F. Grand Total

$2,111,387

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Alamosa   Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)	
A. Production Well System		$15,676	(4%)
Pump electricity	$ 15,366		
B. Transmission Line System		152	(1%)
C. Central Distribution System		20,349	(2%)
Heat Pump electricity	50,103		
Circ. Pump electricity	16,679		
D. Building(s) Retrofit HVAC System	-	4,056	(1%)
E. Reinjection/Disposal System	-	6,249	(2%)
Total	$ 82,148	$46,482	

Conventional Fuel System

Type of System: Natural Gas Fired Steam Boiler

Fuel Cost	
Total Annual Fuel Load	$46,234 \times 10^6$ Btu/yr
1980-81 Estimated Fuel Price	$4.16/$10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 192,238

Maintenance Cost	
Percent of Associated Capital Costs	
Estimated Capital Costs	
Estimated Maintenance Cost	$ 48,000

Electricity Cost	
1980-81 Estimated Total Annual Electricity Cost	$ 1,825

ECONOMIC EVALUATIONS

Location: Alamosa   Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$192,238
Electricity	1,825
Maintenance	48,000
Total	$242,063

Geothermal System Cost	
Capital Cost (1980 Dollars)	$2,111,387
First Year Operating Cost	82,148
First Year Maintenance Cost	46,482
Total	$2,240,017

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	$ -	$248,004
Electricity (9%/yr. escalation)	3,579	161,106
Maintenance (10%/yr. escalation)	70,017	67,802
Conventional Fuel (15%/yr. escalation)	646,939	-
Total Annualized Cost	$720,535	$476,912

Location: Alamosa

Facility: Adams State College

Geothermal Option: Heat Pump with Artesian Flow

C. Total Savings and Payback Period

Year	Conventional System: Fuel (15%)	Conventional System: Elect. (9%)	Conventional System: Maint. (10%)	Geothermal System: Elect. (9%)	Geothermal System: Maint. (10%)	End of Year	Annual Savings	Present Value (i = 10%)
1980						0		
1981	192,238	1,825	48,000	82,148	46,482	1	113,433	103,122
1982	221,074	1,989	52,800	89,541	51,130	2	135,192	111,723
1983	254,235	2,168	58,080	97,600	56,243	3	160,640	120,689
1984	292,370	2,363	63,888	106,384	61,868	4	190,369	130,022
1985	336,225	2,576	70,277	115,959	68,054	5	225,065	139,743
1986	386,659	2,808	77,304	126,395	74,860	6	265,516	149,884
1987	444,658	3,061	85,035	137,770	82,346	7	312,638	160,446
1988	511,357	3,336	93,538	150,170	90,580	8	367,481	171,430
1989	588,060	3,636	102,892	163,685	99,638	9	431,265	182.899
1990	676,269	3,964	113,181	178,417	109,602	10	505,395	194,830
1991	777,710	4,320	124,500	194,474	120,560	11	591,496	207,319
1992	894,366	4,709	136,950	211,977	132,619	12	691,429	220,289
1993	1,028,521	5,133	150,645	231,055	145,880	13	806,569	233,663
1994	1,182,799	5,595	165,709	251,850	160,468	14	941,785	247,972
1995	1,360,219	6,099	182,280	274,516	176,515	15	1,097,567	262,758
1996	1,564,252	6,648	200,508	299,223	194,167	16	1,278,018	278,097
1997	1,798,890	7,246	220,559	326,153	213,583	17	1,486,959	294,120
1998	2,068,723	7,898	242,614	355,506	234,942	18	1,728,787	311,009
1999	2,379,031	8,609	266,876	387,502	258,436	19	2,008,578	328,402
2000	2,735,886	9,384	293,564	422,377	284,280	20	2,332,177	346,562
Totals							$15,670,359	$4,194,979

Capital Investment $2,111,387

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$15,670,359	$4,194,979
Payback Period	9-10 years	13 years

State Highway Department Buildings

On the following pages are presented the geothermal capital improvement costs, the annual operating and maintenance costs for both the geothermal system and the conventional fuel system, and the results of the calculations of the four economic measures for the geothermal option evaluated for the Highway Department Building at Alamosa. The total capital cost is $722,880 for the heat exchanger with Artesian flow. The first year annual operating and maintenance costs are $32,936 for the geothermal system and only $15,988 for the conventional fuel system.

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

	Heat Exchanger System
Simple Payback Period	47 years
Total Annualized Cost:	
Geothermal:	$138,625
Conventional:	$ 50,946
Total Undiscounted Savings:	($247,260)
Total Present Value Savings:	Negative

CAPITAL COSTS

Location: Alamosa — Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with Artesian Flow

A. Production Well System	Costs
Exploration	$ 26,500
Reservoir Engineering	53,000
Wells 1 @ $265,000	265,000
Well Pumps (1) 500 gpm, 340 ft-hd, 75 HP	30,000
Valves and Controls	5,000
Contingency Funds (10%)	Included
Subtotal	379,500
Engineering Design Fee (10%)	Included
Total	$379,500

B. Transmission Line System	
Piping (100 ft.) @ $35/L.F.	3,500
Pumps ( ) gpm, ft-hd, HP	N.R.
Contingency (10%)	350
Subtotal	3,850
Engineering Design Fee (10%)	385
Total	$ 4,235

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

Heat Exchanger, or	10,000
Heat Pump	
Auxillary Building	
Valves and Controls	4,035
Piping 100 ft. @ $22/L.F.	22,000
Circulation Pumps (1)	
162 gpm, 40 ft-hd, 2.9 HP	1,000
Miscellaneous	
Contingency (10%)	3,704
Subtotal	40,739
Engineering Design Fee (10%)	4,074
Total	$44,813

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

Heating Units 4 Fan Coils @ $750	
21 Unit Heaters @ $750	18,750
Retrofit Plumbing	-
Valves and Controls	-
Contingency (10%)	1,875
Subtotal	20,625
Engineering Design Fee (10%)	2,062
Total	$22,687

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

Reinjection Well(s): 1 wells @ $ 212,000	212,000
Piping (500 ft.) @ $20/L.F.	10,000
Pumps ( )	N.R.
Controls and Valves	2,500
Contingency (10%)	22,450
Subtotal	246,950
Engineering Design Fee (10%)	24,695
Total	$271,645

F. <u>Grand Total</u> $722,880

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Alamosa

Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with Artesian Flow

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)	
A. Production Well System Pump electricity	$10,872	$15,180	(4%)
B. Transmission Line System	-	42	(1%)
C. Central Distribution System		872	(2%)
Heat Pump electricity	-		
Circ. Pump electricity	418		
D. Building(s) Retrofit HVAC System	minimal	227	(1%)
E. Reinjection/Disposal System	-	5,433	(2%)
Total	$11,290	$21,646	

Conventional Fuel System

Type of System: Natural Gas & Propane

Fuel Cost	
Total Annual Fuel Load	5097×10^6 Btu/yr.*
1980-81 Estimated Fuel Price	Nat. Gas $3.88/$10^6$ Btu Propane $1.15/$10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 14,488

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	75,000
Estimated Maintenance Cost	$1,500

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

* 62% Natural Gas, 38% Propane

ECONOMIC EVALUATIONS

Location: Alamosa   Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with Artesian Flow

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$14,488
Electricity	-
Maintenance	1,500
Total	$15,988

Geothermal System Cost	
Capital Cost (1980 Dollars)	$722,880
First Year Operating Cost	11,290
First Year Maintenance Cost	21,646
Total	$755,816

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 47 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	$ -	$ 84,909
Electricity (9%/yr. escalation)	0	22,142
Maintenance (10%/yr. escalation)	2,190	31,574
Conventional Fuel (15%/yr. escalation)	48,756	-
Total Annualized Cost	$50,946	$138,625

Location: Alamosa　　　　Facility: Highway Dept. Bldg.

Geothermal Option: Heat Exchanger with 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	14,488		1,500	11,290	21,646	1	(16,948)	
1982	16,661		1,650	12,306	23,811	2	(17,806)	
1983	19,160		1,815	13,414	26,192	3	(18,631)	
1984	22,034		1,996	14,621	28,811	4	(19,402)	
1985	25,340		2,196	15,937	31,692	5	(20,093)	
1986	29,141		2,416	17,371	34,861	6	(20,675)	
1987	33,512		2,657	18,934	38,347	7	(21,112)	
1988	38,538		2,923	20,639	42,182	8	(21,360)	
1989	44,319		3,215	22,496	46,400	9	(21,362)	
1990	50,967		3,537	24,521	51,040	10	(21,057)	
1991	58,612		3,891	26,728	56,144	11	(20,369)	
1992	67,404		4,280	29,133	61,759	12	(19,208)	
1993	77,514		4,708	31,755	67,934	13	(17,467)	
1994	89,142		5,178	34,613	74,728	14	(15,021)	
1995	102,513		5,696	37,728	82,201	15	(11,720)	
1996	117,890		6,266	41,124	90,421	16	(7,389)	
1997	135,573		6,892	44,825	99,463	17	(1,823)	
1998	155,909		7,582	48,859	109,409	18	5,223	
1999	179,296		8,340	53,256	120,350	19	14,030	
2000	206,190		9,174	58,049	132,385	20	24,930	
Totals							($247,260)	$ Negative

Capital Investment　$722,880

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	($245,141)	Negative
Payback Period	-	-

Institutional Requirements

To provide geothermal energy in Alamosa, wells could be drilled on-site or 2 to 3 miles east or west of the City. If wells were drilled on-site, the State would have control of the drill site. If a well or wells were drilled some distance away, surface leases on private land would be required. Similarly, were a well site some distance away from the site of use, private geothermal leases would also be required. If right-of-way is needed, it could probably go along State Highway 160, then along city street R.O.W., depending upon the exact well site (Coe and Forman, 1980). City building permits are required before retrofitting the heating systems (Don Park, pers. comm., 1981).

Environmental Considerations

Based on a review of available information, no significant environmental constraints to geothermal development in the Alamosa area can be identified. The geothermal fluid from existing wells is quite pure. Arsenic (a toxin) and magnesium (a corrosive) are present in high but not excessive concentrations.

Some potential for subsidence and seismic activity may exist but is not considered likely to be significant (Coe, 1980).

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

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FIGURES

DURANGO

Four state-owned building complexes have been evaluated within the city of Durango: The State Fish Hatchery, Fort Lewis College, new State Highway Department Building near the Bodo Industrial Park, and the National Guard Building. The locations of these facilities are indicated in Figure 20.

The immediate area of the city of Durango is not known to be an area with geothermal resources under the surface. However, two areas ten to twelve miles north of the city along U.S. Highway 550 have surface hot springs: Tripp and Trimble Hot Springs and Pinkerton Hot Springs. This general area is presently considered to be the only source of geothermal energy available for use by the facilities studied in this appraisal. Service for the Durango facilities would have to be by approximately 15 miles of insulated pipeline. Furthermore, the resource characteristics alone are not especially favorable to the space heating requirements of the four facilities. Resource assessment data indicate that well depths of 200 to 300 feet are likely, but that the reservoir temperature is less that 150°F and that the prospective production rate is only 100 gpm; total dissolved solids are 3000 to 4000 mg/l.

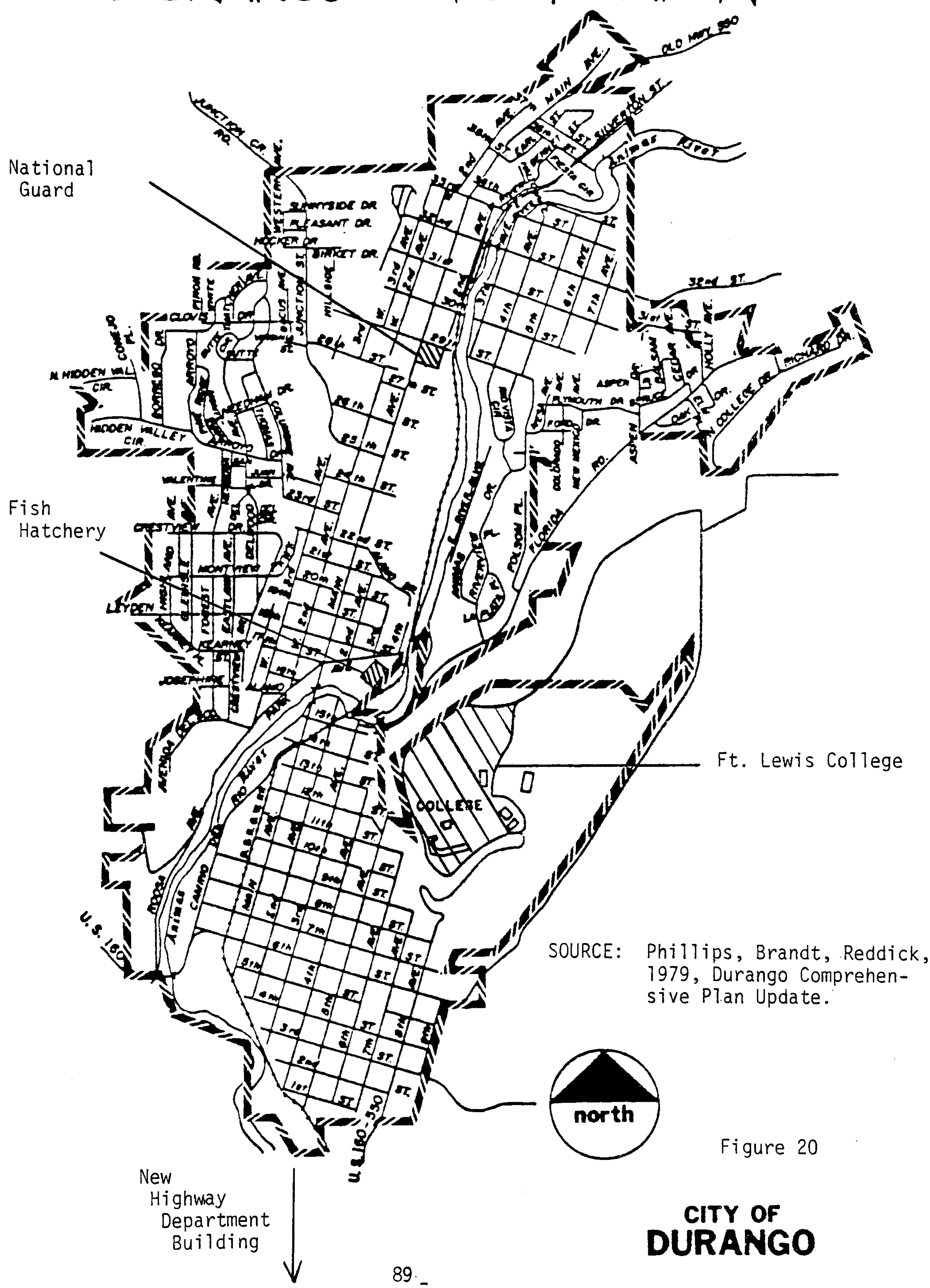
Three of the state facilities in Durango are evaluated for geothermal systems on the assumption of taking geothermal water from a trunk-line originating at the area north of Durango: State Fish Hatchery, Fort Lewis College and new State Highway Department Building. The National Guard Building is evaluated on the basis of a water-to-air heat pump, with warm water derived from a hypothetical shallow aquifer immediately below the building site.

Two geothermal options were separately evaluated for Fort Lewis College: a central heat exchanger system for delivery of 145°F heating water to the campus buildings and a central heat pump system for boosting the heating water to 200°F prior to delivery to the buildings; both systems require the installation of a distribution piping network for the entire campus area.

Retrofit engineering for the State Fish Hatchery provides for the installation of a small scale central distribution piping system to the several buildings, a central heat exchanger coupled to the geothermal trunk line, and the use of various fan coil and unit heaters for space heating. An option is provided for discharge-mixing the geothermal water into the fish ponds and runs in order to raise the hatchery water temperature a couple degrees for increasing fish production and yield.

The heating system for the new State Highway Department Building is redesigned to replace the natural-gas-fired forced-air furnaces with a heat exchanger, hot water fan coils and unit heaters. This building holds

DURANGO STUDY AREA



SOURCE: Phillips, Brandt, Reddick, 1979, Durango Comprehensive Plan Update.

Figure 20

the attractive feature of providing the geothermal heating system as original equipment during the future construction of it.

The geothermal energy economics are evaluated for all four state facilities and for the various heating operations cited above. Two natural gas fuel price escalation rates were treated: a 15 percent per year increase through year 2000; and a 12 percent per year (through 1984)/9 percent per year (thereafter through 2000) increase. All facilities were considered to have an accumulated operational period of 4320 hours per year in order to conserve on electrical energy for well pumps and circulating pumps; the existing heating systems would be retained for back up and peaking requirements. Also assumed but not explicitly treated is a provision for domestic hot water heating to be provided by auxillary conventional fuel heaters during the times when the geothermal system is not operated.

The results of the economic evaluations for the four state-owned building complexes in Durango indicate that only the National Guard Building, with its heat pump system and assumed shallow warm water aquifer, has any economic feasibility. The high costs of constructing and operating the 15-mile trunk line from the Tripp/Trimble and Pinkerton areas and the low water production rate per well preclude economic feasibility for the other facilities.

Access to the geothermal water from the Tripp/Trimble area is a likely institutional barrier of some consequence. Private ownership is involved and plans are underway by the owner to develop the resource for private purposes. Environmental factors are also important, since it would be necessary to dispose of the geothermal water into a separate reinjection well at each of the three points of use. Not only is reinjection costly but also it would not likely be into the same reservoir from which the geothermal water originates.

Detailed information on the Durango facilities are provided in the following topical sections.

Resource Assessment for Durango Area

There are no apparent geothermal resources in the immediate vicinity of Durango. The closest surface suggestions of geothermal activity are ten miles north of town along U.S. Highway 550. Tripp and Trimble Hot Springs are approximately ten miles north of Durango and have a combined discharge rate of less than five gallons per minute at 97°F to 111°F. Several miles further north is the Pinkerton group of hot springs with temperatures at 91°F and flow rates up to 54 gpm. There are no other significant indicators of geothermal heat in the Durango area.

Both hot spring areas are associated with probable faulting along the western side of the Animas Valley. At the Pinkerton location the Leadville Limestone is outcropping at the surface. The Leadville Limestone is a known geothermal aquifer at Glenwood Springs and other localities throughout Colorado and is known to have excellent porosites and permeabilities. For this reason it is believed the geothermal resources north of Durango are confined to the Leadville Limestone and underlying an area approximately one-half mile wide and 2.1 miles long (Figure 21). Near Tripp/Trimble Hot Springs the hot water may be restricted to a small east-west fault zone with a total areal extent of only 0.125 square miles.

Reservoir temperatures are probably less than 150°F at relatively shallow depths. Based upon estimated formation thicknesses, the depth to the geothermal reservoir could be as little as 200 feet. If wells were drilled to intersect the fault zones they would probably not exceed 300 feet.

None of the hot springs exceed 55 gpm in total discharge; Tripp and Trimble Hot Springs only flow at one gallon per minute apiece. Therefore, projected production rates are 100 gpm per well. The Colorado Geological Survey has estimated the useable heat content of the geothermal areas north of Durango at 15×10^{11} Btu.

A summary of the geothermal resources north of Durango is as follows:

Reservoir temperature:	<150°F (2)
Depth:	200-300' (1)
Production/well:	100 gpm (2)
Areal extent:	1.18 square miles (2)
Formation:	Leadville Limestone (3)
TDS:	3000-4000 mg/l
Useable heat:	15×10^{11} Btu (1)

Because of the lack of sufficient resource data, combined with low spring temperatures and flow rates, the quality of geothermal resources north of Durango is very questionable.

Pipeline Right-of-Way

Approximately 15 miles of pipeline right-of-way would have to be obtained to bring the geothermal water from resource areas north of Durango. Following is one specification of a routing from both Pinkerton Hot Springs and Tripp and Trimble Hot Springs.

Leg 1: From Pinkerton Hot Springs (6840') south along U.S. Highway 550 for 2.3 miles (6710').

Leg 2: Then go southwest along the Animas River for 3.07 miles to the junction of U.S. 550 with Tripp/Trimble Hot Springs (6580').

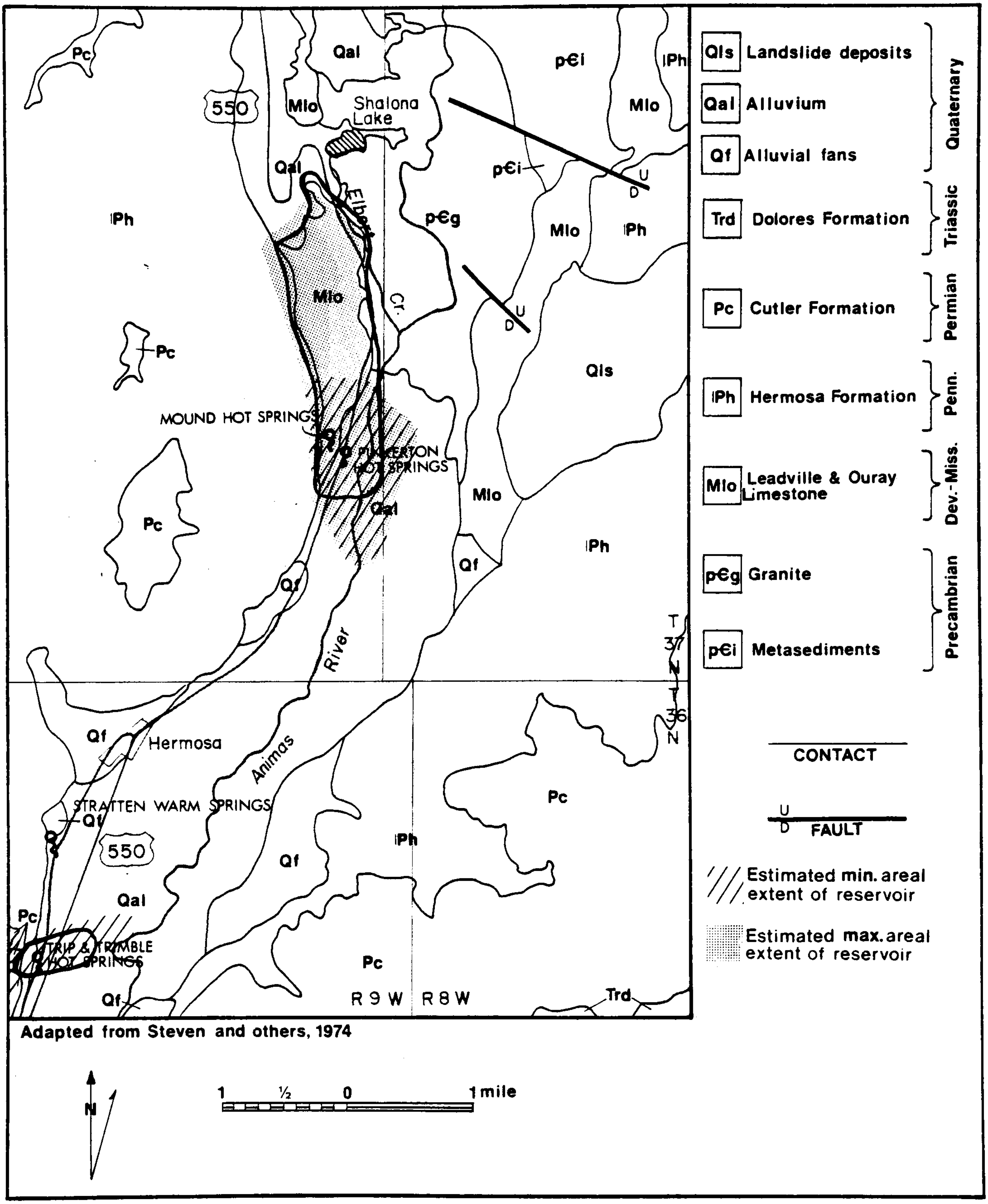


Figure 21: Geothermal ersource areas north of Durango. The areas outlined in bold loops are the projected areal extent of the geothermal reservoirs (Source: Pearl, 1979).

Leg 3: South along U.S. 550 for 5.37 miles to the major highway bend just north of Durango (6580').

Leg 4: Along the railroad right-of-way for 4.22 miles to the State Fish Hatchery (6510').

	distance	relief	grade
Leg 1	2.30 mi.	-130'	-1%
Leg 2	3.07 mi.	-130'	-1%
Leg 3	5.37 mi.	0'	-0-
Leg 4	4.22 mi.	-70'	-0.3%
	14.96 mi.	-330'	-0.4%

Additional right-of-way would be required from the Fish Hatchery to Fort Lewis College and to the new State Highway Department Building.

Production Well Costs and Well Engineering

Total costs for the drilling of production wells to depths of 300 feet each are estimated at $50,000 per well at the resource area north of Durango. Well engineering design and drilling procedures are basically similar to those described in Chapter VI for Glenwood Springs.

Building Retrofit Engineering for Fort Lewis College

Brief summary descriptions of the present heating system, the geothermal system design specifications for both a central heat exchanger option and a central heat pump option, and the equipment cost estimates are presented below. A map of the campus of Fort Lewis College is shown in Figure 22.

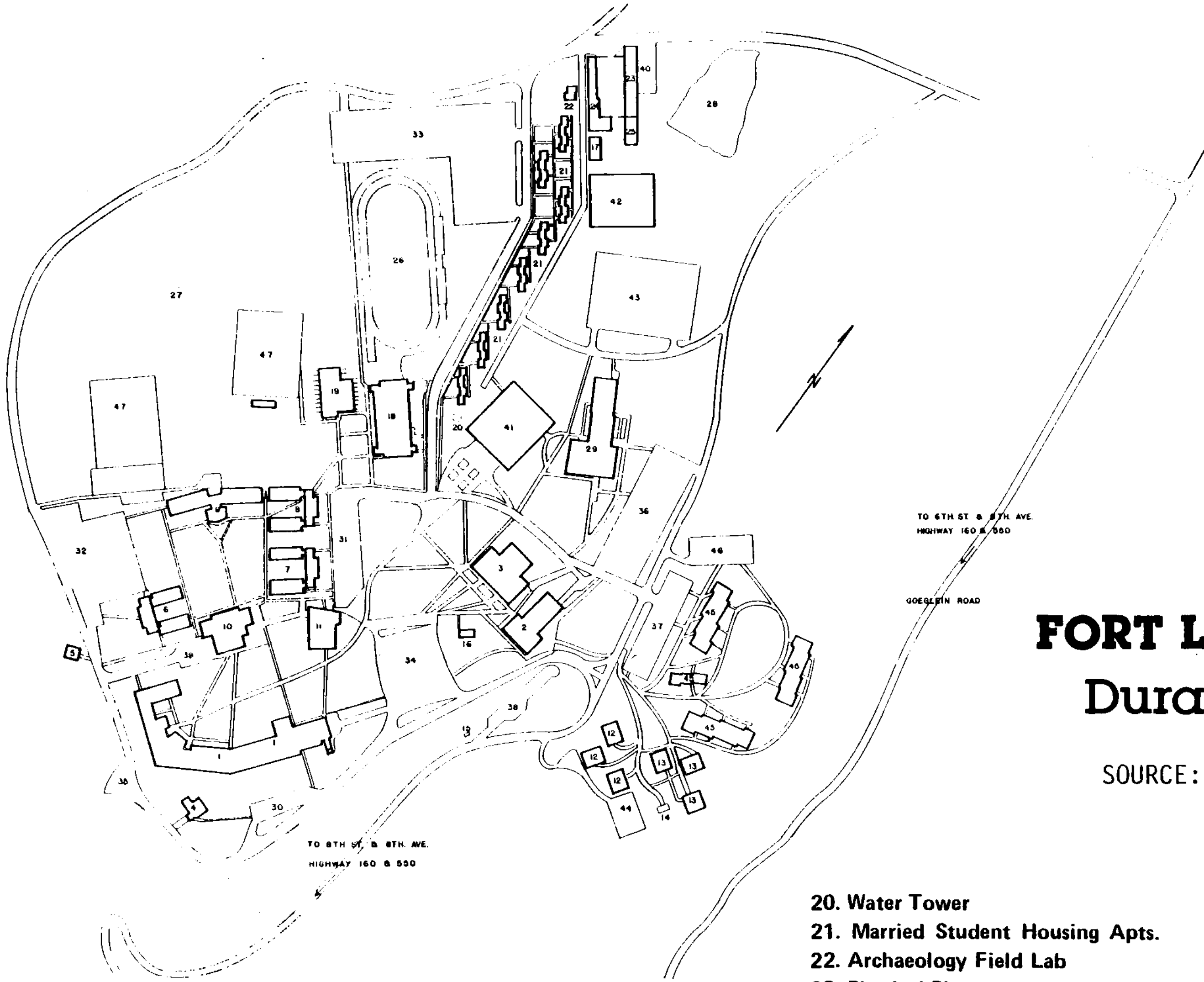
Present Hot Water Boiler Heating System Description

Each building on the Fort Lewis College campus is individually heated with one or more natural-gas-fired water boilers with the hot water being piped to terminal heating units in the rooms of the building. A variety of terminal space heating equipment is used, including fan coils, baseboard radiators, forced air coils, and cabinet units. All heating systems are on a single campus gas meter. The campus is comprised of approximately 44 buildings with a total area of 586,959 square feet (Energy Management Consultants, Inc., 1978). Total heat energy consumption averaged about 51×10^9 Btu per year over the eight year period of 1972-73 to 1979-80; the peak consumption for that period was 62.4×10^9 Btu in 1974-75. In the past three or four years, however, a diligent energy conservation program by Fort Lewis College has reduced the energy consumption. For the purposes of this appraisal, an annual energy consumption of 54×10^9 Btu of natural gas is assumed and a maximum design heat load of 25 million Btu/hr is assumed.

Figure 22

FORT LEWIS COLLEGE
Durango, Colorado

SOURCE: Fort Lewis College



1. Administration/Main Academic Building
2. College Union
3. Library
4. President's Home
5. Chapel
6. Escalante/Palmer Halls
7. Camp/Snyder Halls
8. Crofton/Mears Halls
9. Cooper Hall
10. Roman A. Miller Student Center
11. Theatre
12. Sheridan Halls
13. Bader Halls
14. Picnic Shelter
15. Buddy Stop
16. Health Center
17. Industrial Arts Building
18. Gymnasium
19. Natatorium
20. Water Tower
21. Married Student Housing Apts.
22. Archaeology Field Lab
23. Physical Plant
24. Supply and Receiving
25. Warehouse
26. Dennison Memorial Stadium
27. Outdoor Recreational Area
28. Irrigation Reservoir
29. Fine Arts Building
30. Parking Lot A
31. Parking Lot B
32. Parking Lot C
33. Parking Lot D
34. Parking Lot G
35. Parking Lot I
36. Parking Lot L
37. Parking Lot M
38. Parking – Staff
39. Parking – Life Science
40. Parking – Physical Plant
41. Classroom Building
42. State Forest Service Complex
43. Parking Lot H
44. Parking Lot P
45. Centennial Apartments
46. Parking Lot R
47. Tennis Courts

Central Heat Exchanger Design Specifications

Proposed System and Modifications:

1. Retrofit to utilize geothermal hot water through a heat exchanger for space heating.

2. Provide central heat exchanger to transfer heat to district loop.

3. Provide central pumping system to distribute hot water to buildings.

4. Provide district distribution piping to buildings (two pipe system).

5. Retrofit building systems to achieve design heating with 140°F hot water.

6. Design heat load is 25 x 10^6 Btu/hr.

Engineering Design:

The design heating can be accompished using a central heat exchanger operating under the following conditions:

Geothermal Side	Building Side
2000 gpm at 150°F	2500 gpm at 140°F
10°F approach	ΔT = 20°F
ΔT = 25°F	

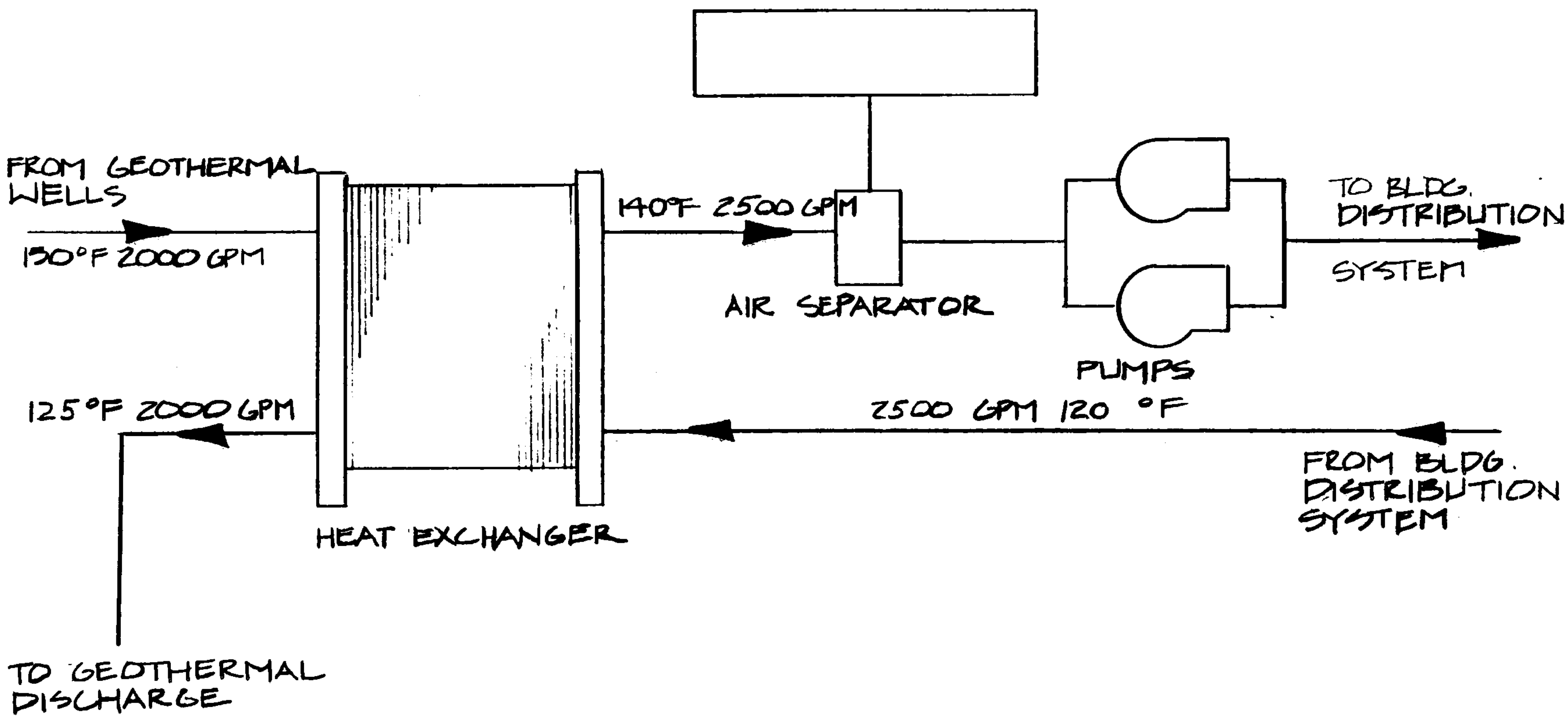
Figure 23 is an engineering schematic of the central heat exchanger design for Fort Lewis College.

Hot Water Distribution Piping:

Figure 24 presents a schematic layout of the piping system required to distribute hot water from the central heat exchanger to the campus buildings. A detailed schedule of piping mains and branch lines is presented below for cost estimation purposes.

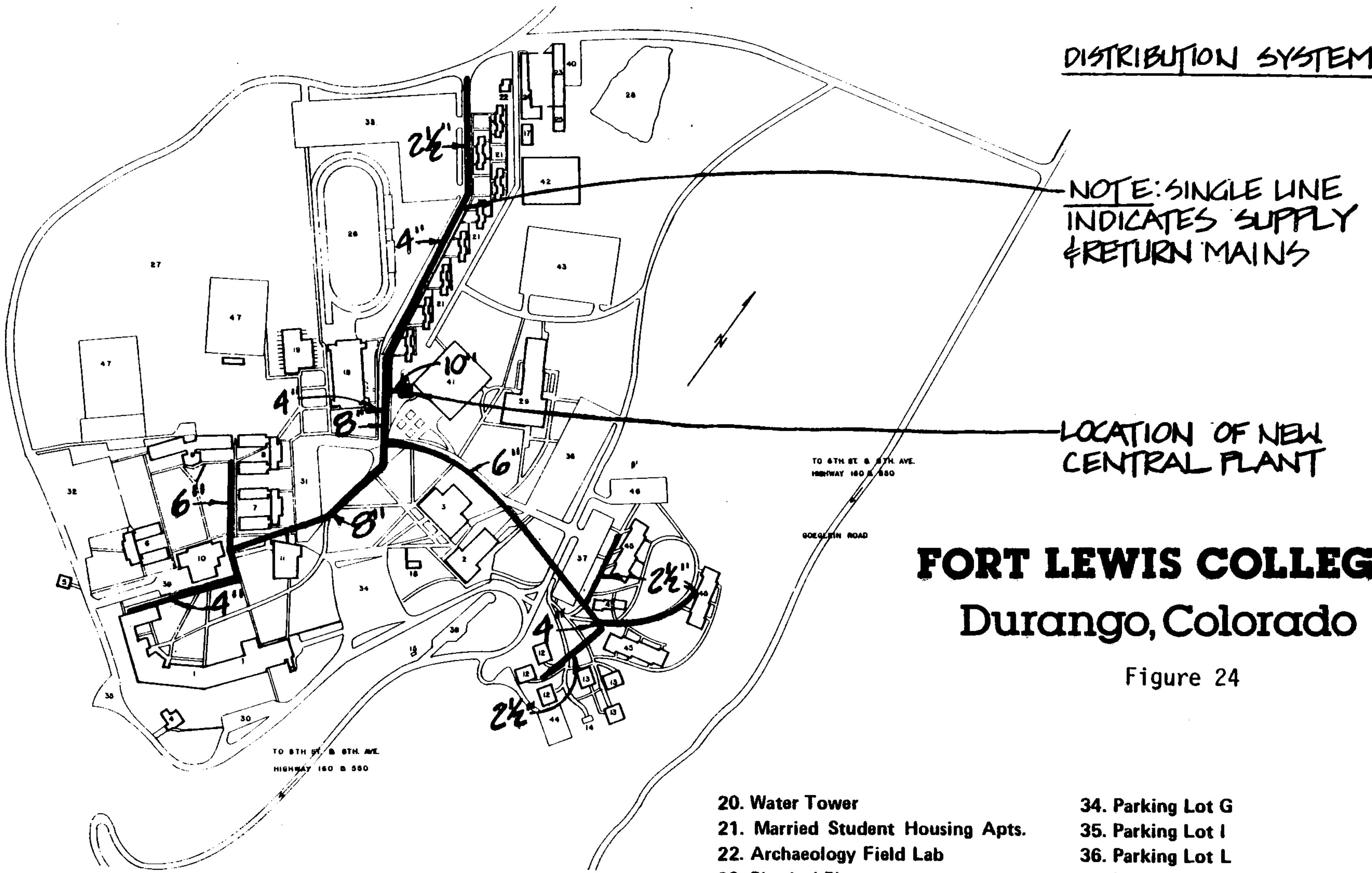
- Piping Mains (double conduit)

Size	Lineal Feet	Unit Cost	Total Cost
10"	100'	$96	$9,600
4"	100'	83	8,300
4"	480'	83	39,840
2½"	500'	68	34,000
8"	240'	78	18,720
8"	600'	78	46,800
6"	240'	63	15,120
9"	480'	83	39,840



HEAT EXCHANGER SYSTEM

FIGURE 23



FORT LEWIS COLLEGE

Durango, Colorado

Figure 24

1. Administration/Main Academic Building
2. College Union
3. Library
4. President's Home
5. Chapel
6. Escalante/Palmer Halls
7. Camp/Snyder Halls
8. Crofton/Mears Halls
9. Cooper Hall
10. Roman A. Miller Student Center
11. Theatre
12. Sheridan Halls
13. Bader Halls
14. Picnic Shelter
15. Buddy Stop
16. Health Center
17. Industrial Arts Building
18. Gymnasium
19. Natatorium
20. Water Tower
21. Married Student Housing Apts.
22. Archaeology Field Lab
23. Physical Plant
24. Supply and Receiving
25. Warehouse
26. Dennison Memorial Stadium
27. Outdoor Recreational Area
28. Irrigation Reservoir
29. Fine Arts Building
30. Parking Lot A
31. Parking Lot B
32. Parking Lot C
33. Parking Lot D
34. Parking Lot G
35. Parking Lot I
36. Parking Lot L
37. Parking Lot M
38. Parking – Staff
39. Parking – Life Science
40. Parking – Physical Plant
41. Classroom Building
42. State Forest Service Complex
43. Parking Lot H
44. Parking Lot P
45. Centennial Apartments
46. Parking Lot R
47. Tennis Courts

Piping Mains (cont'd)

Size	Lineal Feet	Unit Cost	Total Cost
6"	840'	$63	$52,920
2½"	240'	68	16,320
2½"	240'	68	16,320
		Subtotal	$334,020

- Branch Lines

1½"	15 x 50'	60	45,000
2"	4 x 50'	50	10,000
2½"	10 x 50'	68	34,000
3"	2 x 50'	68	6,800
4"	3 x 50'	83	12,450
6"	2 x 50'	63	6,300
		Subtotal	114,550
	Total Distribution Piping Costs		$448,570

(This same piping schedule is applicable to the central heat pump system discussed later.)

Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Heat Exchanger	2000 gpm	1	$15,000	$15,000
Distribution Piping	See information above			448,570
Circulation Pumps	2500 gpm, 170 ft. hd. 188 HP	2	10,000	20,000
Building Retro-fit Plumbing	Additional terminal units	546,218 sq.ft.*	4/S.F.	2,184,000
			Subtotal	$2,668,442
			Contingency (10%)	266,844
			TOTAL	$2,935,286

* After the economic evaluations were completed, it was found that the current total square footage is 586,959 sq. ft.; the 546,218 sq. ft. valve was obtained from data of an earlier year.

Central Heat Pump Design Specifications

Proposed System and Modifications:

1. Retrofit to utilize geothermal hot water as heat pump source for space heating.

2. Provide centrifugal heat pumps (e.g. York pumps, COP = 6.0) to boost 150°F source water to 200°F.

3. Provide central pumping system to distribute hot water to buildings.

4. Provide district distribution piping to buildings (two pipe system).

5. Existing terminal heating equipment to be used without retrofit.

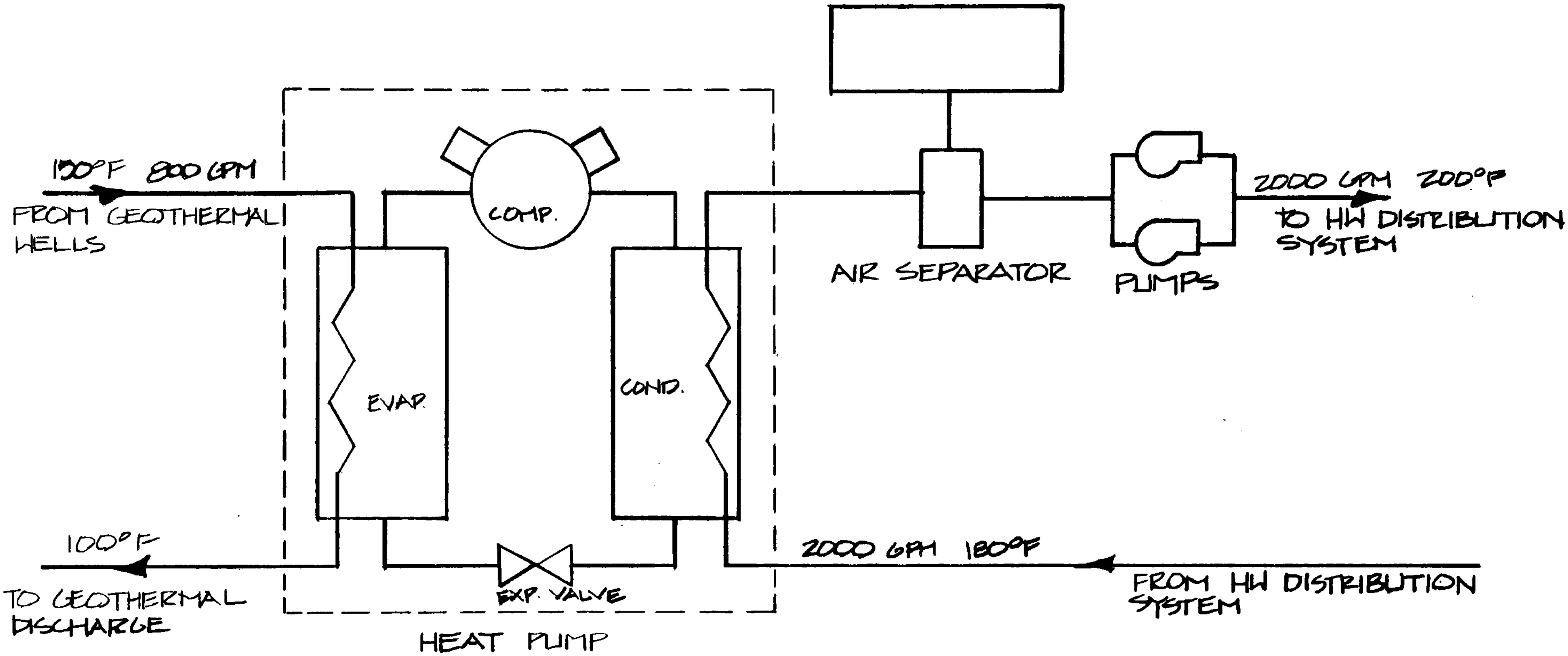
6. Design heat load is 25×10^6 Btu/hr.

Engineering Design:

The hot water distribution piping system shown in Figure 24 for the central heat exchanger system is also applicable to the central heat pump system. Figure 25 presents a generalized schematic of the heat pump system. A more detailed schematic of four 525-ton heat pumps that are staged in series to boost the heating water from 150°F to 200°F is shown in Figure 26. The heat pump system would be specially designed and fabricated for the Fort Lewis College application. One manufacturer (York) indicated that such a system could be constructed and achieve a COP = 6.0 for about $400 per ton of capacity. As conceptualized in Figure 26, the geothermal side requires 1000 gpm of water at 150°F and the building side circulates 2500 gpm of water at 200°F. Temperature drops would be 50°F on the geothermal side and 80°F on the building side.

Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Heat Pumps	COP = 6.0 525 tons/unit	4	$208,000	$832,000
Heat Pump Controls		1	10,000	10,000
Distribution Piping	Same as for central heat exchanger			448,570
Circulation Pumps	250 gpm	2	10,000	20,000
			Subtotal	$1,310,570
			Contingency (10%)	$131,057
			TOTAL	$1,441,627

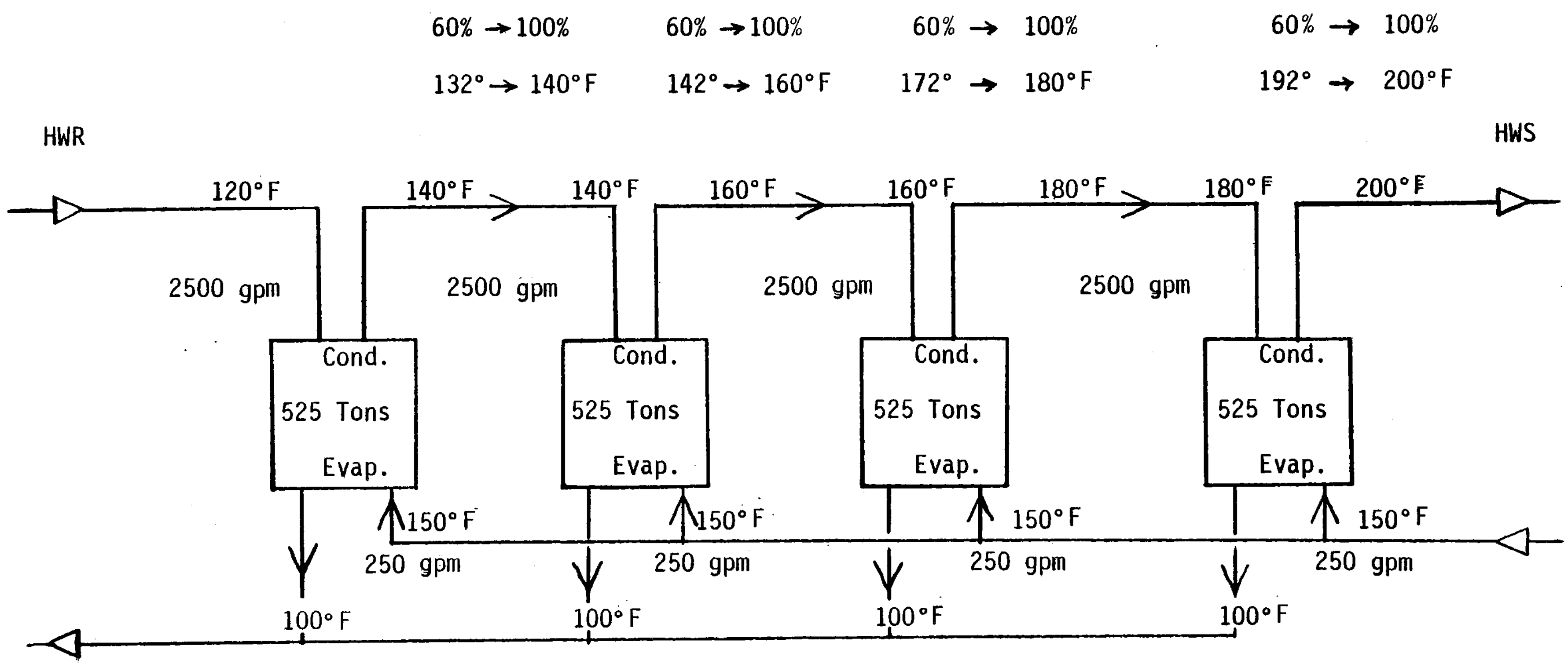


HEAT PUMP SYSTEM

FIGURE 25

Figure 26

Design for Four Heat Pumps in Series
to Provide 200°F Heating Water



Building Retrofit Engineering for State Fish Hatchery

Brief summary descriptions are presented below for the present natural gas heating system, geothermal design assumptions, the advantages and disadvantages of a conversion to geothermal heating, and the geothermal design specifications and cost estimates for an engineering retrofit of the State Fish Hatchery in Durango. A map of the Fish Hatchery is shown in Figure 27.

Present Natural Gas Heating System

1. Fish Hatchery complex consists of a cluster of small individually heated buildings.

2. Individual heating systems consist of various natural gas fired forced air systems and some hot water heating.

3. Estimated total design heat load is 1,038,000 Btu/yr (see detailed estimate below).

4. Spring water is collected and pumped through the various fish ponds and runs (2,500,000 gallons per day).

Estimate of Design Heat Load:

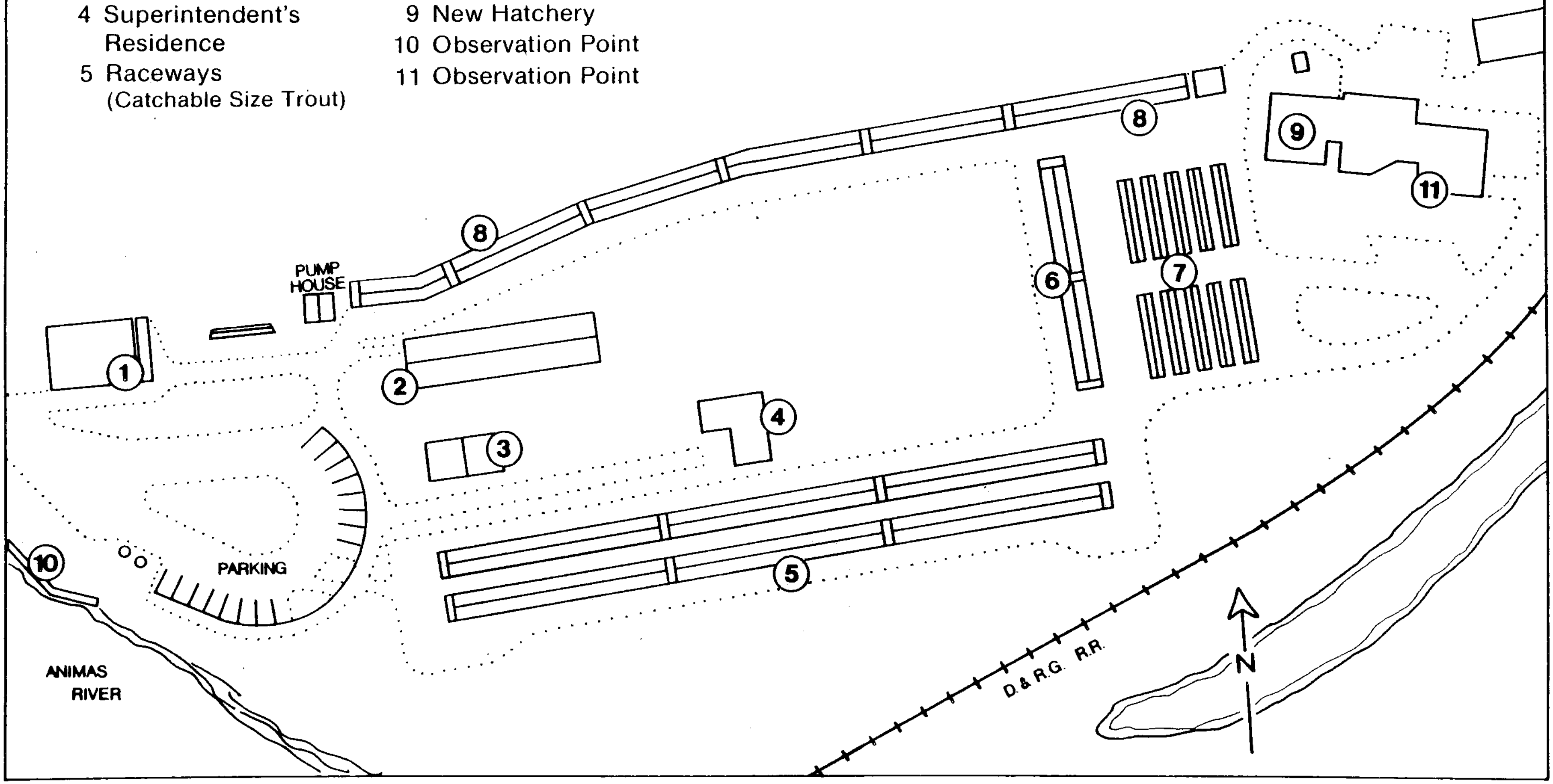
A tabulation of the existing Fish Hatchery buildings, space heating equipment, equipment output specifications, and necessary equipment modifications for hot water heating is presented below:

Building	Existing Equipment	Heating Output (Btu/hr)	Required Hot Water Modifications
Main Office	Gas-Fired Forced Air Furnace	128,000	Coil Duct Heater
Superintendent's House	Gas-Fired Forced Air Furnace	(Est.) 90,000	Coil Duct Heater
Staff House			
Basement	Gas-Fired Wall Furnace	(Est.) 50,000	New Fan Coil
Main Floor	Baseboard	90,000	Double Baseboard
2nd Floor	Gas Heater	120,000	New Fan Coil
New Hatchery			
2nd Floor Office	Gas-Fired Forced Air Furnace	128,000	Coil Duct Heater
Incubator Wings	4 Unit Heaters	256,000	New Coil Unit Heaters
Work Area	Gas-Fired Forced Air Furnace	112,000	Coil Duct Heater
Shop Building	Gas-Fired Heater	64,000	New Coil Unit Heater
	Total =	1,038,000	

Figure 27

DURANGO State Trout Hatchery and Rearing Unit

1 Show Pond. "Big" Fish
2 Old Hatchery
3 Division of Wildlife San Juan Basin Office
4 Superintendent's Residence
5 Raceways (Catchable Size Trout)
6 Raceways (Sub-catchable Trout)
7 Nurse Ponds
8 Brood Fish Ponds
9 New Hatchery
10 Observation Point
11 Observation Point



Geothermal Design Assumptions

1. Water can be discharged into fish ponds and runs.

2. Intent is to minimize initial cost by retrofitting existing gas-fired equipment where possible.

3. $150^{o}F$ geothermal water is available.

Advantages of a Geothermal Retrofit

1. Small number of buildings with simple systems allows for simple retrofit of system.

2. Low heat exchanger approach temperature of $5^{o}F$ is feasible.

3. Geothermal water heat can be cascaded to provide lower grade heat for fish ponds.

Disadvantages of a Geothermal Retrofit

1. Many existing heating units are not adaptable to hot water and must be replaced or modified.

2. Distribution system is required.

Geothermal Central Heat Exchanger Design Specifications

Proposed System and Modifications:

1. Provide a central hot water distribution system for the complex.

2. Run geothermal water ($150^{o}F$) through a plate-type heat exchanger to heat distribution water ($145^{o}F$).

3. Operate heating water with a $40^{o}F$ drop to minimize pipe sizes and thus initial cost; use coil heating.

4. Retrofit gas-fired forced air system with hot water heating coils placed in the duct system.

5. Replace individual gas-fired heaters with fan coil units.

6. Discharge geothermal water from heat exchanger into fish ponds to increase temperature of water for favorable fish production.

7. Pump geothermal water from trunk line into heat exchanger.

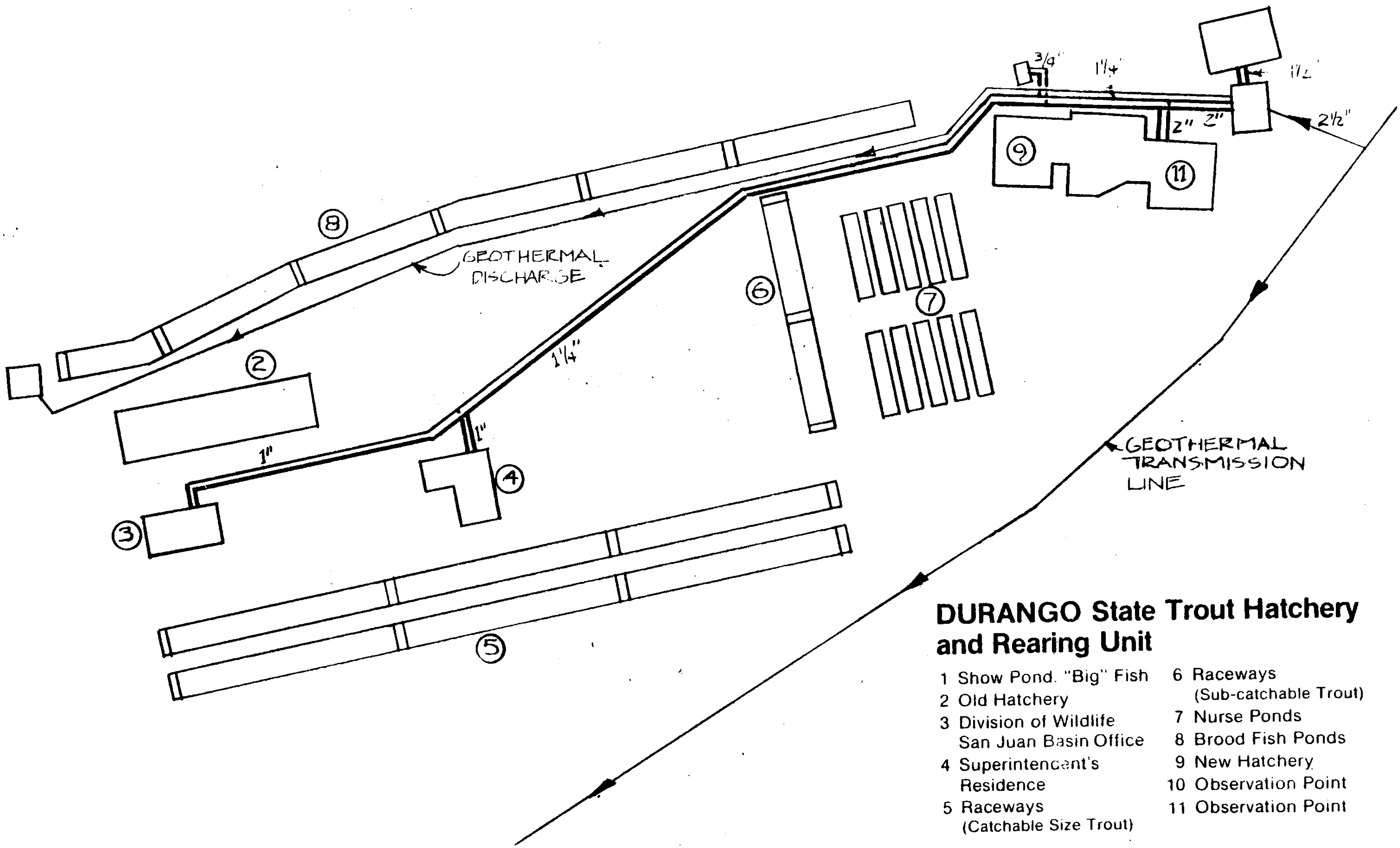
8. Design heat load is 1,038,000 Btu/hr.

Engineering Design:

Figures 28 and 29 present engineering schematics of the hot water distribution piping system and of the heat exchanger and hot water heating equipment for the Fish Hatchery complex. In order to achieve the design heat load of 1,038,000 Btu/hr, geothermal water at 104 gpm and 150°F is required into the exchanger; the temperature drop on the geothermal side is 20°F. Using a 5°F approach specification, the hot water supply to the buildings is 145°F at 52 gpm with a 40°F temperature drop. The discharge geothermal water from the heat exchanger is mixed with the existing spring water (48°F, 1632 gpm) to yield 53°F water for the fish ponds.

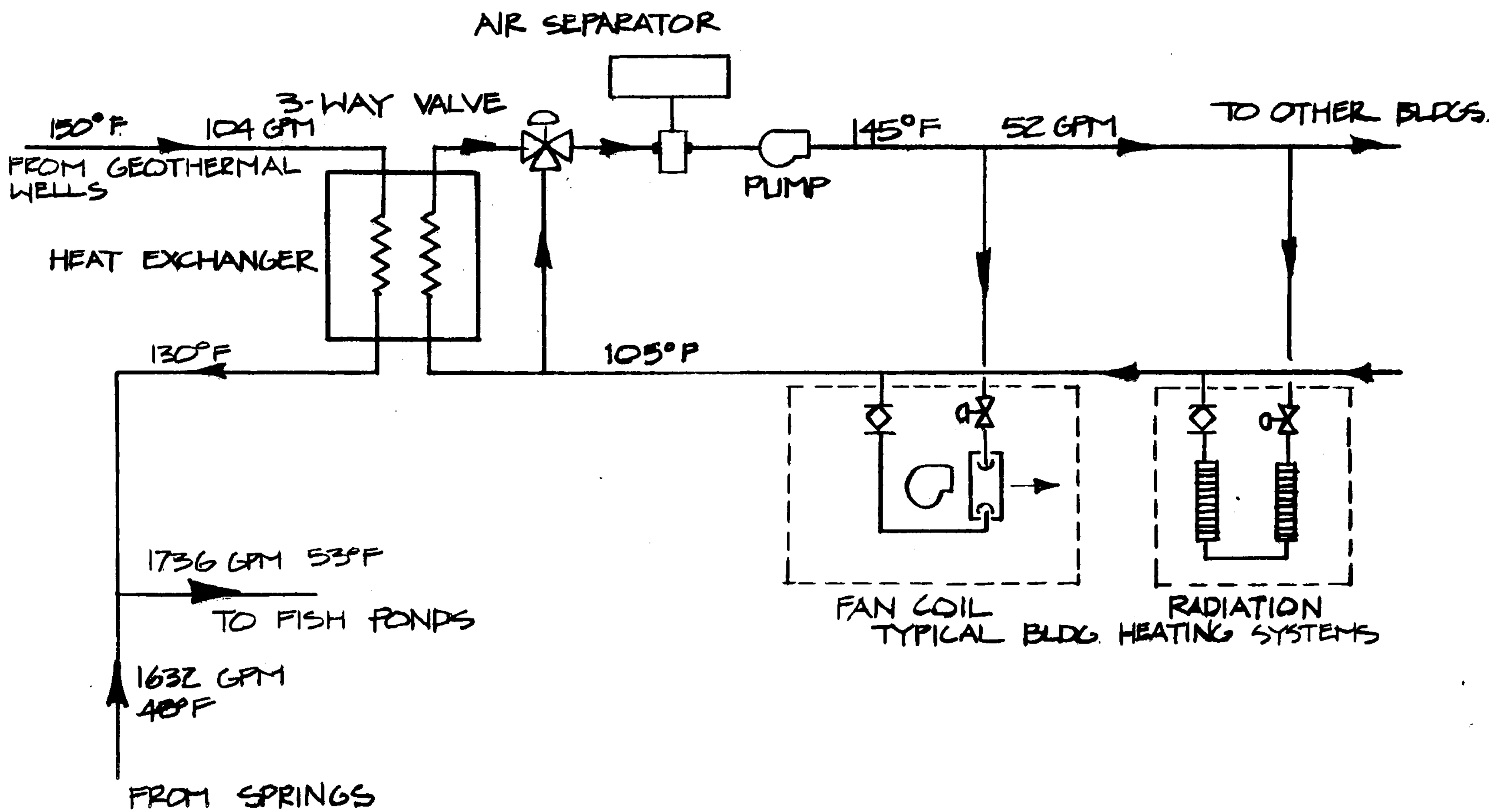
Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Distribution Piping				
	2-3/4" insulated double conduit	140'	30	$ 4,200
	2-1" insulated double conduit	220'	40	8,800
	2-1¼" insulated double conduit	650'	46	3,900
	2-1½" insulated	140'	48	6,720
Heat Exchanger	52 gpm, 5° approach	1	7,000	7,000
Circulation Pump	52 gpm	1	800	800
Fan Coil Units		2	1,000	2,000
Baseboard Units		120'	25	3,000
Unit Heaters		5	800	4,000
Coil Heater		22.5 S.F.	100/S.F.	2,250
Miscellaneous Piping, Fittings, Etc.		L.S.		5,000
		Subtotal		47,670
		Contingency (10%)		4,767
		Total		$52,437



DISTRIBUTION SYSTEM

Figure 28



FISH HATCHERY PIPING SCHEMATIC

Figure 29

Building Retrofit Engineering for New Highway Department Building

The new State Highway Department Building in Durango is in the design phase but has not yet been constructed. Construction may occur in FY 1982. As such, it provides an opportunity for a redesign to incorporate a geothermal hot water heating system in the original construction, without incurring the additional costs of a retrofit after construction is completed. The engineering specifications defined herein, therefore, are for an original placement of the necessary geothermal heating equipment. Presented below are the preliminary design specifications for the currently planned natural gas fired forced air heating system, the design specifications for a geothermal hot water heat exchanger system, and the equipment components and estimated costs.

Natural Gas Fired Forced Air Heating System

The design heat load for the planned natural gas forced air system has been calculated from preliminary "progress drawings" prepared by Yoder Engineering Consultants, Inc. for the State Highway Department; the drawings were kindly provided by Mauck, Stastny and Rassan, architects for the state building. The calculated heat load is 2,484,000 Btu/hr; total square footage is approximately 35,000 square feet. Estimated total current cost for the natural gas fired forced air system is $178,640.

Geothermal Heat Exchanger Design Specifications

Proposed System and Modifications:

1. Design to utilize geothermal hot water for space heating.
2. Replace gas-fired H & V units with hot water H & V units.
3. Air distribution system is approximately the same.
4. Plate-in-frame heat exchanger is required.
5. Circulation pump is required.
6. Air separator and expansion tank are required.
7. Two-pipe distribution system is required.
8. More sophisticated termperature control is required.
9. Ethylene glycol is required for freeze protection.
10. Obtain 150^{o}F geothermal water at 200 gpm from trunk line from resource area.

Engineering Design:

Figure 30 provides an engineering schematic of the heat exchanger, piping, and heating and ventilation unit (H & V units) requirements for the new Highway Department Building in Durango. The heat exchanger operates with input geothermal water flowing at 200 gpm at 150°F, a temperature drop of 25°F on the geothermal side and a 10°F approach condition. On the building side, hot water is supplied to the H & V units at 140°F and 250 gpm, with a temperature drop of 20°F. Specifications on the H & V units are given below.

Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Heat Exchanger	Plate-in-frame type, 10°F approach, 150°F EWT→ 125°F LWT, 200 gpm on geothermal side 120°F EWT→ 140°F LWT, 250 gpm on building side	1	$7,500	$ 7,500
H & V Units	10 @ 3000 CFM 140°F EWT→ 120°F LWT 72°F EAT→ 90°F LAT	10	3,500	35,000
H & V Units	9 @ 3000 CFM 140°F EWT→ 120°F LWT -10°F EAT→ 72°F LAT	9	4,000	36,000
Ductwork	Same as for natural gas system.			108,000
Circulation Pump	250 gpm @ 45 ft. hd.	1	1,000	1,000
Air Separator and Expansion Tank		1	1,200	1,200
Distribution Piping		1000'	16	16,000
Insulation		1000'	6	6,000
Temperature Controller		1		5,135
		Subtotal		$215,835
		Contingency (10%)		21,584
		Total		$237,419

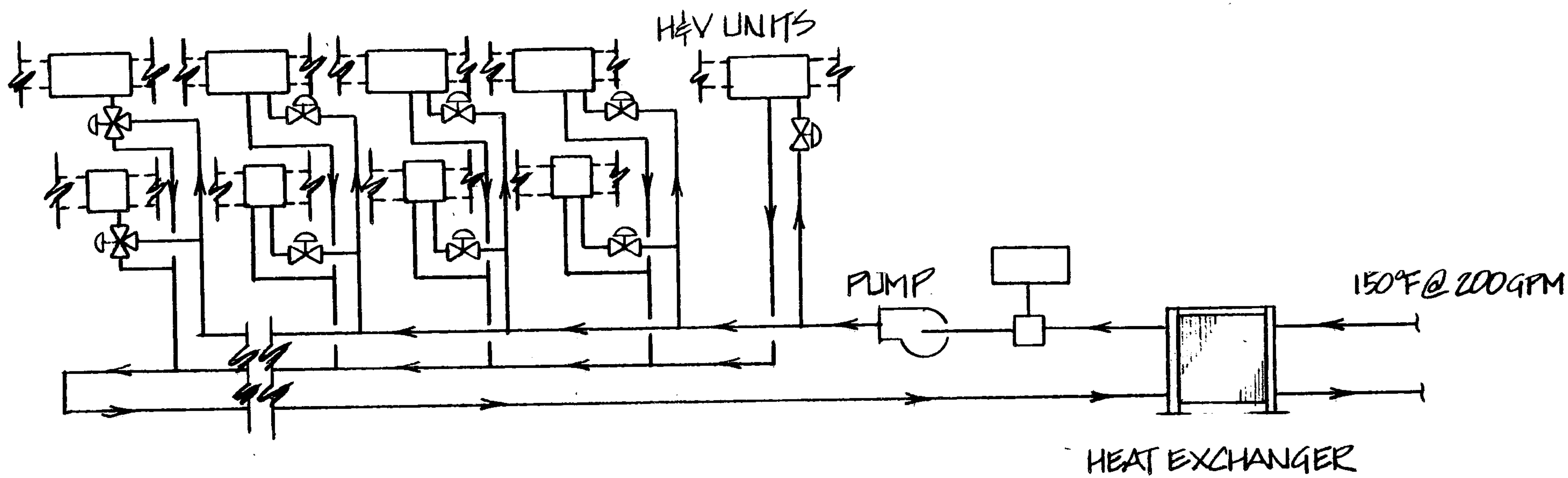


Figure 30

NEW HIGHWAY DEPT. BLDG. DURANGO,CO.

Building Retrofit Engineering for National Guard Building

The National Guard Building in Durango is evaluated herein for a heat pump system, with warm water derived from an assumed shallow aquifer on the site of the building. Therefore, it is considered independent of the other three state-owned facilities in Durango and is not tied to the geothermal trunk line from the resource area north of Durango. A summary of the present natural gas heating system, the proposed heat pump specifications and the equipment components and cost estimates are presented below.

Present Natural Gas Heating System

Building	Square Footage	Fuel	Space Heating Equipment	Peak Heat Load (Btu/hr)
Office Space	7522	Natural gas	Forced air furnace (1)	565,000
Drill Hall		Natural gas	Unit Heaters (4)	

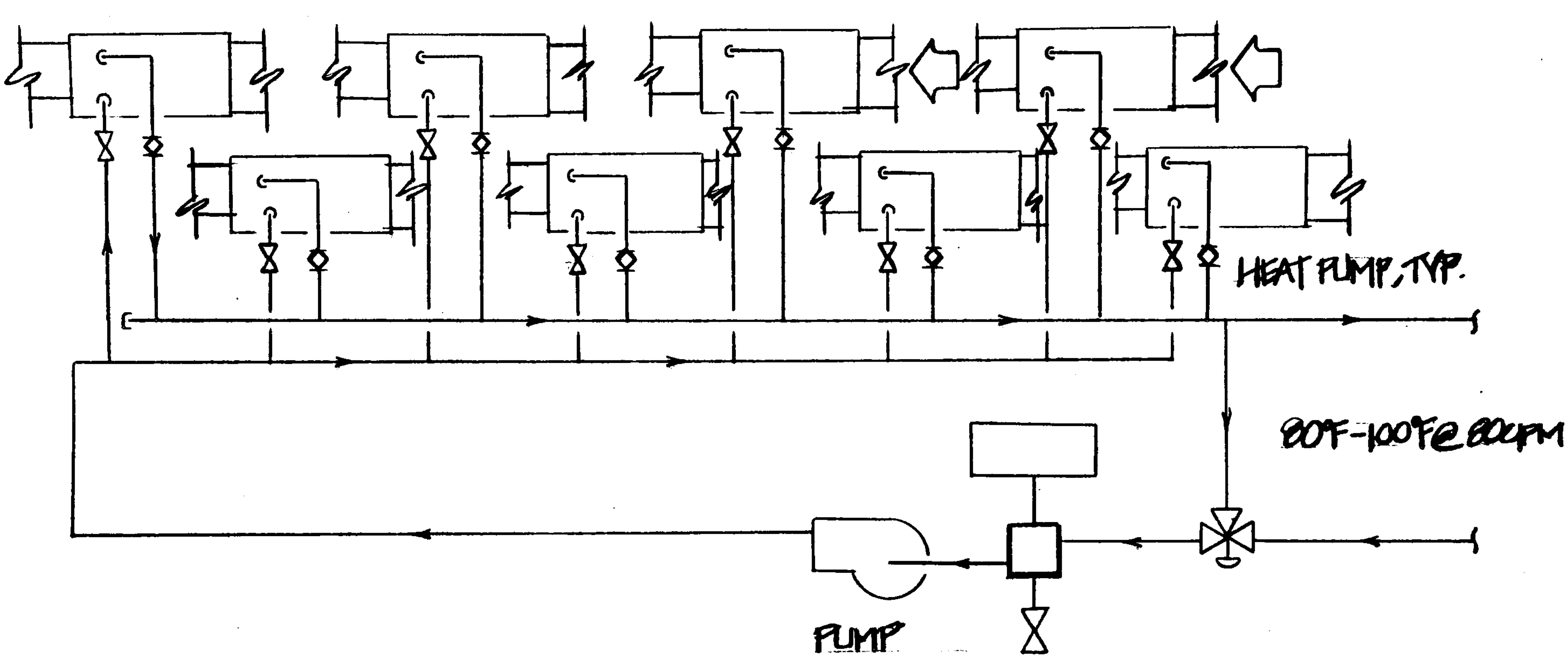
Geothermal Heat Pump Design Specifications

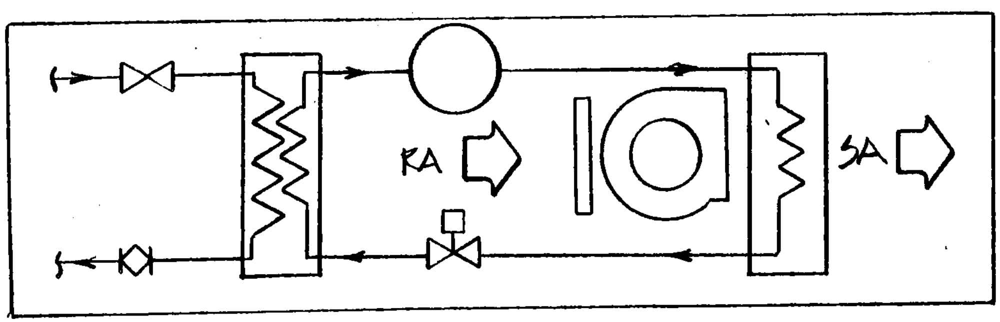
Proposed System and Modifications:

1. Retrofit to utilize shallow aquifer as source for water-to-air heat pumps.
2. Replace gas furnace in office and gas-fired unit heaters in drill hall with water-to-air heat pumps.
3. Existing air distribution will remain; however, additional sheet metal may be required.
4. Circulating 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.
9. Warm water (80°F to 100°F) to be derived from an assumed shallow aquifer.

Engineering Design:

Design heating can be accomplished with eight water-to-air heat pumps with a COP = 4.0 and output of 65,000 Btu/hr each. Warm water at 80°F to 100°F is required at 80 gpm. The engineering schematic is shown in Figure 31.





WATER-TO AIR HEAT PUMP

Figure 31

DURANGO NATIONAL GUARD

Equipment Components and Cost Estimates:

Component	Specifications	Quantity	Unit Cost	Total Cost
Heat Pumps	Water-to-air COP = 4.0 65,000 Btu/hr	8	$1,250	$10,000
Sheet Metal Ducting				2,000
Circulation Pump		1	1,000	1,000
Air Separator and Expansion Tank		1	1,200	1,200
Distribution Piping		325'	16	5,200
Insulation		325'	6	1,950
Temperature Controller		1	1,068	1,068
		Subtotal		$22,418
		Contingency (10%)		2,242
		Total		24,660

Engineering Design for Geothermal Trunk Line

A supply-only geothermal pipeline is prescribed to bring hot water from the Pinkerton Hot Springs and Tripp and Trimble Hot Springs resource area into the city of Durango. The routing of the pipeline follows that routing specified in the Resource Assessment section of this chapter. The main section of the pipeline is brought to the State Fish Hatchery site. Then two spurs take off from that point — one southeast up to the mesa on which Fort Lewis College is situated and the other south to the location of the new State Highway Department Building near the Bodo Industrial Park.

The geothermal trunk line is sized for the total water flow requirements (2,305 gpm at 150°F) for the Fish Hatchery (105 gpm), Fort Lewis College with the heat exchanger option (2000 gpm), and the Highway Department Building (200 gpm). Pumping stations are provided to overcome the frictional losses from the geothermal well location to the Fish Hatchery and to pump the water from that point to Fort Lewis College and the Highway Department Building. Disposal of the discharge water is by injection at Fort Lewis College and the

Highway Department site and by mixing with the water of the fish ponds at the Fish Hatchery.

Engineering Design:

Pipeline Section	Pipe Size	Flowrate (gpm)	Relief (feet)	Distance (feet)	Required Pumping (GPM @ Ft.Hd.)
Leg 1 (from resource area)	12"	2,305	-130	12,144	None
Leg 2	12"		-130	16,210	None
Leg 3	12"		0	28,353	2-(2,300 @ 140)
Leg 4 (to Fish Hatchery)	12"		- 70	22,282	2,300 @ 155
Subtotals		2,305	-330	78,989	
Fish Hatchery to heat exchanger (HX) at Fish Hatchery	3"	105		500	105 @ 25 (includes HX)
Fish Hatchery to Ft. Lewis College heat exchanger (HX)	12"	2,000		2,640	2,000 @ 40 (includes HX)
Fish Hatchery to Highway Department	6"	200		14,520	200 @ 40

Equipment Components and Cost Estimates:

Component	Quantity	Unit Cost	Total Cost
Pipelines			
12" Pipe (Preinsulated & prefab)	81,629'	$120	$ 9,795,480
3" Pipe (Preinsulated & prefab)	500'	40	20,000
6" Pipe (Preinsulated & prefab)	14,520'	63	914,760
	Pipeline Subtotal		$10,730,240

Equipment Components and Cost Estimates (continued):

Component	Quantity	Unit Cost	Total Cost
Pumps (Includes pump head thru heat exchanger)			
2300 gpm @ 140 ft. hd.	2	$ 15,000	$ 30,000
2300 gpm @ 155 ft. hd.	1	15,000	15,000
2000 gpm @ 40 ft. hd.	1	6,500	6,500
105 gpm @ 20 ft. hd.	1	1,000	1,000
200 gpm @ 65 ft. hd.	1	1,200	1,200
		Pump Subtotal	$ 53,700
		Subtotal	$10,783,940
		Contingency (10%)	1,078,394
		Total	$11,862,334

Economic Evaluations

The economic evaluations for the three state-owned facilities, which are supplied geothermal water from the trunk line, include a prorated cost of that trunk line. The proration is based upon the portion of the total flowrate required by each facility. The economic evaluation for the National Guard Building is independent of the trunk line.

Fort Lewis College

On the following pages are presented the itemized geothermal capital improvement costs, the annual operating and maintenance cost for both the geothermal systems and the conventional fuel system, and the results of the calculations of the four economic measures for the central heat exchanger option and the central heat pump option that are evaluated for Fort Lewis College in Durango.

The total geothermal capital improvement cost for the heat exchanger system, including campus distribution piping and additional terminal heating units, is $16,721,437 and for the heat pump system, including campus distribution piping, is $8,365,417. The cost difference derives principally from the proration of the cost of the trunk line; the heat exchanger system requires 2000 gpm of 150°F water, whereas the heat pump system only requires 1000 gpm. The total first year operating and maintenance costs for the two options are $267,183 and $227,382, respectively, as compared to an estimated $308,680 for the existing natural gas fired water boilers.

The calculated economic measures (assuming fuel price escalation of 15% per annum) are summarized as follows for the two geothermal options at Fort Lewis College:

	Heat Exchanger System	Heat Pump System
Simple Payback Period:	55 years	28 years
Total Annualized Cost:		
Geothermal:	$2,404,646	$1,338,312
Conventional:	$905,338	$905,338
Total Undiscounted Savings:	$13,784,921	$16,338,129
Total Present Value Savings:	$3,410,250	$4,220,014

Neither of the geothermal heating options is economically competitive with the existing natural gas fired water boiler system. The unfavorable economics are almost totally due to the absence of a nearby geothermal resource and to the high costs of the 15-mile trunk line.

CAPITAL COSTS

Location: Durango Facility: Ft. Lewis College

Geothermal Option: Heat Exchanger Coupled to Trunk Line

A. Production Well System - Prorated by gpm	Costs
Exploration	$ 100,000
Reservoir Engineering	200,000
Wells 23 @ $50,000 x $\frac{2000}{2305}$	997,831
Well Pumps (23) 2305 gpm, 100 ft-hd, 10^2 HP $25,500 x $\frac{2000}{2305}$	22,126
Valves and Controls	10,000
Contingency Funds (10%)	Included
Subtotal	1,329,957
Engineering Design Fee (10%)	Included
Total	$ 1,329,957

B. Transmission Line System	
Piping (ft.)	N.A.
Pumps ( ) gpm, ft-hd, HP	
Contingency (10%)	Included Below
Subtotal	
Engineering Design Fee (10%)	
Total	$ -0-

B'. Trunk Line- Prorated by gpm

$12,948,567 x $\frac{2000}{2305}$ = $11,235,200

C. Central Distribution System

Heat Exchanger, or	15,000
Heat Pump	-
Auxillary Building	7,500
Valves and Controls	2,500
Piping	448,570
Circulation Pumps ( ) 2500 gpm, 170 ft-hd, 188 HP	20,000
Miscellaneous	
Contingency (10%)	49,357
Subtotal	542,927
Engineering Design Fee (10%)	54,293
Total	$ 597,220

D. Building(s) Retrofit HVAC System

Heating Units / Retrofit Plumbing / Valves and Controls	2,184,872
Contingency (10%)	218,487
Subtotal	2,403,359
Engineering Design Fee (10%)	240,336
Total	$ 2,643,695

E. Reinjection/Disposal System

Reinjection Well(s): wells @ $ (75)	750,000
Piping (50 ft.)	1,500
Pumps ( )	-
Controls and Valves	5,000
Contingency (10%)	75,650
Subtotal	832,150
Engineering Design Fee (10%)	83,215
Total	$ 915,365

F. Grand Total $16,721,437

ANNUAL OPERATING AND MAINTENANCE COSTS
(1980 Dollars)

Location: Durango   Facility: Ft. Lewis College

Geothermal Option: Heat Exchanger Coupled to Trunk Line

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)	
A. Production Well System		$53,198	(4%)
Pump electricity	$ 12,830		
B. Transmission Line System (Trunk Line)	61,038	-	(1%)
C. Central Distribution System		11,944	(2%)
Heat Pump electricity			
Circ. Pump electricity 188 HP	27,253		
D. Building(s) Retrofit HVAC System	-	26,437	(1%)
E. Reinjection/Disposal System	-	18,307	(2%)
Total	$ 101,121	$ 166,062	

Conventional Fuel System

Type of System: Natural Gas Fired Water Boilers and Steam

Fuel Cost	
Total Annual Fuel Load	54,000 x 10^6 Btu/yr
1980-81 Estimated Fuel Price	$4.42/$10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 238,680

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	$ 3,500,000
Estimated Maintenance Cost	$ 70,000

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

ECONOMIC EVALUATIONS

Location: Durango   Facility: Ft. Lewis College

Geothermal Option: Heat Exchanger Coupled to Trunk Line

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$238,680
Electricity	-
Maintenance	70,000
Total	$308,680

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 16,721,437
First Year Operating Cost	101,121
First Year Maintenance Cost	166,062
Total	$ 16,988,620

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 55 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	$ -	$ 1,964,100
Electricity (9%/yr. escalation)	-	198,315
Maintenance (10%/yr. escalation)	102,108	242,231
Conventional Fuel (15%/yr. escalation)	803,230	
Total Annualized Cost	$ 905,338	$ 2,404,646

ECONOMIC EVALUATIONS (cont'd)

Location: Durango

Facility: Ft. Lewis College

Geothermal Option: Heat Exchanger Coupled to Trunk Line

C. Total Savings and Payback Period

	Conventional System			Geothermal System				
Year	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	End of Year	Annual Savings	Present Value (i = 10%)
1980						0		
1981	$238,680	-0-	$70,000	$166,062	$101,121	1	$41,497	$37,725
1982	274,482		77,000	182,668	110,222	2	58,592	48,420
1983	315,654		84,700	200,935	120,142	3	79,277	59,561
1984	363,002		93,170	221,029	130,955	4	104,188	71,160
1985	417,453		102,487	243,131	142,741	5	143,068	88,831
1986	480,071		112,736	267,445	155,587	6	169,775	95,838
1987	522,081		124,009	294,189	169,590	7	212,311	108,958
1988	634,894		136,410	323,608	184,853	8	262,843	122,616
1989	730,128		150,051	355,969	201,490	9	322,720	136,866
1990	839,647		165,056	391,566	219,624	10	393,513	151,699
1991	925,594		181,562	430,722	239,390	11	477,044	167,204
1992	1,110,433		199,718	473,794	260,935	12	575,422	183,329
1993	1,276,998		219,690	521,174	284,419	13	691,095	200,210
1994	1,468,547		241,659	573,291	310,017	14	826,898	217,722
1995	1,688,829		265,825	630,620	337,919	15	986,115	236,076
1996	1,942,154		292,407	693,682	368,331	16	1,172,548	255,146
1997	2,233,477		321,648	763,050	401,481	17	1,390,594	275,059
1998	2,568,499		353,813	839,355	437,615	18	1,645,342	295,997
1999	2,953,773		389,194	923,291	477,000	19	1,942,676	317,628
2000	3,396,839		428,114	1,015,620	519,930	20	2,289,403	340,205
Totals							$13,784,921	$ 3,410,250

Capital Investment $16,721,437

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$13,784,921	$3,410,250
Payback Period	>20 years	>20 years

CAPITAL COSTS

Location: Durango Facility: Ft. Lewis College

Geothermal Option: Heat Pump Coupled to Trunk Line

	Costs
A. Production Well System - Prorated by gpm	
Exploration	$ 50,000
Reservoir Engineering	100,000
Wells 23 @ $ 50,000 x $\frac{1000}{2305}$	500,000
Well Pumps (23) 2305 gpm, ft-hd, 102 HP, Prorated	11,000
Valves and Controls	5,000
Contingency Funds (10%)	Included
Subtotal	666,000
Engineering Design Fee (10%)	Included
Total	$ 666,000
B. Transmission Line System	
Piping (ft.)	N.A.
Pumps ( ) gpm, ft-hd, HP	Included Below
Contingency (10%)	
Subtotal	
Engineering Design Fee (10%)	
Total	$ -0-
B'. Trunk Line - Prorated by gpm	
$\$13,000,000 \times \frac{1000}{2305} =$	$5,639,912

C. Central Distribution System

Heat Exchanger, or Heat Pump (COP=6)	842,000
Auxillary Building	7,500
Valves and Controls	2,500
Piping	448,570
Circulation Pumps ( ) 2500 gpm, 214 ft-hd, 238 HP	20,000
Miscellaneous	
Contingency (10%)	132,057
Subtotal	1,452,627
Engineering Design Fee (10%)	145,263
Total	$1,597,890

D. Building(s) Retrofit HVAC System

Heating Units	
Retrofit Plumbing	Included Above
Valves and Controls	
Contingency (10%)	
Subtotal	
Engineering Design Fee (10%)	
Total	$ -0-

E. Reinjection/Disposal System

Reinjection Well(s): wells @ $ $75%)	375,000
Piping (ft.)	1,500
Pumps ( )	-
Controls and Valves	5,000
Contingency (10%)	38,150
Subtotal	419,650
Engineering Design Fee (10%)	41,965
Total	$ 461,615

F. Grand Total $8,365,417

ANNUAL OPERATING AND MAINTENANCE COSTS
(1980 Dollars)

Location: Durango Facility: Ft. Lewis College

Geothermal Option: Heat Pump Coupled to Trunk Line

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)
A. Production Well System		
Pump electricity	$ 6,415	$ 26,640 (4%)
B. Transmission Line System	30,519	28,200 (½%)
C. Central Distribution System		
Heat Pump electricity	75,896	15,979 (1%)
Circ. Pump electricity	34,501	
D. Building(s) Retrofit HVAC System	-	-
E. Reinjection/Disposal System	-	9,232 (2%)
Total	$147,331	$ 80,051

Conventional Fuel System

Type of System: Natural gas fired water boilers and steam

Fuel Cost	
Total Annual Fuel Load	54,000 x 10^6 Btu
1980-81 Estimated Fuel Price	$4.42/$10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 238,680

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	$3,500,000
Estimated Maintenance Cost	$ 70,000

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

ECONOMIC EVALUATIONS

Location: Durango Facility: Ft. Lewis College

Geothermal Option: Heat Pump Coupled to Trunk Line

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$ 238,680
Electricity	-
Maintenance	70,000
Total	$ 308,680

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 8,365,417
First Year Operating Cost	147,331
First Year Maintenance Cost	80,051
Total	$ 8,592,799

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 28 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	$ -	$ 982,602
Electricity (9%/yr. escalation)	-0-	288,941
Maintenance (10%/yr. escalation)	102,108	116,769
Conventional Fuel (15%/yr. escalation)	803,230	-
Total Annualized Cost	$ 905,338	$ 1,338,312

Location: Durango Facility: Ft. Lewis College

Geothermal Option: Heat Pump Coupled to Trunk Line

C. Total Savings and Payback Period

Year	Conventional System			Geothermal System		End of		Present Value
	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year	Annual Savings	(i = 10%)
1980						0		
1981	$238,680	-0-	$70,000	$147,331	$80,051	1	$81,298	$73,908
1982	274,482		77,000	160,591	88,056	2	102,835	84,983
1983	315,654		84,700	175,044	96,862	3	128,488	96,533
1984	363,002		93,170	190,798	106,548	4	158,826	108,478
1985	417,453		102,487	207,970	117,203	5	194,767	120,931
1986	480,071		112,736	226,687	128,923	6	237,197	133,898
1987	552,081		124,009	247,089	141,815	7	287,186	147,384
1988	634,894		136,410	269,327	155,997	8	345,980	161,400
1989	730,128		150,051	293,566	171,596	9	415,017	176,009
1990	839,647		165,056	319,987	188,756	10	495,960	191,193
1991	956,594		181,562	348,786	207,632	11	590,738	207,054
1992	1,110,433		199,718	380,177	228,395	12	701,579	223,523
1993	1,276,998		219,690	414,393	251,234	13	831,061	240,758
1994	1,468,547		241,659	451,688	276,358	14	982,160	258,603
1995	1,688,829		265,825	492,340	303,994	15	1,158,320	277,302
1996	1,942,154		292,407	536,651	334,393	16	1,363,517	296,701
1997	2,233,477		321,648	584,949	367,832	17	1,602,344	316,944
1998	2,568,499		353,813	637,595	404,615	18	1,880,102	338,230
1999	2,953,773		389,194	694,978	445,077	19	2,202,912	360,176
2000	3,396,839		428,114	757,526	489,585	20	2,577,842	383,067
Totals							$16,338,129	$ 4,220,014

Capital Investment $8,365,417

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$16,338,129	$4,220,014
Payback Period	16 years	>20 years

State Fish Hatchery

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 geothermal heat exchanger and hot water distribution system that is evaluated for the State Fish Hatchery.

The total geothermal capital improvement cost is $721,138, which includes $492,191 for the prorated cost of the trunk line from the resource area north of Druango. The total first year operating and maintenance cost for the geothermal system is $7,590 compared to an estimated $12,333 for the natural gas heaters.

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

	Heat Exchanger/ Piping System
Simple Payback Period:	59 years
Total Annualized Cost:	
Geothermal:	$97,090
Conventional:	$40,170
Total Undiscounted Savings:	$798,258
Total Present Value Savings:	$209,530

The geothermal heating option for the State Fish Hatchery is not economically competitive with the existing natural gas furnaces and heaters.

CAPITAL COSTS

Location: Durango   Facility: Fish Hatchery

Geothermal Option: Heat Exchanger Coupled to Trunk Line

	Costs
A. Production Well System -Prorated by gpm	
Exploration	$ 5,250
Reservoir Engineering	10,500
Wells 23 @ $ 50,000 x $\frac{105}{2305}$	52,386
Well Pumps (23) 2305 gpm, 100 ft-hd, 102 HP $25,500 x 105/2305 =	1,162
Valves and Controls	1,000
Contingency Funds (10%)	Included
Subtotal	70,298
Engineering Design Fee (10%)	Included
Total	$ 70,298
B. Transmission Line System	N.A.
Piping (ft.)	Included in Trunk Line
Pumps ( ) gpm, ft-hd, HP	
Contingency (10%)	
Subtotal	
Engineering Design Fee (10%)	
Total	$
B'. Trunk Line-Prorated by gpm $13,000,000 x $\frac{105}{2305}$ =	$592,191

C. Central Distribution System

Heat Exchanger, or		7,000
Heat Pump	52 gpm, 5 approach	-
Auxillary Building		-
Valves and Controls		-
Piping		23,620
Circulation Pumps ( ) 52 gpm, 50 ft-hd, 1.15 HP		800
Miscellaneous		
Contingency (10%)		3,142
Subtotal		34,562
Engineering Design Fee (10%)		3,456
Total		$ 38,018

D. Building(s) Retrofit HVAC System

Heating Units	2 Fan coil units @ $1000	2,000
	120 LF Baseboard Heaters	3,000
Retrofit Plumbing	5 unit Heaters	4,000
Valves and Controls	22.5 sq. ft. coil heater	2,250
	Misc.	5,000
Contingency (10%)		1,625
Subtotal		17,875
Engineering Design Fee (10%)		1,788
Total		$ 19,663

E. Reinjection/Disposal System

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

F. Grand Total $721,138

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Durango   Facility: Fish Hatchery

Geothermal Option: Heat Exchanger Coupled to Trunk Line

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)
A. Production Well System		$2,812 (4%)
Pump electricity $14,786 \times \frac{105}{2305}$	$ 674	
B. Transmission Line System (Trunk Line)	-	2,961 (½%)
C. Central Distribution System		
Heat Pump electricity	-	760 (2%)
Circ. Pump electricity 1.15 HP	167	
D. Building(s) Retrofit HVAC System	minimal	197 (1%)
E. Reinjection/Disposal System	-	19
Total	$ 841	$ 6,749

Conventional Fuel System

Type of System:

Fuel Cost	
Total Annual Fuel Load	$2,632 \times 10^6$ Btu/yr
1980-81 Estimated Fuel Price	$4.42/$10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 11,633

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	$35,000
Estimated Maintenance Cost	$ 700

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

Location: Durango Facility: Fish Hatchery

Geothermal Option: Heat Exchanger Coupled to Trunk Line

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$ 11,633
Electricity	0
Maintenance	700
Total	$ 12,333

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 721,138
First Year Operating Cost	841
First Year Maintenance Cost	6,749
Total	$ 728,728

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 59 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	$ -	$ 85,596
Electricity (9%/yr. escalation)	0	1,649
Maintenance (10%/yr. escalation)	1,021	9,845
Conventional Fuel (15%/yr. escalation)	39,149	-
Total Annualized Cost	$ 40,170	$ 97,090

Location: Durango

Facility: Fish Hatchery

Geothermal Option: Heat Exchanger Copuled to Trunk Line

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	$11,633	-0-	$700	$841	$6,749	1	$4,743	$4,312
1982	13,378		770	917	7,424	2	5,807	4,799
1983	15,385		847	999	8,166	3	7,067	5,309
1984	17,692		932	1,089	8,983	4	8,552	6,046
1985	20,346		1,025	1,187	9,881	5	10,303	6,397
1986	23,398		1,127	1,294	10,869	6	12,362	6,978
1987	26,908		1,240	1,410	11,956	7	14,782	7,586
1988	30,944		1,364	1,537	13,152	8	17,624	8,222
1989	35,586		1,500	1,676	14,467	9	20,943	8,882
1990	40,923		1,651	1,827	15,914	10	24,833	9,573
1991	47,062		1,816	1,991	17,505	11	29,382	10,298
1992	54,121		1,997	2,170	19,256	12	34,692	11,053
1993	62,239		2,197	2,365	21,181	13	40,890	11,846
1994	71,575		2,417	2,578	23,299	14	48,115	12,669
1995	82,312		2,658	2,810	25,629	15	56,531	13,534
1996	94,658		2,924	3,063	28,192	16	66,327	14,433
1997	108,857		3,217	3,339	31,011	17	77,724	15,374
1998	125,186		3,538	3,640	34,113	18	90,971	16,366
1999	143,964		3,892	3,967	37,524	19	106,365	17,391
2000	165,558		4,281	4,324	41,276	20	124,239	18,462
Totals							$ 798,258	$ 209,530

Capital Investment $728,728

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$798,258	$209,530
Payback Period	20 years	>20 years

State Highway Department Building (new)

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 geothermal heating option that is evaluated for the new Highway Department Building to be located near the Bodo Industrial Park in Durango.

The total geothermal capital equipment cost is $1,543,087, which includes $1,123,520 for the prorated cost of the geothermal trunk line. The estimated current capital cost for the proposed natural gas fired forced air system is only $178,640. The total first year operating and maintenance costs are $20,682 for the geothermal system and $31,373 for the natural gas system.

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

	Geothermal System
Simple Payback Period:	44 years
Total Annualized Cost:	
Geothermal:	$215,442
Conventional:	$119,737
Total Undiscounted Savings:	$1,917,916
Total Present Value Savings:	$497,658

The economics for a geothermal heating system at the new State Highway Department Building in Durango are clearly not competitive with the natural gas forced air system.

CAPITAL COSTS

Location: Durango   Facility: Highway Department Building (new)

Geothermal Option: Heat Exchanger Coupled to Trunk Line

	Costs
A. Production Well System - Prorated by gpm	
Exploration	$ 10,000
Reservoir Engineering	20,000
Wells 23 @ $ 50,000 x 200/2305	99,783
Well Pumps (23) 2305 gpm, 100 ft-hd, 102 HP $25,500 x 200/2305	2,213
Valves and Controls	1,000
Contingency Funds (10%)	Included
Subtotal	132,996
Engineering Design Fee (10%)	Included
Total	$ 132,996
B. Transmission Line System - From Trunk Line	
Piping (50 ft.)	3,150
Valve ( ) gpm, ft-hd, HP	250
Contingency (10%)	340
Subtotal	3,740
Engineering Design Fee (10%)	374
Total	$ 4,114
B'. Trunk Line- Prorated by gpm	
$12,948,567 x 200/2305	$1,543,087

C. Central Distribution System

Heat Exchanger, or	7,500
Heat Pump	-
Auxillary Building	-
Valves and Controls	6,335
Piping	-
Circulation Pumps ( ) 240 gpm, 40 ft-hd, 4.26 HP	1,000
Miscellaneous	-
Contingency (10%)	1,484
Subtotal	16,319
Engineering Design Fee (10%)	1,632
Total	$ 17,951

D. Building(s) Retrofit HVAC System

Heating Units 10 @ $3,500 9 @ $4,000	71,000
Retrofit Plumbing (1000 ft)	22,000
Valves and Controls	-
Ductwork	108,000
Contingency (10%)	20,000
Subtotal	221,100
Engineering Design Fee (10%)	22,110
Total	$ 243,210

E. Reinjection/Disposal System

Reinjection Well(s): 1 wells @ $ 15,000	15,000
Piping (ft.)	1,600
Pumps ( )	N.R.
Controls and Valves	1,000
Contingency (10%)	1,760
Subtotal	19,360
Engineering Design Fee (10%)	1,936
Total	$ 21,296

F. Grand Total $1,543,087

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Durango | Facility: Highway Department Building (new)

Geothermal Option: Heat Exchanger Coupled to Trunk Line

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)
A. Production Well System		$5,320 (4%)
Pump electricity	$ 1,283	
B. Transmission Line System & Trunk Line	6,104	5,659 (1%)
C. Central Distribution System		
Heat Pump electricity		360 (2%)
Circ. Pump electricity 4.26 HP	618	
D. Building(s) Retrofit HVAC System	-	1,125 (1%)
E. Reinjection/Disposal System	-	213 (1%)
Total	$ 8,005	$ 12,677

Conventional Fuel System (Proposed)

Type of System: Natural Gas Fired Forced Air

Fuel Cost	
Total Annual Fuel Load	$6,288 \times 10^6$ Btu/yr
1980-81 Estimated Fuel Price	$\$4.42/10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 27,793

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	$179,000
Estimated Maintenance Cost	$ 3,580

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

Location: Durango Facility: Highway Department Building (new)

Geothermal Option: Heat Exchanger Coupled to Trunk Line

A. Simple Payback Calculation

Proposed Annual Conventional System Cost		Geothermal System Cost	
Natural Gas	$ 31,373	Capital Cost (1980 Dollars)	$ 1,364,447*
Electricity	0	First Year Operating Cost	8,005
Maintenance	3,580	First Year Maintenance Cost	9,097*
Total	$ 31,373	Total	$ 1,381,549*

Simple Payback Period: $\frac{\text{Total Geothermal System Cost*}}{\text{Total Conventional System Cost}}$ = 44 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	$ 20,983**	$ 181,251
Electricity (9%/yr. escalation)	-	15,699
Maintenance (10%/yr. escalation)	5,222	18,492
Conventional Fuel	93,532	-
Total Annualized Cost	$ 119,737	$ 215,442

* incremental cost with respect to a natural gas system
** original cost = $178,640

Location: Durango

Facility: Highway Department Building (new)

Geothermal Option: Heat Exchanger Coupled to Trunk Line

C. Total Savings and Payback Period

	Conventional System			Geothermal System				
Year	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	End of Year	Annual Savings	Present Value (i = 10%)
1980						0		
1981	$27,793		$3,580	$8,005	$12,677	1	$10,961	$9,719
1982	31,962		3,938	8,725	13,945	2	13,230	10,933
1983	36,756		4,332	9,511	15,339	3	16,238	12,200
1984	42,270		4,765	10,367	16,873	4	19,795	13,520
1985	48,610		5,241	11,300	18,560	5	23,991	14,896
1986	55,902		5,766	12,317	20,416	6	28,935	16,334
1987	64,287		6,342	13,425	22,458	7	34,746	17,832
1988	73,930		6,976	14,633	24,704	8	41,569	19,392
1989	85,019		7,674	15,950	27,174	9	49,569	21,022
1990	97,772		8,441	17,386	29,892	10	58,935	22,719
1991	112,438		9,286	18,951	32,881	11	69,892	24,497
1992	129,304		10,214	20,656	36,169	12	82,693	26,346
1993	148,699		11,236	22,515	38,786	13	98,634	28,574
1994	171,004		12,359	24,542	43,764	14	115,057	30,295
1995	196,655		13,595	26,751	48,141	15	135,358	32,405
1996	226,153		14,955	29,158	52,955	16	158,995	34,597
1997	260,076		16,450	31,782	58,250	17	186,494	36,889
1998	299,088		18,095	34,643	64,076	18	218,464	39,302
1999	343,951		19,904	37,761	70,483	19	255,611	41,792
2000	395,544		21,895	41,159	77,531	20	298,749	44,394
Totals							$1,917,916	$ 497,658

Capital Investment $1,364,447

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$1,917,916	$497,658
Payback Period	19 years	>20 years

National Guard Building

On the following pages are presented the itemized geothermal capital improvement costs, the annual operating and maintenance costs for both the geothermal system and the conventional fuel system, and the results of the calculations of the four economic measures for the geothermal heating option that is evaluated for the National Guard Building in Durango.

The total geothermal capital improvement costs is $40,565, including the on-site shallow well. The total first year operating and maintenance cost is estimated at $4,771 compared to $4,553 for the natural gas heating system.

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

	Heat Pump System
Simple Payback Period:	10 years
Total Annualized Cost:	
Geothermal:	$13,599
Conventional:	$14,327
Total Undiscounted Savings:	$192,606
Total Present Value Savings:	$43,955

The economics for the heat pump system, based upon the existence of a shallow warm water aquifer, are definitely favorable. The actual application of a heat pump to the Durango National Guard Building, is entirely dependent upon obtaining warm water (80°F to°100 F) from a shallow well.

CAPITAL COSTS

Location: Durango   Facility: National Guard

Geothermal Option: Heat Pump with Shallow Well

	Costs
A. Production Well System	
Exploration	$ 900
Reservoir Engineering	N.R.
Wells 1 @ $ 9,000 300 feet	9,000
Well Pumps (1) 80 gpm, 140 ft-hd, 5 HP	1,250
Valves and Controls	1,000
Contingency Funds (10%)	Included
Subtotal	12,150
Engineering Design Fee (10%)	Included
Total	$ 12,150
B. Transmission Line System	
Piping (50 ft.)	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 Heat Pump	N.A.
Auxillary Building	
Valves and Controls	
Piping	
Circulation Pumps ( ) gpm, ft-hd, HP	
Miscellaneous	
Contingency (10%)	
Subtotal	
Engineering Design Fee (10%)	
Total	$ 0

D. Building(s) Retrofit HVAC System

Heating Units 8 Heat Pumps @ $1,250	10,000
Retrofit Plumbing	10,350
Valves and Controls	1,068
Contingency (10%)	2,142
Subtotal	23,560
Engineering Design Fee (10%)	2,556
Total	$ 26,116

E. Reinjection/Disposal System - 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. Grand Total $ 40,565

ANNUAL OPERATING AND MAINTENANCE COSTS
(1980 Dollars)

Location: Durango   Facility: National Guard

Geothermal Option: Heat Pump with Shallow Well

Geothermal System

Cost Item	Electricity Cost	Maintenance Cost/ (% of C. C.)
A. Production Well System		$486 (4%)
Pump electricity 5 HP	$ 725	
B. Transmission Line System	-	13 (1%)
C. Central Distribution System	-	-
Heat Pump electricity		
Circ. Pump electricity		
D. Building(s) Retrofit HVAC System	3,006*	522 (2%)
E. Reinjection/Disposal System	-	19 (2%)
Total	$ 3,731	$ 1,040

* for Heat Pumps

Conventional Fuel System

Type of System: Natural Gas Fired Unit Heaters

Fuel Cost	
Total Annual Fuel Load	912×10^6 Btu
1980-81 Estimated Fuel Price	$\$4.42/10^6$ Btu
1980-81 Estimated Total Annual Fuel Cost	$ 4,031

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	$ 26,100
Estimated Maintenance Cost	$ 522

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

ECONOMIC EVALUATIONS

Location: Durango   Facility: National Guard

Geothermal Option: Heat Pump with Shallow Well on-site

A. Simple Payback Calculation

Current Annual Conventional System Cost	
Natural Gas	$ 4,031
Electricity	0
Maintenance	522
Total	$ 4,553

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 40,565
First Year Operating Cost	3,731
First Year Maintenance Cost	1,040
Total	$ 45,336

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 10 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	$ -	$ 4,765
Electricity (9%/yr. escalation)	0	7,317
Maintenance (10%/yr. escalation)	761	1,517
Conventional Fuel (15%/yr escalation)	13,566	-
Total Annualized Cost	$ 14,327	$ 13,599

ECONOMIC EVALUATIONS (cont'd)

Location: Durango Facility: National Guard

Geothermal Option: Heat Pump with Shallow Well

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	$4,031	-0-	$522	$3,731	$1,040	1	($218)	($198)
1982	4,636		574	4,067	1,144	2	(1)	(1)
1983	5,531		632	4,433	1,258	3	472	354
1984	6,131		695	4,832	1,384	4	610	417
1985	7,050		764	5,267	1,523	5	1,024	636
1986	8,108		841	5,741	1,675	6	1,533	865
1987	9,324		925	6,257	1,842	7	2,150	1,103
1988	10,723		1,017	6,820	2,027	8	2,893	1,350
1989	12,331		1,119	7,434	2,229	9	3,787	1,606
1990	14,181		1,231	8,103	2,452	10	4,857	1,872
1991	16,308		1,354	8,833	2,697	11	6,132	2,149
1992	18,754		1,489	9,628	2,967	12	7,648	2,437
1993	21,567		1,638	10,494	3,264	13	9,447	2,737
1994	24,802		1,802	11,439	3,590	14	11,575	3,048
1995	28,522		1,982	12,468	3,949	15	14,087	3,372
1996	32,800		2,181	13,590	4,344	16	17,047	3,709
1997	37,721		2,399	14,813	4,779	17	20,528	4,060
1998	43,379		2,638	16,146	5,257	18	24,614	4,428
1999	49,885		2,902	17,600	5,782	19	29,405	4,808
2000	57,368		3,193	19,184	6,361	20	35,016	5,203
Totals							$ 192,606	$ 43,955

Capital Investment $40,565

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$192,606	$43,955
Payback Period	13 years	19-20 years

Institutional Requirements

For geothermally heating the new State Highway Department, the Fish Hatchery and Fort Lewis College, two separate resource areas are considered to be necessary to supply the required energy: the Tripp and Trimble Hot Springs area and the Pinkerton Hot Springs area. Since the resource at Tripp and Trimble is controlled by private owners, leases from them would be require (Coe & Zimmerman, in prep.) Alternatively, the owners could develop and sell the energy to the State. If the resource area at Pinkerton Hot Springs were also tapped, as suggested, then either federal or fee leases would be required depending upon the specific drill site proposed. Since the west half of the section is U.S. National Forest, lease applications would be subject to the approval of the U.S. Forest Service, generally a very time consuming process. The east half of the section is privately owned.

Right-of-way would be required from the State Division of Highways to allow the construction of pipeline along U.S. Highway 550, intersecting with a pipeline from Tripp and Trimble Springs, then continuing along U.S. 550 into and through the City.

If only the resource at Tripp/Trimble were tapped, the pipeline could run along the County Road on the west side of the Valley, then along U.S. 550 from the intersection into and through the City to the Bodo Industrial Park. At Fort Lewis College, the pipeline would diverge and run along the D & RG Railroad right-of-way. Right-of-way would be needed, therefore, from the County, the State Highway Department, and the Denver and Rio Grande Railroad.

For construction of the pipeline within the County, Planning Commission and County Commissioner review is required (Dallas Reynolds, pers. comm., 1980). Within the City, City Public Works Department review is required. A City plumbing permit from the Public Works Department is required prior to retrofitting.

For a heat pump system in the National Guard Building, a plumbing permit would be required as would notification of the City prior to drilling a well (Harvey Green, pers. comm., 1980).

Disposal of fluids after heat removal would in each case require a permit from the State Division of Water Quality. For the National Guard Building, since shallow ground water would be used, surface disposal is considered to be acceptable. It would, however, require that water rights be obtained. For the two other sites, on-site reinjection wells are suggested. Reinjection wells require permits from the State Division of Water Quality (Coe and Forman, 1980). For the Fish Hatchery, discharge-mixing of the geothermal ponds is suggested.

Environmental Considerations

As with the other Colorado sites, too little information is available for definite statements about the environmental impacts of geothermal development. Because a larger number of buildings are being considered for geothermal use in the Durango area and because the resource would be transported further than at the other sites, the opportunities for environmental pollution are somewhat greater. For example, there would be a greater potential for leakage of fluid from pipelines, with possible contamination of ground water or surface water. Dissolved minerals content ranges from 3,340 mg/l at the Trimble Hot Springs to 3,990 mg/l at the Pinkerton Hot Springs (Barrett and Pearl, 1976). Reports indicate that existing spring discharge has damaged trees (Coe, in prep.). This implies that careful handling of the resource would be needed if the recovered fluid exhibited characteristics similar to those of the springs. In any case, the fluid must by law be managed in a way that will limit pollution (Coe and Forman, 1980).

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

1981

$1.50

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FIGURES

GLENWOOD SPRINGS

The State Highway Department Buildings in Glenwood Springs have been evaluated in this appraisal for the use of geothermal energy in state-owned buildings. Glenwood Springs is the location of surface hot springs and has been assessed by various parties for several geothermal appliations. A recent geothermal utilization analysis has been performed by the Denver Research Institute (1980) on the engineering and economic feasibility of heating a group of municipal buildings. The study showed that a geothermal district heating system for the public buildings in the downtown area of Glenwood Springs is feasible.

The resource assessment for this appraisal study is based largely upon the DRI evaluation. The resource characteristics indicate geothermal water at 150°F from 500 to 800 feet deep wells and flowrates of 1000 gpm per well. The total dissolved solids are high at 17,000 to 20,000 mg/l. A geothermal well can probably be drilled on the site of the Highway Department Buildings.

The Glenwood Highway Department Buildings consist of an office building and a maintenance garage. These two buildings currently use an array of natural gas forced air furnaces and electric heaters for space/heating purpose; a propane unit is used for one water heater. Retrofit engineering for geothermal heating is based upon a central plate-in-frame heat exchanger coupled to several fan coil heaters and unit heaters. Design heating can be accomplished with 150°F geothermal water at 140 gpm.

The geothermal energy economics are evaluated for a single deep well, with and without a proration of the total production well cost for the required 140 gpm out of the 1000 gpm production capacity. Only the prorated well cost option provides an economically feasible geothermal system. The feasibility, therefore, depends on the use of the excess geothermal water by private or municipal facilities.

The principal institutional/environmental issue for a geothermal heating system for the Highway Department Buildings 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.

Resource Assessment for Glenwood Springs

Surface expressions of subterranean heat are found in the Glenwood Springs area in up to 31 hot springs (Figure 32). Massive basalt flows of recent Quaternary age, also an indicator of geothermal energy, are common through-

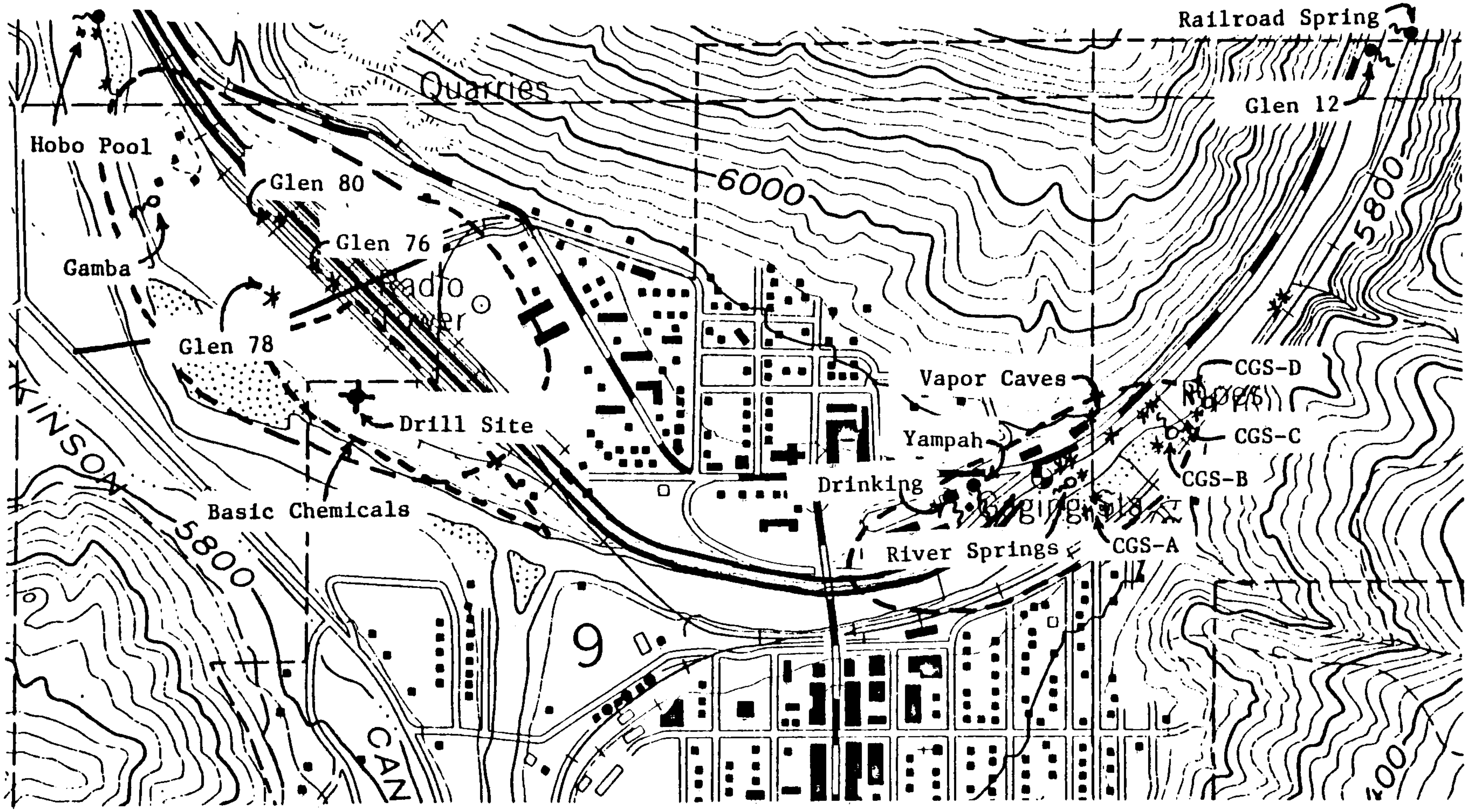


Figure 32. Anomalous geothermal resource areas in Glenwood Springs, Colorado. The dashed lines outline geophysical target areas. Also shown are the locations of hot springs with approximate flow rates represented by:

>150 gpm = [symbol: filled circle], 50 - 150 gpm = [symbol: open circle], <50 gpm = *

Source: Chaffee Geothermal, Ltd., 1980

out the area. Glenwood Springs is in fact, named for the many hot springs that lie along the banks of the Colorado River for approximately one mile within town. The Yampah Hot Springs has the greatest discharge rate of any hot springs in Colorado at 2263 gpm (Pearl, 1979). Other hot springs in the area have flow rates varying from one to 150 gpm. Surface temperatures are uniform through the springs in the area, ranging from 110°F to 125°F. These hot springs have the highest salinity in Colorado (Pearl, 1972) with total dissolved solids ranging from 17,000 to 20,000 mg/l. The U.S. Bureau of Reclamation (1976) has calculated that the hot springs within a 16-mile region between Glenwood Springs and Dotsero discharge 500,000 tons per year of dissolved solids into the Colorado River.

In a resource model projected by the Colorado Geological Survey (Pearl, 1979), geothermal fluids may be ascending the highly porous and steeply dipping Leadville Limestone. As the geothermal waters ascend through the Leadville Limestone, they may encounter a highly fractured zone near the surface where the Storm King thrust fault intersects with several other northwest and northeast trending faults. This fractured zone may be an area of shallow groundwater mixing, and hotter geothermal fluids could be encountered down-dip in the Leadville Limestone, prior to ground water interference in the fractured fault zones. The localities of the existing hot springs imply definite controls by the Storm King and other local faults in the area but geophysical surveys limit potential geothermal activity to the area immediately adjacent to the Storm King thrust fault. From the resource model projected herein, the hottest geothermal reservoir is probably within the Leadville Limestone southwest of the Storm King thrust fault.

The areal extent of the geothermal reservoir at Glenwood Springs can most accurately be defined by the localities of hot springs and by a seismic survey which was conducted by the Colorado School of Mines.

Hot springs discharge for several hundred yards to the northeast of town and for two miles to the west, as shown by thermal infrared photography (Hansen, 1975). The geothermal resources at Glenwood Springs may include an area of 1.5 to 2.0 square miles with the main reservoir limited to less than 0.5 square miles as shown in Figure 32 .

Estimates by the Colorado Geological Survey (Barrett and Pearl, 1978) and by (Fitzpatrick, 1980) show that subsurface reservoir temperature may be from 140°F to 180°F. At an unknown depth the reservoir temperature probably does approach 180°F but not necessarily immediately beneath Glenwood Springs. At reasonably shallow drilling depths below Glenwood Springs, the targeted reservoir temperatures are estimated to be 150°F.

Assuming the geothermal fluids are moving in the manner hypothesized by researchers , then a geothermal well drilled at the location shown on Figure 32 at a depth of about 500 to 800 feet should produce hot water. The further southwest a well is drilled the greater the depth required, but then the higher the reservoir temperature expected.

The Leadville Limestone, the formation hypothesized to contain the hot water in this area, is known to be a very porous and cavernous formation with execptionally good groundwater movement. Hot springs flowing from the Leadville Limestone generally have good flow rates ranging up to 150 gpm with a discharge of greater than 2200 gpm from the Yampah Hot Springs. Providing proper precautions are taken to prevent scaling in the wellbore, it is anticipated that production rates of 1000 gpm or greater may be feasible from each of several geothermal wells drilled into the Leadville Limestone.

The relative heat content of the geothermal system at Glenwood Springs has been projected by Pearl (1979) to be approximately 23.1 x 10^{11} Btu of useable energy.

A summary of the various geothermal resource characteristics (with the associated validity rating) as projected herein includes:

Reservoir temperature:	150°F (2)
Depth:	500-800 feet (2)
Production/well:	1000 gpm (1)
Areal extent:	0.5 - 2.0 square miles (3)
Formation:	Leadville Limestone (3)
TDS:	17,000 - 20,000 mg/l
Useable heat:	23 x 10^{11} Btu (1)

Glenwood Springs is an excellent location for the use of geothermal energy in state-owned buildings and facilities. A greater than adequate resource exists on-site at reasonable drilling depths. No pipeline would be required to bring geothermal fluids from the geothermal area to the facility and it is probable that sufficient resources exist for the expansion of facilities or the sale of excess energy to other potential users.

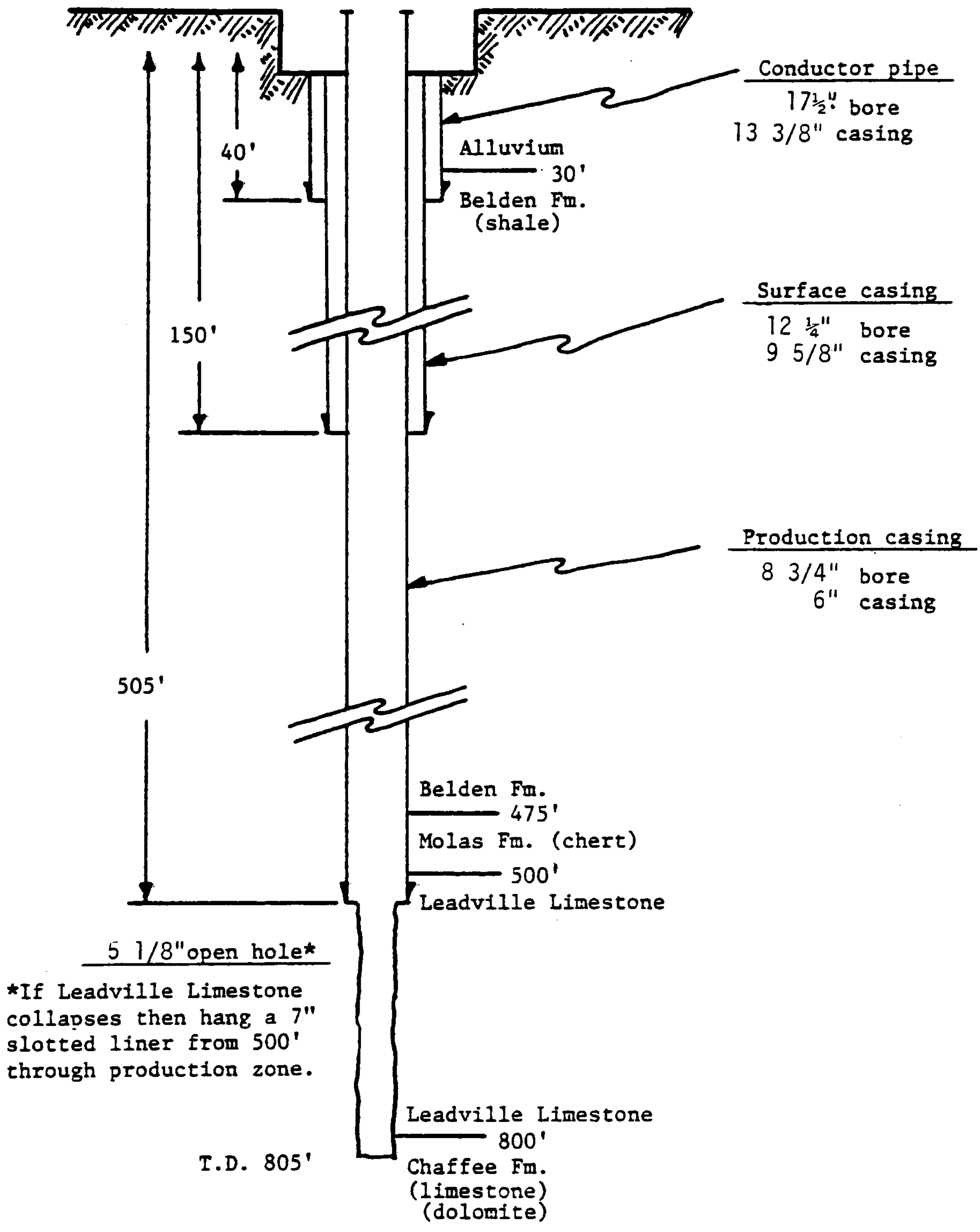
<u>Well Design and Drilling Program</u>

A detailed description of a well design and drilling program is presented here for Glenwood Springs as a specific example of the requisite designs for all geothermal wells in this appraisal. The description is derived from work performed by Chaffee Geothermal, Ltd., for the Denver Research Institute. The design information follows:

Due to anticipated high production rates of 1000 gpm or greater, the exploratory well is designed with a slightly smaller than full-bore to not restrict Artesian flow. Also, the bore is large enough to accommodate downhole impellers or a submersible pump if the need arises. A well profile is shown in Figure 33 .

FIGURE 33

WELL PROFILE FOR GLENWOOD SPRINGS



SOURCE: Chaffee Geothermal, Ltd.,1980

The first exploration well for this project is herein numbered "GS 9-1" because it is in Glenwood Springs and is the first geothermal well drilled within Section 9 (T.6S., R.89W.). As shown in Figure 33, a 13 3/8 inch conductor pipe (grade: F-25, weight: 48 pounds/foot) will be set to a depth of 40 feet or through the surface gravels and river boulders and into the shales of the Belden Formation. Then 9 5/8 inch surface casing (grade: H-40, weight: 32.3 pounds/foot) will be set into the Belden Formation to a depth of approximately 150 feet. It is very important that the surface casing be set prior to encountering any large volume flow rates because blowout prevention equipment will be placed on this casing during final drilling. Prior to beginning the well, all existing wells in the immediate vicinity will be checked to approximate the true depths to flowing aquifers. It is very feasible that the surface casing could be set as shallow as 100 feet if the shales of the Belden Formation prove sufficiently competent to hold a shallow surface casing.

Production casing of 6 inches (grade: H-40, weight: 22 pounds/foot) will then be run from the surface to a depth of 505 feet and anchored into the upper portion of the Leadville Limestone. Since the Leadville is the anticipated production horizon, it will be completed through its total thickness with a 5 1/8 inch open hole. This 5 1/8 inch bore will be drilled until it penetrates the upper limestone sequences in the underlying Chaffee Formation. This will give a proposed total depth for GS 9-1 of near 805 feet. Should the Leadville Limestone not prove sufficiently competent to maintain an open hole through the production zone, then the well can be re-entered, cleaned, and a 3-inch slotted liner can be hung from the 500-foot level of the production casing and through the entire producing aquifer.

The general procedure for drilling a geothermal well to the specifications as described herein is as follows:

1. Level a drilling pad of approximately 100' by 50' and excavate a 10' by 20' mud pit (8' deep). Also excavate a drilling cellar of 5' by 5' (3' deep) and a flow line to the Colorado River (pending Colorado Health Department and U.S. Bureau of Reclamation approval) or to a settling pond (also to be excavated if needed). A plan of the drilling site is shown in Figure 34. The total area to be impacted is less than one-half acre.

2. Cement-line the drilling cellar and install drains. Cover the drilling cellar with steel grating.

3. Move in cable-tool drilling rig and rig-up over the drilling cellar.

4. Drill a little bore to a depth of 40' or through the surface gravels and river boulders.

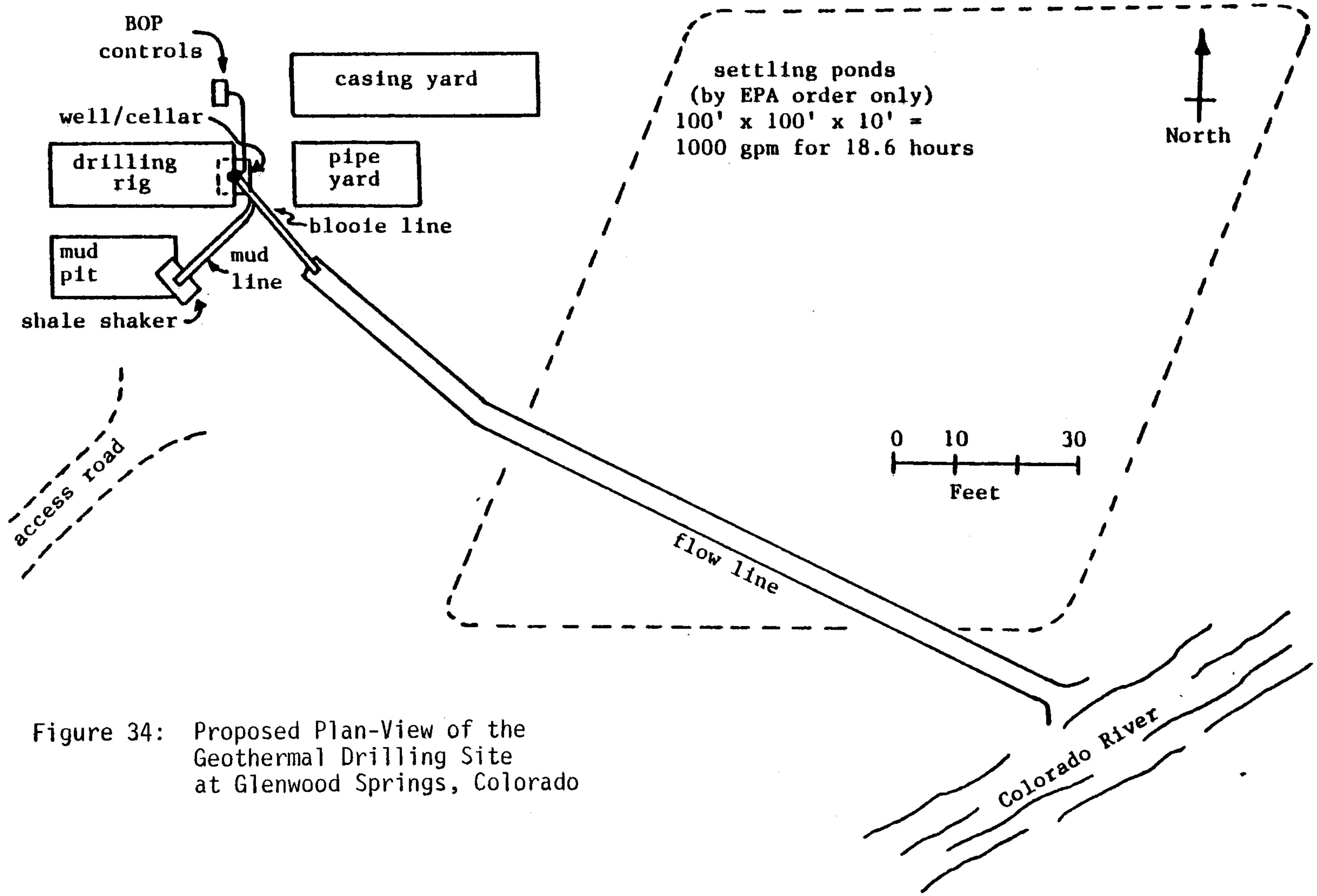


Figure 34: Proposed Plan-View of the Geothermal Drilling Site at Glenwood Springs, Colorado

SOURCE: Chaffee Geothermal, Ltd., 1980

5. Set and cement the 13 3/8" conductor pipe to a depth of 40'. Use ready-mix and wait on the cement to set for 8 hours.

6. Rig-down and move off cable-tool rig.

7. Move in and rig-up rotary drilling rig. Begin mixing drilling mud.

8. Spud-in and begin drilling a 6-3/4" pilot bore to 150' or to whatever depth the surface casing is to be set.

9. Ream hole to 150' with a 6-3/4" pilot and 12¼" cutter bit.

10. Run 9 5/8" casing to 150'. Thread guide shoe on bottom threads and place an insert fill-up valve at the first collar. Weld a centralizer in the middle of the first joint (depth 135') and place centralizers at the bottom collar (depth 120') and the top collar (depth 40').

11. Set and cement 150' of 9 5/8" casing with approximately 125 sacks, or until adequate returns are obtained at the surface, of Class "G" cement with 2% CaCl additive. If returns are not obtained at the surface then grout annulus from the surface with Class "G" cement minus CaCl (if possible). Wait on the cement to set for 12 hours.

12. Pressurize casing to 100 psi and hold for 10 minutes. This will check the threaded connections on the collars.

13. Re-enter the hole to the top of the cement (about 120' or at the insert fill-up valve) and drill-out the insert fill-up valve, the cement, guide shoe and 5' of formation with the 8 3/4" bit.

14. Test the casing seat with 100 psi for one hour. Observe the pressure gauge for leak off. If pressure bleeds off rig-up to squeeze.

    - Pick up RTTS packer and go to 145' and set packer. Pump 20 sacks of Class "G" cement plus 2% CaCl and squeeze casing shoe. Do not exceed 250 psi pressure during squeeze. Keep the bore pressurized and wait on the cement to set for 12 hours.

15. Retrieve RTTS packers and re-enter the hole with the 8 3/4" bit and drill-out the squeezed cement. Retest casing seat to 100 psi. Resqueeze if pressure bleeds off.

16. Thread (weld) casinghead flange on to the 9 5/8" surface casing and nipple-up drilling stack (Figure 35).

17. Enter bore with 6-3/4" pilot bit and begin drilling to 505', or into the Leadville Limestone. This drilling will take place with normal weight mud (9-10 pounds/gallon) even if large flows are encountered. Drilling will continue through flowing zones with

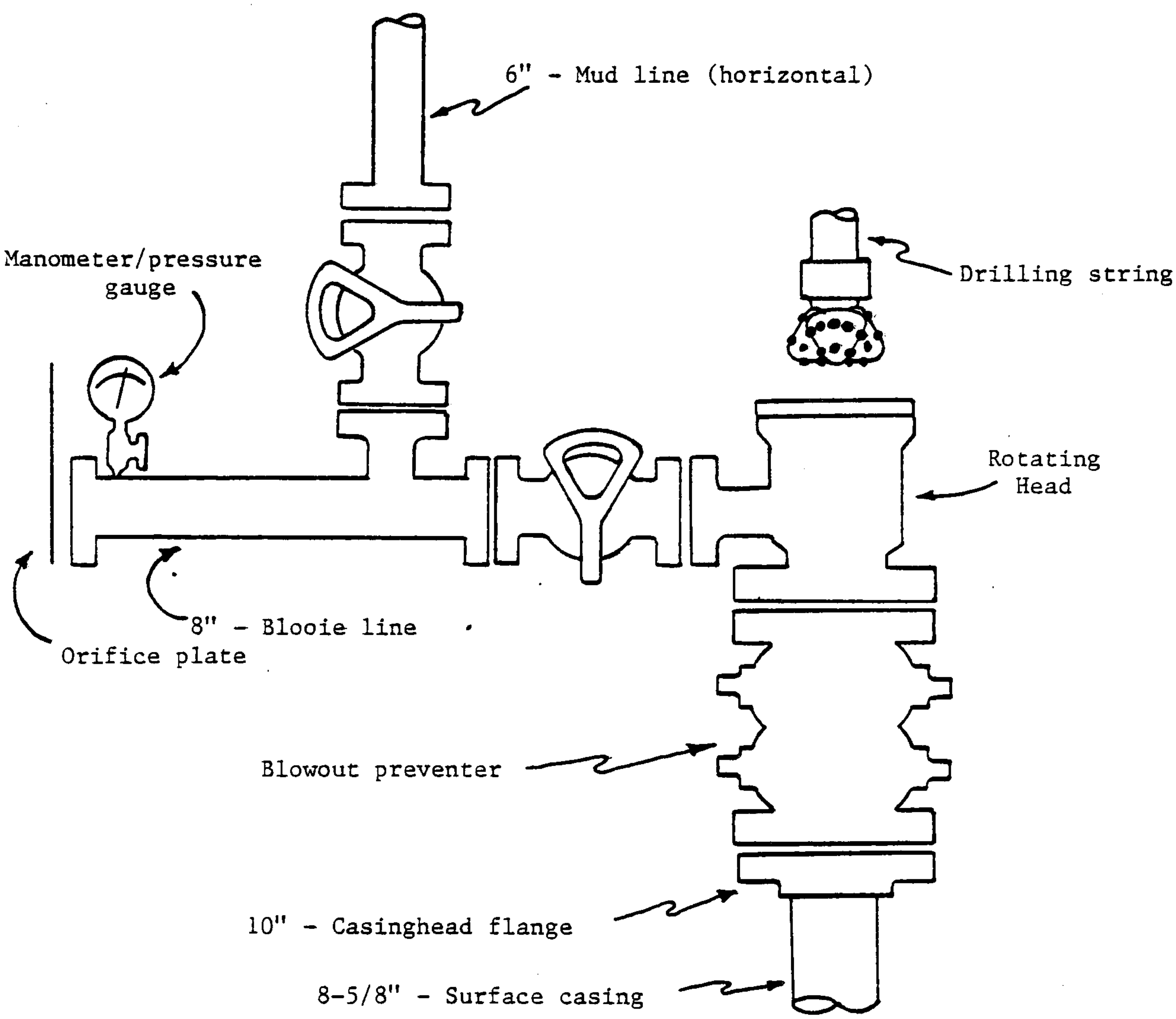


Figure 35: Drilling Stack Assembly

SOURCE: Chaffee Geothermal, Ltd., 1980.

normal weight mud which will lift cuttings up the bore to be flushed out by the producing formation.

- Should mud returns not occur at the surface, then the blow-out preventer (pipe rams) will be suth and lost circulation materials, plus mica flakes, will be pumped into the lost circulation zone until shut-in pressures increase. Then the blowout preventer (BOP) will be opened and mud returns will occur at the surface.

18. Trip out of the hole with the 6-3/4" pilot bit and ream-out the bore to a depth of 505' with a 6-3/4" pilot and 8 3/4" cutter bit.

19. If large flows are encountered while the 8 3/4" bit is in the hole, shut pipe rams (BOP) and begin mixing 14-16 pound/gallon mud (barite additive) or whatever weight is required to kill the flows. When the mud is up to weight, open the pipe rams (BOP) and circulate mud until flow is killed.

20. Trip out of hole and tear down the drilling stack.

21. Run 6" production casing to the bottom of the hole. An insert fill-up valve will be placed at the first collar and a guide shoe threaded to the bottom of the casing. Centralizers will be placed on the bottom joint (depth 490') and then at 440', 320', 200' and 80' of depth.

22. Cement the production casing with 200 sacks, or until returns occur at the surface, of Class "G" cement plus 2% CaCl (3% CaCl if major flows were encountered). Cement weight must be 16 pounds/gallon (depending on pressure of producing zones) and pumped very slowly at 2 barrels/minute. If returns are not obtained at the surface then grout annulus from the surface. No flushing plug of fresh water should be run ahead of the cement. Wait on the cement to set for 12 hours.

23. Repeat steps 12 through 15.

24. Cut off casinghead flange from 9 5/8" surface casing and thread on (weld) permanent casinghead flange to 6" production casing. Nipple-up master valve, banjo box and rotating head.

25. Enter bore with 5 1/8" bit and begin drilling in the Leadville Limestone by using both pumped and produced water as the drilling fluid. Drill through the Leadville or to a depth of approximately 805'. Flow rates during drilling can be measured at the blooie line via an orifice plate and manometer tube.

26. Trip-out of well and shut-in master valve while retrieving 5 1/8" bit through rotating head.

27. Reclose rotating head and open master valve and allow the production zone to produce and clean itself by flowing through the blooie line.

28. Shut-in well, rig-down and move all rotary and support equipment off site.

29. Conduct 24-hour and long-term reservoir tests by flowing production zone through banjo box and blooie line.

20. After reservoir tests, shut-in master valve and unbolt banjo box and rotating head and dismantle mud line and kill line. Bolt on second master valve (if desired for safety) and weldneck flange and connect pipeline to wellhead (Figure 36).

Approximate well costs to drill a six inch geothermal exploration well to a depth of 800 to 1000 feet at Glenwood Springs are estimated herein. A major portion of drilling costs are dependent on drilling rates and these projections are merely estimates. Notice that total well costs include a 25% contingency to cover unanticipated drilling conditions. Drilling costs are estimated at approximately $95,000; but to cover unanticipated drilling conditions and problems, costs could run as high as $118,000.

Retrofit Engineering for the State Highway Department Buildings

The retrofit building engineering design specifications for the Highway Department Buildings in Glenwood Springs are presented below. Figure 37 shows a schematic of the geothermal system using a central plate-in-frame heat exchanger to supply circulating hot water to fan coil heaters and unit heaters in the two buildings.

Present Conventional Fuel Heating System

BUILDING	SQUARE FOOTAGE	FUEL	HEATING EQUIPMENT	PEAK HEAT LOAD
Office	6,790	Natural Gas	Forced Air Furnaces (2)	277,500
		Electricity	Electric heaters (3)	35,826
Garage	6,720	Natural Gas	Unit heaters(8)	384,000
TOTALS:	13,510			697,326

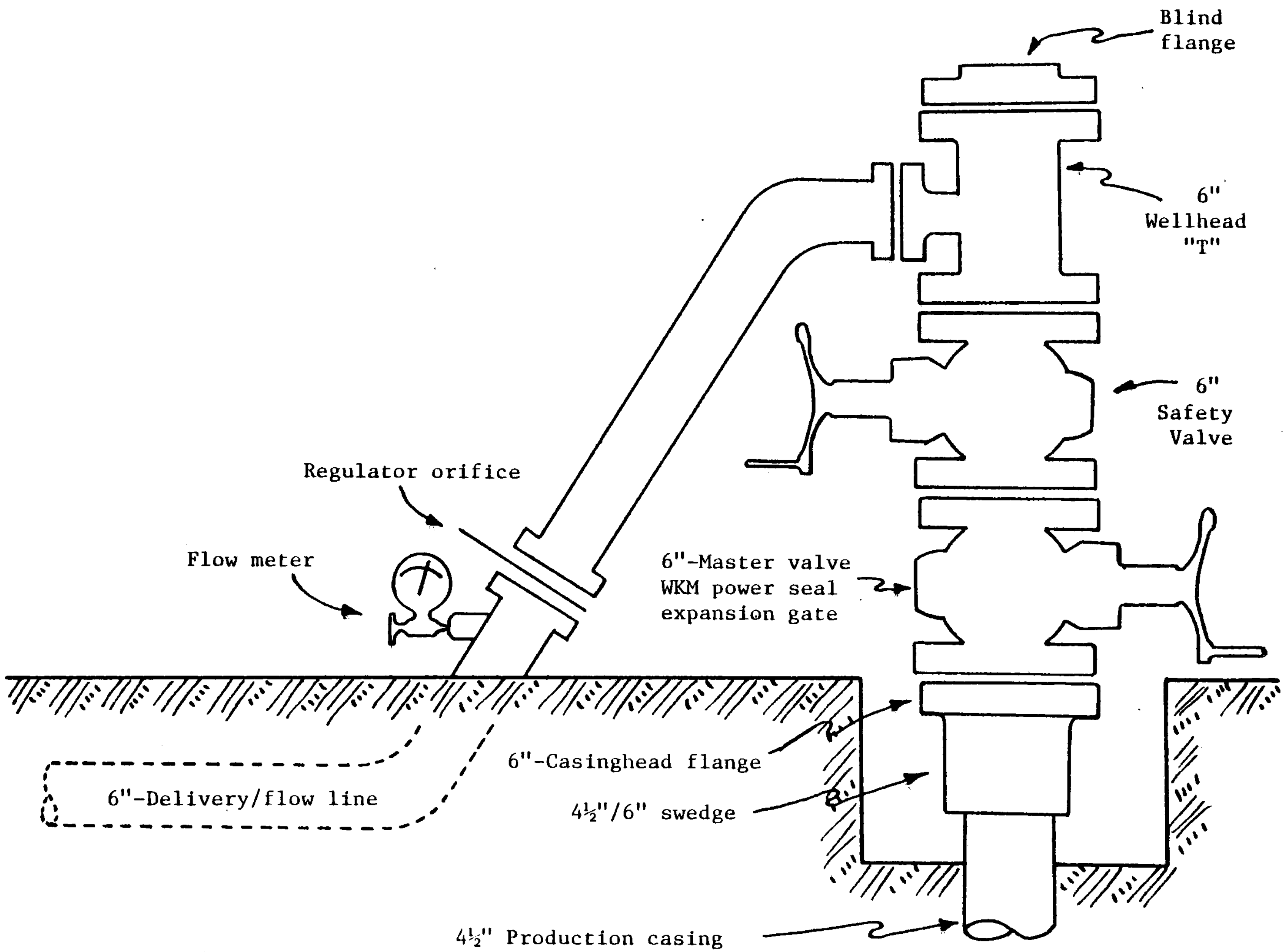
Geothermal System Design Specifications

Proposed System and Modifications:

1. Retrofit to utilize geothermal hot water for space heating.

2. Replace existing gas forced air furnace, unit heaters and electric units with hot water coil units capable of satisfying design loads with low approach temperatures.

3. Plate-in-frame heat exchanger is required.



SOURCE: Chaffee Geothermal, Ltd., 1980

Figure 36: Well Head Completion Assembly

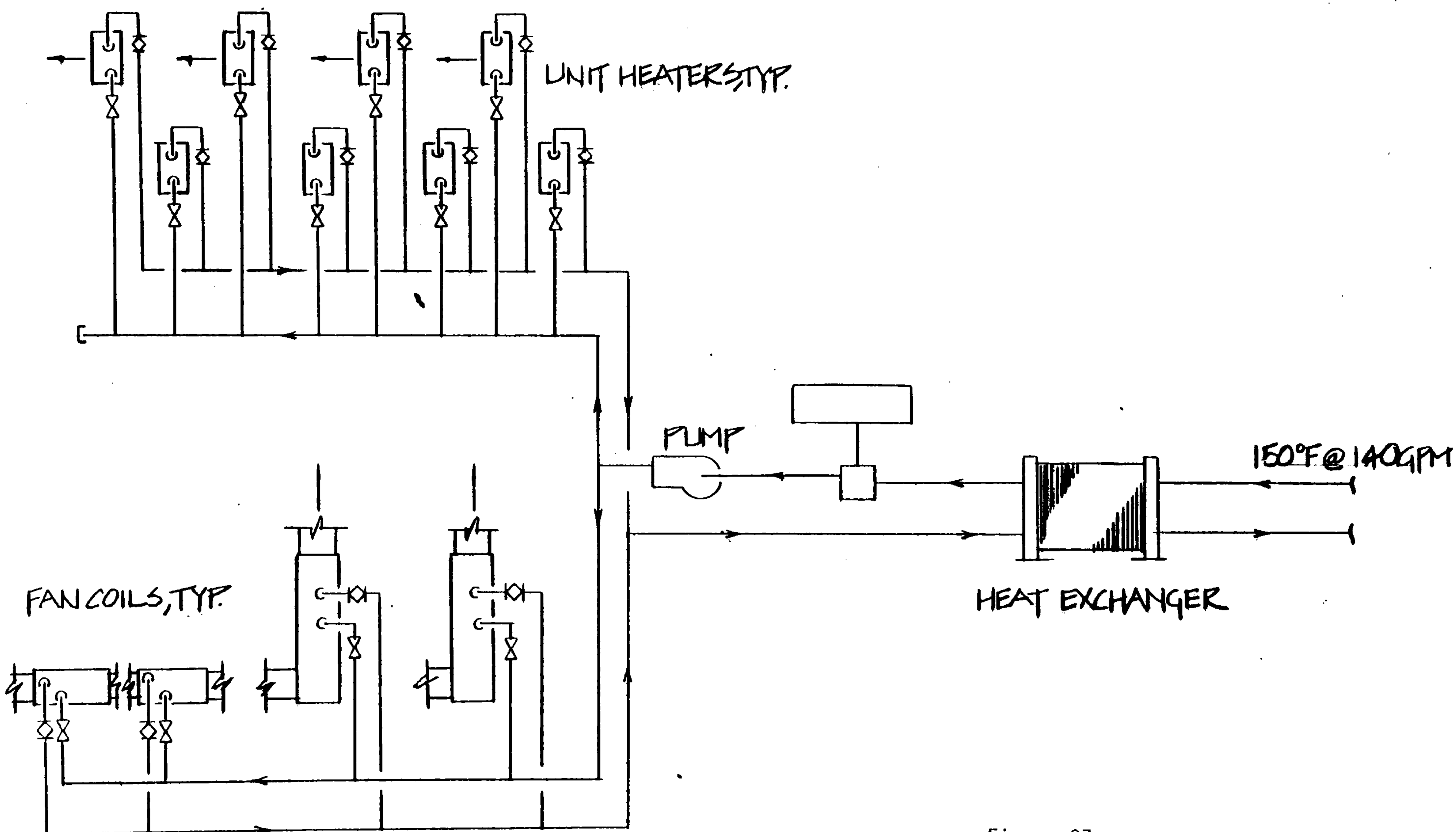


Figure 37

GLENWOOD SPRINGS HIGHWAY DEPT.

4. Heating water pump is required.

5. Air separator and expansion tank are required.

6. Supply and return piping is required.

7. More sophisticated temperature control is required.

8. Assume 150°F geothermal water is available.

Engineering Deisgn:

The design peak heating load of 700,000 Btu/hr can be accomplished utilizing 150°F geothermal into a plate-in-frame heat exchanger with approach of 10°F at 140 gpm; input circulating water of 70 gpm at 140°F will supply the heating load with a $\Delta T = 20^{\circ}F$.

Equipment Components and Cost Estimates:

	Specifications	Quantity	Unit Cost	Total Cost
• Office Building				
Fan Coils	3000 CFM	4	$1,000	$4,000
Fan Coils	6000 CFM	1	1,000	1,000
Circulation Pump		1	1,000	1,000
Air Separator and Expansion Tank		1	1,200	1,200
Distribution Piping		600'	16	9,600
Insulation		600'	6	3,600
• Garage Building		8	1,000	8,000
Unit heaters	1200 CFM			
Circulation Pump		1	1,000	1,000
Air Separator and Expansion Tank		1	1,200	1,200
Distribution Piping		600'	16	9,600
Insulation		600'	6	3,600
• Heat Exchanger Plate-in-Frame Type 140 gpm 150°F→140°F for geothermal side 70 gpm 140°F→120°F for building side				5,000
• Temperature Controller		1	2,440	2,440
			Subtotal	$51,240
			Contingency (10%)	5,124
			TOTAL	$56,364

Economic Evaluations

On the following pages are presented the itemized geothermal capital improvement costs, the annual operating and maintenance costs for both the geothermal system and the conventional fuel system, and the results of the calculations of the four economic measures for the geothermal option evaluated for the State Highway Department Buildings in Glenwood Springs.

The total geothermal capital improvement cost, based upon a prorated production well system, is estimated to be $114,356; the total capital costs without proration of the production well is $368,580. The first year operating and maintenance cost for the prorated-well geothermal system is $3,985, as compared to $10,214 for the conventional fuel system.

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

	Central Heat Exchanger and Prorated Deep Well
Simple Payback Period:	12 years
Total Annualized Costs:	
Geothermal:	$ 20,081
Conventional:	$ 29,974
Total Undiscounted Savings:	$697,883
Total Present Value Savings:	$192,360

The geothermal heating system is definitely economically competitive with the conventional heating systems for the State Highway Department Buildings at Glenwood Springs. The State can recover the capital improvement costs in energy savings over a period of years.

CAPITAL COSTS

Location: Glenwood Springs   Facility: Highway Department Building

Geothermal Option: Heat Exchanger with Deep Well on-site

A. Production Well System	Costs
Exploration	$ 1,680
Reservoir Engineering	3,360
Wells 1 @ $ 120,000 x 140/1000 (500-800 ft,1000gpm)	16,800
Well Pumps (1) 140 gpm, 140 ft-hd, 9 HP	3,600
Valves and Controls	1,000
Contingency Funds (10%)	Included
Subtotal	
Engineering Design Fee (10%)	Included
Total	$ 26,440

B. Transmission Line System	
Piping (ft.)	0
Pumps ( ) gpm, ft-hd, HP	
Contingency (10%)	
Subtotal	
Engineering Design Fee (10%)	
Total	$ 0

C. Central Distribution System & Garage

Heat Exchanger or	5,000
8 Unit Heaters @ $100	8,000
Auxillary Building	-
Valves and Controls	3,640
Piping	13,200
Circulation Pumps (2) 140 gpm, 40 ft-hd, 2.48 HP	2,000
Miscellaneous	-
Contingency (10%)	2,984
Subtotal	34,824
Engineering Design Fee (10%)	3,482
Total	$ 38,306

D. Building(s) Retrofit HVAC System -Office

Heating Units 5 Fan Coils @ $1,000	5,000
Retrofit Plumbing	13,200
Valves and Controls	1,200
Contingency (10%)	1,940
Subtotal	21,340
Engineering Design Fee (10%)	2,134
Total	$ 23,474

E. Reinjection/Disposal System

Reinjection Well(s): 1 wells @ $ 90,000 x 140/1000	12,600
Piping (500 ft.)	8,000
Pumps ( )	N.R.
Controls and Valves	1,000
Contingency (10%)	2,160
Subtotal	23,760
Engineering Design Fee (10%)	2,376
Total	$ 26,136

F. Grand Total $ 114,356

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Glenwood 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		$ 1,058 (4%)
Pump electricity 9 HP	$ 1,305	
B. Transmission Line System	-	-
C. Central Distribution System		
Heat Pump electricity	-	766 (2%)
Circ. Pump electricity	360	
D. Building(s) Retrofit HVAC System	-	235 (1%)
E. Reinjection/Disposal System	-	261 (1%)
Total	$ 1,665	$ 2,320

Conventional Fuel System

Type of System: Natural Gas Furnances (95%) and Electric Heaters (5%)

Fuel Cost		
Total Annual Fuel Load	$2,200 \times 10^6$ Btu/yr	
1980-81 Estimated Fuel Price	$3.60/$10^6$ Btu	
1980-81 Estimated Total Annual Fuel Cost	$ 7,524	

Maintenance Cost	
Percent of Associated Capital Costs	2%
Estimated Capital Costs	$62,000
Estimated Maintenance Cost	$1,240

Electricity Cost	
1980-81 Estimated Total Annual Electricity Cost	$ 1,450*

*fuel cost

ECONOMIC EVALUATIONS

Location: Glenwood 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	$ 7,524
Electricity	1,450*
Maintenance	1,240
Total	$ 10,214

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 114,356
First Year Operating Cost	1,665
First Year Maintenance Cost	2,320
Total	$ 118,241

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}}$ = 12 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	$ -	$ 13,432
Electricity (9%/yr. escalation)	2,844*	3,265
Maintenance (10%/yr. escalation)	1,809	3,384
Conventional Fuel (15%/yr. escalation)	25,321	-
Total Annualized Cost	$ 29,974	$ 20,081

*For fuel.

ECONOMIC EVALUATIONS (cont'd)

Location: Glenwood 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	N.G. (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year	Annual Savings	(i = 10%)
1980						0		
1981	$7,524	$1,450	$1,240	$1,665	$2,320	1	$6,229	$5,663
1982	8,653	1,580	1,364	1,815	2,552	2	7,230	5,975
1983	9,950	1,723	1,500	1,978	2,807	3	8,388	6,302
1984	11,443	1,878	1,650	2,156	3,088	4	9,727	6,644
1985	13,160	2,047	1,815	2,350	3,397	5	11,275	7,001
1986	15,133	2,231	1,997	2,562	3,736	6	13,063	7,374
1987	17,403	2,432	2,197	2,792	4,110	7	15,130	7,765
1988	20,014	2,651	2,416	3,044	4,521	8	17,516	8,171
1989	23,016	2,889	2,658	3,318	4,973	9	20,272	8,597
1990	26,468	3,149	2,924	3,616	5,470	10	23,455	9,042
1991	30,439	3,433	3,216	3,942	6,017	11	27,129	9,509
1992	35,005	3,742	3,538	4,296	6,619	12	31,370	9,994
1993	40,255	4,078	3,892	4,683	7,281	13	36,231	10,496
1994	46,294	4,445	4,281	5,105	8,007	14	41,908	11,034
1995	53,238	4,846	4,709	5,564	8,809	15	48,420	11,592
1996	61,223	5,282	5,180	6,065	9,690	16	55,930	12,170
1997	70,407	5,757	5,698	6,611	10,659	17	64,592	12,776
1998	80,968	6,275	6,298	7,206	11,752	18	74,553	13,412
1999	93,113	6,840	6,894	7,854	12,898	19	86,095	14,077
2000	107,080	7,455	7,584	8,561	14,188	20	99,370	14,766
Totals							$ 697,883	$ 192,360

Capital Investment　$114,356

	Undiscounted	Present Value (discounted at 10%)
Total 20-Year Savings	$697,883	$192,360
Payback Period	9-10 years	14 years

Institutional Requirements

At Glenwood Springs, the resource assessment indicates that a geothermal well can be drilled on site at the Highway Department. If this is so, control of the drilling site is already assured by its State ownership. Geothermal resources may be required, depending upon the results of a title search to determine whether or not the rights are owned by the State at this site.

Water rights are not likely to be required because on-site reinjection is proposed. A well permit from the State would be required along with a disposal permit.

Although the City currently has no regulations specific to geothermal energy, officials have expressed an interest in adopting such regulations if development activity were proposed. The City would require that a plumbing permit be obtained for retrofitting the structure. In Glenwood Springs, a quit claim deed in 1962 conveyed to a Robert L. Nicholas all of the mineral water within Glenwood Springs (Denver Research Institute, 1980). Because it is unclear whether this claim would be supported in a court test, officials have expressed concerns about the legality of drilling a geothermal well in Glenwood Springs (Glenwood Springs Geothermal Advisory Group, pers. comm., 1977).

Environmental Considerations

For Glenwood Springs, a preliminary environmental report on the probable effects of geothermal energy development was performed by the Denver Research Institute for the Colorado Geological Survey (Draft). According to this report, "potentially harmful environmental impacts from the drilling and flow testing of the well (proposed by the CGS) are expected to be minor." Noise, contamination of water supplies and alteration of the existing hydrothermal flow pattern are potential impacts considered in that study to require consideration. Because of the relatively high dissolved minerals content (20,000 mg/l), the potential for negative impacts is greater than in the other areas. The DRI study describes methods for protecting the environment from contamination, the most significant of the methods being reinjection of the fluids (DRI, Draft).