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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

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DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
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$1.50

DISCLAIMER

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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.

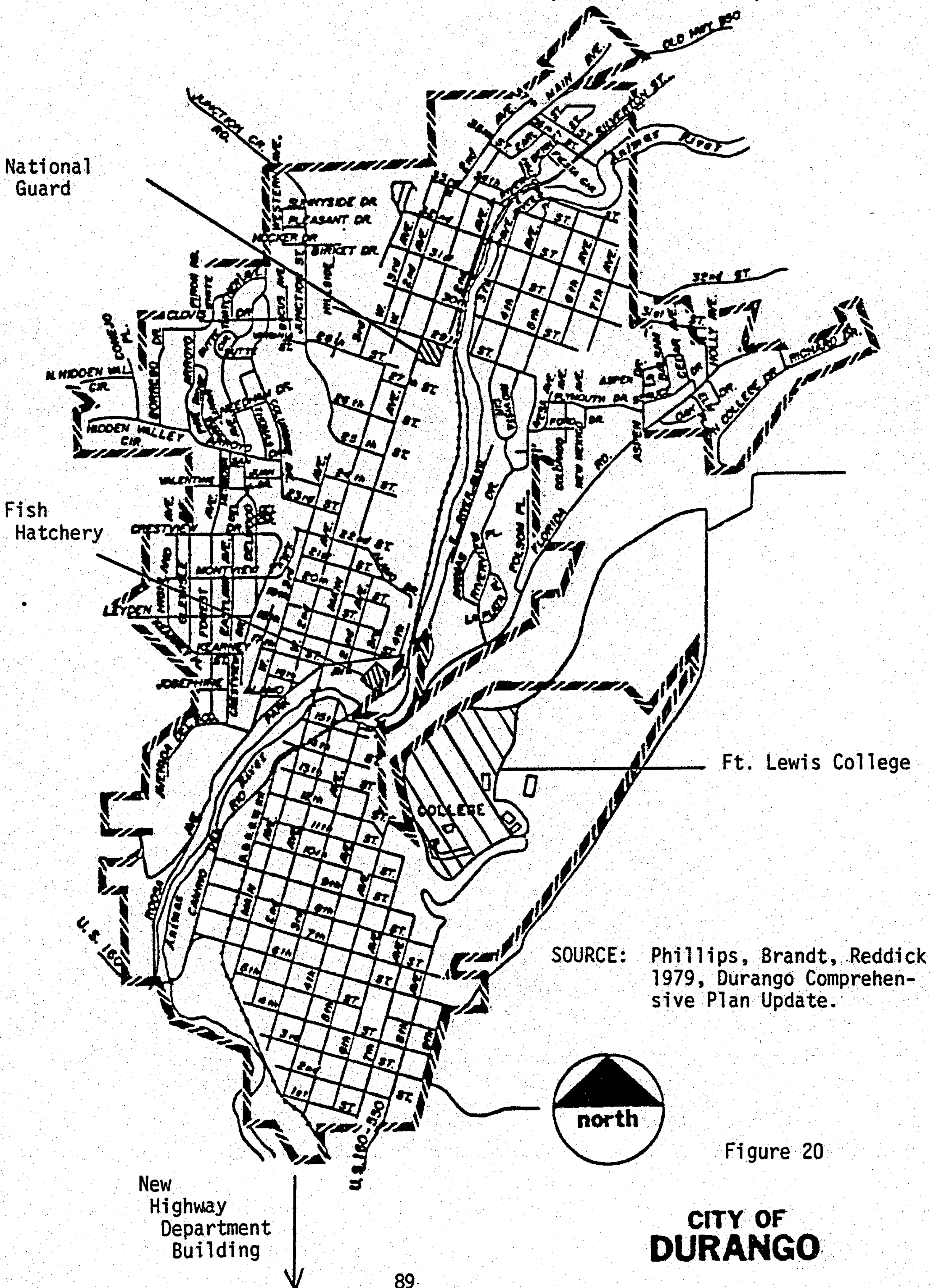
Three of the state facilities in Durango are evaluated for geothermal systems on the assumption of taking geothermal water from a trunk-line originating at the area north of Durango: State Fish Hatchery, Fort Lewis College and new State Highway Department Building. The National Guard Building is evaluated 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

CITY OF DURANGO

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').

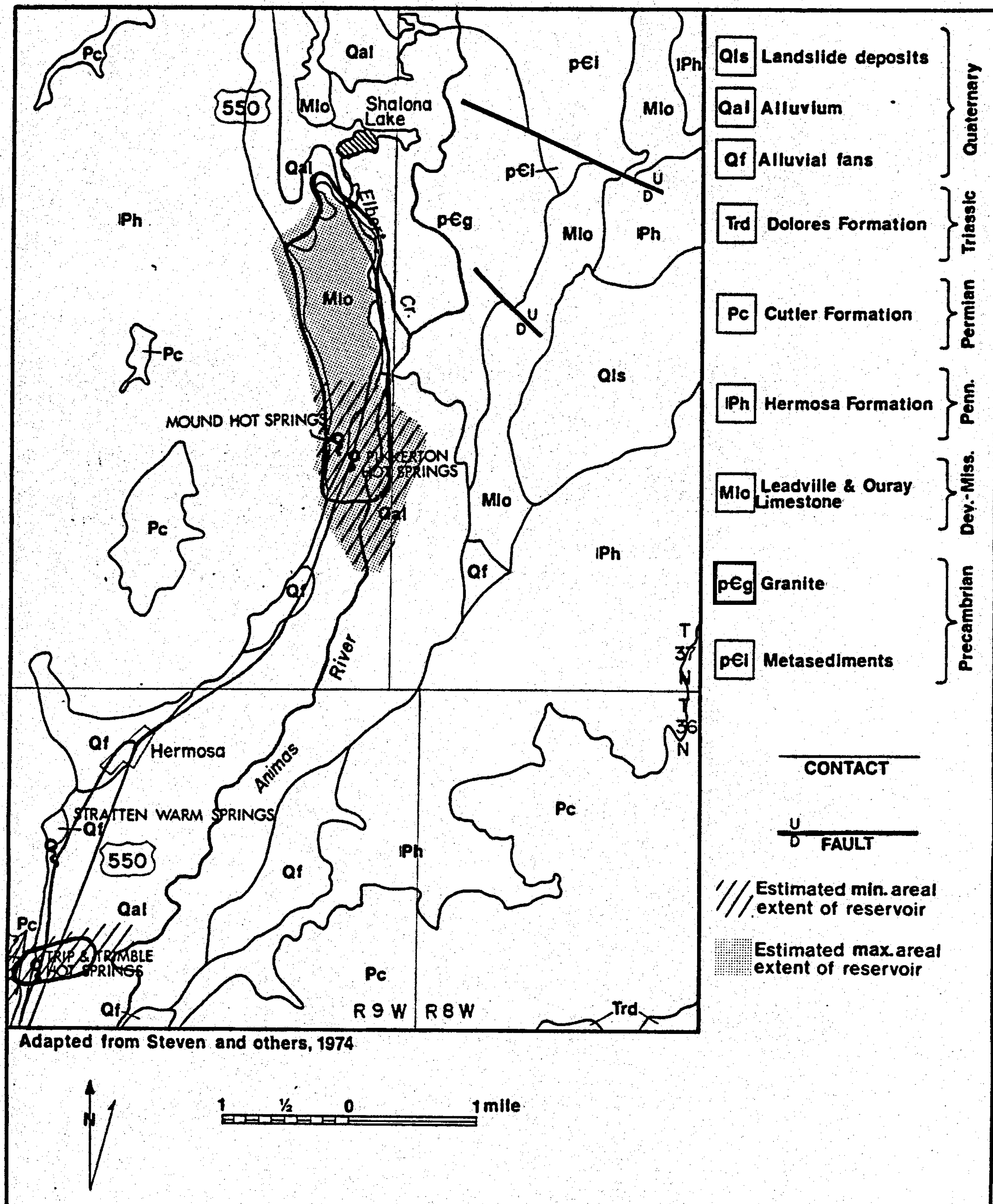


Figure 21: Geothermal ersource areas north of Durango. The areas outlined in bold loops are the projected areal extent of the geothermal reservoirs (Source: Pearl, 1979).

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 x 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 x 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 x 10^9 Btu of natural gas is assumed and a maximum design heat load of 25 million Btu/hr is assumed.

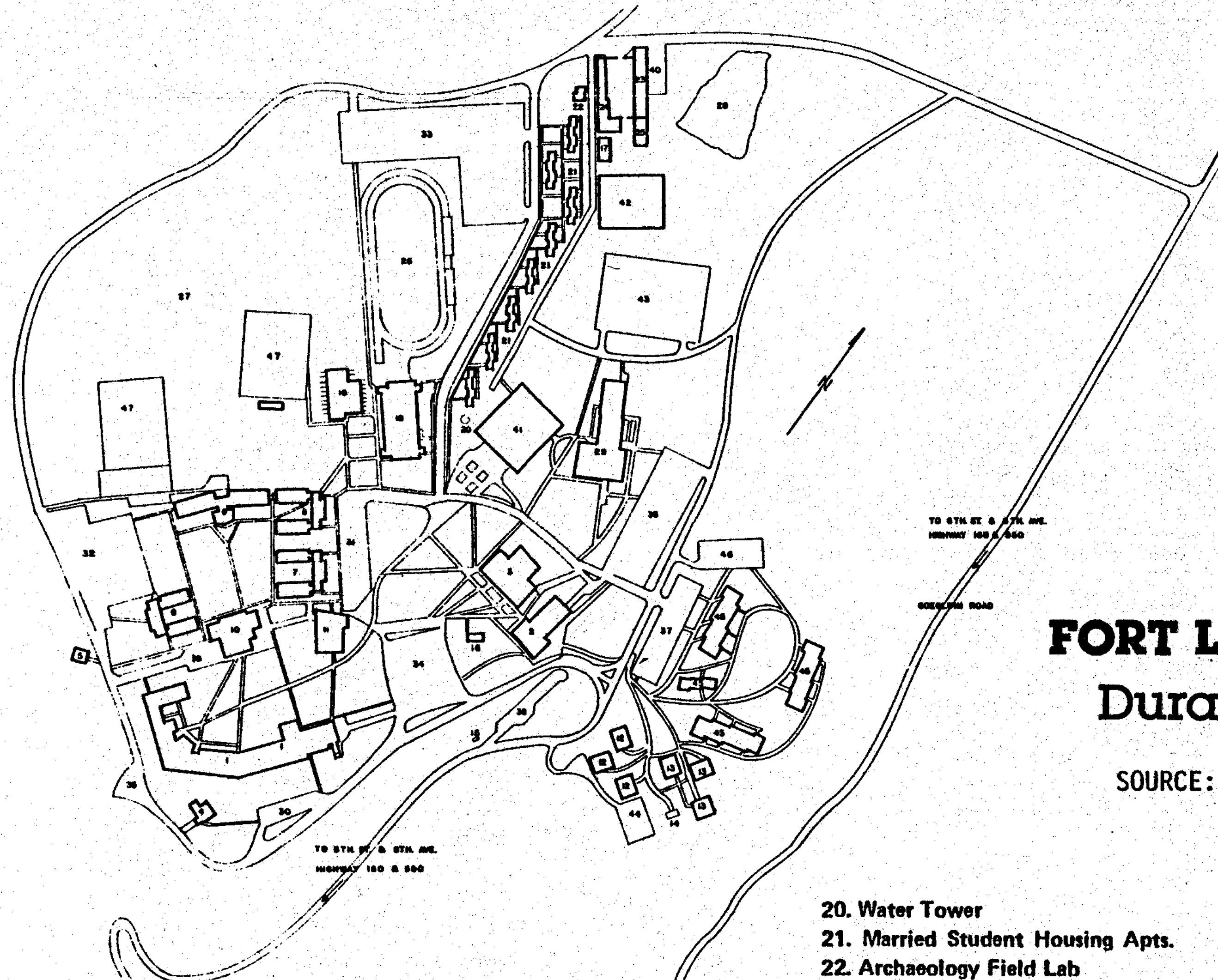


Figure 22

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 accomplished using a central heat exchanger operating under the following conditions:

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

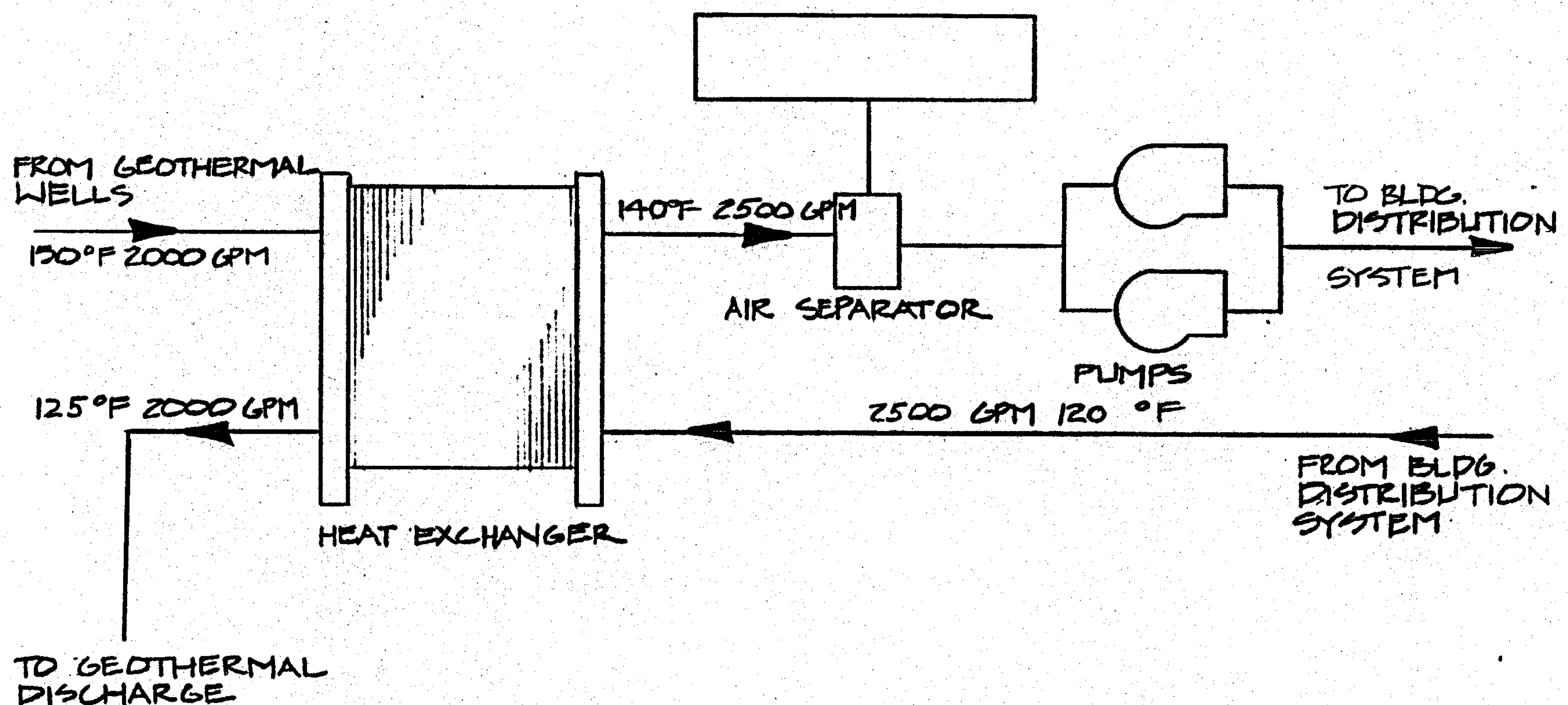
Figure 23 is an engineering schematic of the central heat exchanger design for Fort Lewis College.

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

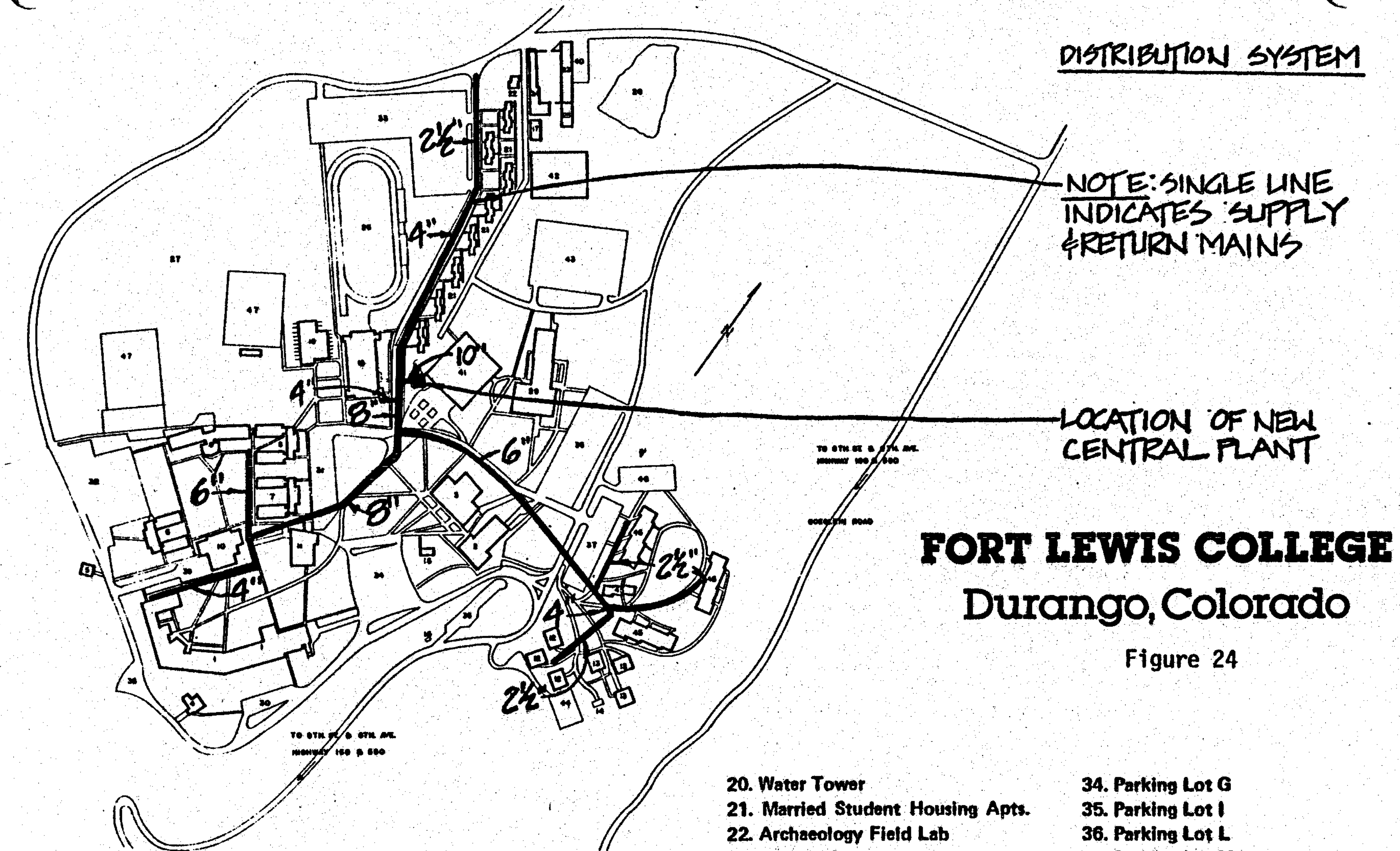


Figure 24

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
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30. Parking Lot A
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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:

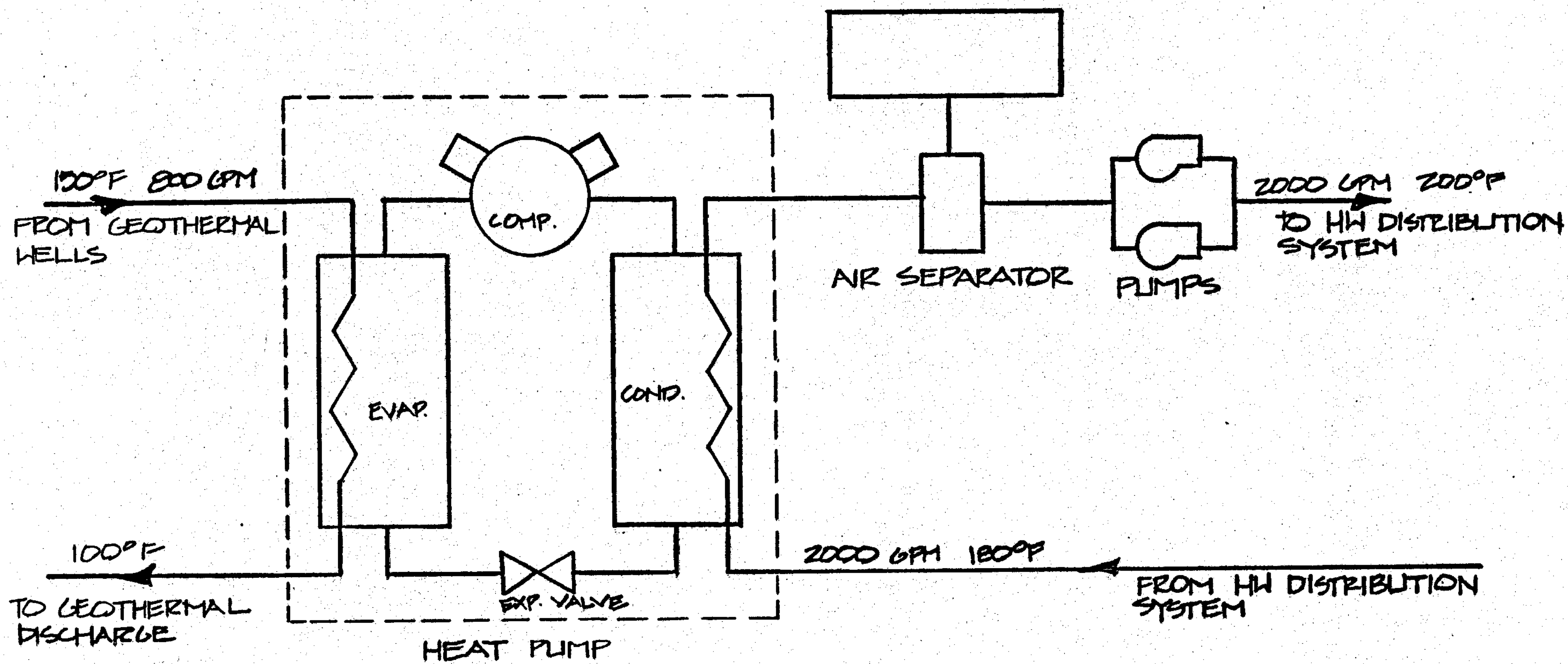
1. Retrofit to utilize geothermal hot water as heat pump source for space heating.
2. Provide centrifugal heat pumps (e.g. York pumps, COP = 6.0) to boost 150°F source water to 200°F.
3. Provide central pumping system to distribute hot water to buildings.
4. Provide district distribution piping to buildings (two pipe system).
5. Existing terminal heating equipment to be used without retrofit.
6. Design heat load is 25 x 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

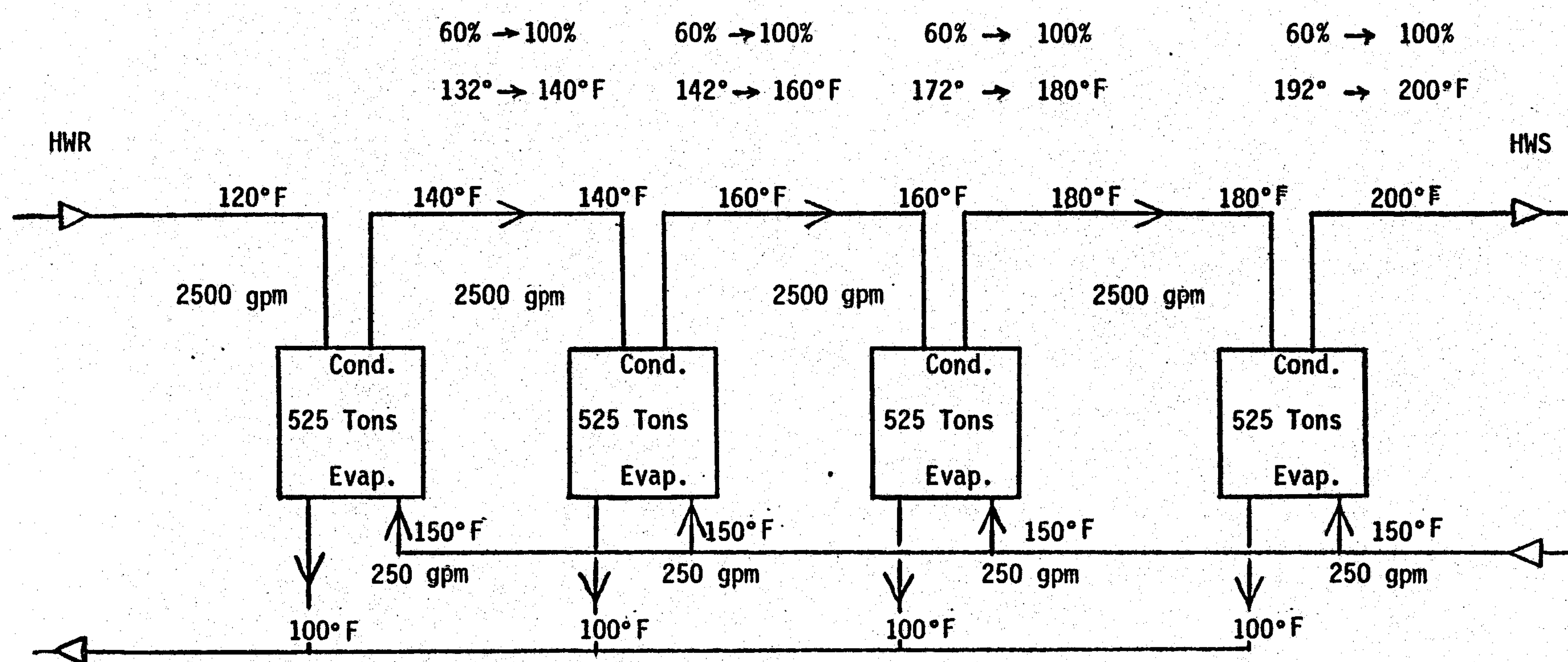


HEAT PUMP SYSTEM

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:

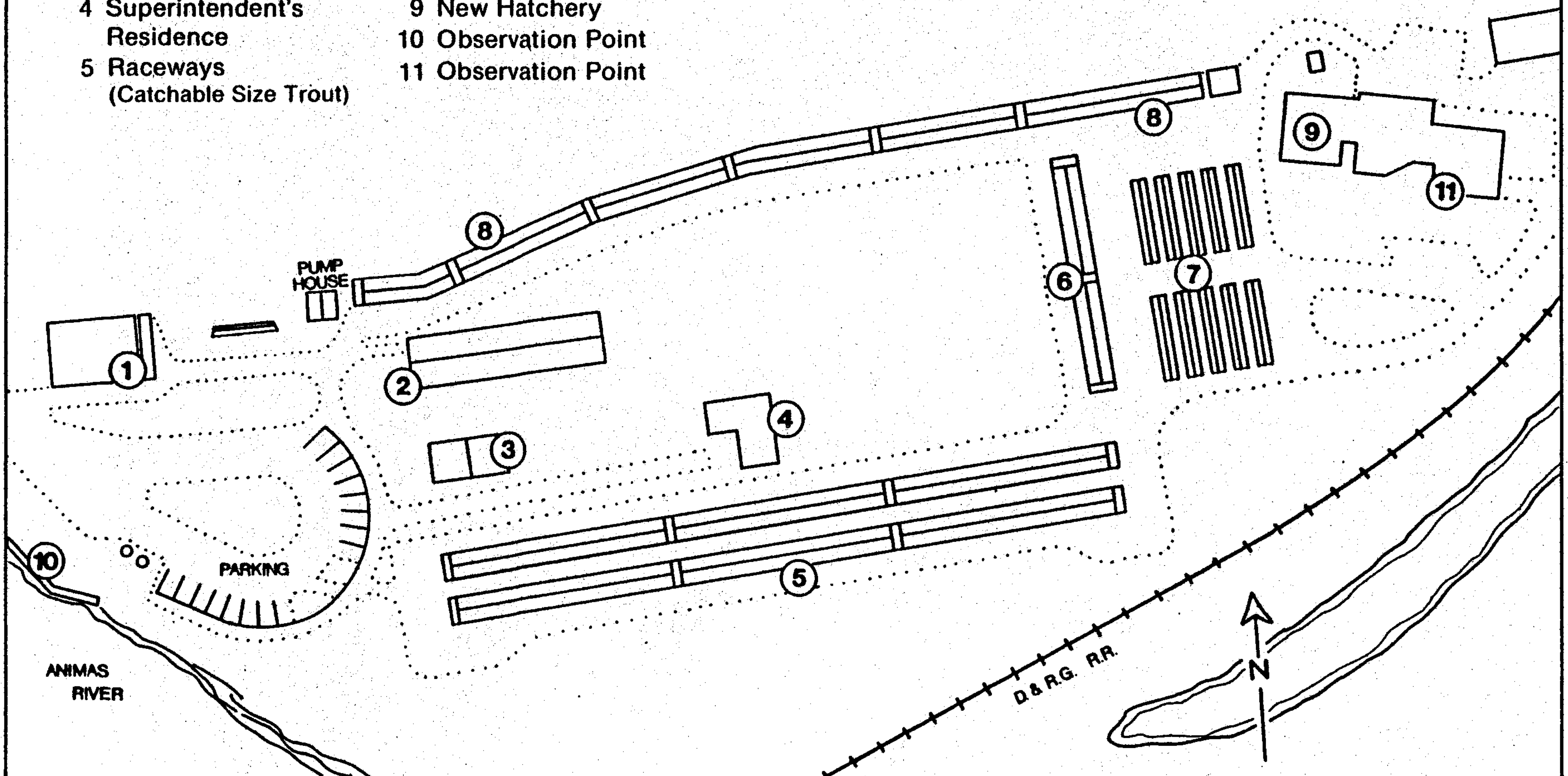
A tabulation of the existing Fish Hatchery buildings, space heating equipment, equipment output specifications, and necessary equipment modifications for hot water heating is presented below:

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°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°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°F) through a plate-type heat exchanger to heat distribution water (145°F).

3. Operate heating water with a 40°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.

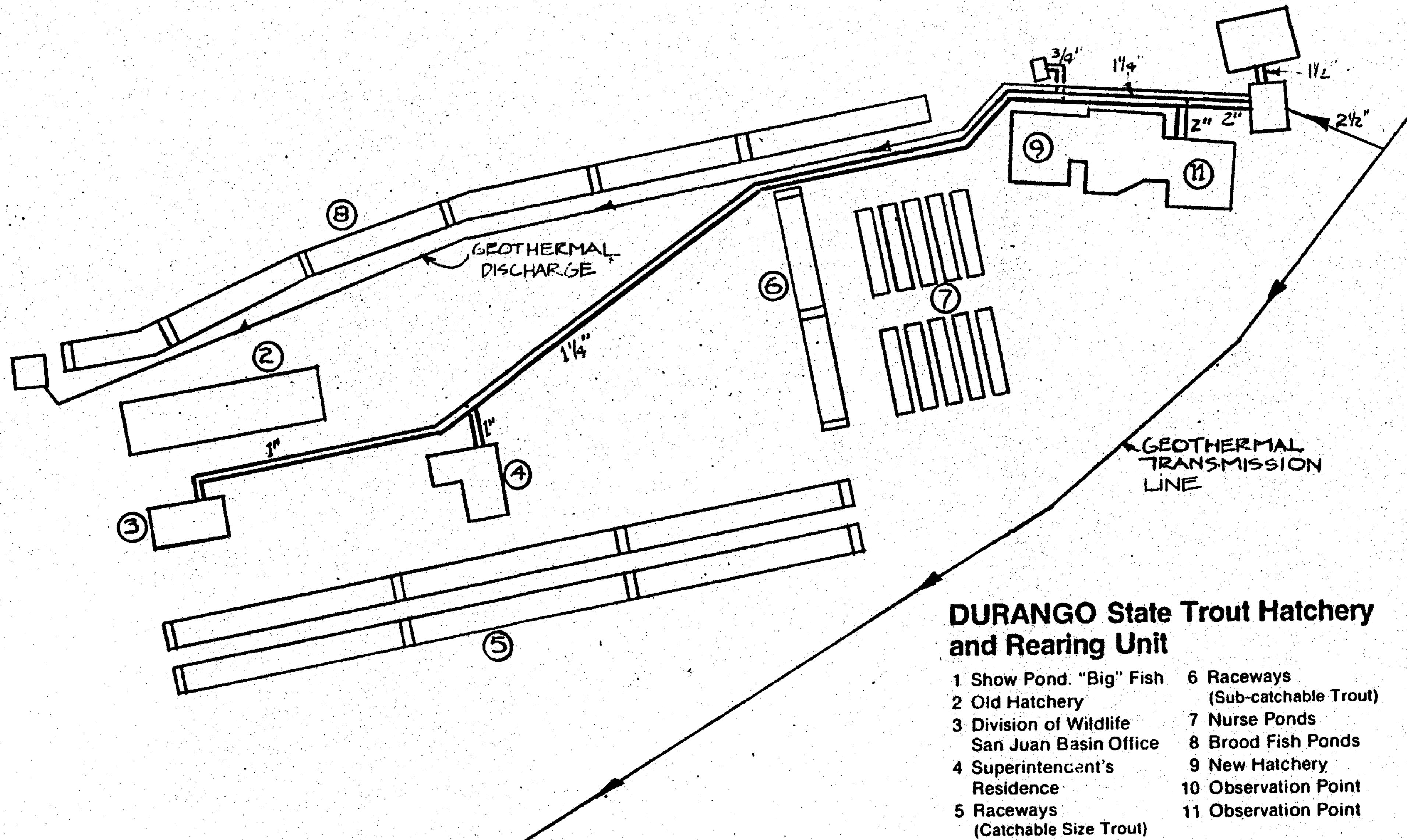
8. Design heat load is 1,038,000 Btu/hr.

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^{o}F is required into the exchanger; the temperature drop on the geothermal side is 20^{o}F. Using a 5^{o}F approach specification, the hot water supply to the buildings is 145^{o}F at 52 gpm with a 40^{o}F temperature drop. The discharge geothermal water from the heat exchanger is mixed with the existing spring water (48^{o}F, 1632 gpm) to yield 53^{o}F water for the fish ponds.

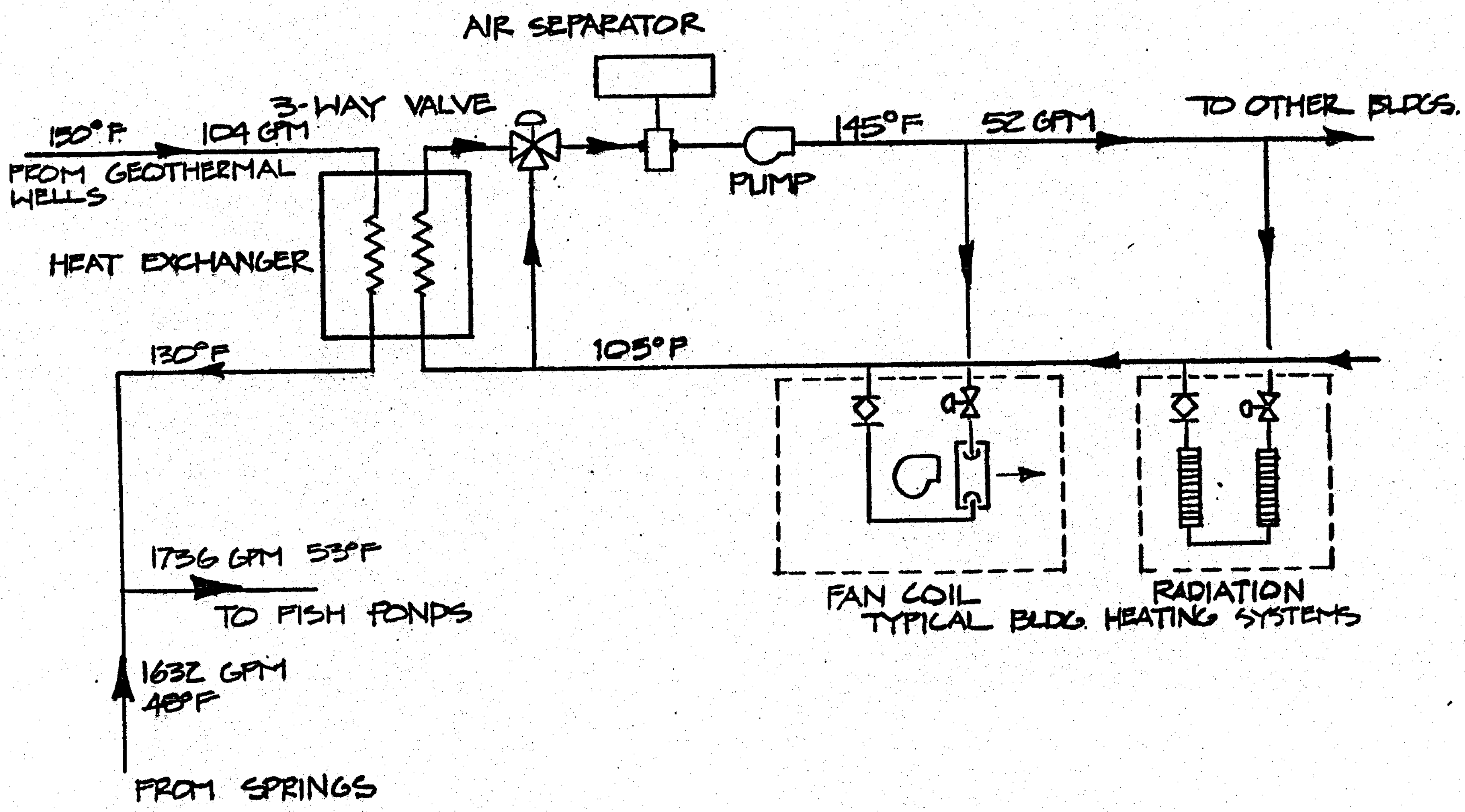
Equipment Components and Cost Estimates:

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^{0} 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

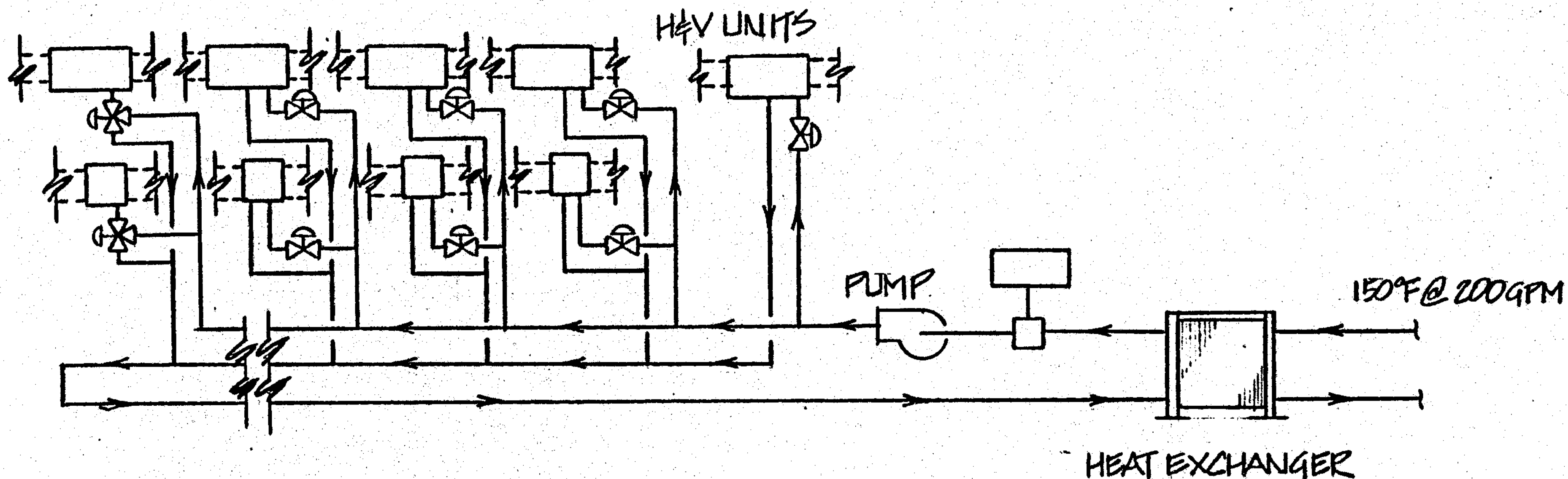


Figure 30

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)	

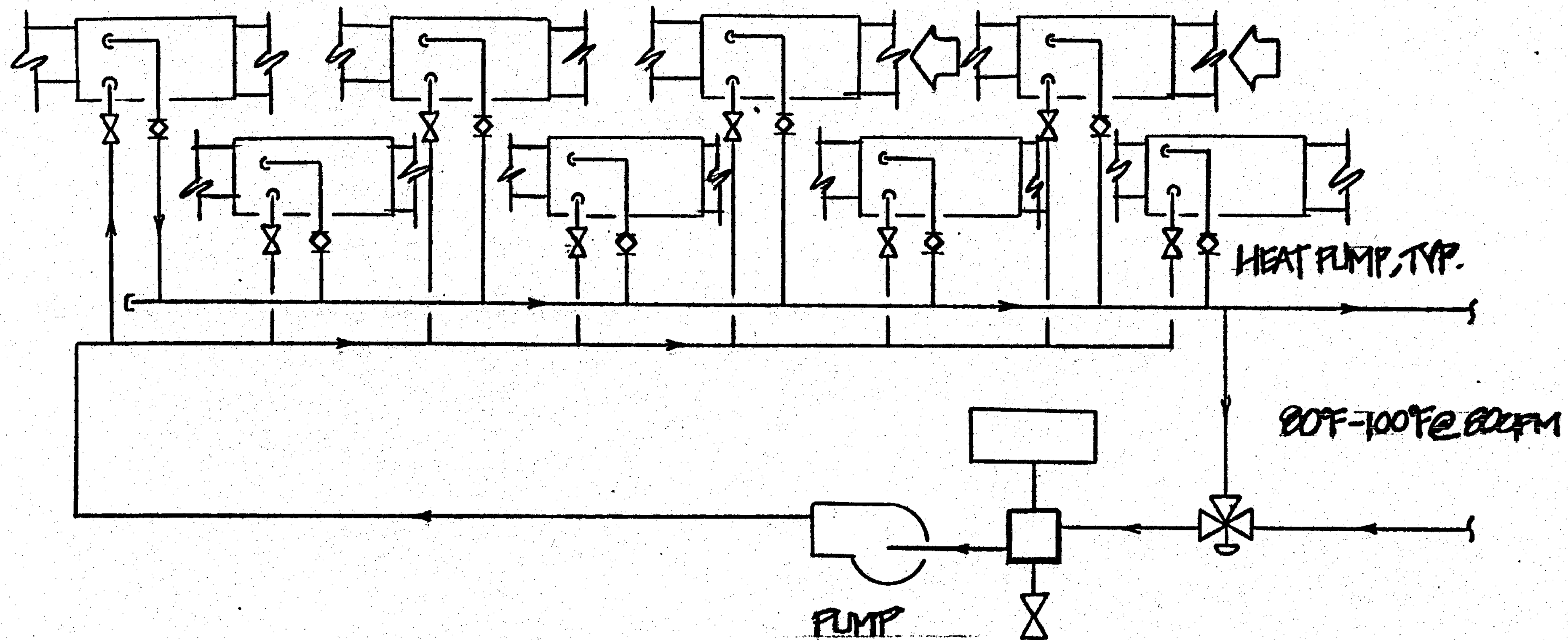
Geothermal Heat Pump Design Specifications

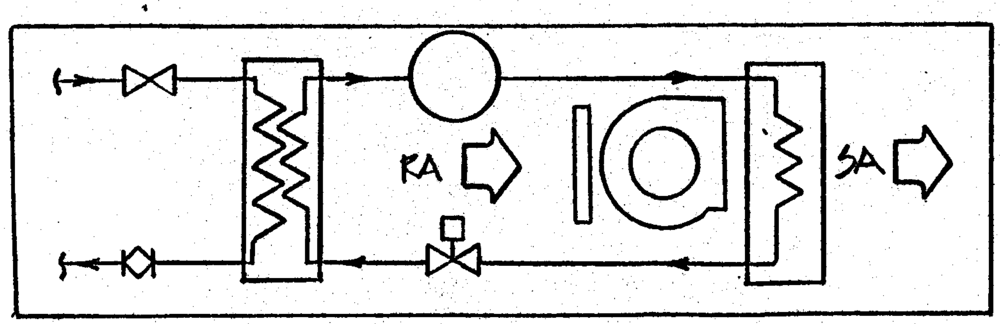
Proposed System and Modifications:

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

	Costs
A. Production Well System - Prorated by gpm	
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	Included Below
Contingency (10%)	
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	$54,000 \times 10^6$ 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		Geothermal System Cost	
Natural Gas	$238,680	Capital Cost (1980 Dollars)	$ 16,721,437
Electricity	-	First Year Operating Cost	101,121
Maintenance	70,000	First Year Maintenance Cost	166,062
Total	$308,680	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

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 x $\frac{1000}{2305}$ =	$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	$54,000 \times 10^6$ 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

ECONOMIC EVALUATIONS (cont'd)

Location: Durango   Facility: Ft. Lewis College

Geothermal Option: Heat Pump Coupled 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	$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

A. Production Well System -Prorated by gpm	Costs
Exploration	$ 5,250
Reservoir Engineering	10,500
Wells 23 @ $ 50,000 x 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 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

ECONOMIC EVALUATIONS

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

ECONOMIC EVALUATIONS (cont'd)

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

ECONOMIC EVALUATIONS

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

Geothermal Option: Heat Exchanger Coupled to Trunk Line

A. Simple Payback Calculation

Proposed Annual Conventional System Cost	
Natural Gas	$ 31,373
Electricity	0
Maintenance	3,580
Total	$ 31,373

Geothermal System Cost	
Capital Cost (1980 Dollars)	$ 1,364,447*
First Year Operating Cost	8,005
First Year Maintenance Cost	9,097*
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

ECONOMIC EVALUATIONS (cont'd)

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		End of		Present Value
Year	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year	Annual Savings	(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).