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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

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

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

1981

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BUENA VISTA

Two state-owned building complexes have been evaluated within the vicinity of Buena Vista: the Colorado State Reformatory south of Buena Vista and the State Highway Department Building in downtown Buena Vista.

The resource assessment for the Colorado State Reformatory is based upon the Cottonwood Canyon and Chalk Creek areas approximately six miles west and seven to eight miles southwest of Buena Vista, respectively. For the purposes of this analysis, three separate drilling locations for the geothermal wells have been evaluated - one at Cottonwood Canyon and two at Chalk Creek. The resource assessment indicates that 250°F to 350°F water may be available at flow rates of 150 to 250 gpm per well, at well depths of 300 to 500 feet (except for a drilling depth of 2000 to 3000 feet on the mesa north of Chalk Creek), and at concentrations of total dissolved solids of 250 to 350 mg/l. Gravity flow is possible from two of the drill sites to the Reformatory.

No specific resource assessment has been performed for the State Highway Department Building. Any extensive use of geothermal energy in downtown Buena Vista would likely tap into the pipeline from Cottonwood Canyon or Chalk Creek to the State Reformatory. Because of the small annual energy consumption of the building, it is not feasible to install a pipeline from the Reformatory to the Highway Building strictly for its use. Therefore, for the purposes of this appraisal, it is assumed that a warm to moderately hot (80°F to 100°F) shallow aquifer exists below the Highway Department Building which can be tapped for a water-to-air heat pump application.

One building retrofit engineering option and the three different drilling site options are evaluated for the Colorado State Reformatory. Complete replacement of the energy supplied by the existing natural gas fired steam boiler system is assumed. A new twin pipe hot water supply and return piping system is designed to provide at least 250°F geothermal water directly to the space heating equipment in the buildings. No additional terminal heating units are required, but a pumping bridge with a three-way mixing valve is added to each building to facilitate mixing of geothermal water with the building circulation water. The geothermal water exits the buildings at 180°F and is discharged to a surface disposal system. The relatively high chemical purity of the geothermal water permits it to be used for irrigation water for agricultural purposes on Reformatory acreage.

Retrofit engineering for the State Highway Department Building provides for a decentralized set of water-to-air heat pumps as the direct space heating mechanism. The existing array of natural gas fired unit heaters can be retained for a back-up or peaking system.

The geothermal energy economics for the Colorado State Reformatory are evaluated for the direct use of geothermal water derived from each of the three prospective drilling sites: Cottonwood Canyon, Chalk Creek No. 1, and Chalk Creek No. 2. The natural topographic downgrade from the Cottonwood and Chalk Creek No. 2 sites permits gravity flow of the geothermal water, whereas pumping is required from the Chalk Creek No. 1 site.

Continuous year-round operation of the geothermal heating system is prescribed for the Reformatory because of the large quantities of hot water required for cooking, laundry, bathing and cleaning purposes throughout the year, in addition to the space heating requirement during the cold months. Increasing maintenance costs for the existing 20 to 25-year old steam boiler and piping system are allowed for in the economic evaluations. Two rates of natural gas price escalation are evaluated: 15 percent per annum and 12 percent/9 percent per year (through 1984/through 2000).

The economic evaluations for the Highway Department Building are based upon obtaining 80°F to 100°F water from a shallow aquifer, with surface disposal of the discharge water. Operation for a period of 4320 hours per year is assumed.

Results of the economic evaluations for the Colorado State Reformatory show that the geothermal systems are highly competitive with the conventional fuel system and that the State could save large sums of money by retrofitting the Reformatory to a geothermal heating system. These results are a consequence of the high temperature and high quality of the geothermal water, even though the drill sites are six to eight miles away. The year round demand for hot water also contributes to the favorable economics.

The economics associated with the use of heat pumps at the Buena Vista Highway Department Building are also favorable. The only uncertainty is whether or not a shallow aquifer exists under the building site.

Institutional and environmental requirements for both of the Buena Vista facilities are minimal. If the well drilling site is placed at Chalk Creek No. 1, new federal leases or assignments of existing federal leases are required. The environmental factors are negligible because of the high quality of the geothermal water.

Detailed information on the Buena Vista facilities is provided in the following sections.

Resource Assessment for the Buena Vista Area

The Buena Vista geothermal resource is restricted to two reservoir areas within Chalk Creek and Cottonwood Canyon. Geothermal indicators at Chalk Creek include numerous hot springs and shallow wells ranging in

temperature from 135°F to 300°F and massive mineralization posed in the Chalk Cliffs. Cottonwood Canyon contains three hot springs and wells with temperatures up to 136°F, but identical mineralization as in Chalk Creek.

The Chalk Creek geothermal area is situated in a narrow valley eight miles southwest of Buena Vista. Within the valley are several hot water wells and hot springs, the most notable of these being the Hortense Hot Spring at 184°F (hottest springs in Colorado). Mt Princeton Hot Springs is 135°F and several wells with temperatures ranging from 160°F to greater than 300°F at shallow depths (Proprietary industrial data, 1980) are also found in the area. The geology of Chalk Creek is controlled by the north-south trending fault, and where this fault intersects with a cross fault paralleling Chalk Creek the geothermal activity is found (Figure 14). As hot waters have ascended these fault zones, they have extensively altered the rocks of the area; the Chalk Cliffs are an example.

Researchers project that the geothermal resources at well depths of less than 500 feet will be from 250°F to 350°F. Existing flow rates from the wells and springs in the Chalk Creek area are not excessively high. Mt. Princeton Hot Springs has the greatest flow in the valley at 175 gpm. Production rates in wells may average only 200 to 250 gpm per production well.

The Cottonwood Canyon geothermal area is within a narrow valley six miles west of Buena Vista. The hot springs in the area are the Cottonwood Hot Springs at 136°F, Jump Steady Hot Springs at 130°F and the Merrifield Hot Well at 115°F. The geology of this area is identical to that along Chalk Creek, but the magnitude of the mineral alteration is less extensive. The reservoir temperatures are projected to be from 250° to 300°F. Production rates are projected to be very low at 150 gpm per well, based upon the low rates of the existing hot springs and the apparent lack of permeability of the rocks and their associated fractures. In the vicinity of the fault zones the depth to geothermal resources is probably less than 300 feet. The geothermal resources in Cottonwood Canyon are probably limited to the immediate canyon itself. They extend eastward to the fault at the mouth of the canyon and westward for approximately one mile from Cottonwood Hot Springs (Figure 14).

Summaries of the two resource areas at Buena Vista are as follows:

	Chalk Creek	Cottonwood Canyon
Reservoir temperature:	250°F - 350°F (2)	250°F - 300°F (2)
Depth:	<500 feet (2)*	<300 feet (3)
Production/well:	200-250 gpm (1)	150 gpm (2)
Areal extent:	3.0+ square miles (2)	1.3 square miles (3)
Formation:	Fractures in the altered Mt. Princeton Quartz Monzonite	
TDS:	250-300 mg/l	<350 mg/l
Useable heat:	640 x 10 ¹¹ Btu (2)	230 x 10 ¹¹ Btu (2)

* Drilling depths on the mesa north of Chalk Creek would be from 2000 to 3000 feet (3).

Figure 14: Geologic map of the Buena Vista geothermal area, Chalk Creek and Cottonwood Canyon, Colorado. Those areas outlined in bold closed loops are projected to be the most realistic areal extents of the geothermal reservoirs. (Source: Pearl, 1979)

The geothermal resources near Buena Vista are probably the best of all those in this study. They have high reservoir temperatures (250°F to 350°F) at very shallow depths (less than 500 feet).

Pipeline Right-of-Way

Three different pipeline routes to the Colorado State Reformatory are evaluated, corresponding to the three different drilling sites at Cottonwood Canyon and Chalk Creek. The specifications for those three routes are as follows:

Cottonwood Canyon:

- Leg 1: From Cottonwood Hot Springs (elev, 8620') east along the highway for 1.24 miles to the crest of the canyon (8470').
- Leg 2: East-northeast through the Upper Arkansas Valley for 4.95 miles directly to the Colorado State Reformatory (7880').

	<u>distance</u>	<u>relief</u>	<u>grade</u>
Leg 1	1.24 mi.	-150'	-2%
Leg 2	4.95 mi.	-590'	-2%
	6.19 mi.	-740'	-2%

Chalk Creek No. 1

- Leg 1: From Mt. Princeton Hot Springs (8160') northeast along the hill front for 0.35 miles to the irrigation ditch (8160').
- Leg 2: Along the ditch 1.75 miles to the crest of the hill (8137').
- Leg 3: North along the section-line for 4.04 miles to Sailor's Ranch (7980').
- Leg 4: Northeast 1.59 miles to the Colorado State Reformatory (7880').

	<u>distance</u>	<u>relief</u>	<u>grade</u>
Leg 1	0.35 mi.	0'	-0-
Leg 2	1.75 mi.	-23'	-0.2%
Leg 3	4.04 mi.	-157'	-1%
Leg 4	1.59 mi.	-100'	-1%

Chalk Creek No. 2

- Leg 1: On the mesa near Frontier Ranch (8595') northeast for 1.36 miles to the junction of Dry Creek and the County Road (8192').
- Leg 2: North along the County Road for 3.85 miles to the Johnson Ditch (8050').

Leg 3: East-northeast 1.59 miles directly to the Colorado State Reformatory (7880').

	<u>distance</u>	<u>relief</u>	<u>grade</u>
Leg 1	1.36 mi.	-403'	-6%
Leg 2	3.85 mi.	-142'	-1%
Leg 3	1.59 mi.	-170'	-2%
	6.80 mi.	-715'	-2%

Production Well Costs and Well Engineering

The production well drilling costs differ for each drilling site at Buena Vista due to both well depth and geologic structure. The estimated well depths, well costs and pumping depths are listed below; all drilling is expected to encounter high temperature and highly altered rock structures.

<u>Drilling Site</u>	<u>Well Depth</u>	<u>Cost Per Well</u>	<u>Pumping Depth</u>
Cottonwood	300'	\$60,000	100'
Chalk Creek No. 1	500'	\$100,000	100'
Chalk Creek No. 2	2000'	\$135,000	300'

Building Retrofit Engineering for Colorado State Reformatory

Brief summary descriptions of the present steam heating system, assumptions for geothermal system, the advantages and disadvantages of a geothermal system, and the proposed geothermal system design specifications are presented below. A map of the Reformatory complex is shown in Figure 15.

Present Steam Heating System Description

1. Central steam plant, with
 - a. three 17,000 lb/hr (sea level) output boilers
 - b. 100 psi steam distribution system
 - c. 10-15 psi steam at heat exchanger/or unit heater in each building.
2. 90% of buildings use hot water heating (steam to water heat exchanger).
3. Each building with hot water heating has a pump circulation system.

Assumptions for Geothermal System

1. 250°F geothermal water at 35 psia is available at reformatory site from pipeline to resource area.
2. 90% of the hot water heating systems are assumed to be designed for 200°F water with a 20°F ΔT .
3. Geothermal water can be used directly because of its high purity.

Advantages of a Geothermal Retrofit

1. 250°F water is more than adequate for all water heating systems.
2. Geothermal water is low enough in solids to allow for direct use.
3. Drop in geothermal water temperature from 250°F to 180°F allows for minimal pumping requirements and pipe sizes.
4. The 180°F water leaving the system may be utilized for secondary heating (e.g. heating a fish hatchery, additional space heating, snow melting, etc.) before it is used as an irrigation water source (agriculture).
5. The present hot water heating systems will not have to be changed.

Disadvantages of a Geothermal Retrofit

1. 250°F water at 35 psig is not sufficient for conversion to steam.
2. Additional water distribution lines will be required.
3. Steam heated buildings must be converted to hot water.
4. Processes (cooling) requiring steam must require separate steam source or convert to another source of heat.

Geothermal System Design Specifications

Proposed System and Modifications:

1. Proposed system is a hot water distribution system to all buildings (250°F geothermal water).
2. The geothermal water will be mixed in each building with the building's hot water heating circulation system.
3. At design conditions, the geothermal water will leave the distribution system at 180°F; this energy can be used for additional heating.
4. Existing buildings using steam (10% of total) will be converted to hot water systems.
5. The existing steam distribution system will be used when the steam supply piping is at least as large as the hot water piping. A

companion insulated pipe will be installed along with the steam supply pipe to provide for return water.

6. In cases where the steam piping is too small, dual hot water return and supply lines will be installed to serve the necessary buildings.
7. In buildings presently using hot water heating, the steam to water heat exchanger will be removed and a pumping bridle with a 3-way mixing valve will be added to facilitate mixing of geothermal water with the building circulation water.
8. All present hot water heating terminal units will remain the same.
9. Buildings retrofitted from steam to water heating will use baseboard or hot water heating coils.
10. 250°F geothermal water @ 700 gpm (based on $\Delta T = 70^{\circ}\text{F}$) is required.

Engineering Design:

The new hot water distribution piping system is shown in Figure 16 . Figure 17 provides the design for the retrofit of a typical building from the existing steam to the geothermal hot water system.

Equipment Components and Cost Estimates:

	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total Cost</u>
■ Hot water distribution piping system			
2-4" Underground Conduit	360'	\$ 83	\$29,880
2-3" " "	340'	68	23,120
2-2½" " "	350'	55	19,250
2-1½" " "	720'	38	27,360
2-1¼" " "	140'	36	5,040
2-1" " "	1100'	30	33,000
1-6" Underground Conduit W/Insulating Jacket	420'	78	32,760
1-2½" " " " "	520'	40	23,600
1-2" " " " "	1150'	35	40,250
1-1½" " " " "	470'	30	14,100
1-1" " " " "	1580'	20	31,600
1-6" Above Ground Conduit (In Bldg)	1720'	30	51,600
1-4" " " " "	720'	25	18,000
	Subtotal		\$349,560

Figure 16: REFORMATORY GEOTHERMAL DISTRIBUTION SYSTEM

TYPICAL BLDG. RETROFIT
FOR GEOTHERMAL USE

FIGURE 17

	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total Cost</u>
• Conversion of Steam Heated Buildings (10% of Buildings)	40,002 S.F.	\$6	\$240,012
• Conversion of steam-to-water systems to geothermal mixing (20 modifications)	20	2,000	40,000
• Conversion of steam to hot water for DHW, cooking, laundry			<u>10,000</u>
		Subtotal	\$639,572
		Contingency (10%)	<u>\$63,957</u>
		TOTAL	\$703,529

Pipeline Costs for Alternative Routes from Drilling Sites

In prescribing the design specifications for the three pipeline routes, the design principle has been to size the piping to permit gravity flow if possible and to minimize pumping costs. Friction losses in the pipeline are accounted for and a final head of 260 feet is allowed for the Reformatory distribution system. The final specifications and costs are as follows:

Cottonwood Canyon (Gravity flow):

Total gravity head = 740 feet; friction loss = 480 feet.

<u>Pipe Size</u>	<u>Length</u>	<u>Unit Cost</u>	<u>Total Cost</u>
6"	9,934'	\$63	\$625,842
8"	22,749'	78	<u>1,774,422</u>
			\$2,400,264

Chalk Creek No. 1 (Pumped flow):

Total gravity head = 280 feet; friction loss = 1,224 feet.

Total pumping head = 1,240 feet.

<u>Pipe Size</u>	<u>Length</u>	<u>Unit Cost</u>	<u>Total Cost</u>
6"	40,814'	\$63	\$2,571,282

Chalk Creek No. 2 (Gravity flow):

Total gravity head = 715 feet; friction loss = 455 feet.

<u>Pipe Size</u>	<u>Length</u>	<u>Unit Cost</u>	<u>Total Cost</u>
6"	7,627'	\$63	\$480,501
8"	28,276'	78	<u>2,205,528</u>
			\$2,686,029

Retrofit Building Engineering for State Highway Department Building

The retrofit building engineering design specifications for the Highway Department Building in downtown Buena Vista are presented below. Figure 18 shows a schematic of the geothermal system using water-to-air heat pumps for the space heating requirements.

Present Conventional Fuel Heating System

<u>Building</u>	<u>Square Footage</u>	<u>Fuel</u>	<u>Heating Equipment</u>	<u>Peak Heat Load (Btu/hr)</u>
Garage	6,380	Natural Gas	Unit heaters (3)	480,000

Geothermal System Design Specifications

Proposed System and Modifications:

1. Retrofit to utilize geothermal hot water as source for water-to-air heat pumps.
2. Replace gas-fired unit heaters with water-to-air heat pumps.
3. Additional sheet metal is 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.

Engineering Design:

The design peak load of 480,000 Btu/hr can be accomplished with water-to-air heat pumps (COP = 4.0) utilizing a 100°F direct geothermal source at 70 gpm and a $\Delta T = 15^\circ\text{F}$.

Equipment Components and Cost Estimates:

<u>Component</u>	<u>Specifications</u>	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total Cost</u>
Heat Pumps	65,000 Btu/hr	7	\$1,250	\$8,750
Sheet Metal			1,000	1,000
Circulating Pump		1	1,000	1,000
Air Separator and Expansion Tank		1	1,200	1,200

WATER TO AIR HEAT PUMP

Figure 18

BUENA VISTA HIGHWAY DEPT.

Equipment Components and Cost Estimates-cont'd

<u>Component</u>	<u>Specifications</u>	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total Cost</u>
Distribution Piping		250'	16	\$4,000
Insulation		250'	6	1,500
Temperature Controller				875
Subtotal				\$18,325
Contingency (10%)				1,835
TOTAL				20,160

Economic Evaluations

Colorado State Reformatory

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 result of the calculations of the four economic measures for the geothermal option with three different drilling sites that are evaluated for the Colorado State Reformatory.

The total capital costs range from \$4,117,445 to \$4,642,421. The differences in capital costs for the three drilling sites are attributable to the variations in well depths and pipeline distances. The first year operating and maintenance costs for the geothermal system range from \$51,181 for gravity flow from Cottonwood Canyon to \$163,714 for the pumped flow from Chalk Creek No. 1; all are less than the \$368,000 operating and maintenance costs for the existing natural gas fired steam boiler system.

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

	<u>Cottonwood</u>	<u>Chalk Creek No. 1</u>	<u>Chalk Creek No. 2</u>
Simple Payback Period:	11 years	12 years	13 years
Total Annualized Cost:			
Geothermal:	\$562,871	\$819,544	\$691,077
Conventional:	\$1,159,497	\$1,159,497	\$1,159,497
Total Undiscounted Savings:	\$32,970,061	\$27,202,360	\$32,063,857
Total Present Value Savings:	\$9,215,012	\$7,333,888	\$8,597,520

All three geothermal options are highly favorable on all economic measures. A geothermal capital improvement at the Colorado State Reformatory would yield considerable energy cost savings for the State of Colorado.

CAPITAL COSTS

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Cottonwood

A. Production Well System

Costs

Exploration	\$ 30,000
Reservoir Engineering	60,000
Wells 5 @ \$ 60,000 (300 feet)	300,000
Well Pumps (5) 700gpm, 100ft-hd, 31HP	12,400
Valves and Controls	5,000
Contingency Funds (10%)	<u>Included</u>
Subtotal	402,900
Engineering Design Fee (10%)	<u>Included</u>
Total	\$ 402,900

B. Transmission Line System

Piping (32,683 ft.)	2,400,264
Pumps () gpm, ft-hd, HP	N.R.
Contingency (10%)	<u>240,026</u>
Subtotal	2,640,290
Engineering Design Fee (10%)	<u>264,029</u>
Total	\$2,904,319

C. Central Distribution System

Heat Exchanger, or	N.R.
Heat Pump	N.R.
Auxillary Building	-
Valves and Controls	-
Piping	349,560
Circulation Pumps ()	
gpm, ft-hd, HP	
Miscellaneous	-
Contingency (10%)	35,000
Subtotal	384,560
Engineering Design Fee (10%)	38,456
Total	\$ 423,016

D. Building(s) Retrofit HVAC System

Heating Units (10% of Buildings)	240,010
Retrofit Plumbing (20 modifications)	40,000
Valves and Controls	-
DHW, Cooking, Laundry Conversion	10,000
Contingency (10%)	29,000
Subtotal	319,010
Engineering Design Fee (10%)	31,900
Total	\$ 350,910

E. Reinjection/Disposal System

Reinjection Well(s): wells @ \$	N.R.
Piping (1000 ft.)	30,000
Pumps ()	N.R.
Controls and Valves	-
Contingency (10%)	3,000
Subtotal	33,000
Engineering Design Fee (10%)	3,300
Total	\$ 36,300

F. Grand Total \$4,117,445

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Cottonwood

Geothermal System

<u>Cost Item</u>	<u>Electricity Cost</u>	<u>Maintenance Cost/ (% of C. C.)</u>
A. Production Well System		
Pump electricity	\$ 9,113	\$ 16,116 (4%)
B. Transmission Line System	-	14,522 (1/2%)
C. Central Distribution System		
Heat Pump electricity	-	
Circ. Pump electricity	-	4,230 (1%)
D. Building(s) Retrofit HVAC System	-	7,018 (2%)
E. Reinjection/Disposal System	-	182 (1/2%)
Total	\$ 9,113	\$ 42,068

Conventional Fuel System

Type of System: Natural Gas Fired Steam Boilers

<u>Fuel Cost</u>			<u>Maintenance Cost</u>	
Total Annual Fuel Load	85,000 x 10 ⁶	Btu/yr	Percent of Associated	2%
1980-81 Estimated Fuel Price	\$3.80/10 ⁶	Btu	Capital Costs	
1980-81 Estimated Total Annual Fuel Cost	\$323,000		Estimated Capital Costs	\$2,000,000+
			Estimated Maintenance Cost	\$45,000
<u>Electricity Cost</u>				
1980-81 Estimated Total Annual Electricity Cost	\$ 3,500			

ECONOMIC EVALUATIONS

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Cottonwood

A. Simple Payback Calculation

Current Annual Conventional System Cost

Natural Gas	\$ 323,000
Electricity	3,500
Maintenance	45,000
Total	\$ 371,500

Geothermal System Cost

Capital Cost (1980 Dollars)	\$ 4,117,445
First Year Operating Cost	9,113
First Year Maintenance Cost	42,068
Total	\$ 4,168,626

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

B. Annual Cost Comparison

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

<u>Cost Item</u>	<u>Conventional System Annualized Cost</u>	<u>Geothermal System Annualized Cost</u>
Capital Investment	\$ -	\$ 483,635
Electricity (9%/yr. escalation)	6,864	17,872
Maintenance (10%/yr. escalation)	65,641	61,364
Conventional Fuel (15%/yr. escalation)	1,086,992	-
Total Annualized Cost	\$1,159,497	\$ 562,871

ECONOMIC EVALUATIONS (cont'd)

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Cottonwood

C. Total Savings and Payback Period

Year	<u>Conventional System</u>			<u>Geothermal System</u>		<u>End of</u>	<u>Annual Savings</u>	<u>Present Value</u>
	<u>Fuel (15%)</u>	<u>Elect. (9%)</u>	<u>Maint. (10%)</u>	<u>Elect. (9%)</u>	<u>Maint. (10%)</u>	<u>Year</u>		<u>(i = 10%)</u>
1980						0		\$291,202
1981	\$323,000	\$3,500	\$45,000	\$9,113	\$42,068	1	\$320,319	304,576
1982	371,450	3,815	49,500	9,933	46,275	2	368,557	318,587
1983	427,168	4,158	54,450	10,827	50,902	3	424,047	333,219
1984	491,243	4,533	59,895	11,802	55,993	4	487,876	348,510
1985	564,929	4,941	65,884	12,864	61,592	5	561,298	364,528
1986	649,668	5,385	72,473	14,021	67,751	6	645,754	381,256
1987	747,119	5,870	79,720	15,283	74,526	7	742,900	398,689
1988	859,186	6,398	87,692	16,659	81,979	8	854,638	416,960
1989	988,064	6,974	96,461	18,158	90,176	9	983,165	436,000
1990	1,136,274	7,602	106,108	19,792	99,194	10	1,130,998	456,011
1991	1,306,715	8,286	116,718	21,574	109,114	11	1,301,031	476,818
1992	1,502,722	9,031	128,390	23,515	120,025	12	1,496,603	498,732
1993	1,728,131	9,844	141,229	25,632	132,027	13	1,721,545	521,403
1994	1,987,350	10,730	155,352	27,939	145,230	14	1,980,263	545,312
1995	2,285,453	11,696	170,887	30,453	159,753	15	2,277,830	570,128
1996	2,628,270	12,749	187,976	33,194	175,728	16	2,620,073	596,110
1997	3,022,511	13,896	206,774	36,181	193,301	17	3,013,699	623,608
1998	3,475,888	15,147	227,451	39,438	212,631	18	3,466,417	651,893
1999	3,997,271	16,510	250,196	42,987	233,895	19	3,987,115	681,470
2000	4,596,861	17,996	275,216	46,856	257,284	20	4,585,933	
Totals							\$32,970,061	\$ 9,215,012

Capital Investment \$4,117,445

	<u>Undiscounted</u>	<u>Present Value (discounted at 10%)</u>
Total 20-Year Savings	\$32,970,061	\$9,215,012
Payback Period	7-8 years	11-12 years

CAPITAL COSTS

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Pumped Flow from Chalk Creek No. 1

A. Production Well System

Costs

Exploration	\$ 30,000
Reservoir Engineering	60,000
Wells 3 @ \$ 100,000	300,000
Well Pumps (3) 700 gpm, 110 ft-hd, 34 HP	13,600
Valves and Controls	5,000
Contingency Funds (10%)	<u>Included</u>
Subtotal	408,600
Engineering Design Fee (10%)	<u>Included</u>
Total	\$ 408,600

B. Transmission Line System

Piping (40,814 ft.)	\$2,571,282
Pumps () 700 gpm, 1204 ft-hd, 374 HP	74,800
Contingency (10%)	<u>264,608</u>
Subtotal	2,910,690
Engineering Design Fee (10%)	<u>291,069</u>
Total	\$3,201,759

C. Central Distribution System

Heat Exchanger, or	N.R.
Heat Pump	N.R.
Auxillary Building	-
Valves and Controls	-
Piping	349,560
Circulation Pumps ()	N.R.
gpm, ft-hd, HP	
Miscellaneous	35,000
Contingency (10%)	<u>384,560</u>
Subtotal	38,456
Engineering Design Fee (10%)	<u></u>
Total	\$ 423,016

D. Building(s) Retrofit HVAC System

Heating Units	240,010
	40,000
Retrofit Plumbing	-
Valves and Controls	10,000
DHW, Cooking, Laundry Conversion	29,000
Contingency (10%)	<u>319,010</u>
Subtotal	31,900
Engineering Design Fee (10%)	<u></u>
Total	\$ 350,910

E. Reinjection/Disposal System

Reinjection Well(s): wells @ \$	N.R.
Piping (100 ft.)	30,000
Pumps ()	N.R.
Controls and Valves	3,000
Contingency (10%)	<u>33,000</u>
Subtotal	3,300
Engineering Design Fee (10%)	<u></u>
Total	\$ 36,300

F. Grand Total

\$4,420,585

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Pumped Flow from Chalk Creek No. 1

Geothermal System

<u>Cost Item</u>	<u>Electricity Cost</u>	<u>Maintenance Cost/ (% of C. C.)</u>
A. Production Well System		
Pump electricity	\$ 9,993	\$ 16,344 (4%)
B. Transmission Line System	109,938	16,009 (1½%)
C. Central Distribution System		
Heat Pump electricity	-	4,230 (1%)
Circ. Pump electricity	-	
D. Building(s) Retrofit HVAC System	-	7,018 (2%)
E. Reinjection/Disposal System	-	182 (½%)
Total	\$ 119,931	\$ 43,783

Conventional Fuel System

Type of System: Natural Gas Fired Steam Boilers

<u>Fuel Cost</u>		<u>Maintenance Cost</u>	
Total Annual Fuel Load	85,000 x 10 ⁶ Btu/yr	Percent of Associated	2%
1980-81 Estimated Fuel Price	\$3.80/10 ⁶ Btu	Capital Costs	
1980-81 Estimated Total Annual Fuel Cost	\$ 323,000	Estimated Capital Costs	\$2,000,000+
		Estimated Maintenance Cost	\$ 45,000

<u>Electricity Cost</u>
1980-81 Estimated Total Annual Electricity Cost
\$ 3,500

ECONOMIC EVALUATIONS

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Pumped Flow from Chalk Creek No. 1

A. Simple Payback Calculation

Current Annual Conventional System Cost

Natural Gas	\$ 323,000
Electricity	3,500
Maintenance	45,000
Total	\$ 371,500

Geothermal System Cost

Capital Cost (1980 Dollars)	\$ 4,420,585
First Year Operating Cost	119,931
First Year Maintenance Cost	43,783
Total	\$ 4,584,299

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}} = 12 \text{ years}$

B. Annual Cost Comparison

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

<u>Cost Item</u>	<u>Conventional System Annualized Cost</u>	<u>Geothermal System Annualized Cost</u>
Capital Investment	\$ -	\$ 519,242
Electricity (9%/yr. escalation)	6,864	235,205
Maintenance (10%/yr. escalation)	65,641	65,097
Conventional Fuel (15%/yr escalation)	1,086,992	-
Total Annualized Cost	\$1,159,497	\$ 819,544

ECONOMIC EVALUATIONS (cont'd)

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Pumped Flow from Chalk Creek No. 1

C. Total Savings and Payback Period

Year	Conventional System			Geothermal System		End of	Annual Savings	Present Value
	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year		(i = 10%)
1980						0		
1981	\$323,000	\$3,500	\$45,000	\$119,931	\$43,783	1	\$207,786	\$188,898
1982	371,450	3,815	49,500	130,725	48,161	2	245,879	203,194
1983	427,168	4,158	54,450	142,490	52,977	3	290,309	218,109
1984	491,243	4,533	59,895	155,314	58,275	4	342,082	233,642
1985	564,929	4,941	65,885	169,292	64,103	5	402,360	249,825
1986	649,668	5,385	72,473	184,529	70,513	6	472,484	266,717
1987	747,119	5,870	79,720	201,136	77,564	7	554,009	284,317
1988	859,186	6,398	87,692	219,239	85,321	8	648,716	302,626
1989	988,064	6,974	96,462	238,970	93,853	9	758,677	321,755
1990	1,136,274	7,602	106,108	260,477	103,234	10	886,273	341,658
1991	1,306,715	8,286	116,718	283,920	113,562	11	1,034,237	362,500
1992	1,502,722	9,032	128,390	309,473	124,918	12	1,205,753	384,153
1993	1,728,131	9,844	141,229	337,326	137,410	13	1,404,468	406,874
1994	1,987,350	10,730	155,352	367,685	151,151	14	1,634,596	430,389
1995	2,285,453	11,696	170,887	406,777	166,266	15	1,900,993	455,098
1996	2,628,271	12,749	187,976	436,847	182,892	16	2,209,257	480,734
1997	3,022,512	13,896	206,774	476,163	201,182	17	2,565,837	507,523
1998	3,475,888	15,147	227,451	519,017	221,230	18	2,978,169	535,773
1999	3,997,272	16,510	250,196	565,729	243,430	19	3,454,819	564,863
2000	4,596,862	17,996	275,216	616,645	267,773	20	4,005,656	595,240
Totals							\$27,202,360	\$7,333,888

Capital Investment \$4,420,585

	<u>Undiscounted</u>	<u>Present Value (discounted at 10%)</u>
Total 20-Year Savings	\$27,202,360	\$7,333,888
Payback Period	10 years	15 years

CAPITAL COSTS

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Chalk Creek No. 2

A. Production Well System

	<u>Costs</u>
Exploration	\$ 40,500
Reservoir Engineering	81,000
Wells 3 @ \$ 135,000 (2,000 feet)	405,000
Well Pumps (3) 700 gpm, 400ft-hd, 124 HP	49,600
Valves and Controls	5,000
Contingency Funds (10%)	<u>Included</u>
Subtotal	581,100
Engineering Design Fee (10%)	<u>Included</u>
Total	\$ 581,100

B. Transmission Line System

Piping (35,904 ft.)	2,686,029
Pumps () gpm, ft-hd, HP	^{N.R.}
Contingency (10%)	268,603
Subtotal	<u>2,954,632</u>
Engineering Design Fee (10%)	295,463
Total	<u>\$ 3,251,095</u>

C. Central Distribution System

Heat Exchanger, or	N.R.
Heat Pump	N.R.
Auxillary Building	-
Valves and Controls	-
Piping	349,560
Circulation Pumps ()	
gpm, ft-hd, HP	-
Miscellaneous	35,000
Contingency (10%)	
Subtotal	384,560
Engineering Design Fee (10%)	38,456
Total	\$ 423,016

D. Building(s) Retrofit HVAC System

Heating Units (10% of Buildings)	240,010
Retrofit Plumbing (20 modifications)	40,000
Valves and Controls	-
DHW, Cooking, Laundry Conversion	10,000
Contingency (10%)	29,000
Subtotal	319,010
Engineering Design Fee (10%)	31,900
Total	\$ 350,910

E. Reinjection/Disposal System -Surface

Reinjection Well(s): wells @ \$	N.R.
Piping (100 ft.)	30,000
Pumps ()	N.R.
Controls and Valves	3,000
Contingency (10%)	
Subtotal	33,000
Engineering Design Fee (10%)	3,300
Total	\$ 36,300

F. Grand Total

\$4,642,421

ANNUAL OPERATING AND MAINTENANCE COSTS
(1980 Dollars)

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Chalk Creek No. 2

Geothermal System

<u>Cost Item</u>	<u>Electricity Cost</u>	<u>Maintenance Cost/ (% of C. C.)</u>
A. Production Well System Pump electricity 124 HP	\$ 36,452	\$23,244 (4%)
B. Transmission Line System	-	16,255 (1½%)
C. Central Distribution System Heat Pump electricity Circ. Pump electricity	- - -	4,230 (1%)
D. Building(s) Retrofit HVAC System	-	7,018 (2%)
E. ReInjection/Disposal System	-	182 (½%)
Total	\$ 36,452	\$ 50,929

Conventional Fuel System

Type of System: Natural Gas Fired Steam Boilers

<u>Fuel Cost</u>		<u>Maintenance Cost</u>	
Total Annual Fuel Load	85,000 x 10 ⁶ Btu/yr	Percent of Associated	2%
1980-81 Estimated Fuel Price	\$3.80/10 ⁶ Btu	Capital Costs	
1980-81 Estimated Total Annual Fuel Cost	\$ 323,000	Estimated Capital Costs	\$2,000,000+
		Estimated Maintenance Cost	\$ 45,000

<u>Electricity Cost</u>
1980-81 Estimated Total Annual Electricity Cost
\$ 3,500

ECONOMIC EVALUATIONS

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Chalk Creek No. 2

A. Simple Payback Calculation

Current Annual Conventional System Cost

Natural Gas	\$ 323,000
Electricity	3,500
Maintenance	<u>45,000</u>
Total	\$ 371,500

Geothermal System Cost

Capital Cost (1980 Dollars)	\$ 4,642,421
First Year Operating Cost	36,452
First Year Maintenance Cost	<u>50,929</u>
Total	\$ 4,729,802

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}} = 13 \text{ years}$

B. Annual Cost Comparison

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

<u>Cost Item</u>	<u>Conventional System Annualized Cost</u>	<u>Geothermal System Annualized Cost</u>
Capital Investment	\$ -	\$ 545,299
Electricity (9%/yr. escalation)	6,864	71,489
Maintenance (10%/yr. escalation)	65,641	74,289
Conventional Fuel (15%/yr. escalation)	1,086,992	-
Total Annualized Cost	<u>\$1,159,497</u>	<u>\$ 691,077</u>

ECONOMIC EVALUATIONS (cont'd)

Location: Buena Vista

Facility: Colorado State Reformatory

Geothermal Option: Direct Heating with Gravity Flow from Chalk Creek No. 2

C. Total Savings and Payback Period

Year	Conventional System			Geothermal System		End of	Annual Savings	Present Value (i = 10%)
	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year		
1980						0		
1981	\$323,000	\$3,500	\$45,000	\$36,452	\$50,929	1	\$284,119	\$258,293
1982	371,450	3,815	49,500	39,733	56,022	2	329,010	271,894
1983	427,168	4,158	54,450	43,309	61,624	3	380,843	286,127
1984	491,243	4,533	59,895	47,206	67,786	4	440,679	300,984
1985	564,929	4,941	65,884	51,455	74,565	5	509,734	316,494
1986	649,668	5,385	72,473	56,086	82,022	6	589,418	332,726
1987	747,119	5,870	79,720	61,134	90,224	7	681,351	349,669
1988	859,186	6,398	87,692	66,636	99,246	8	787,394	367,319
1989	988,064	6,974	96,461	72,633	109,171	9	909,695	385,802
1990	1,136,274	7,602	106,108	79,170	120,088	10	1,050,726	405,055
1991	1,306,715	8,286	116,718	86,295	132,097	11	1,213,327	425,271
1992	1,502,722	9,031	128,390	94,062	145,306	12	1,400,775	446,287
1993	1,728,131	9,844	141,229	102,527	159,837	13	1,616,840	468,399
1994	1,987,350	10,730	155,352	111,755	175,821	14	1,865,856	491,280
1995	2,285,453	11,696	170,887	121,813	193,403	15	2,152,820	515,385
1996	2,628,270	12,749	187,976	132,776	212,743	16	2,483,476	540,404
1997	3,022,511	13,896	206,774	144,726	234,017	17	2,864,438	566,586
1998	3,475,888	15,147	227,451	157,751	257,419	18	3,303,316	594,267
1999	3,997,271	16,510	250,196	171,948	283,161	19	3,808,868	622,750
2000	4,596,861	17,996	275,216	187,424	311,477	20	4,391,172	652,528
Totals							\$31,063,857	\$ 8,597,520

Capital Investment \$4,642,421

	<u>Undiscounted</u>	<u>Present Value (discounted at 10%)</u>
Total 20-Year Savings	\$31,063,857	\$8,597,520
Payback Period	8-9 years	13 years

State Highway Department 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 heat pump option that are evaluated for the State Highway Department Building in downtown Buena Vista.

The total capital cost for the water-to-air heat pump system is estimated at \$34,253, if warm to moderately hot water can be obtained from a shallow aquifer at the building site. The first year operating and maintenance cost for the heat pump system is \$1,490 compared to \$2,964 for the conventional system.

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

	<u>Heat Pump System</u>
Simple Payback Period:	12 years
Total Annualized Cost:	
Geothermal:	\$ 6,600
Conventional:	\$ 9,021
Total Undiscounted Savings:	\$200,629
Total Present Value Savings:	\$ 53,800

A heat pump system is clearly economically competitive with the conventional fuel system at the Highway Department Building.

CAPITAL COSTS

Location: Buena Vista

Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well on-site

A. Production Well System

Costs

Exploration	\$ 900
Reservoir Engineering	N.R.
Wells 1 @ \$ 9,000 (300 feet)	9,000
Well Pumps (1) 70 gpm, 140 ft-hd, 4.3 HP	1,075
Valves and Controls	500
Contingency Funds (10%)	<u>Included</u>
Subtotal	11,475
Engineering Design Fee (10%)	<u>Included</u>
Total	\$ 11,475

B. Transmission Line System

Piping (50 ft.) Insulated	1,100
Pumps () gpm, ft-hd, HP	N.R.
Contingency (10%)	<u>110</u>
Subtotal	1,210
Engineering Design Fee (10%)	<u>121</u>
Total	\$ 1,331

C. Central Distribution System

N.A.

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

\$ -0-

D. Building(s) Retrofit HVAC System

Heating Units
7 Heat Pumps (cop=4.0) @ \$1,250
Retrofit Plumbing
Valves and Controls

Contingency (10%)
Subtotal
Engineering Design Fee (10%)
Total

8,750
6,500
2,075

1,732

19,057

1,906

\$ 20,963

E. Reinjection/Disposal System-Surface

Reinjection Well(s): wells @ \$
Piping (50 ft.)
Pumps ()
Controls and Valves
Contingency (10%)
Subtotal
Engineering Design Fee (10%)
Total

N.R.
400

N.R.

-
40

440

44

\$ 484

F. Grand Total

\$34,253

ANNUAL OPERATING AND MAINTENANCE COSTS

(1980 Dollars)

Location: Buena Vista

Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well On-site

Geothermal System

<u>Cost Item</u>	<u>Electricity Cost</u>	<u>Maintenance Cost/ (% of C. C.)</u>
A. Production Well System Pump electricity	\$ 623	\$ 459 (4%)
B. Transmission Line System	-	13 (1%)
C. Central Distribution System Heat Pump electricity Circ. Pump electricity	-	-
D. Building(s) Retrofit HVAC System	180	210 (1%)
E. Reinjection/Disposal System	-	5 (1%)
Total	\$ 803	\$ 687

Conventional Fuel System

Type of System: Natural Gas Fired Unit Heaters

<u>Fuel Cost</u>		<u>Maintenance Cost</u>	
Total Annual Fuel Load	694 x 10 ⁶ Btu/yr	Percent of Associated	2%
1980-81 Estimated Fuel		Capital Costs	
Price	<u>\$3.55/10⁶Btu</u>	Estimated Capital	\$ 25,000
1980-81 Estimated Total		Costs	
Annual Fuel Cost	\$ 2,464	Estimated Maintenance	
		Cost	\$ 500
<u>Electricity Cost</u>			
1980-81 Estimated Total			
Annual Electricity Cost	\$ -0-		

ECONOMIC EVALUATIONS

Location: Buena Vista

Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well on-site

A. Simple Payback Calculation

Current Annual Conventional System Cost

Natural Gas	\$2,464
Electricity	0
Maintenance	500
Total	\$2,964

Geothermal System Cost

Capital Cost (1980 Dollars)	\$ 34,253
First Year Operating Cost	803
First Year Maintenance Cost	687
Total	\$ 35,743

Simple Payback Period: $\frac{\text{Total Geothermal System Cost}}{\text{Total Conventional System Cost}} = 12 \text{ years}$

B. Annual Cost Comparison

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

<u>Cost Item</u>	<u>Conventional System Annualized Cost</u>	<u>Geothermal System Annualized Cost</u>
Capital Investment	\$ -	\$ 4,023
Electricity (9%/yr. escalation)	0	1,575
Maintenance (10%/yr. escalation)	729	1,002
Conventional Fuel (15%/yr. escalation)	8,292	-
Total Annualized Cost	\$9,021	\$ 6,600

ECONOMIC EVALUATIONS (cont'd)

Location: Buena Vista

Facility: Highway Department Building

Geothermal Option: Heat Pump with Shallow Well On-site

C. Total Savings and Payback Period

Year	Conventional System			Geothermal System		End of	Annual Savings	Present Value
	Fuel (15%)	Elect. (9%)	Maint. (10%)	Elect. (9%)	Maint. (10%)	Year		(i = 10%)
1980						0		
1981	\$2,464	-0-	\$500	\$803	\$687	1	\$1,474	\$1,340
1982	2,834		550	875	756	2	1,753	1,449
1983	3,259		605	954	831	3	2,079	1,562
1984	3,747		666	1,040	914	4	2,459	1,680
1985	4,310		732	1,133	1,006	5	2,903	1,802
1986	4,956		805	1,236	1,106	6	3,419	1,930
1987	5,699		886	1,347	1,217	7	4,021	2,064
1988	6,554		974	1,468	1,339	8	4,721	2,202
1989	7,537		1,072	1,600	1,473	9	5,536	2,348
1990	8,668		1,179	1,744	1,620	10	6,483	2,499
1991	9,968		1,297	1,901	1,782	11	7,582	2,657
1992	11,463		1,427	2,072	1,960	12	8,858	2,822
1993	13,183		1,569	2,259	2,156	13	10,337	2,995
1994	15,161		1,726	2,462	2,372	14	12,053	3,174
1995	17,435		1,899	2,683	2,609	15	14,042	3,362
1996	20,050		2,089	2,925	2,870	16	16,344	3,556
1997	23,057		2,298	3,188	3,157	17	19,010	3,760
1998	26,516		2,527	3,475	3,472	18	22,096	3,975
1999	30,493		2,780	3,788	3,820	19	25,665	4,196
2000	35,067		3,058	4,129	4,202	20	29,794	4,427
Totals							\$ 200,629	\$ 53,800

Capital Investment \$34,253

	<u>Undiscounted</u>	<u>Present Value (discounted at 10%)</u>
Total 20-Year Savings	\$200,629	\$53,800
Payback Period	11 years	17years

Institutional Requirements

If the Cottonwood drilling site is chosen for the Reformatory geothermal system, private leases would be needed for the surface rights and the geothermal rights. Right-of-way to cross private land would be required, along with right-of-way along County Road 306 near the drill site.

If the Chalk Creek No. 1 site is chosen, private surface and geothermal rights would be needed. Some state and some private right-of-ways would be needed (Coe & Forman, 1980). If the Chalk Creek No. 2 site were chosen, federal as well as private leases are currently held by a private company. If this were the preferred site, it might be advisable to attempt to negotiate an agreement with that company to obtain the geothermal rights from them. Right-of-way from the County as well as private right-of-way for the pipelines would be needed.

For any of the alternatives, a Special Use Permit from the County would likely be needed for well drilling, along with a County building permit. Applications would be submitted to the County Administrator. The County Administrator can issue the building permit. He would refer the Special Use Permit Application to the Board of Adjustment for their review, which would include a 15-day posting period to allow public comment (Robert Stotler, pers. comm., 1981).

For the Highway Department Building, a City well permit from the Board of Trustees is necessary, usually requiring payment of a \$60 fee. For retrofitting, a remodeling permit must also be obtained from the Board of Trustees. Applications are submitted to the City Clerk. A permit fee is normally charged, based on the project cost, but might be waived for a government agency (Julie Hupper, pers. comm., 1981).

Environmental Considerations

No significant environmental impacts from geothermal development can be identified at this site from the information available. The U.S. Forest Service recently completed an extensive environmental assessment relative to geothermal leasing in the Chalk Creek resource area. It showed that no significant impact was likely from leasing federal lands for geothermal exploration and development. The possibility of water pollution, noise, visual impact, climatic changes, wildlife impact, land disturbance, land subsidence and seismicity from large scale geothermal development were discussed but were considered to be mitigable impacts. The nuisance of pos-

sible odors from hydrogen sulfide emission was discussed but not considered likely at this site (Rupp,1980).

For limited development of the nature discussed in this study, the potential for impact is much less. Review of the water chemistry indicated that there is a high fluoride content. However, the water from local springs is consumed for drinking and other domestic purposes. No other threats of contamination by surface disposal are evident.