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Residential and Commercial
Space Heating and Cooling
With Possible Greenhouse Operation;
Baca Grande Development
San Luis Valley, Colorado

Final Report

Steven W. Goering
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Glenn E. Coury
Eugene A. Fritzler

MASTER

May 1980

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Coury and Associates, Inc.
Lakewood, Colorado (U.S.A.)

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

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POSSIBLE GREENHOUSE OPERATION; BACA GRANDE DEVELOPMENT,
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7625 West 5th Avenue
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May 1980

Prepared for the

IDAHO OPERATIONS OFFICE
DEPARTMENT OF ENERGY
DIVISION OF GEOTHERMAL ENERGY

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Coury and Associates, Inc.

ABSTRACT

A feasibility study was performed to evaluate the potential of multi-purpose applications of moderate-temperature geothermal waters in the vicinity of the Baca Grande community development in the San Luis Valley, Colorado. The project resource assessment, based on a thorough review of existing data, indicates that a substantial resource likely exists in the Baca Grande region capable of supporting residential and light industrial activity. Engineering designs were developed for geothermal district heating systems for space heating and domestic hot water heating for residences, including a mobile home park, an existing motel, a greenhouse complex, and other small commercial uses such as aquaculture. In addition, a thorough institutional analysis of the study area was performed to highlight factors which might pose barriers to the ultimate commercial development of the resource. Finally, an environmental evaluation of the possible impacts of the proposed action was also performed.

The feasibility evaluation indicates the economics of the residential areas are dependent on the continued rate of housing construction. If essentially complete development could occur over a 30-year period, the economics are favorable as compared to existing alternatives. For the commercial area, the economics are good as compared to existing conventional energy sources. This is especially true as related to proposed greenhouse operations. The institutional and environmental analyses indicate that no significant barriers to development are apparent.

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There are numerous individuals who have made significant contributions to the development of this study. We wish to express our appreciation for their assistance.

First, Mr. Gerald W. Ricker and the Baca Grande Corporation provided excellent cooperation and also a significant direct cost-sharing support throughout the duration of the study effort.

Dr. Richard W. Davis ably assembled and evaluated a broad spectrum of materials describing the hydrothermal potential of the Baca Grande study area. Messrs. Melvin Stuart, Mark Daily, Michael Wynn, and Ralph Lopez, of Melvin Stuart and Associates, conducted the in-depth institutional analysis of the study area within the context of the San Luis Valley region. Mr. Donald Stuart of Coe, Van Loo and Jaschke Engineering, Inc., contributed significantly to the engineering design of the residential geothermal distribution and collection systems. Mr. Jay D. Dick developed portions of the Environmental Report, and Dr. Richard T. Meyers of Western Energy Planners Ltd., performed portions of the final economic analysis.

Finally, Ms. Flora K. Walker diligently, proficiently, and patiently typed our interim and final project reports.

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I. SUMMARY

Located just north of the Great Sand Dunes National Monument in the San Luis Valley, Colorado, the Baca Grande resort and residential development is nestled in the foothills of the rugged Sangre de Cristo range of the Rocky Mountains at an elevation of 7,500 feet. The development is platted into six main subdivisions covering over 14,000 acres; these subdivisions represent more than 6,300 individual lots, over half of which have been sold. The Baca Grande will provide general utilities including water, sewer, electricity, and telephone to the majority of these lots. To complement the subdivision development, the Corporation has also constructed the 40-room Baca Grande Inn, a golf course, rodeo and horseback riding facilities, and a full set of tennis courts. The objective of the project summarized herein is to develop feasibility engineering designs and associated economic evaluations of district geothermal systems capable of providing all space heating and hot water heating needs of the Baca Grande residential and light commercial areas. The Baca Grande is expressing an active interest in potential geothermal systems development for the region.

A review and analysis of the existing data pertaining to the Baca Grande study area indicates that a resource likely exists in the region capable of supporting residential and light industrial development. Water temperatures of 150°F are estimated at depths of 2,000 feet. The resource is most promising within the boundaries of the Baca Grande graben, which is a deep, long sediment filled trough or valley which parallels the western slope of the foothills. This graben covers a large areal extent and allows production wells to be optimally located so as to minimize surface piping costs. The resource water quality is expected to be good, with projected dissolved solids concentrations of less than 1,000 mg/l; well production rates are estimated at 1,000 gallons per minute. Existing irrigation wells were surveyed and chemical analyses were conducted which verified the suggested thermal profile and indicated chemical pre-treatment of the waters will not be required. Geothermal system water use will be essentially nonconsumptive in that the cooled geothermal waters will be reinjected into the producing aquifer; therefore, existing water use patterns in the general area will be maintained.

Feasibility geothermal system designs were developed for the two principal areas of development activity. These two regions are the "residential" subdivisions and the "commercial" region, the latter of which includes the Inn, the mobile home subdivision, and the light industrial park. A comprehensive review of available piping materials was conducted to provide a sound basis for the engineering design considerations of the two geothermal systems. For the distribution systems delivering hot water to the users, pre-insulated and uninsulated concrete asbestos; pre-insulated carbon steel, and pre-insulated copper are the preferred materials of construction, the specific choice being dependent on cost, pipe capacity, and pressure ratings. Pre-insulated fiberglass with an outer PVC covering should also be considered for district heating applications. The collection system carrying the cooled waters to disposal is not insulated and consists of small diameter high density polyethylene and larger diameter concrete asbestos pipe.

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The "residential" area district heating system was designed to serve 4,251 houses requiring 27,100 gpm of hot geothermal water to meet peak design space heating and hot water heating needs. Important design considerations are the flexibility required to economically serve the heating system during phased periods of housing construction, and the engineering requirements associated with the extensive elevation changes which occur throughout the platted foothills subdivisions. Two basic alternatives were evaluated economically, the major difference being the rate of housing construction as the development matures. The 30-year analysis indicated that geothermal energy costs to the user will average \$10.94-11.90 per million Btu for the case of complete development over the 30-year period. The comparable cost for electrical heating is \$10.05 per million Btu based on the existing rate structure. To assure a complete cost estimate, the distribution and collection piping systems were designed right up to the actual housing location as compared to the edge of the lots. This eliminates future individual tap fees.

The costs presented above are based on a zero-percent inflation rate. A parametric analysis of the effect of inflation rates of zero to 15 percent was also performed. For a 30-year 5-percent inflation rate, the levelized cost rises to \$15.94 per million Btu and for a 10-percent rate to \$25.90. These costs must be evaluated in the perspective of a national shortage for fossil fuel resources. The cost of these resources is expected to rise in ranges of 7 to 10 percent per year, which presently would account mainly for inflationary price increases and allows little room for supply-and-demand forces raising fossil fuel prices. The current \$10.05 per million Btu electrical cost escalated at 7 percent per year gives a cost of \$76.50 per million Btu in the year 2009. Geothermal systems should not experience increasing costs to the same extent as fossil fuels, since geothermal costs are more exclusively associated with capital goods and labor.

In addition to the heating of the residential area, a retrofit design was developed to meet space heating and hot water heating needs for the Inn; also, preliminary designs for proposed greenhouse space heating systems were developed. Two base case alternatives were evaluated for the commercial area in similar fashion to those of the residential areas. The principal variant in these alternatives was the rate of mobile home activity and greenhouse construction. The case reflecting a moderate development rate indicated average costs of \$4.81-6.01 per million Btu; the case illustrating a quick and more complete development gave costs of \$5.45 per million Btu over the 30-year period. Finally, the additional case evaluating costs associated with only the geothermal greenhouse system gave average user costs of \$2.99-3.51 per million Btu, which is competitive with greenhouse heating costs currently experienced on the Colorado front range.

In addition to the technical effort, a rigorous institutional analysis of the San Luis Valley region was completed and indicates a favorable climate towards this type of geothermal development. The general population, including government, business leaders, and environmental groups, appears positively receptive towards the proposed action.

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Saguache County, Colorado, is an economically depressed area with high unemployment and low median incomes. Because of this, both State agencies and local governments are equally anxious to establish the badly needed employment base for alleviating the current situation. Saguache County economics are heavily agricultural and the principal institutional concern is related to the requirement to honor and maintain the existing water use patterns in nearby areas. The geothermal design is such that all existing water rights can be maintained without injury.

Finally, an environmental report was prepared to develop, collect, and organize the information and technical data necessary for an evaluation of the potential impacts the proposed geothermal utilization could have on the project area. Currently, only electricity and propane are available to the residential and commercial participants; the development of the geothermal resource provides the option for an alternate and environmentally preferable energy source to meet these energy demands. Environmental impacts with respect to land use, subsidence, water use, water quality, air quality, and the socio-economic environment are not significant.

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II. THE BACA GRANDE COMMUNITY DEVELOPMENT

A. Background

The Baca Grande community and leisure resort development was established in early 1971 in the northeastern corner of the San Luis Valley, Colorado. The principal entity directing the overall development effort is the Baca Grande Corporation which is a wholly owned subsidiary of AZL Resources, Inc. The parent Corporation also owns a similar development in northern New Mexico.

The Baca Grande development is located approximately 200 miles southwest of Denver and 50 miles north of Alamosa, as shown on Figures 1 and 2. The land on which the Baca Grande is located is part of an 1823 grant from King Ferdinand VII of Spain, as a gesture of appreciation to his loyal subject Luis Maria Cabeza de Baca. Since that time, there have been several owners, and various portions of the tract have been identified with cattle raising, dairy operations, real estate ventures, transportation and mining. Around the turn of the century, boom towns sprang up along the creeks transversing the property; the neighboring town of Crestone reached its peak in 1900 with some 3,500 people supporting five stores, pool halls, a golf course, a school, a hotel, and a bank, not to mention seven saloons and two newspapers. Gold had been discovered; the Independence Mine on the Baca Grant and other strikes in the area are said to have produced an estimated 50 million dollars worth of precious metals. A narrow-gauge railroad was even built from Moffat to Crestone and extended southerly to serve the mines and the boomtown communities of Cottonwood, Duncan, Liberty, and Freedom, all now ghost towns. Crestone currently enjoys only about 50 full-time residents although its summer population does significantly increase above that figure.

The location of the Baca Grande is in the foothills of the western slope of the Sangre de Cristo range of the Rocky Mountains. The Sangre de Cristos rise precipitously from the Valley and in doing so create an impressive natural setting for the area. The Valley region is a major agricultural area producing barley, alfalfa, hay, potatoes, dairy products, and beef.

B. The Baca Grande Development

In 1971, the Baca Grande development land area of approximately 14,000 acres was separated from the Baca Grant Ranch (Fig. 3) which spreads out over some 140,000 acres of the Valley. The development was then formally platted into five main housing subdivisions as can be seen on Figure 4. A sixth subdivision, the Ranchettes, was also later added to the overall development plans. In addition, an area of approximately 100 acres has also been set aside to encourage light industrial development. The Corporation is committed to providing water, sewer, electricity, and telephone services to the lots within ten years of the purchase date. Water and septic tank expenses in the Grants region are at owners expense as are extensions of the telephone and electrical services.

Figure 1. Geographical Location of Baca Grande Development

Figure 2. Baca Grande Study Area Relative to the San Luis Valley Region

Figure 3. Boundary of Baca Grande Grant

the baca grande - colorado

Figure 4. Subdivisions of Baca Grande

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The Chalet Units are generally pine covered with areas of meadow. The Grants Unit, located closer to the Valley floor, exhibits only scattered trees. The property is rolling land with generally sandy soil, interspersed with some clays and gravels in certain areas. The elevation changes within the subdivisions are substantial--the highest point being at 8,790 feet and the lowest at 7,620 feet above sea level. The current status of the subdivisions is given in Table 1.

TABLE 1

Subdivision	Lots Platted for Active Development	Average Size
Chalets Unit One	2,338	0.6 Acre
Chalets Unit Two	1,913	0.6 Acre
Chalets Unit Three	70	0.6 Acre
*Grants Unit One	1,626	3 Acres
• Mobile Home Estates	403	7,000 sq. ft.
Ranchettes	10	35-45 Acres

* Services will be provided to approximately 400 of these Grant lots.

Almost 50 percent of these lots have been sold with most of this selling activity occurring in the 1971-1973 time-frame. In order to facilitate the most economic distribution of utilities to the various sites, the Corporation is emphasizing lot sales in the Chalets Units One and Two and in the westerly Mobile Home sites.

The existing development area is that of the Baca Grande Inn, Administration Building, Pro Sport Shop, and the Mobile Home Estates. The Baca Grande Inn is a modern 40-room motel with a fairly expansive lobby, restaurant, cocktail lounge, visitor reception center, banquet and meeting rooms. The Inn is electrically heated and cooled while the pool is heated via propane.

Although a substantial number of lots have been sold, the actual rate of residential construction has been moderate. Approximately 15 housing starts per year have been recorded at the site; as of July 1978, 95 homes had been constructed, 18 of which are mobile homes. This is one of the principal reasons why the Baca Grande Corporation is quite interested in actively pursuing geothermal development. If various light industries could be attracted to the area via this resource development, an employment base could be established in the northern part of the Valley to the benefit of both local residents and the Corporation.

C. Utility Services

As noted earlier, the development is committed to supply utility service to the Chalet areas within ten years of lot sale. To efficiently and economically meet that goal, however, the actual utility installation timing will depend mainly on the trends in home construction. Thus, the

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Corporation is intending to proceed with a skeleton-backbone utility network system approach wherein the main large distribution lines will be installed first. Construction will progress in such a manner that the maximum number of lots will be served, within 500 feet, for the minimum amount of initial construction. As home construction continues, utility lines will be run from the backbone system to the individual lots, similar to interceptor, trunk, and lateral sewers in a large municipal system.

It is anticipated that construction in the Mobile Home Estates will progress to the north and east. In Chalets I, it is expected that utility construction will proceed southerly to the east and west of Camino Baca Grande to Willow Creek, as shown on Figure 4, and then to the easterly section of Chalets I north of Willow Creek. The final areas serviced in Chalet I lie between Willow and Spanish Creeks, mainly to the west of Camino Baca Grande.

Chalets II home construction will initially proceed in the area north of Camino Del Rey, followed by the southwest section, and finally the southeast section.

A summary of the projected installation of the utility system is given below in Table 2.

TABLE 2

Estimated Schedule of Utility Construction^{6,7}
Baca Grande, Crestone, Colorado

	Number of Lots to Be Served by Backbone System in Each Area		
	Mobile Home Estates	Chalets I	Chalets II
1977	131(1)	228(1)	642(2)
1978	257(3)	228(1)	642(2)
1979	280(3)	330(4)	642(2)
1980	310(3)	530(4)	700(4)
1981	350(3)	900(4)	800(4)
1982	403	1284(4)	1000(4)
1983		(5)	(4,5)

Notes:

- (1) Water, Sanitary Sewer, Electric and Telephone
- (2) Serviced by water and sewer only
- (3) Serviced directly or within 100 feet of lot
- (4) Serviced directly or within 500 feet of lot
- (5) Further utility construction will coincide with actual house construction
- (6) Chalets III area lots are being switched into the Chalets I and II areas; no utility construction is planned at present
- (7) Grants and Ranchette areas will have individual wells and septic systems

The significance of the above discussion, besides informational purposes, is that the extent of geothermal development in the residential areas will logically parallel the magnitude of the actual housing construction activity; thus, the proposed geothermal system must be defined and engineered so as to most economically account for these varying rates of construction activity.

III. RESOURCE ASSESSMENT

A. Background

The San Luis Valley, located in south-central Colorado, is at the northern head of the Rio Grande Rift System which runs south and southeast to the Gulf of Mexico. Nestled between the Sangre de Cristo and San Juan Mountain ranges, the Valley extends about 90 miles north of the New Mexico border, and stretches about 35 miles in width at an approximate elevation of 7,700 feet. The Valley floor covers about 3,200 square miles. Previous analyses of the hydrothermal potential of the Valley indicate a substantial hot water resource may exist, capable of supporting industrial and residential applications (80). The objective of the assessment for the current study is thus to define the hydrothermal resource specifically in the Baca Grande development area.

B. San Luis Valley Water System

Before the more detailed discussion of the geothermal resource characteristics, it is instructive to first briefly take a look at the overall water use patterns of the Valley region. Figure 5 represents a cross-sectional schematic of the basic hydrologic system. The Valley is a collecting point for about 8,000 square miles of watershed, including parts of the surrounding mountains. Water enters the Valley directly as precipitation to become surface water; additional surface water enters by stream flow from the mountains. Some surface water migrates to the underground aquifer by way of faults, or it percolates from the surface downward through highly permeable strata at the margins of the Valley, entering the lower strata that make up the confined aquifer. Little is known of the subsequent flow paths of water in the confined aquifer, except that minor amounts of water do migrate to the surface through or around the overlapping clay and shale beds above. Other small amounts may migrate horizontally to the south, but it is thought the path for such flow is probably highly restricted in cross-sectional area. Well water used for irrigation, which in many cases is artesian flow from the confined aquifer, augment surface water supplies.

Over a period of time, a system such as that described reaches somewhat of a balance between precipitation, surface flows in and out of the Valley, and evaporation. The latter term, the most significant portion of which is evapotranspiration, is the moisture given off by crops and non-beneficial, non-agricultural plant life.

Water use patterns and water rights in the State of Colorado are governed by the Appropriation Water Law. Essentially, the first party to utilize the water resource for beneficial use establishes a water right which is adjudicated in the State water court. Water rights established junior to that original use may not infringe upon the rights of those holding senior rights to continue to utilize the resource. Thus, water rights are considered property and as such may be purchased or traded. As is the case in many areas of the Western United States, the surface waters of the Valley are already over appropriated; i.e., adjudicated rights exceed the natural stream flows. Groundwater flows which recharge

Not to scale

Figure 5.--Cross-section of San Luis Valley Water Systems (Emery, et al, p. 5).

surface flows are also considered part of those surface flows for water rights purposes. Since the Colorado State Water Engineer's office feels a relationship exists between the artesian pressures of the confined aquifer in the northern and central San Luis Valley and recharge to the Rio Grande River to the south, no permits for consumptive use of water drawn from the confined aquifer have been granted since 1972.

The regional water system as described leads to two basic problems. First, in the past, due to the continual increases in the amounts of water withdrawn from the Rio Grande River for irrigation and other uses, downstream inhabitants were suffering, or were in danger of suffering, severe water shortages in the early decades of this century. As a result, in 1929 the States of Texas, New Mexico, and Colorado signed the Rio Grande Compact on the management of Rio Grande waters, delineating annual river flows which the several States would guarantee to cross their common borders. In actual practice, this limits the amount of irrigation that can go on at the expense of the residual volume of the Rio Grande River flow. Under the terms of the Compact, Colorado is presently indebted for approximately one million acre-feet of water because of excessive utilization in past years, which resulted in smaller stream flows across the New Mexico border than required by the Compact.

The second problem also results, to a large extent, from the heavy regional dependence on irrigation. A portion of the Valley northeast of Alamosa, as seen in Figure 6 called the Closed Basin, is the lowest point in the Valley and is hydraulically bounded to the south by alluvium of the Rio Grande River. Consequently, it tends to act as a sump and both surface waters and groundwaters from much of the northern portion of the Valley migrate to the Closed Basin. As a consequence, the region exhibits many areas of salt marsh surface. About one million acre-feet of water evaporate non-beneficially from this area annually, and the marshland areas are largely unused, though it has developed into an important water fowl habitat. Due to increased irrigation, the water table in much of the Valley has risen markedly in this century and significant amounts of land have been lost to the marshes area.

In response to these two problems, the U.S. Bureau of Reclamation proposed the Closed Basin Project which would reduce the debit of the State of Colorado under the terms of the Rio Grande Compact and also lower the water table of these lower areas, thereby reclaiming marsh areas for future beneficial agricultural use. Shallow wells would be drilled into the unconfined aquifer and excess water would be withdrawn and conveyed to the Rio Grande Basin by systems of canals. Approximately 130 wells and some 100 miles of canals would be required. The Closed Basin Project is currently in the final study-design feasibility stages. A NEPA environmental impact statement is currently being developed.

The principal significance of the above discussions for the geothermal study at hand is to emphasize the concern which area farmers and ranchers are expressing towards activities which may affect current adjudicated water rights. These water supply considerations also suggest that if no long-term environmental effects are evident, additional agricultural use of the utilized geothermal brines certainly is a possibility because of the demonstrated demand for agricultural water.

Figure 6.--San Luis Valley Area Map

C. The Geothermal Resource

The objective of the geothermal resource assessment was to characterize, on the basis of existing data, the geothermal aquifer, its size and anticipated life, its hydrologic circulation and recharge mechanism, and interaction with surface aquifers. Based on these findings, projected well characteristics were adopted, describing temperature gradients, pressures, water quality, production capabilities, and injection capabilities. Finally, a resource exploration program was outlined and environmental effects specifically related to the hot water withdrawal were identified.

Previous investigations (Davis, 1977) verified the existence of high temperature water at depth in the graben or trough which runs along the west flank of the Sangre de Cristo Range as shown in Figure 7. The graben originates at the northern edge of the Baca Grant Ranch near Saguache County Road 62 and continues south to an area just north of U.S. 160. Depths of sediment in the graben have been estimated to be as much as 20,000 to 25,000 feet. An analysis of temperature gradients documented by Powell (1958) and gradients from field surveys conducted as part of the current study, definitely indicates that the graben area located over the Baca Grant Ranch is one of the two most favorable locations in the San Luis Valley for geothermal prospecting. The other Valley area showing above normal geothermal promise is located southwest of the town of Alamosa; the potential of this second area has not been extensively investigated since that was beyond the scope of the current study. The evidence at hand indicates that the geothermal resource in the Baca Grande development represents a large reservoir of water distributed throughout the graben area. The uppermost geologic unit of sediment in the graben is the Alamosa formation. This, along with the unconfined reservoir nearer the surface, is the source of water for most existing irrigation wells and extends to a depth of about 2,000 feet. The Santa Fe formation, which directly underlies the Alamosa, is also about 2,000 feet thick but is expected to have a much lower average permeability than the Alamosa formation.

The definition of an accurate thermal profile for wells to be drilled in the Baca Grande region is difficult since no deep wells, greater than 1,200 feet, exist near the area. The Mapco well drilled in 1974 for oil exploration purposes, approximately 20 miles south of the Baca Grande, is located in the southern reaches of the graben. The Mapco well data provide the most defensible basis for thermal profiles further north. The temperature gradients thus documented are given in Figure 8. As can be seen, the temperature gradients near the surface are quite high, especially during the first 1,000 feet. After that point, they are expected to decrease sharply until reaching much deeper depths of approximately 7,500 feet. The profile as described is consistent with the project field surveys which recorded temperature levels for deep irrigation wells near the graben area and which showed high gradients near the surface. Thus, for planning purposes and for the purposes of the study's economic evaluation, a profile giving a resource temperature of 150°F at a depth of 2,000 feet was adopted. Due to the small change of temperature with

Guide: — — Indicates graben boundary

$\frac{U}{D}$ Fault trace with relative movement (U=up, D=down)

Figure 7.--Graben Location on the Baca Grant Ranch.

Figure 8. Mapco Well Thermal Profile

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depth in the 1,500-2,500-foot range, economic comparisons of 150°F water at these alternate depths will also be included. The 2,000-foot depth should tend towards the conservative temperature-wise, and at the same time, provide for a safety factor against geothermal wells interfering with the shallower irrigation wells located in the region. This latter point is not as significant if reinjection will be required to satisfy water rights considerations.

Based on chemical analyses conducted during the recent field surveys and also on Mapco well samples, the geothermal water chemistry at the 2,000-foot level or above should be good, containing 1,000 mg/l or less of dissolved solids with no significant scaling or corrosive constituents. In addition, production capabilities from the Alamosa should be quite good; values of 1,000 gpm per well can be expected. Based on existing documented reservoir pressures and evidence of artesian flows in nearby irrigation wells, these wells are also expected to exhibit artesian flow. For production rates of 1,000 gpm, the estimated drawdown might approach 200 feet and pump placement is recommended for that depth.

Certainly, one of the major unanswered questions still remaining pertains to the nature of the exact pattern of hydrologic circulation. As noted previously and illustrated in Figure 8, the thermal profile is very straight between depths of 1,000 and 7,500 feet. It is reasonable to assume that the thermal parameters of the sediments in that interval and up to the surface are vertically homogeneous. The constant thermal gradient indicates that conductive heat transfer is the only mechanism operating in that interval. The convex upward shape of the thermal profile above 1,000 feet indicates convective heat flow mechanisms in this interval. Thus, it is speculated that the situation here is analogous to the flow of water across a hotplate, the hotplate being the top of the Santa Fe formation. The convective flow is groundwater movement through aquifers in the upper Alamosa formation; this movement is assumed to be vigorous enough to render the conductive heat flow component negligible by comparison to the convective component in this region.

There is an alternate or perhaps supplementary heat transfer mechanism which could be operational in the Baca Grande area, although there is little data with which to evaluate this mechanism at present. It is quite possible that groundwater moving upward from deeper aquifers along the faults bounding the graben is providing a convective heat flux mechanism extending to great depths. As pointed out in previous studies of the Mapco well data (Davis, 1977), the quality of water in the thermal reservoirs below 7,500 feet suggests good groundwater circulation. In order to have such circulation, aquifer discharge and recharge are necessary. If they provide recharge conduits, water temperatures will be lower along the faults. If, as seems more likely, they are lines of discharge, temperatures near the fault zones will be higher. In actuality, there may well be some of each.

Geothermal prospects east of the fault bounding the eastern side of the graben are not good. Here, basement rock occurs at much shallower depths of about 4,400 feet. The most easterly conduit for significant thermal heat flux, either by convection or conduction, is the fault bounding the east side of the graben. It is logical to assume that any thermal waters moving upward along this conduit will be offset westward,

not eastward, by the westward flow in the shallow aquifers. This westward flow results from logical recharge of the Alamosa and Santa Fe formations from mountain origins. Prospects west of the graben are not defined, but the fault-conduit mechanism just described might occur there also. The significance of these various hydrological relationships is that the 150°F water at depths of 2,000 feet should exist fairly uniformly throughout the graben area, and the ultimate decision as to choice of specific production area locations can be made on the basis of economic considerations such as piping distances to user areas.

D. Proposed Exploration Activities

Since the evaluation program has proceeded about as far as feasible without more subsurface data, we are now at the point where actual field exploration activities are the only way to more accurately define the extent of the resource.

A two-phased exploration program is recommended. In the first phase, more data from existing wells would be obtained. The most important cost item in an exploration program will be drilling and completing wells. Any data obtainable from existing wells will be economic by comparison and will enhance chances of success of a phase two drilling program. Static shut-in pressures, rates of pressure buildup, current production rates, temperature profiles, and downhole flow velocities should be measured in selected artesian wells. Probably four would suffice. Drawdown tests and temperature profiles should be run on non-flowing wells. The data so obtained would reveal zones of production; define aquifer parameters, and give more accurate temperature profiles.

Following evaluation of data from the first phase, final locations should be selected for two exploration test wells. The drilling and completion program should yield further information on temperature profiles, geology, and aquifer parameters under better controlled conditions and in areas where data is needed but lacking at present. A recommended hierarchy of criteria for locating the wells indicates the primary consideration should be to place them in the area underlain by the Baca Grande graben. The secondary consideration should be to place them where, if commercial production appears feasible, the production could be economically used. The tertiary consideration would be to place one well near and west of the eastern boundary of the Baca Grande graben in order to see if fluids are being discharged upward along the fault zone. Such fluids could be expected to have much higher temperatures than the shallow water with which they mix.

A target depth of 2,000 feet is recommended for the first well. This should bottom with a sandy sequence near the top of the Santa Fe formation. The well should be drilled using the smallest practical bit size and logged in the uncased hole. If the open hole logs indicate a potential geothermal resource, the hole could then be reamed to a size sufficient to accommodate the casing needed and completed both as a test and as a production well. A design basis production well with 18-inch surface casing and 8-5/8-inch bottom hole casing is recommended. This well would have an estimated production capacity of 1,000 gpm. Pending the results of an actual chemical analysis of the water, it is not anticipated that special corrosion-resistant steel will be needed.

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for the casing. If the well appears to be of marginal value, 6-inch steel casing perforated in the most promising geothermal aquifer sequence might be installed rather than the 8-5/8-inch casing. This would permit extensive testing and evaluation with a smaller commitment of funds. Production capabilities of a 6-inch casing are estimated at less than 200 gpm.

When the results from the first test well are available, a final location and design for the second test hole could be selected. It is assumed that a second well will not be needed if the results from the first well are not encouraging. If a second well is drilled, it should be preceded by a small hole as on the first well and reamed to production size if preliminary evaluation indicates the hole warrants further work.

Environmental Considerations

The detailed summary of the environmental report is included in a later chapter. However, certain environmental considerations specifically related to the geohydrological investigation are briefly discussed in the following text.

The major environmental topics to be addressed prior to beginning a geothermal development are:

1. Effects of development upon surrounding wells, springs and streams. Any adverse impacts upon water rights are likely to be met with strenuous objection in the arid San Luis Valley.
2. Potential subsidence effects caused by lowering of reservoir pressures.
3. Adverse environmental effects which might result from disposal of spent geothermal fluids, since subsurface disposal is under consideration.

Data are lacking at present with which to do a complete analysis of the three topics. However, it is possible to make reasonable preliminary judgments concerning environmental impacts. The source of geothermal water will probably be from sediments below or in the base of the Alamosa formation. Because of the nature of alluvial fan aquifers, this will probably involve other, separate aquifers from those presently in use for irrigation. It is probable that the various clay layers will effectively isolate the deeper aquifers from those in shallow horizons so that negligible impact upon existing water rights is anticipated. Also, the reinjection of cooled geothermal waters back into the production zone should insure negligible impact on existing water use patterns.

Subsidence of the sediments due to consolidation caused by pressure declines in deep aquifers normally has a potential for affecting a greater area than do such declines due to pumping shallow aquifers. At the same time, effects from deeper wells are less intense in any one area. In the case at hand, irrigation pumpage has not caused notable

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subsidence. This pumpage appears to be so much greater than the 2,000 gpm proposed for near-term geothermal pumpage rates that it can be used as an indication of the magnitude of the problem. In other words, no problem is presently anticipated with initial pumpage rates. It also seems likely that subsidence would not be a problem when using reinjection and if the pumpage is properly distributed over a wide area.

As noted previously, the reinjection of the cooled brines¹ into the production zones is the recommended brine disposal method. Permeabilities in the Alamosa formation should improve as the front of the Sangre de Cristo Range is approached. Provided the chemical quality of the water is compatible with the aquifer and water into which it will be injected, no problems are foreseen. With reinjection, the entire development would constitute a non-consumptive use and eliminate any concern with respect to the water rights question. It is possible that, instead of reinjection wells, spreading ponds may be feasible and economical. Infiltration rates near the mountain front should be quite good. If subsidence effects become significant or water rights concerns arise, pressure reinjection through wells would probably be necessary in order to alleviate the problem.

Water in the aquifers down to 2,000 feet deep is probably good. If later tests show it is too rich in undesirable chemicals, regulatory agencies will regard it as a pollutant and require treatment prior to discharge to surface waters or possibly to certain groundwaters. On the positive side, good quality water recharged to the Alamosa formation would enhance supplies available for irrigation from the Alamosa. Water low in salinity, sodium adsorption ratio, boron, and toxic trace elements is required for agricultural use.

F. Land Ownership, Mineral Rights, and Associated Royalties

All lands being investigated with respect to geothermal resource potential are owned either by the Baca Grande Corporation directly or by its parent company, AZL Resources, Inc. These parties are interested in geothermal development for reasons discussed previously.

As a result of recent court decisions, geothermal resources may be considered a mineral rather than a water resource. The Newhall Land and Farming Company, the previous owners of the Baca Grant Ranch, retained 50 percent of all mineral rights at the time of sale. Newhall is also encouraging geothermal development; however, royalty compensation will be required for the rights to the hot water resource. For the economic portions of this study, a royalty amounting to 10.0 percent of the extracted heat content based on current, comparable fossil fuel price structures has been assessed.

¹The term "brines" is used in this report to generally note the geothermal fluid; however, the geothermal fluid is expected to be much better than the U.S.G.S. definition of a brine as being more saline than seawater, which has 35,000 ppm TDS.

G. Well Drilling Considerations and Associated Costs

1. General Optimization Procedure

An important aspect of the overall geothermal economic comparison is the optimization analysis of the necessary well drilling and associated costs. Several factors must be included in these considerations and several different courses of action must be balanced to obtain the least cost system. The following discussion, although somewhat simplistic in nature, serves to illustrate the interrelationships of the considerations which must be addressed.

In many direct use geothermal systems, two of the most significant capital costs are well costs, both production and reinjection, and surface piping costs. Seemingly the most obvious aim of an optimization is to reduce the number of wells required and also the transmission distance from the well to the user and subsequently to the disposal area.

The principal avenue by which the number of wells can be reduced is through obtaining a higher temperature geothermal fluid, thus allowing the extraction of more Btu of energy from each pound of fluid. This would also reduce surface pipeline sizes. The cost conflict arises in that geothermal fluid temperature is often times a direct function of depth; since the cost of a well is also directly related to well depth, the economic advantage of increased temperature is balanced to varying degrees by the increased well costs. The quantitative cost relationships of these factors are, of course, site specific. Thus, rigorous optimization would at least include consideration of the following: (1) reservoir temperature versus well depth; (2) well costs versus well depth; (3) well location and associated piping distances to users; (4) surface process application temperature requirements; (5) reservoir production capabilities; and (6) acceptable disposal well locations.

The site-specific variance of these factors is emphasized for the Baca Grande resource. As noted earlier, the geology and hydrology is such that between 1,500 feet and 2,500 feet in depth, very little temperature increase is projected to occur. Thus, there would be no incentive to drill deeper for increased fluid temperature. Second, the resource is projected to be widespread and of similar quality throughout the Baca Grande graben region; i.e., one can probably drill anywhere in the graben to a depth of 1,500-2,000 feet and obtain 150°F water. Consequently, the well production areas can be placed optimally to reduce surface piping costs.

2. Technical Drilling Considerations

The principal limitations of readily available water well, hydraulic rotary method drilling equipment is normally related to the weight of the pipe which the drilling structure itself is able to support.

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Thus, there is often a break in drill rig size for wells up to 2,000 feet, and again at 5,000 feet. To drill at depths greater than 5,000 feet will require the use of oil and gas drilling equipment which has higher unit costs. The hydraulic rotary method is the most applicable drilling method for the sedimentary drilling found at the Baca Grande site. The alternate reverse circulation rotary system of drilling is more expensive and is generally more applicable to hard rock drilling situations as compared to those in the Valley.

Between 100 feet to 300 feet of cemented-in surface casing is required to maintain the alignment and stability of the drilled hole. Below this casing several drilling muds are available for normal conditions, but an uncased hole stabilized with drilling mud is required. A special salt-based mud is recommended for compatibility with brine so that the integrity of the hole will be maintained and that drilling mud is not broken down.

Access roads in the area proposed will have to be constructed to allow movement of heavy equipment and trucks. Water is available within 2 to 3 miles of any proposed drilling site and can be easily hauled in tank trucks, for mud fabrication, dust control, cleaning and washing, and other construction requirements. Data obtained from previous drilling in the area indicate that only minimal blow-out prevention equipment will be required. Because of the abundance of alluvium and aeolian deposits and locally high water table in the various areas of probable well sites, the use of walking and support mats may be required for well rigs located off access roads.

Dependent upon the type of drilling equipment utilized, various different physical support plants are required. This variation can be from a self-contained truck mounted rig which requires no additional support for short periods to that of a drilling camp. A drilling camp could conceivably contain the rig, office building, sleeping quarters, kitchen, sanitary facilities, maintenance shop, mud prep tanks, mud re-circulation tanks, classifier, settling pond, and other peripheral support items requiring about two acres per drilling site. In most cases, regardless of the complexity of the drilling plant utilized, the area surrounding the well site is returned to its natural undisturbed state and the access road to the site left in a good usable condition that is also esthetically acceptable.

For test hole cost estimation and construction, the best method of contracting for the exploratory program is on a time and materials (T&M) basis. A T&M contract will result in lower cost since the contractor does not have to bid additional costs for contingencies. The cost of mobilization and demobilization of a well rig is approximately \$5,000.00 to \$10,000.00. The rate for rig and crews is approximately \$150.00 an hour plus cost of mud, casing, and any other third party materials that might be needed, plus 10% to 15% for handling and administration overhead costs. The cost of constructing the access roads must be added to the contract value. Overall costs for one slimhole well, uncased, no core recovery, no auxiliary tests, drilled to 2,000 feet is estimated at \$15/foot or \$30,000. All access roads, special materials, supplemental programs, special testing, well testing, and studies would be in addition to this base cost.

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For a 1,500-2,500-foot deep well cased to an 18-inch surface diameter, the hole would likely be drilled and cased in two stages. The first 300 feet of the well would be drilled and reamed to final size in three stages, probably of 11-, 18-, and 20-inch successive diameters, and then cased back to 18 inches. This first 300-foot section of casing should be sufficient to penetrate through the alluvium material found throughout the Baca development. The remaining depth would be drilled to 11 inches and cased to 8-5/8 inches. Figure 9 is a schematic diagram of a typical production well.

Figure 9.--Schematic Diagram of a Typical Production Well

Several water well contractors including Layne-Western Co., Inc., James Drilling Co., and the Beeman Brothers Drilling Co. are active in the project region. Some contractors have a 2- to 3-week lead time requirement and others may be as great as 4 to 6 months because of their backlog. For the purposes of this feasibility study, it was assumed

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that the required equipment is available at the desired time at industry competitive prices.

To reiterate prior text, the cost of only drilling the well is not the total cost of a well site. The development of access roads, special materials, supplemental program, special testing studies, clean-up and disposal of wastes, OSHA and EPA requirements, and restoration to original conditions are all added-value project costs directly attributable to the cost of the well site regardless if the well is usable or unusable.

3. Specific Projected Well Costs for the Baca Grande Site

Several of the water-well drilling contractors were contacted for cost estimates of San Luis Valley drilling costs. The responses varied widely; however, based on the results of those inquiries, the following drilling costs were adopted for use in the project economic analysis. For ease of comparison, they are presented in tabular form below.

TABLE 3

Projected Drilling Costs, San Luis Valley, Colorado

Type of Well	Depth (feet)	Cost per Foot	Total Est. Cost (Jan. 1979)
Slimhole 5" uncased	2,000	\$10-15	\$ 30,000
Production well, cased 8-5/8"	1,500	40	60,000
Production well, cased top 300 ft--18" cased remainder--8-5/8"	1,500	55	82,500
Production well, cased top 300 ft--18" cased remainder--8-5/8"	2,000	65	130,000
Production well, cased 300 ft--18" cased remainder--8-5/8"	2,500	75	187,500
Disposal well, cased 8-5/8"	1,000	40	40,000

Cased wells include normal wellhead piping and valving suitable for pump installation.

Drilling costs are very site-dependent; if unexpected geological features are encountered during drilling, costs will vary accordingly.

IV. DESCRIPTION OF THE GEOTHERMAL SYSTEM ALTERNATIVES

A. Commercial and Residential Service Areas

The current Baca Grande land development activities are primarily centered in two separate regions of the Baca Grant Ranch. The first of these is the residential areas consisting of the Chalets Units I, II, III, and the Grants Unit I, and are located on the far eastern flanks of the land grant in the tree-covered foothills. The second principal development area is that surrounding the Baca Grande Inn, including the Mobile Home subdivision, the Ranchettes, the light industrial development area, the administration building, the pro sport shop, and the proposed small shopping center. This second region will henceforth be referred to as the "commercial" area to clearly differentiate it from the "residential division" referenced previously.

The physical layout of these two regions is markedly different, and the proposed geothermal systems serving these areas are also quite different. Thus, the alternative summaries and economic feasibility assessments for the study have also been kept separate and their respective feasibilities evaluated on their individual merits. The physical boundaries of both the residential and commercial areas are presented in Figure 10.

B. Resource Production Areas

Originally, at the start of the study, the different geothermal production areas were expected to exhibit different temperature gradients as a function of depth to resource. As it turned out, however, the resource assessment conclusions indicate that 150°F water is projected at a depth of 2,000 feet consistently throughout those portions of the Baca Grant Ranch which overlie the graben. The temperature gradients would be identical in this case and this tends to relegate the economics to comparisons of distances to users and the associated piping costs. One must keep in mind, however, that these resource evaluations are educated judgments and can be proven only by an exploration program. To illustrate the economic importance of drilling costs and the distribution piping costs, several production areas and different temperature gradients have been comparatively evaluated. Well depths of 1,500 and 2,000 feet for 150°F water were considered. Four production areas have been defined as shown in Figure 10 and discussed below.

Production Area I is located approximately five miles west and one mile south of the development entrance to the Chalet I area. Production Area II corresponds to wells in the vicinity of the Commercial Area, four miles west and immediately south of County Road 62, and is located to minimize distribution costs to that service area. Production Area III represents a north-south strip approximately one mile wide, five miles long (north-south), and located immediately west of the eastern boundary of the Baca Grande graben. In this instance, the producing wells would be immediately west of the primary residential service areas and could be phased into production as the need for their energy production is demanded. Production Area IV is located approximately one-half mile west

Guide: PAI--Production Areas I

$\frac{U}{D}$ Fault trace with relative movement (U=up, D=down)

Figure 10.--Location of service and production areas.

and two miles south of the development entrance and is immediately adjacent to Production Area III.

C. Base Case Alternatives

Four base case design alternatives dependent on production area location and housing construction rates have been defined for study as part of the parametric analysis. Two of these alternatives describe the "residential" geothermal system and two are for the "commercial" area. These alternatives assume that the brine does not present corrosion or scale formation problems, and for these cases, the raw brine is used directly in all radiators and heaters. As will be discussed further in the individual economic sections, a second alternative assumes that the brine chemistry indicates a more significant problem with respect to corrosion or scaling and that pretreatment will be required. Yet another alternate to this would be the use of a central heat exchanger to heat a clean circulating water stream; in this case the brine is in contact with only the central exchanger, which can be more easily maintained and cleaned, while only the clean water contacts the many individual home heating units.

It is noted that there is presently insufficient data to positively determine which type of brine will be found. However, indications are that the water quality will be high so that pretreatment, which is more expensive, will not be required.

As is evident from the preceding discussions, the ultimate preference for any of these base case alternatives or their alternates will strongly be a function of two considerations: (1) the effects of the various production locations on the economics of the distribution and collection systems; and (2) the project water quality at the various producing areas.

D. Alternatives Dropped from Further Consideration

Four additional alternatives were considered in the preliminary engineering analysis and then dropped from further consideration. The first such case would have placed a production area immediately east of the four main residential service areas and at higher elevations than the served districts. This is an attractive option in that the distribution system routings could be the same as those used for the potable water system and sewerage system serving the residential development. Also, all flows could be supplied by gravity, thus eliminating significant operating and maintenance, and power expense associated with pumping. This formal alternative, however, was dropped since the resource potential is judged to be limited in that area.

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A second alternative, somewhat unique as compared to the options previously discussed, would have used downhole heat exchangers to supply groups of homes or businesses with the geothermal heat energy. In this case, a heat exchanger would be placed down in the well casing proper. The geothermal heat would be transferred to the fluid within the exchanger and pumped via an entirely closed circuit to the individual users. The attractiveness of this alternate depends on resource depth, aquifer permeability, resource location, and the total required heat transfer area. After reviewing the geohydrological reports, it was decided this option was not viable since the wells are comparatively deep and expensive, and since numerous wells would be required because limited heat can be extracted from each well.

A third alternative was related to the desirability of installing insulated surge tanks into the system to help meet peak demands and optimize the capital costs associated with well drilling and the primary distribution systems. This alternative was dropped, however, due to the very large tank size requirements, insulation requirements, and high capital costs associated with this option.

Finally, the potential for space cooling was also evaluated in the study and provision for convective space cooling was designed in the climate control system of the Baca Grande Inn. However, the climatic investigation showed that cooling loads during summer months in the San Luis Valley are limited; thus, space cooling of the residential areas was judged to be not desirable. This is consistent with current residential construction practices. The potential for absorption refrigeration applications is further discussed in Chapter V.

CHAPTER V. GEOHERMAL SYSTEM DESIGN CONSIDERATIONS

A. Climatic Investigation and Design Temperatures

The methodology used for determining HVAC geothermal system design capacities and the overall economic feasibility of a proposed system requires the determination of two important system parameters. First, the design temperature and associated wind conditions, together with such factors as exposed surface area, insulation, and materials of construction, set the peak heating demands and the sizing of the proposed system. Design temperature levels are application dependent in that the appropriate levels can be different for greenhouses as compared to residential systems or other space heating systems. This parameter is a most important input since it determines the physical size of the heating plant and thus the capital cost requirements for a geothermal energy supply system.

The second important factor of evaluating the rate of return on investment, and hence the economic feasibility of a project, is the calculation of the average annual energy consumption for a system. One method for accomplishing this is on the basis of the annual heating degree days for the study area. Experience has shown that for buildings requiring an inside air temperature of approximately 70°F, the amount of fuel or heat energy input required per day is proportional to the number of degrees the average outside temperature falls below 65°F. Thus, by definition the number of degree days per day, 65°F base, is the difference between 65°F and the daily mean temperature when the latter is less than 65°F. Likewise, the number of degree days for longer periods, such as for 1 year, is the summation of the daily degree days for as many days as the period covers.

Figure 11 illustrates the variability of annual degree days experienced from year to year; thus, it is important to base figures on longer periods of historical data, with 30 years being generally used, if the data are available. A detailed analysis of the study area climatology is required to properly determine these two factors.

There are three weather stations in the project vicinity for which climatological data exist; the Great Sand Dunes National Monument Station is located immediately south of the Baca Grant Ranch. Saguache is located approximately 30 miles west, and Alamosa is about 50 miles southwest of the development site. Historical climatology data were collected from all three stations to document the temperature ranges recorded in that region. The data show the Valley region experiences harsh winters, with extremes of -30°F to -50°F, and also mild comfortable summers.

For purposes of determining valid design temperature levels, the ASHRAE Handbook of Fundamentals (3) data is accepted throughout the HVAC industry. For numerous selected communities throughout the United States, ASHRAE has determined winter design temperatures based on historical frequency of occurrence data; for buildings of normal heat capacity characteristics, ASHRAE recommends utilizing a 99 percent design

Figure 11. San Luis Valley Degree Day Variations

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level, i.e., that temperature level such that 99 percent of all winter temperature minimums would be above that level. A -11°F temperature represents the 99 percent design level for the cities of Alamosa and Saguache, Colorado, and is thought to represent the climatic conditions at the Baca Grande development site with reasonable conservation. This number formed the basis for the Baca Grande residential, mobile home, and motel heat load calculations.

As one might expect, a somewhat different criteria applies to developing design temperature levels for greenhouses. The National Greenhouse Manufacturers Association recommends an outside design temperature 15°F above the lowest temperature previously recorded at a certain locale. The recorded extremes for both Saguache and the Great Sand Dunes stations are somewhat warmer than seen at Alamosa and are thought to better reflect conditions in the northern Valley region. The extreme low for Saguache is -34°F ; therefore, a -20°F design temperature was adopted. With an inside design temperature of 65°F , the occurrence of the extreme would still provide for a 50°F maintenance in the facility--a temperature which most plants can withstand for at least short periods of time. Additional greenhouse design temperature considerations are presented in Chapter VIII.

For determining annual energy consumption values, the Saguache station 30-year figure of 8,027 degree days was adopted. This is about 7 percent less than for Alamosa and slightly higher than recent 5-year averages at the Great Sand Dunes. The adopted figure is judged to be reflective of the long-term northeast Valley weather patterns.

One additional comment is noted with respect to design temperature levels for space cooling system design. A value of 82°F , representing a 97.5 percent probability dry bulb temperature level, was adopted for the Baca Grande Inn.

B. Cost of Conventional Energy Sources

Natural gas is not available in the Baca Grande Region of the San Luis Valley. The current natural gas pricing structure for the metropolitan Denver area, one of the competitive locations for greenhouses which might settle in the Valley, is \$2.08 per million Btu as of February 15, 1979.

Propane is available in the Baca Grande region at a cost of \$0.38/gallon. Based on a heating value of 91,065 Btu/gallon this represents a cost of \$4.17 per million BTU exclusive of storage tank rentals and other costs.

The Baca Grande development's electrical needs are supplied by the San Luis Valley Rural Electric Cooperative, Inc. Rates do vary with consumption. For underground residential service, the rates are \$9.50/month plus \$0.0544/KWH for the first 100 KWH and \$0.0343/KWH for all use greater than that figure. The Baca Grande Inn has a \$51.50 minimum service cost. In addition, there is a peak load demand charge based on the motel maximum usage rate during any one hour of \$5.84/KWH plus \$0.032047/KWH for the actual use. Also, due to extensive irrigation in the Valley, the local REA has established a special pumping electrical rate structure consisting of an annual charge of \$6.95 per connected horsepower and a \$0.03358/KWH rate on consumed power. These rates are also reflective of

electrical rate structures applicable to light commercial entities such as greenhouses. It should be noted that for space heating applications, electrical heating is 100 percent efficient while propane and natural gas are 50-60 percent efficient at the elevation of the Valley.

C. Piping Materials

1. Technical Considerations

The production and transmission piping systems are important to the project design since the project viability depends on the economic delivery of the hot waters to the user. Both capital costs and heat loss to surroundings must be minimized. Also, installation requirements should conform with normal construction practices. Finally, resistance to corrosion and deformation, and pressure limitations can also be important.

A particularly important parameter noteworthy of consideration is that of anticipated heat loss. When excessive losses are incurred, the delivered fluid temperature may be lowered to an extent causing inefficiencies or even non-viability in the user system application. The mechanism of this heat transfer in well casing and buried pipeline is complex and is a function of piping materials, insulation, and soil and rock formation characteristics. In addition, for a documented heat transfer per linear foot of pipe, the mass flow rate of fluid within the pipeline determines the temperature loss per pound of water and, hence, the final fluid temperature to the user. The considerations governing the optimum design of the production and transmission piping systems are discussed in the following sections.

a) Materials of Construction

For the purposes of this study, ten different combinations of piping materials and insulation were evaluated. Materials considered were insulated and uninsulated carbon steel, insulated and uninsulated asbestos concrete, chlorinated polyvinyl chloride (CPVC), polyvinyl chloride (PVC), polyethylene, reinforced fiberglass, field insulated asbestos concrete, and custom manufactured piping. The advantages and disadvantages of each are briefly reviewed below.

-Polyvinyl Chloride (PVC).--The principal advantage of PVC pipe is its inexpensive cost. The heat loss through this pipe is relatively high, and PVC begins to lose its strength at temperatures above 80°F. At 140°F, the pipe has less than 22 percent of its original strength. For example, an ASTM D2241 160 psi rated pipe, one of the highest rated PVC pipelines, would be derated to only 28 psi at 140°F. Thus, when buried and operated at elevated temperatures, the pipe has a tendency to deform and lose its shape. Additionally, extra care must be taken when backfilling the pipeline trench to avoid damage to the pipe since it lacks the impact strength of other conventional materials.

-Chlorinated Polyvinyl Chloride (CPVC).--The heat loss through CPVC pipe is again relatively high and is comparable to that of PVC. The pipe is not currently available in sizes greater than 10-inch diameter and is expensive. CPVC also loses its structural integrity at temperatures above 100°F; however, the problem is not as severe as with PVC. For example, CPVC loses 20 to 40 percent of its original design strength at a temperature of 150°. Special care must also be taken with this product when backfilling the pipeline trench to avoid damage to the pipe since it lacks the strength of other conventional materials.

-High-Density Polyethylene (PE).--The main attribute to polyethylene pipe is its resistance to corrosion and scaling. However, the major drawback is its pressure derating at elevated temperatures. For example, a pipe with an initial rating of 100 psi at 75°F will be rated at only 50 psi with a 150°F operating temperature. Additionally, PE pipe, capable of operating at the temperatures and pressures expected in the distribution system of the development is of high cost due to the wall thicknesses required. This piping material could be used where pressure limitations are not a major concern. This piping material also has a high heat loss.

-Fiberglass.--There are numerous reinforced fiberglass products available; however, only a few are recommended for operating temperatures greater than 150°F. The main advantage of the fiberglass piping is its resistance to corrosion and scaling; the disadvantages with the material are the high cost and relatively high heat loss. Additionally, care must be taken when backfilling the pipeline trench to avoid damage to the outer epoxy coating of the pipe. If the outer protective epoxy coating is broken, water will quickly infiltrate the wound fiberglass filaments, adversely affecting the structural integrity of the pipe.

-Concrete Asbestos (Uninsulated).--The foremost advantage of this material is its low cost, while its chief drawback is its high heat loss, which is comparable to an uninsulated carbon steel line. Other disadvantages include special bedding requirements and extra care necessary when backfilling the trench. Also, corrosion can occur on the interior when carrying low pH fluids. Joints of the installed pipe are sealed with o-rings which can handle temperatures up to 220°F; operating pressures of 150 psi are acceptable for this piping alternative.

-Carbon Steel (Uninsulated and Insulated).--The major advantages of carbon steel are its availability, strength, and ability to operate at high pressures. It is also relatively easy to install, and there are no special bedding requirements. The chief disadvantages are its high cost and high heat loss if insulation is not used. An uninsulated bare steel line will lose up to 10 times as much heat as a comparably sized pre-insulated concrete asbestos pipe length. Insulation via wrapping with spun fiberglass or rock wool is one possible alternative. It is not, however,

recommended for buried lines since moisture encroaches over time, thereby reducing the insulating effectiveness. Field wrapped carbon steel is comparatively expensive. Pre-insulated carbon steel is available; however, costs are high.

-Pre-insulated Asbestos Concrete.--A pre-insulated pipe product consisting of two concentric concrete asbestos pipes with a polyurethane foam insulation in between was evaluated for this example. The major attributes for the material are its low heat loss, and ease of installation. The special bedding requirements for a singular concrete asbestos pipe are not needed for this product due to the strength imparted by bonding two concrete asbestos pipes with the foam insulation. The potential for interior corrosion problems is mitigated by coating the interior of the pipe with epoxy. The polyurethane insulation is very effective with resulting low heat losses. The principal disadvantages of this product are that care must be taken to avoid damage during the backfilling of the trench and pressure limitations of 150 psi apply here also. In conclusion, the pre-insulated asbestos concrete is an attractive piping material except where carbon steel is necessary to overcome pressure limitations. Specific heat loss data and costing information are presented in a later discussion.

-Field Installed Urethane Insulation.--An alternative to pre-insulated concrete asbestos is to spray an insulating urethane foam onto the pipe after its placement in the trench. The major advantage for this technique is the reduction in cost as compared to the pre-insulated product. The major disadvantage with this procedure is the projected degradation of the unprotected insulation over extended time periods and in the presence of soil moisture. Discussions with urethane insulators indicate that without a protective outer covering, buried urethane insulation could be rendered ineffective in 5 years or less. Adding an outer protective casing, such as PVC, in addition to the insulation costs, makes this piping material comparable in cost to the pre-insulated product.

-Insulated Copper Pipe.--The primary attribute for pre-insulated copper piping is its availability in small diameter sizes (<3") for use where materials such as asbestos concrete and synthetic plastic are not available. Handling and installation characteristics are good and with insulation, the heat loss is low. High cost is the principal disadvantage of pre-insulated copper piping.

2. Specific Heat Loss Evaluation

The design of pipeline distribution systems normally requires trade-off between pipe sizing, pumping requirements, and temperature loss. For example, as the diameter of the pipe is reduced, the initial capital cost of the pipeline is likewise reduced; however, the power

necessary for pumping is increased due to the additional frictional loss incurred. Conversely, as the pipe diameter is increased, the capital cost of the pipeline is increased but the required horsepower for pumping is reduced. For the purposes of this study an average fluid velocity of 6 feet per second was assumed. This velocity is normally a good compromise and is sufficient to retain solids in suspension rather than settling out in the pipe. A more precise optimization of velocity versus line size can at times be attained, but that detail is beyond the scope of the current study.

Temperature loss through a pipeline is a function of the mass flow rate and thus, this factor will also be based on fluid velocities of 6 feet per second. Table 4 shows the estimated temperature loss of the fluid as it is transported through various types of pipelines.

Table 4.--Estimated Temperature (°F) Loss per 1,000-Feet Pipeline
Fluid Flow Velocity--6 Feet per Second

Basis:

Fluid temperature 150°F
Ground temperature @ 6-foot depth¹ 35°F
Burial depth 6 feet
Soil thermal conductivity 12 Btu-in/hr - ft² - °F

Material	Nominal Pipe Diameter			
	4"	8"	12"	16"
Bare carbon steel	1.39°F	0.43°F	0.22°F	0.16°F
Insulated carbon steel	0.18	0.071	0.049	0.039
Concrete asbestos	1.27	0.39	0.20	0.14
Insulated concrete asbestos	0.16	0.068	0.053	0.034
Uninsulated fiberglass	0.96	0.30	0.15	0.11

¹Criteria for Underground Heat Distribution Systems," Federal Construction Council Tech. Report No. 66, Nat. Acad. Sci., 1975.

As seen in the above table, the heat loss through the insulated concrete asbestos is one-eighth to one-quarter that of other piping materials. The lesser temperature loss is a distinct advantage since initial brine temperatures are moderate and for certain alternatives piping distances are significant. Figure 12 shows the estimated temperature loss through the insulated steel and concrete asbestos piping with a fluid velocity of 6 feet per second at pipe diameters of 3 to 30 inches. As seen in Figure 12, for pipe sizes greater than 8 inch, the temperature loss per 1,000 feet is less than 0.1°F per 1,000 feet.

The significance of the above discussion lies with the fact that for 8-inch diameter insulated asbestos pipe the temperature loss over the 5.5 miles from the farthest production area to the residential service area boundary is 2.0 F°. For uninsulated pipe that temperature

TEMPERATURE
Loss
°F
per
1,000 ft

Figure 12. Estimated Temperature Loss Vs. Pipe Diameter
Insulated Steel and Concrete Asbestos at 6 fps.

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loss grows to 11.3 F⁰ which is significant in the context of the moderate 150°F water temperature. Temperature losses in the residential distribution mains within the service area are in addition to the above figures. Since minimum temperatures of approximately 140°F are desirable at the point of actual application, substantial portions of the overall residential distribution system will have to be insulated, thus increasing the system capital costs. Additional heat loss information is presented in the specific detailed discussions of the various geothermal systems.

3. Pipeline Economics

As briefly referenced earlier in this section, pre-insulated asbestos concrete is an attractive pipeline material when considering both thermal losses and cost. Table 5 lists the costs for selected sizes of various piping materials. The costs listed in Table 5 are as delivered on site and do not include installation costs.

TABLE 5

Approximate Uninstalled Discounted Costs for Various Piping Materials (\$/ft)

		4"	8"	12"	16"
Bare Carbon Steel	Sch. 40	4.20	10.52	18.23	23.71
	Sch. 80	6.53	16.35	24.47	31.51
PVC		2.40	5.25	9.45	21.07
CPVC		7.26	35.34	***	
Concrete Asbestos		1.95	4.03	7.53	11.32
Pre-insulated Asbestos		7.20	12.00	19.00	38.80
Reinforced Fiberglass		3.56	10.97	16.26	24.80
High Density Polyethylene*		1.60	5.53	12.06	19.00
	**	5.88	10.75	26.32	**

- * 100 psi rating @ 75°F, or 50 psi @ 150°F
- ** 200 psi rating @ 75°F, or 100 psi @ 150°F
- *** Pipe is not readily available

When field insulation costs are added, the costs in Table 5 escalate between 30 and 50 percent. Considering this 30 to 50 percent increase, the pre-insulated products look to be competitive with other piping materials. The low cost, the reduced heat loss, and the ease of installation all combine to make the pre-insulated asbestos concrete product an attractive choice. Table 6 presents current estimated installed costs for bare steel, field insulated carbon steel, and the pre-insulated concrete asbestos.

TABLE 6
Estimated Installed Piping Costs

Nominal Pipe Diameter (inches)	Carbon Steel (Sch. 40) (\$/ft)	Insulated Carbon Steel (Sch. 40) (\$/ft)	Pre-insulated Asbestos Concrete (\$/ft)
4	14.20	15.46	17.20
8	20.52	23.67	22.00
12	28.23	33.70	29.00
16	33.71	40.82	48.80

To again summarize the considerations governing piping materials selection, PVC piping is an unacceptable material due to its lack of strength at the expected temperatures (150°F). CPVC piping is not attractive for similar reasons and also due to its high cost and limited availability in larger size pipes. High density polyethylene is also expensive at high temperature and pressure ratings. Bare carbon steel exhibits excellent longevity and maintenance characteristics; however, it also has a high heat loss. Furthermore, concrete asbestos can often-times provide adequate service at significantly lower capital costs. Thus, except in situations where pressure requirements dictate carbon steel, other alternates are preferred. Uninsulated concrete asbestos is attractive because of its low cost; however, with its high heat loss it cannot be used in piping of any great distance. It might be acceptable for shorter routes such as for transporting fluids from Production Area II to the Commercial area across the road, where the heat loss would be small. Field-installed polyurethane insulation is subject to unacceptable degradation over a 30-year system life. High temperature fiberglass pipe with urethane insulation encased with PVC shows promise and looks to be cost competitive with pre-insulated asbestos concrete. For alternates of long distance, moderate water temperature transmission where heat loss is important, the pre-insulated concrete asbestos is the preferred choice because of its competitive cost and low thermal losses.

D. Temperature Loss Within the Well Bore

In addition to the surface pipeline heat losses addressed above, potential losses can also occur in the well casing itself and merit at least a preliminary quantification. The temperature loss in the well would be due to the transfer of heat from the hot fluid within the well to the cooler formations surrounding it. The mechanism of heat transfer is complex, since an absolute steady state is never attained. The hot fluid warms the rock surrounding the well bore, until the temperature of this

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rock approaches the geothermal fluid temperature. The rate of heat loss depends on the manner in which heat is carried away from the rock immediately surrounding the well to the more distant rock. The smallest heat losses occur when heat flow through the rock is due only to conduction. Somewhat higher rates will be found in those zones where the well passes through a water-filled strata if there is significant vertical permeability in that zone so that a natural convection heat transfer cell is established; in this case, heated water will rise locally around the bore, and cooler water will descend at some distance from the bore to complete the circulation pattern. The combination of heat transfer, e.g., both conduction and natural convection, lends to greater heat losses.

The above analysis indicates the complexity of temperature losses due to changes in the mechanism as the well passes through different strata. In addition, the complexity is magnified by the fact that the rate of heat loss changes with time, and the time factor may be different for each stratum. To illustrate, in the first few days after startup when the rock next to the well is still close to its original temperature, the temperature difference between fluid in the well and this rock, and thus also the rate of heat loss, will both be at their highest values. As time goes on and the rock near the well heats up, the distance from the well bore to rock, still at its original temperature, increases. The increased distance acts as a resistance to heat flow and the rate of temperature loss decreases.

Several papers have been published on the subject of heat loss that takes place only by the conduction mechanism. These indicate that the temperature loss of geothermal brine will be negligible under the design conditions considered here. This can be deduced from the study by Ramey (62). On the basis of this analysis, a temperature loss of less than 10°F, from the production zone to the wellhead, is estimated for the following design conditions:

Production temperature:	150°F
Production depth:	2,000 feet
Production rate:	1,000 gpm
Temperature formation in reservoir rock:	Linear variation from 41°F at surface to 150°F at 2,000 feet
Heat transfer mechanism:	Thermal conduction into formation

Since this temperature loss is negligibly low, no attempt was made to refine the analysis of Ramey, even though Ramey's work was not developed for exactly the same flow situation.

In the case where the natural convection mechanism results in heat transfer in parallel with conduction, calculations required are even more involved. However, a simple worst case analysis shows that temperature loss in the geothermal fluid is negligible even under extreme conditions. The worst case would be one where the rate of vertical

water flow in the reservoir, outside of the casing, is so large that it imposes no resistance to heat flow. At the same time, it is also assumed that there is no resistance to heat transfer due to the flow of geothermal fluid inside the well. Thus, the only resistance is that due to the steel casing and the cement outside the casing, which is assumed to be 2 inches thick and have a thermal conductivity of 0.4 Btu/hour-°F-ft. It is also assumed that the well diameter is 10 inches, so that the total casing surface area, over its 2,000 feet of length, is about 5,260 square feet.

The effective heat transfer coefficient for the cement barrier is 2.4 Btu/hour-°F-ft². Thus,

$$Q = 22,600 \cdot \Delta T$$

where Q is the total heat loss from the brine in Btu/hour, and ΔT is the log mean average temperature difference from the well fluid to the formation. The local temperature differences are about 109°F at the top of the well (150-41) and is assumed to be 10°F at the bottom of the casing (150-140).

$$\text{Then, } \Delta T = \frac{(109-10)}{\ln \left(\frac{109}{10} \right)} = 41.4^\circ\text{F}$$

Thus, the total heat loss is 935,600 Btu/hour.

For a well capable of producing 1,000 gpm, or about 500,000 pounds/hr of geothermal fluid at 150°F, and the worst case heat loss, the temperature loss of the fluid is less than 1.9°F. A more realistic assessment would account for the actual resistance to heat transfer outside the cement barrier, and would consider that natural convection does not apply over the entire depth. In this case, the actual temperature loss is likely to be in the order of 0.1 to 0.2°F, which is not significant.

E. Analysis of Geothermal Water Brine Pretreatment Requirements

1. General Discussion

Chemical analyses were conducted on samples from thirteen shallow wells near the study area, nine of which were utilized for this pretreatment evaluation; these latter wells ranged in depth between 400-700 feet. Based on these data and subsequent projections of the water chemistry for the geothermal resource, an analysis of the scaling and corrosion potentials was performed using both solubility equilibria relationships and the Langlier index. These analyses indicate scaling and corrosion will not be serious problems and that the geothermal fluid can be used directly in the heating network. The decision on brine pretreatment cannot be finalized until a test well has actually been drilled to tap the resource. If the water quality proves to be of poorer quality than currently anticipated, a modest pretreatment for controlling CO₃²⁻ scaling potentials might be advised. The details of these brine chemistry considerations and applicable treatment options, should they be needed, are outlined in the following sections.

2. Brine Sample Analyses and Chemical Interpretation

Table 7 presents the results of the water analyses for the nine warm wells in the study area. Sample 12A showed the highest total solids concentration at 1270 parts per million. For conservatism, this sample is used as a basis for estimating treatment requirements. The TDS content of sample 12A represents a level nearly three times that of the next highest concentration of dissolved solids, in sample 12, and nearly six times the average TDS level of the other eight samples.

The principal scaling constituents for these waters are silica and CaCO_3 . Silica is consistently present in the samples in concentrations of 50-75 mg/l which probably represents saturation with respect to the host rock from which the silica was dissolved. Silica solubility decreases with decreasing temperature, thus, as heat is extracted from the brine the waters will develop a slight silica supersaturation. However, precipitation back to the stable format of host rock structure is an extremely slow process, requiring years according to some investigations. Rather the silica will first precipitate as amorphous silica, which is much more soluble than the various rock forms. It is highly unlikely that the brine will cool enough to exceed the solubility of the amorphous form. As a point for reference, the electric utility industry utilizes the rule of thumb allowing maximums of 150-200 mg/l of silica (SiO_2) in cooling tower recirculation water; this is approximately twice that seen in the Baca Grande samples and indicates that silica is not a cause for serious concern.

The carbonate concentrations in sample 12A are at levels that indicate slight supersaturation with respect to calcium ions, and about one-fourth the necessary concentration to form MgCO_3 , the latter of which there should be no problem.

Carbonate concentrations were calculated from the equilibrium relationship between the bicarbonate, carbonate, and hydrogen ion species, using dissociation constants, K_{dis} , from Helgesson (39). Bicarbonate concentrations in the laboratory were determined titrimetrically. Both the titration method and the dissociation constants are subject to degrees of uncertainty. Furthermore, the K_{dis} values were not adjusted for the ionic strength of these samples. Thus, there is an inherent error in the determinations for CO_3^{2-} concentrations. The worst-case calculations of the CaCO_3 solubility indicated that slight pH adjustment would be required to control CO_3^{2-} scaling tendencies. If sulfuric acid were used for this purpose, the concentrations of calcium and sulfate ions would still be well below the calcium sulfate saturation point; sulfuric acid is probably the least expensive acidification medium.

In contrast to the above analysis via solubility and solute equilibria, the calculated Langlier index indicates that sample 12A is very slightly undersaturated with respect to carbonate scale formation, and, therefore, also slightly corrosive to carbon steel pipe.

Table 7

Results of Well Sample Chemical Analyses

	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>12A</u>	<u>13</u>
pH (Units)	8.4	8.4	8.5	8.5	8.3	8.2	8.1	8.2	7.8
E.C. (mmhos/cm)	129	130	225	148	225	141	450	1330	425
<u>mg/Liter</u>									
Calcium	8	7	4	4	10	17	10	4	25
Magnesium	-1	-1	-1	-1	-1	-1	2	2	5
Sodium	24	26	54	33	44	16	109	345	73
Potassium	4	4	2	2	7	5	8	10	7
Iron	-.01	-.01	-.01	-.01	-.01	-.01	-.05	-.01	.07
Silica SiO ₂ (mg/l)	53	53	25	41	56	51	56	73	71
Alkalinity (CaCO ₃ Equiv)	47	49	88	57	99	55	236	723	219
Carbonates	1	1	2	1	1	1	2	7	1
Bicarbonates	58	61	107	67	118	66	293	883	260
Sulfate - S	9.0	8.8	13	9.0	10	9.0	12	17	11
Chloride	1.0	1.0	1.3	1.1	1.3	1.1	1.8	2.8	2.2
Nitrate - N	.80	.61	.83	1.2	.71	.70	.94	2.2	.39
Total Dissolved salts	109	118	195	126	207	122	449	1270	391
Surface Temperature (°F)	70	74	78	78	67	62	63	72	62
Depth (ft)	625	625	690	600	500	400	400	400*	400
Flow Rates (gpm)	50	150-200	900- 1100	200-300	?	20	25	15-20	?

Minus sign indicates less than reporting minima.

The Langelier index is an empirical tool that evaluates scale and corrosion tendencies in terms of the combined factors of pH, alkalinity, ionic strength, and the concentration of carbonate ions. Therefore, the Langelier method accounts for the solubility of the salts and the dissociation relationships between hydrogen, carbonate, and bicarbonate ions. Given the character of a water sample, the Langelier index leads to a solution for the hydrogen ion concentration, expressed as pH_s , at which the carbonate concentration is just at its saturation level.

The Langelier index is specifically oriented toward carbon steel pipe. The zero point of the index, where the solution pH is equal to pH_s , indicates the approximate level of solute species at which carbon steel would begin to acquire an internal scale coating. Below the zero point, carbon steel tends to corrode. For other materials, the acceptable saturation level may be higher or lower due to the varying susceptibilities to corrosion. As noted, our evaluation of the Langelier index, using empirical constants from Standard Methods for Examination of Water and Wastewater (66), and from Clark et al. (12), indicating that sample 12A would be slightly undersaturated with respect to CaCO_3 scaling. This balances the earlier solubility estimate showing slight supersaturation, though the latter evaluation did not take account of the solubility enhancement due to the ionic strength of the solution.

Two other points are worth noting in this discussion. First, physical investigation of the various well sites showed no accumulations of calcium carbonate as would be expected if the water truly were of a scaling quality. Furthermore, the wells continue to flow, so precipitation of appreciable CaCO_3 is apparently not occurring in the wells. Second, it is also important that both the slight CaCO_3 inverse solubility with temperature, and also the carbonate species equilibria and solubility relationships tend to reduce relative CaCO_3 saturation levels; hence the scaling potentials with decreasing process water temperatures decrease also.

In view of all of the above, it is concluded that pretreatment will not be required and that the geothermal fluids can be used directly in the heating equipment system.

3. Pretreatment Options

If upon drilling the exploration wells, it is apparent that scaling potentials exist, the following two treatment alternates would likely be applicable.

First, small dosages, in the parts per million range, of an appropriate scale and corrosion inhibitor could be added to the brine. The choice of the chemical inhibitor would be consistent with the brine chemistry and would be environmentally acceptable to the reinjection system. The chief disadvantage of this approach is its ongoing operating expense for chemicals.

Second, the brine could be acidified to convert dissolved carbonate and bicarbonate ions to their volatile form, and a small flash system might be necessary to remove the CO₂ gas from the liquid. The stripped brine would then be treated with caustic to restore its pH to a non-corrosive level. The criteria by which chemicals would be chosen for this purpose would include simplicity and reliability of usage as well as cost. H₂S is not expected to pose a problem since wells in the San Luis Valley have not exhibited significant quantities of the H₂S constituent.

In both of the two treatment cases mentioned above, the system will be designed to prevent inleakage of air. The presence of oxygen resulting from such leakage is a major factor in corrosion. Even more significant than the corrosion, itself, is the plugging of lines and valves by accumulated corrosion products. Accordingly, every effort should be made to minimize this potential problem.

F. Potentials for Absorption Refrigeration Applications

Previous analyses have been made of ammonia absorption refrigeration systems using geothermal water as the source of heat (38). These analyses were based on relatively hot geothermal resources with brine temperatures of 300°F or more, in order to achieve a reasonably high efficiency. For this service, efficiency is defined as the ratio of energy removed from the low-temperature load to the energy supplied by the high-temperature source. This efficiency factor, called coefficient of performance and abbreviated as COP, is of the order of 0.4 when the source water is at 300°F (38).

The minimum source temperature for a refrigeration system is generally considered to be 200-300°F. Although the COP decreases rapidly as the geothermal temperature falls below this level, the nature of the San Luis Valley geothermal resource is such that a cursory reexamination of the use of lower temperature brines was warranted. It was believed possible that San Luis Valley brines at 150°F might be economical energy sources, despite their low efficiencies, because they occur at such shallow depths. Accordingly, some approximate calculations were made to estimate the cost of such systems and determine if applications to facilities such as small locker plants might be viable.

Two approaches were taken. First, the maximum attainable value of the coefficient of performance, COP_m, can be determined on theoretical grounds as a function of three parameters: T_G, T_{CW}, and T_C, which are, respectively, the absolute temperatures of geothermal brine, cooling water, and the cold load (60). These temperatures are identified on the schematic diagram shown on Figure 13. COP_m is defined by the following physical and mathematical relationship.

$$COP_m = \frac{T_C}{T_G} \times \frac{T_G - T_{CW}}{T_{CW} - T_C}$$

When the load temperature (T_C) is 0°F and the cooling water temperature (T_{CW}) is 80°F, this equation leads to a value for COP_m of about 0.66 when the geothermal brine temperature (T_G) is 150°F. In contrast, the value of COP_m increases to about 1.66 when the geothermal temperature

Figure 13

Schematic of NH₃ Absorption Refrigeration System

increases to 300°F. For the 150°F case, this means that for every 100 Btu given up by the geothermal brine in an ideal refrigeration system, 66 Btu will be removed from the cold load.

In practicality, however, ideal performance represented by COP_m is only a measure of ultimate efficiency. The actual performance of real machines is much less than COP_m . The refrigeration efficiency (RE) is a measure of actual performance, and is defined as:

$$RE = COP_{actual} / COP_m$$

The value of RE tends to be low, and decreases as the geothermal temperature decreases. Thus, the actual performance (COP_{actual}) drops rapidly with decreasing temperatures, as shown by the above equation, since both RE and COP_m are decreasing independently as the resource temperature drops.

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The value of RE for a specific case can only be determined by making a lengthy and complex series of thermodynamic calculations. The nature of these calculations can be illustrated by referring to Figure 13. For each equipment item, material and energy balances must be made. In addition, a series of equilibrium calculations must be made for the distillation column, the condenser, the generator, and the absorber. Furthermore, because of the recycle streams involved, an iterative calculational procedure must be used. Because of the complexity of these calculations, and because only an estimate of the performance was required, only approximate calculations were made, and complete material and energy balances were not developed to their entirety.

For the case of geothermal brines at 150°F, refrigeration efficiency is estimated to be between 10 and 15 percent. Thus, with COP_m equal to about 0.66, the actual coefficient of performance will be between about 0.07 and 0.10. Expressed differently, for every 100 Btu supplied by the geothermal brine, only 7 to 10 Btu will be removed from the cold load.

The low performance coefficient provides a thermodynamic indication of high costs for the refrigeration system. In addition, there are other process requirements that magnify these cost factors. These effects can be described qualitatively by referring to Figure 13. Primary among these factors is the amount of energy that can be removed from each pound of geothermal brine, a value that cannot be determined by the thermodynamic determination of COP_m . For the 150°F brine, it is estimated that the brine can be cooled by no more than 20°F in the generator. Thus, each pound of brine produces less than 2 Btu of refrigeration, or 500,000 pounds of brine as required to provide a million Btu of cooling. Assuming that a 2,000-foot well produces 1000 gpm of 150°F brine and costs \$150,000 to drill and establish production, and assuming that capital costs are annualized at a rate of 20 percent, this leads to an energy cost of about \$3.75/MBtu of cooling without counting operating costs. An electrical refrigeration, based on a charge of 3¢/kwh for energy, has an energy cost of about \$2.20/MBtu of cooling.

Another costly process factor due to the low geothermal temperature is the relatively high concentration of weak aqua leaving the absorber. Thus, the flow rate of recirculating weak aqua, from the generator to the absorber where ammonia vapor is recaptured and sent back to the distillation column, will be relatively large. This increases significantly the costs of pumping, and the capital costs for vessels, pumps, and lines. The third significant process factor that adds to costs because of the low geothermal source temperature is the cost of cooling towers. Because of the low efficiency of the system, the relative cooling load will increase, thus increasing the operating and capital costs for the cooling system. This also dictates what could be a significant consumptive water use in a water-short area.

In summary, the analysis indicated that a study in more depth was not warranted because of the low efficiency of the system. This was true even though resource production costs are expected to be relatively

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low. It may be of interest at a future time to investigate an integral system, where the ammonia refrigeration unit acts as a topping unit, taking only the first 10 or 20°F from the geothermal brine. The partially cooled brine would then be used for normal heating purposes. In order for this process to be economic, it would be necessary that the refrigeration and heating loads are reasonably well balanced, and that the capital cost of geothermal production facilities could be borne primarily by the heat user.

VI. DESIGN AND ECONOMIC EVALUATION OF THE RESIDENTIAL
GEOTHERMAL DISTRICT HEATING SYSTEM

A. Basic Description of the Geothermal Circulation System

Feasibility designs for a geothermal district heating system were developed to serve the Baca Grande residential areas consisting of the Chalet Units I, II, and III and the Grants Unit I. Greater detail was given to the designs of Chalet Units I and II since there is currently doubt as to the ultimate development of the Chalet Unit III area. The general designs developed for Chalets I and II will be applicable to both Chalet III and the Grants region, although the latter may require adjustments due to a lower overall residential density. Only limited services are to be provided to the Grants area which consists of 3-5 acre lots.

The proposed geothermal district heating system consists of four basic sections necessary to produce, transport, and dispose of the hot waters during the heat extraction process. Figure 14 schematically illustrates the system's flow path. First, the hot waters are pumped from the production wells and directed to the pipelines leading to the area containing the served residences. These delivery pipelines may be fairly long or quite short, depending on the production field location relative to the service areas. Once at the service area, the water feeds into a high pressure main trunk line, called the backbone system, which completely loops the service region. Low pressure distribution lines will be connected to this backbone system at selected points as housing construction demands merit. These low pressure lines will receive the geothermal waters through pressure-reducing valves and will then deliver water to the consumer. After consumer utilization of the delivered water for both space heating and hot water heating needs, affecting about a 20°F temperature drop, the waters will be discharged into a collection system. This system transports the waters to the disposal site for reinjection. In certain instances, the geothermal waters may be used prior to reinjection for lower temperature process needs, such as for an aquaculture facility.

The district system proposed is comparatively complex, principally due to the extensive elevation changes which occur throughout the platted areas of the development. A second complicating factor was the phased construction activity for the development projected for the next 30 years. This mandated a system design with flexibility for continual expansion as the demand for services grows.

The feasibility design effort considered several possible engineering system approaches including (1) the storage of waters in insulated reservoirs to minimize peak pumping requirements; (2) the use of staged pumping through successively higher elevations with direct laterals serving the residences; (3) service to individual zones as completely independent systems; and (4) the high pressure backbone system chosen as the preferred approach. That approach is the most economical and the most flexible

Figure 14
GEOTHERMAL CIRCULATION SYSTEM
MODIFIED TWO PUMP / TWO PIPE DIRECT AND REVERSE-
RETURN SYSTEM

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system for gradually expanding the initial installed systems to meet the increasing consumer needs.

The feasibility analysis for evaluating the geothermal residential hot water and space heating was organized as a five-step process and involves the following tasks: (1) calculate the single residence peak heat load and subsequently the total peak load for the served areas; (2) calculate the annual heating requirement; (3) calculate the required geothermal water flows to meet the peak demand; (4) size and locate the delivery and collection piping system necessary to transport the waters; and (5) evaluate the economic attractiveness of the systems. These results are discussed below.

B. Residential Peak Heat Load Calculations

The initial step in determining the expected single residence peak heat load is to ascertain the style, construction characteristics, and size of an "average" development home. Communications with Baca Grande officials indicate that approximately one-third of the current residents are retired folk who live in the development the year round with homes approximating 1,800 square feet of floor area. A second third of the residents are younger people holding down full-time employment and living in homes normally ranging between 1,400 and 1,600 square feet in size. A third group of homes are more summer vacation oriented but are often rented in the winter months; these are usually of the 1,000-square-foot variety. Based on these distributions, the "average" residence for determining peak heating needs is defined as one with 1,433 square feet of finished floor area. Generally, it is also of contemporary design. The structure on which our heat load figures are based is two-story with approximately 850 square on the first floor. The floor surface area, dimensions, height, insulation, and construction materials are important since the heat load analysis used the basic heat transfer relationship as given in Equation 1 to calculate the heat loss through the walls, doors, windows, floor, and ceiling of the home.

That equation is of the form: $Q = U \times A \times \Delta T$ (1)

where Q = Peak residential heat loss in Btu/hour
 U = Heat transfer coefficient, in Btu/hour- $^{\circ}\text{F-ft}^2$
 A = Exposed surface area, ft^2
 ΔT = Temperature difference between inside and outside conditions, $^{\circ}\text{F}$.

A -11°F design temperature was adopted based on documented weather data for the area and as discussed previously in Chapter V. Assuming a 70°F inside temperature level, the ΔT would equal 81°F .

Since the individual heat loss calculations for the walls, ceilings, and floors get laborious and are similar, the procedure for determining the load through the exposed walls is provided below for reference. The total loss, including the contributions from the other parts of the structure, is then summarized for brevity.

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The total outside exposed wall surface area of the home is 1,693 square feet. Construction is with 2 x 4's supporting 1/2-inch sheet rock on the interior, an R-11 insulation inside the wall, 5/8-inch plywood outside covered with a wood siding. Table 8 shows the schematic view of the wall construction and the R values of each of the building materials.

Table 8 .--Wall Construction and Resistances

(R = hour - °F - ft²/Btu)

Outside film coefficient	R = 0.17
Outside wall siding	R = 0.81
5/8-inch plywood	R = 0.78
R-11 insulation	R = 11.0
1/2-inch sheet rock	R = 0.45
Inside film coefficient	R = 0.68
Total	13.89

Thus, the equivalent R value for the walls is 13.89; the R value is simply $\frac{1}{U}$; therefore, the overall heat transfer coefficient is 0.072 Btu/hour-°F-ft². Since the walls are of 2 x 4 construction, with wood studding occupying up to 20 percent of interior wall space, the overall wall coefficient should be increased by about 10 percent giving a U value of 0.079. The total peak load figure thus calculated from Equation 1 is 10,833 Btu/hour.

Similar computational procedures were used for the doors, windows, ceiling, and floor. Windows were all designated as double pane; ceiling insulation was to R-19 values. Finally, outside air infiltration was assumed to equal 9.6 Btu/hour per square foot of floor surface.

The sum total home peak heat loss was then found by adding the six components as summarized in Table 9. The total calculated loss came to 0.048 million Btu/hour.

Table 9.--Projected Residential Peak Heating Loads

Component	Heat Loss (Btu/hour)
Walls	10,833
Doors	1,827
Windows	9,793
Floor	7,910
Ceiling	3,800
Infiltration	13,757
Total	47,920

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The above numbers were verified through computer calculated values obtained from local vendors.

In addition to the space heating demand just discussed, hot water heating requirements can also be substantial. Based on ASHRAE guidelines outlining recommended hot water heater capacities, a 19,000 Btu/hour capacity unit is suggested for the "average" house as identified in this study. With a heat exchanger area of 3.8 square feet, approximately 1 gpm of geothermal water flow is required to meet those requirements.

C. Geothermal Water Flow Requirements

To calculate the geothermal water flow requirements to the "average" home, one must first determine the type of home heating system most suited to the available resource and, second, the amount of energy that can be extracted from each pound of hot water during the application. For the delivered water temperatures of 140-150°F available at the site, a forced air system is preferred as compared to hot water convection or radiant systems (18). A geothermal forced air system is simple, consisting of a properly sized coil placed in front of a conventional furnace fan. All components are commercially available; the ductwork network is identical to that used with common forced air units. Recent studies show that approximately a 20°F temperature drop or 20 Btu/lb of water can be extracted from the source for these temperature ranges (18). Using this figure and the 48,000 Btu/hour total heat loss calculated earlier, the required geothermal flow rate is 4.8 gpm. The hot water heating geothermal water demand represents an extra 1.0 gpm and when adding a 10 percent safety factor, the design geothermal water flow per house is 6.4 gallons per minute. The sum total geothermal water flows for the entire development can then easily be calculated by multiplying by the number of lots being marketed. For example, for the Chalet I area which has 2,338 platted lots, the ultimate design peak demand would be 14,960 gpm.

D. Annual Heating Requirements

The previous section discussed the design conditions to supply heating requirements during peak winter conditions. However, in determining the payback period for the project it is also necessary to define the annual fuel consumption. Annual heating requirements are related to both the annual degree days of 8,027 and the design heating load of 48,000 Btu/hr. For the purposes of this study, two different calculational methods were utilized and then checked for consistency. The first calculational method is from ASHRAE (2) and is as follows:

$$F = U \times N_b \times D \times C_f \times C_d$$

where

F = Fuel consumption in therms (1 therm = 100,000 Btu)

U = Unit fuel consumption (from ASHRAE table). For our case, U = .00392 for a 100-percent energy efficient system.

N_b = Design heating load in 1000 Btu/hr

D = Number of degree days

C_f = Temperature correction factor

C_d = Correction factor for additional degree days.

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For the case at hand:

$$F = (0.00392) \times (48) \times (8027) \times (.875) \times (.90) = 1,189 \text{ therms/year}$$

or

$$119 \times 10^6 \text{ Btu/year.}$$

The above number is based on a 100-percent efficient system such as electric or geothermal. For a propane or natural gas system the delivered Btu to the site would be 70 percent higher due to the inefficiencies of those systems at the 8,000-foot elevation.

A check was performed on the above results, using methods outlined in Strock (71). That relationship is stated as follows:

$$H = KD \frac{h}{1000}$$

where

H = Annual heat load, (Btu/yr)

D = Annual degree days

K = Empirically derived constant which is a function of climate.

For the Baca Grande case, K = 325.

$$\frac{h}{1000} = \text{Design heat load per 1,000 Btu}$$

Thus,

$$\begin{aligned} H &= (325) \times (8027) \times \left(\frac{48,000 \text{ Btu/hr}}{1000} \right) \\ &= 125 \times 10^6 \text{ Btu/yr} \end{aligned}$$

Based on the consistency of values obtained from both methods, an average annual heating requirement of 120×10^6 Btu/yr for conventional homes was selected for use in the economic portion of this report. A similar calculation procedure was performed for the mobil homes which have a design load of 39,300 Btu/hr. With this information, the annual heating load as adopted is 100×10^6 Btu/yr.

An attempt was made to substantiate these calculated annual heating requirements with actual heating bills from residents living in the development. This effort met with limited success. For homes using propane, the actual heating bills were approximately 20 percent less than the calculated value. For homes utilizing electric heating there was a large discrepancy, of between 30-50 percent, between the calculated and actual heating loads. The following tabulates possible reasons explaining the lower than expected actual heating requirements.

-The current makeup of people in the development is generally an older population, many retirees, who are very cognizant of fuel bills. As such, they make a concerted effort to reduce fuel bills by

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lowering thermostats and keeping windows and doors closed. Families with children have more difficulty consistently accomplishing this, with family members often entering and leaving the household premises.

-Many of the homes supplement heating requirements with highly efficient wood-burning stoves and fireplaces.

-In homes with electric heating, individual controls are located in each room. This may permit a significant fuel saving when rooms are not heated as in the case of retired couples.

As the Baca development continues to grow, some of the above factors will be minimized. For instance, a larger percentage of younger people with families will move in, requiring larger homes as compared to vacation homes, which in turn increases the heating requirements. Thus, the calculated annual heating value of 120×10^6 Btu/yr is assumed for the life of the project.

The hot water requirements of the residences will also be supplied by the geothermal resource. Based on ASHRAE guidelines, an average home demands 75 gallons per day of 140°F water. A domestic hot water temperature of 135°F can be expected utilizing the available geothermal resource. Thus, a total of 78 gallons per day is required at the 135°F temperature. With an average annual inlet water temperature of 50°F , the total annual hot water heating requirement is 20.1×10^6 Btu/hr. To summarize, Table 10 lists the design and annual heating requirements for the homes of the residential area.

Table 10.--Design and Annual Heating Loads

	<u>Conventional Homes</u>	
	<u>Design Btu/hr</u>	<u>Annual Btu/yr</u>
Space heating	48,000	120.0×10^6
Hot water	19,000	20.1×10^6
Total	67,000	140.1×10^6

E. Engineering Description of the Distribution and Collection System

The design of the geothermal distribution system for the residential areas involves three distinct piping segments. The first concerns delivery of the geothermal fluid via major trunk pipelines from the well production area to the boundaries of the residential area. The second segment is the backbone of the distribution system which loops the service area and delivers hot waters throughout the residential section. The third segment involves distribution of the geothermal water from the large backbone loop through smaller pipes to the individual homes. Each of the segments is discussed individually in the following text.

F. Geothermal Water Production Delivery Lines

This segment of the distribution system involves the collection and transportation of the geothermal fluid from the well field to the residential area. Figure 15 shows the routing of these trunklines to Chalet I and II areas. The trunklines were sized, for normal operating conditions, to carry the production from three geothermal wells, or for a capacity of approximately three thousand gallons per minute each. A 3,000 gpm flow rate permits an orderly phased development of the residential areas. At this flow rate a new trunkline will be connected to the distribution system for each 450 homes added to the subdivision. The trunklines were designed for a maximum flow of 4,500 gpm to provide additional capacity in the event one of the lines was shut down. If one of these trunklines requires shutdown for repair or routine maintenance the two adjacent lines are capable of supplying the necessary flow.

Vertical pumps with a capacity of 1000 gpm at 500 feet of head are located in each well at a 200-foot depth. The 500-foot discharge pressure is required to lift the fluid 200 feet to the surface, an 80-foot frictional pipeline loss, and an additional 200-foot rise in elevation to the booster pumps. These vertical well pumps are ten stage and require a 200 hp motor. The cost for each well pump, motor, and associated surface valving is \$20,540.

For the design capacities discussed above, the trunkline is a 14-inch diameter pipe running about 1 mile from the geothermal field to the booster pumps. The pressure requirements on the pipe are a result of a 200-foot rise in elevation from the wells to the booster pumps and a 100-foot pressure loss due to frictional factors. Thus the pipe can be made of concrete asbestos since the total dynamic head does not exceed the 150-pound rating of the pipe.

At normal operating conditions the temperature loss through an un-insulated concrete asbestos trunkline is about 0.8°F; however, during the spring, summer, and fall when peak demand is not required, the temperature loss increases substantially. During summer months when heating demand is primarily for hot water, the temperature loss could be as high as 4°F. Therefore, to conserve the moderate heating value of the geothermal resource the pipeline must be insulated. As discussed earlier in the piping materials section, a pre-insulated concrete asbestos pipe with a protective outer casing is necessary for this service. The economics of this report are based on utilizing a pre-insulated product for this segment of the distribution system. However, it should be noted that in a final detailed design a pre-insulated reinforced fiberglass piping with an outer casing also merits consideration and may be cost competitive.

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Figure 15. Distribution Trunkline Routing

G. Main Trunk-Backbone Distribution System

This segment of the distribution system facilitates the delivery of the large quantities of hot water from the trunklines to the branch feeder lines. The backbone system was designed to permit any one of the trunklines to be removed from service and continue to transport water to remote areas in the residential sectors. Figures 16 and 17 show the backbone distribution system for Chalet Units I and II, respectively. As seen in these figures, the pipeline size is reduced at the farther reaches of the Chalets. As seen in Figure 17, the backbone system of Chalet II has several loops which permit sectional construction. This permits the backbone system to be phased in as housing activity develops in any area. Table 11 lists the approximate lengths of the various size pipe of the backbone system as shown on Figures 16 and 17.

Table 11.--Required Piping Lengths for the Chalet I and II Backbone System

Pipe Size (inches)	Chalet I Total Length (feet)	Chalet II Total Length (feet)
8	8,100	7,200
10	3,800	25,700
12	31,200	12,200

The pressure requirements on this portion of the distribution system are a result of the 450-foot rise in elevation from the booster pumps to the uppermost portions of the chalet areas, the 150-foot frictional pressure drop, and the minimum delivery pressure of 350 feet to the branch feeders. This comparatively high pressure requirement necessitates the use of carbon steel pipe.

The temperature loss within the backbone network varies throughout the system. The drop in temperature from the booster pumps to the backside of the system is dependent on the fluid velocity and the total distance traveled. All system piping will be buried at 6-foot depths. For an uninsulated steel line the expected temperature loss is nearly 4°F when operating at design conditions. During non-peak periods the temperature loss could increase to 20°F. To compensate for this large temperature drop, additional pumping power is required, which adds to already substantial annual operating costs or the pipe size could be increased which increases the initial capital costs. Additionally, when starting with only a 145°F source temperature a 20°F drop greatly reduces effective applications of the supply for direct space heating applications.

An attractive alternative to either larger pipe sizes or additional pumping capacity is to insulate the pipe. Using a pre-insulated steel pipe with the piping configuration on Figures 16 and 17 and the values from Table 4, the maximum expected temperature loss operating at design conditions is 1.0°F. The temperature loss increases to 3.5°F when the system

Figure 16. Backbone Loop for Chalet Unit I

Figure 17. Backbone loop for Chalet Unit II.

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is operated at non-peak conditions. The economic considerations of this segment of the distribution system are based on a pre-insulated steel piping with a PVC outer casing.

As noted earlier, booster pumps located at the end of the initial trunkline are used to pressurize the remaining portion of the distribution system. Each booster pump station develops a pressure of 450 psi necessary to distribute the fluid to the homes. The pump stations are sized to provide a normal operating flow of 3000 gpm. To help minimize electrical consumption during periods of low geothermal demand, four smaller pumps are specified rather than one large pump and associated motor. Each pumping station contains the following five centrifugal pumps:

- two (2) 1500 gpm constant speed pumps with 500 hp motors (1 complete spare)
- two (2) 500 gpm constant speed pumps with 200 hp motors
- one (1) 500 gpm variable speed pump with 200 hp motor

The pumps are used in parallel and additional capacity is supplied as demanded. The first 500 gpm demanded is supplied by the variable speed pump, the next 500 gpm by the first 500 gpm constant speed pump, etc. For example, a flow of 2400 gpm is supplied by using the 1500 gpm constant speed pump, one of the 500 gpm constant speed pumps, and the variable speed pump. The pump costs summarized in Table 12 include the necessary valving and electrical controls.

Table 12.--Pump Costs

1500 gpm 1000-ft head constant speed with 500 hp motor	\$21,281.00
500 gpm 1000-ft head constant speed with 200 hp motor	\$10,743.00
500 gpm 1000-ft head variable speed with 200 hp motor	\$24,743.00

H. Branch Feeder System

In this segment of the distribution system, the geothermal fluid is withdrawn from the backbone system and piped to the individual homes. The fluid passes through progressively smaller pipe sizes as it travels from the backbone pipeline to the homes. Figure 18 shows the average distribution of pipe sizes versus flow requirements for the individual branch systems. Table 13 tabulates the distribution breakdown of pipe requirements for the example presented on Figure 18 for branch system distributing 1000 gpm, or the equivalent of 156 homes, assuming 70 linear feet of 3/4-inch pipe per home.

DISTRIBUTION PIPE REQUIREMENTS

CHALET UNITS 1 & 2 - LOT DENSITY = 1.70 LOTS / ACRE; 6.38 GPM PER UNIT

MOBILE HOME ESTATES - LOT DENSITY = 2.97 LOTS / ACRE; 5.40 GPM PER UNIT - MULTIPLY ALL VALUES BY 1.90

CHK'D DES. <u>WJZ/28</u>	DESIGN <u>---</u>	DOE NO. <u>ET-78-C-07-1703</u>	SHEET <u>6</u> OF <u>75</u>
APP'D DES. <u>WJZ/28</u>	DRAWN <u>R.K. WJZ/28</u>	ENGINEERING SURVEYING JACOB ENGINEERING, INC. 1000 JACOB AVENUE, SUITE 100, FARMINGTON, CONNECTICUT 06030	

Table 13.--Pipe Distribution Requirements

Pipe Size (inches)	Total Length (linear feet)
3/4	11,050
1	625
1-1/4	625
1-1/2	625
2	1,790
2-1/2	1,650
3	1,570
4	1,210
6	250

The flow through the various branch systems varies from about 400 gpm to 1200 gpm. In the economic portion of this report the piping distribution requirements presented in Table 13 were used for each 1000 gpm peak demand of the residential section. Table 14 lists the total piping requirement for the Chalet I and Chalet II residential sections.

Table 14.--Total Pipe Distribution Requirements
for Branch Systems

Pipe Size (inches)	Chalet Unit I Total length (ft)	Chalet Unit II Total length (ft)
3/4	171,300	138,000
1	9,700	7,800
1-1/4	9,700	7,800
1-1/2	9,700	7,800
2	27,800	22,400
2-1/2	25,600	20,600
3	24,300	19,600
4	18,800	15,100
6	3,900	3,200

The pressure limitations in the branch feeder segment of the distribution system permit the use of low-pressure pipe, since the total dynamic head is less than 350 feet. The total head on the pipe is due to frictional losses of 125 feet, elevation changes of 100 feet, and a delivery pressure to the homes of approximately 100 feet. Due to this lower pressure and the necessity to minimize costs it is advantageous to use concrete asbestos for the large pipe sizes of 3- through 6-inch diameter. For the smaller pipe sizes, 2-1/2-inch and less, copper piping is used.

A temperature loss of 6.5 degrees could be expected through an uninsulated branch system operating at peak design conditions. A significantly larger temperature loss about 25°F is possible when the system is operating at non-peak conditions. This great temperature loss requires the

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use of insulation to maintain the geothermal fluid at usable temperatures. By insulating just the copper piping the temperature loss is cut to 3.5°F and 9°F for peak and non-peak periods, respectively. Thus, the economics of this distribution section were based on a non-insulated concrete asbestos pipe and a pre-insulated copper pipe with a PVC outer casing.

To maintain and regulate a pressure of 150 psi in the branch system, it is necessary to install a pressure-reducing valve at each junction of the backbone and branch systems. Additionally, a pressure-regulating valve will be installed at each home to provide a constant supply pressure. To insure an adequate temperature of the geothermal fluid during non-peak demand periods, temperature control valves are located throughout the branch and backbone systems. These valves remain inoperative if the fluid temperature is greater than 135°F. However, at temperatures less than 135°F the valve will open and the cooled geothermal fluid will drain to the collection system. The valve will close when the fluid temperature increases to 137°F.

The following is a schematic diagram of the valving requirements necessary at each junction point of the backbone systems and the branch feeder lines, and also at the final point of application.

Figure 19. Schematic Diagram of Valving Requirements

These valving costs are identified in Table 15 by reference to the above diagram.

Table 15.--Average Valving Costs per Branch

<u>Equipment</u>	<u>Cost</u>
High pressure valve	\$ 600
Pressure-reducing valve	1,800
Low pressure valve	300
Pressure relief valve	1,200
Low pressure valve	<u>300</u>
Total	\$4,200

Since there are 27 branch systems in the two Chalet areas, these valving costs would total \$113,400 in a fully-developed system. There are additional valving costs of \$150 per home for a low pressure shut-in valve and a pressure reducing valve. The temperature control apparatus in each branch system costs \$800, consisting of one temperature control valve at \$500 each and one low pressure shut-in valve costing \$300 each.

I. Residential Collection System

The collection system is utilized to carry the cooled geothermal fluid from the homes to the disposal area. The collection system generally follows the layout of the distribution system; however, in some areas it is necessary to follow topographical contours to permit gravity flow. The system is built and phased into operation similarly to the distribution system in that a backbone system is to be installed first, the feeder lines are constructed as required, and then larger diameter collecting pipelines return the fluid to the reinjection site. The differences between the collection and distribution systems are that insulation of the piping is not required and there are no high pressure regions in the collection system.

The collection system is of a gravity return design similar to normal sanitary sewers with only a few modifications. The first alteration is that the system is closed to prevent infiltration of air. The presence of air increases potentials for the introduction and propagation of algae and bacteria. These increase the frictional losses through the pipeline as well as the possibility of clogging valves and reinjection wells.

The second modification is the placement of pressure-reducing valves placed in the collection system at each major intersection and approximately every 100 feet vertically. These reducing valves effectively throttle the flow and also prevent excessive back pressure at the tie-in points of the homes. With the distribution system pressure to the homes set at 30 to 40 psig depending on its elevation within the system, this inlet pressure less the small line losses within the unit is equal to the outlet

pressure. Therefore, under packed conditions, the collection system has the residual pressure after utilization of about 20 to 30 psig, and the inlet pressure into the collection system must be less than this to maintain proper flow. By placing pressure reducing valves approximately every 100 feet vertically, about 45 psig, and setting those valves at about 50 psig, residual line pressures will be maintained at about 15 psig on the outlet of the valve and stabilized flow at less than 10 feet per second will be realized. Thus, a gravity system modified to provide a minimum back pressure to maintain a packed line and no air entrainment is feasible.

The design temperature and pressure of the collection system are 130°F and 50 psi, respectively. At these design conditions the initial capital cost is minimized by using concrete asbestos and high density polyethylene for piping materials. Concrete asbestos is used for pipe sizes greater than 3 inch and polyethylene used for the smaller sizes. All pipe normally sized less than 3 inch will be replaced with a 3-inch pipe for simplicity of installation, reduction of frictional losses, and because of the small incremental cost between 3/4-inch through 3-inch diameter polyethylene pipe. Table 16 lists the total pipe requirements for the collection system for the fully developed Baca Grande residential area.

Table 16.--Piping Requirements for Collection System

Pipe Size (inches)	Material of Construction	Chalet I Pipe Length (feet)	Chalet II Pipe Length (feet)
3	Polyethylene	278,100	224,100
4	Concrete asbestos	18,800	15,100
6	Concrete asbestos	3,900	3,200
8	Concrete asbestos	8,100	7,200
10	Concrete asbestos	7,800	25,700
12	Concrete asbestos	31,200	12,200
14	Concrete asbestos	26,400	21,100

The pipe lengths presented in this table are used to determine the ultimate cost of the collection system. Typical routings of the primary collection system are illustrated in Figure 20.

J. Disposal System

Disposal system design focused on three basic alternatives as follows: (1) reinjection; (2) surface disposal to area waterways; and (3) spreading ponds and agricultural irrigation. ReInjection is the preferred alternative and the one used in the economic evaluation, since

CHALET'S UNIT ONE

Figure 20. Collection System Piping Routings

<div> <div> <div>J. J. CASCHKE ENGINEERING, INC.</div> <div>ENGINEERING SURVEYING</div> </div> </div>	<div> <div>DOE NO.</div> <div>ET-78-C-03-1703</div> </div>		<div> <div>CHK'D</div> <div>_____</div> </div>
	<div> <div>SHEET</div> <div>_____</div> <div>OF</div> <div>_____</div> </div>	<div> <div>DRAWN</div> <div>_____</div> </div>	<div> <div>APPD</div> <div>_____</div> </div>

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this effectively mitigates water rights concerns; well drilling permits for consumptive use from the artesian aquifer have not been granted for several years due to potentials for decreasing recharge to the Rio Grande River further south.

Groundwater impact with reinjection would be minimal since basic water chemistry is unchanged by use. Disposal wells should be located at least six-tenths mile from nearby production wells to eliminate cold water short-circuiting during the anticipated 30-year life of the system. The wells probably will not need to be drilled to the full production depth according to State water engineering information. However, they would at least have to penetrate into the confined aquifer. One 8-5/8 disposal well is designed to serve three production wells; the vertical injection zones of these wells will be larger than the comparative production zones of the production wells so as to reduce injection pressure requirements.

Infiltration systems such as spreading ponds and irrigation are sound environmentally assuming a high quality geothermal water. This choice would tend to augment unconfined aquifers but would not replace water back to the original confined aquifer from where it was withdrawn. Discharge to surface waterways is in practice similar to the infiltration alternatives because of the intermittent nature of area streams which infiltrate and lose surface flows before leaving development properties. Thermal effects would have to be carefully considered for this alternate, however, to prevent damage to aquatic life. Also, the discharge of dissolved salts might also pose concerns depending on the final quality of the resource.

K. Economic Analysis

Two separate economic analyses were prepared to evaluate the feasibility of establishing the residential district heating system proposed for serving the Chalet Units I and II regions. Two base case alternates were considered, the major difference being the rate of actual housing construction as the development matures. Residential Alternative 1 assumes a continuing housing construction rate of 20 homes per year for a 30-year total of 762 homes. Residential Alternative 2 assumes a full development rate of 139 homes per year over 30 years for a total of 4,242 homes. For a peak demand rate of 6.4 gpm per house, Alternative 1 requires 4,300 gpm of geothermal well capacity; Alternative 2 requires 27,100 gpm production capacity. One disposal well is provided for every three production wells. Production Area III, located immediately adjacent to the residential service area, was used to determine piping lengths. In each case, the annual capital costs required to install the designed systems were determined for each year of the 30-year period.

For the first analysis, an annualized cost methodology was utilized; annualized costs were calculated at 15 percent capital costs. These annualized costs include amortization of principal, cost of money, insurance, and system maintenance. This 15-percent figure is considered conservative for a public system. Since the system is capital intensive, a reduction in this value impacts the economics considerably.

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Total annual operating costs were also calculated for each year and included electrical pumping costs, administration costs, and royalties. Proposed royalties were derived from royalty structures currently in practice in the petroleum industry. Based on a \$15 per barrel wellhead price, a 10-percent royalty amounts to \$0.25 per million Btu. After total annual costs were summed, the total heat load directly utilized in the system was determined and the cost per million Btu calculated.

The results of those analyses for the two base cases give 30-year average costs to the user of \$18.40 per million Btu for Alternative 1 and \$10.94 per million Btu for Alternative 2. The electrical heating cost under the existing rate structure is equivalent to \$10.05 per million Btu. The results of these analyses are presented in Tables 17 and 18.

A second independent economic review was also performed. This computer-based analysis included 30-year cash flow projections, municipal bond issuance schedules, interest rate evaluations, and bond pay-off schedules. Results of this work are consistent with the annualized economic review presented above. The 30-year levelized energy cost to the consumer is \$20.89 for Residential Alternative 1 and \$11.90 for Residential Alternative 2; this is predicated on an 8-percent bond interest rate and a 9-percent rate of accumulation which would be turned over to the district reserve fund for future capital investments and for an in-lieu-of-tax payment to the district. A parametric analysis of the effects of inflation rates ranging from 0 to 15 percent over the 30-year period was also performed. As an example, for Residential Alternative 1, a 30-year 5-percent inflation rate would raise the levelized consumer cost to \$15.94 per million Btu. Fossil fuel costs would be expected to increase similarly or to higher levels.

The complete details of this analysis and the 30-year cash flow projections are given in Appendix D.

The data as presented highlight several important conclusions. First, the economics of the proposed systems are heavily dependent on the rate of housing activity. The comparatively high \$18.40-20.89 per million Btu user cost is caused principally by the extensive piping costs associated with the backbone distribution system and collection systems, which are not fully utilized. The Alternative 2 full development case with a cost of \$10.94-11.90 per million Btu is competitive with electrical space heating costs based on existing rate structures. Another factor which had notable impact on the final system energy cost was the inclusion in the cost estimates of the small diameter piping required to deliver the hot water from the lot boundary to the house site. Normally, this might be taken care of via an individual water or electrical tap fee and often represents a hidden cost to each homeowner. In the present analysis, this amounted to more than 50 miles of installed piping, costing more than \$10 million. The exclusion of this final hookup cost would markedly decrease the projected energy cost rates. Third, because of the important effect of the annualized capital costs, the economics of these facilities improve dramatically for the life of the system beyond the 30-year base. Since distribution systems are often operable for a 50- to 75-year life, this again improves the overall economic picture. Finally, although

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Table 17
Economic Summary

Residential Alternative 1

Housing construction - 20 units per year
Total development - 672 housing units
Geothermal System peak design capacity - 4,300 gpm
Distribution from Production Area III

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10 ⁹ Btu/yr	User Energy Cost \$/10 ⁶ Btu
1	472.3	44.2	12.9	
5	543.2	68.5	24.1	
10	791.8	111.2	38.1	
15	867.0	129.9	52.1	
20	1,044.5	158.3	66.1	
25	1,098.4	203.9	80.1	
30	1,175.6	219.8	94.1	
				30-year average user cost \$18.40

Table 18

Economic Summary

Residential Alternative 2

Housing construction - 139 units per year
Total development - 4,242 units per year
Geothermal system peak design capacity - 27,100 gpm
Distribution from Production Area III
Annualized costs @ 15%

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10 ⁹ Btu/yr	User Energy Cost \$/10 ⁶ Btu
1	794.6	79.5	29.6	
5	1,463.6	214.8	107.5	
10	2,170.7	415.4	204.8	
15	2,846.6	594.2	302.2	
20	3,557.6	778.1	399.6	
25	4,131.5	951.5	496.9	
30	4,699.4	1,125.3	594.3	
				30-year average user cost \$10.94

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electrical pumping costs due to the substantial changes in elevation between the production area and the subdivisions are substantial, they are not large as compared to the annualized cost referenced earlier and represent less than 10% of the delivered energy cost.

It is true that currently there are available conventional resources which are competitive with the energy cost figures presented. However, such resources continue to be managed from the perspective of a national energy shortage; the costs of these resources are projected to rise in ranges of 7 to 10 percent per year, which presently would account mainly for inflationary price increases and allows little room for supply-and-demand forces raising fossil fuel prices. The geothermal system, on the other hand, should not experience this increasing cost trend to a corresponding degree, depending more nearly exclusively on inflation in labor and capital goods costs. Thus, a geothermal energy system is seen to be a continually more attractive and reliable energy resource in future years.

In addition to the base case alternatives discussed above, additional sensitivity analyses were conducted to determine what effect a poorer than anticipated water quality would impart. In this instance, the geothermal water would be pretreated to remove potential scale forming constituents before direct use in the heating systems. Such a system might consist of acid injection and the addition of small quantities of anti-scalants; its estimated cost is \$0.10 per 1,000 gallons of treated water.

The evaluation showed the economic impact of this continuing operating cost to be \$0.85 per million Btu, or roughly 8 percent of the previously identified \$10.94 figure.

An analysis was also developed to evaluate the impact of both well depth and well production sites on the average energy cost. Because of the overriding importance of the annualized capital costs, the effect of both of these factors are pronounced and their effects can be seen immediately. For instance, if Production Area II, located 3.5 miles west of the service region, is the source area as compared to Production III as used in the base case evaluation, distribution costs would be increased by almost \$18.5 million, resulting in increases in delivered energy costs of 32 percent for the Alternative 2 case.

Well costs at a 1,500-foot depth are \$82,500 per well versus the \$130,000 per well figure for the 2,000-foot depth. Thus, if exploratory drilling proves the resource to be available at 1,500 feet, total capital costs would be decreased approximately \$1.3 million for the 30-year Alternative 2 case and the resultant delivered energy costs would be reduced about 3 percent.

CHAPTER VII. RETROFIT DESIGN AND ECONOMIC ANALYSIS--BACA
GRANDE INN AND POOL

A. Introduction

The Baca Grande Inn is a modern "Best Western" 40-room motel with a large dining room-lobby area and adjacent lounge. Figure 21 illustrates the basic layout of the facility. The external appearance of the structure resembles that of southwestern adobe although construction materials are modern. The facility is built around a center court area where the swimming pool is located. Currently, the Inn is on total electrical heat; the pool is heated via propane. In the summer, the individual rooms are cooled using window air conditioners. These are expensive energy sources and provide incentive for considering a conversion to a geothermal source.

The discussions describing the design and economic evaluation of the potential for retrofitting the Inn to a geothermal system are organized according to the various component tasks of the analysis. The following text is presented in sections providing: (1) a general description of the motel facility; (2) peak heat load calculations; (3) a review of current energy consumption; (4) projections of annual fuel consumption; (5) alternate space heating and hot water systems utilizing geothermal energy; and (6) capital cost estimates of the proposed conversion.

B. General Description

This section describes the Baca Grande Inn relative to its general layout, type of construction, square footage, and current space heating and hot water heating systems.

As can be seen in Figure 21, the Inn is situated diagonally in a north to south position. Thus, the walls of the Inn are situated either to the northwest, northeast, southeast, or southwest direction. The majority of the motel rooms have either a northwest or northeast exposure, necessitating maximum heating during the winter months, while minimizing cooling during the summer months. The dining, banquet and kitchen areas, on the other hand, receive sunlight during the winter months, helping to lower the peak space heating load. However, during the summer months, one can anticipate maximum cooling due to the large glass area in the dining room.

The Inn is comprised of 40 motel rooms of which 37 are available for guests. Three rooms are used continuously for commercial purposes. All rooms have a typical layout as shown in Figure 22. Twenty-nine of the motel rooms are located on the ground floor. The motel rooms each encompass approximately 336 square feet; each room has a 5' X 5' single-pane window, exterior exposed. The doors are wood with the entrance to the enclosed corridor.

The rooms are heated by electric convection heaters, Electromode Model No. AST-71, with a capacity of 20,490 Btu/hour. A Carrier window mount air conditioner is installed in each window for summer temperature control. The capacities of air conditioning and heating equipment for the Inn are

Figure 21. Baca Grande Inn Layout

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Figure 22. Typical Corner Motel Room

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summarized in Table 19. Each room is equipped with a 60 CFM exhaust fan, which is one of the main sources of outside air infiltration, and also an electric 20-gallon capacity National Steel automatic water heater with two electric heating elements. These 20-gallon tanks are proving inadequate for the guests' needs, especially when two or more people are utilizing the same room. The electric water heater is located in the closet, with easy access. The piping system is a one-pipe system, supplying cold water to the heater and to the bathroom cold water taps.

C. Dining Room, Kitchen, Bar, Lobby, and Banquet Room

The southern end of the Inn contains the dining room, kitchen, bar, lobby, and the banquet room. These areas are divided into three separate systems for heating and air conditioning.

The dining room and kitchen are served by the same Lennox unit, with a heating capacity of 962,860 Btu/hour and a cooling capacity of 273,000 Btu/hour. The air flow rate of the Lennox unit is 10,000 CFM. These units have a maximum air makeup of outside air of 35 percent of the total air flow. The kitchen also contains its own air conditioner, an Arctic Circle 3100 BD-Z.

The hot water for the kitchen and the public lavatories is supplied by a 200-gallon National Steel electric hot water heater with a total capacity of 36,000 watts or 122,918 Btu/hour. As in the case of the motel rooms, the water supply to the hot water tank is a one-pipe supply system. The dining room and kitchen encompass an area of approximately 2,700 square feet.

The bar and lobby are heated and cooled via a common heating and air conditioning system. The heating unit again is of the forced air variety with air passing over electric elements; its rated capacity is 577,716 Btu/hour. The air conditioning system utilizes the same forced air system but cools via a conventional freon system. Its cooling capacity is 200,000 Btu/hour. The combined floor area of the bar and lobby is approximately 1,560 square feet.

The banquet room is heated and cooled by a separate Lennox roof-top model unit with a heating capacity of 577,458 Btu/hour and a cooling capacity of 96,000 Btu/hour. The fan is rated at approximately 5,000 CFM. The floor area of the banquet room covers about 900 square feet. The specific locations of the dining room, kitchen, bar, lobby, and banquet room can be seen in Figure 21.

To summarize, the combined space heating capacity of the 40 motel rooms is 819,600 Btu/hour; the kitchen, dining room, bar, lobby and banquet room have an installed capacity of 2.12 million Btu/hour.

D. Design Temperature and Peak Heat Load Calculations

The primary considerations governing the selection of the minimum design temperature level were discussed previously in Chapter V and

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Table 19.--Existing Space and Hot Water Heating Equipment Ratings for the
Baca Grande Inn.

Equipment Description	Cooling		Heating	
	Btu/hr	Kw	Btu/hr	Kw
<u>Motel Rooms:</u>				
Electromode Model # AST-7I	----	----	20,490	6.0
40 Rooms:	----	----	819,600	240.0
Carrier Air Conditioner	6,800	2.0	----	----
40 Rooms	272,000	80.0	----	----
National Steel Automatic Electric Hot Water Heater	----	----	30,729	9.0
(20-gal. capacity)				
40 Rooms	----	----	1,229,184	360.0
<u>Kitchen and Dining Room</u>				
Lennox CHA8-2753-440 Approx. 10,000 CFM	273,000	80.0	962,860	282.0
National Steel Automatic Electric Hot Water Heater				
(200 gal. capacity)	----	----	122,918	36.0
<u>Bar and Lobby</u>				
Lennox Model # CHA8-1853-440 (7500 CFM)	200,000	59.0	577,716	169.0
<u>Banquet Room</u>				
Lennox Model # CHA8-1353 (5000 CFM)	130,000	38.0	577,458	169.0
<u>Laundry Room</u>				
National Steel Automatic Electric Hot Water Heater (200 gal. capacity)	----	----	1,229,184	360.0

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need not be reiterated here. The adopted temperature of -11°F represents the 99 percent design level as defined by ASHRAE for the cities of Alamosa and Saguache, Colorado, and is thought to accurately represent the climatic conditions at the Baca Grande development site. The Saguache 30-year figure of 8,027 degree days was adopted for use in calculating annual energy consumption values. For purposes of cooling system evaluation, a 97.5 percent probability dry bulb temperature level of 82°F was adopted.

Peak heat load calculations form the basis for specifying heating and cooling equipment installations at a facility. The most significant parameters affecting peak load design values are the exposed area through which heat is lost, the materials of construction which fix the resistance to thermal conductance, infiltration losses, and the design temperature driving force which was discussed previously.

Peak load heat losses were no doubt originally computed for the sizing of the original HVAC systems. However, the questionable insulation practices and the inadequacy of the domestic hot water system prompted a decision to re-evaluate those numbers.

The following section explains in detail the construction specifics of the Inn and the methodology of the peak load analysis performed. The estimated heat loads for each of the separate Inn areas are developed and finally, the heat loads required for hot water, laundry, and the swimming pool are identified.

E. Construction Specifics

Even though located in a geographical region exhibiting a severe winter climate, the Baca Grande Inn unfortunately was not designed to recommended insulation standards when constructed in 1972. The absence of appreciable insulation markedly increases thermal losses; the building is considered to be of a New Mexico-Arizona construction design.

The walls of the Inn are 2" X 4" construction with 1-inch stucco on the outside and 1/2-inch gypsum wallboard on the inside. Maintenance personnel at the Inn state that the walls contain no insulation. The overall heat transfer coefficient (U), which is a measure of heat transmission through materials, for the wall was calculated to be $0.237 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$). This is a high U value. For comparison, if the same wall were insulated with fiberglass insulation with an R value of 11.0, the U value of the wall is $0.086 \text{ Btu/hr-}^{\circ}\text{F-ft}^2$. We can see that the addition of fiberglass insulation nearly triples the thermal efficiency of the walls and it is recommended that this insulation addition should be considered by the owner. For the inside corridor wall, the U value is 0.284. Construction is with normal gypsum board and studding.

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The ceiling was assumed to be a 2" x 8" built-up roof construction. As in the case of the walls, the ceiling heat transfer coefficient is calculated based on no insulation giving a U value of 0.201 Btu/hr-°F-ft².

Table 20 shows the heat transfer coefficient for windows (1.1 Btu/hr-°F-ft²), doors (0.62 Btu/hr-°F-ft²), and floor (0.1 Btu/hr-°F-ft²). A 20°F temperature difference between the inside and the ground was used for the floor heat transfer calculations (2).

Calculations of the peak heating load for sizing room heating equipment are based on the maximum outside exposed area for a room in the Inn. The room corridor wall is exposed to corridor air of 45°F. Heat is supplied to the corridor by solar penetration due to the high glass area, the lobby rooftop heater, and heat conduction from the rooms. Infiltration for each room is supplied by a 60-CFM exhaust fan in the bathrooms. This fan supplies more than an ample air change of 1.34 air changes per hour, and all air is assumed to be from the outside. From Table 20, we can see that a corner room requires a maximum of 20,661 Btu/hr at the design temperature of -11°F. For all 40 rooms, the energy demand is 684,930 Btu/hr including 174,960 Btu/hr infiltration. This number can be considered to be the peak heating load for the motel rooms and is broken down by source in Table 21.

Calculations of peak heating loads for the dining room, kitchen, bar, and banquet room are based on the same construction specifics as for the motel rooms. The dining room doors are glass and their U value is considered to be 1.1, the same as the glass windows. Infiltration, or in this case ventilation, heat losses were calculated on the basis of a 35-percent maximum makeup air per the equipment specification. Table 22 shows the heating requirements of these areas. The peak heating load is seen to be 928,538 Btu/hr, of which 702,713 Btu/hr is related to influx of outside air. This is approximately 76 percent of the total peak heating demand for the areas of concern.

Total space heating requirements for the Baca Grande Inn are summarized in Table 23. For space heating of the Inn, peak heating load is estimated to be 1,613,468 Btu/hr, which is equal to a 472.6 kilowatt load at a design temperature of -11°F.

Figure 23 shows the design peak load as a function of outside design temperature. The significance of this graph is to illustrate the importance of utilizing an accurate design temperature for equipment design purposes. The peak heating load is nearly linear as a function of temperature; a difference of 10°F in the temperature driving force approximates a 200,000 Btu/hr difference in peak heat load requirements.

F. Hot Water Heating

Estimating the hot water demand for the Baca Grande Inn was accomplished using methods published in the 1970 ASRAE Guide and Data Book. Two basic

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Table 20.--Peak Heat Loss for a Corner Guest Room¹

Description	Area (ft ²)	U (Btu/hr-°F-ft ²)	ΔT (°F)	Q (Btu/hr)
Outside wall ²	354	0.237	81	6,796
Corridor wall ³	126	0.284	25	896
Door	14.5	0.62	25	225
Ceiling	336	0.201	81	5,470
Window	25	1.10	81	2,228
Floor	336	0.1	20	672
				16,287
Infiltration ⁴ 60 CFM				4,374
Total ⁵				20,661

¹Calculations based on blueprints received from Gonzales Associates.

²Maximum outside wall area in corner room with two exterior walls, outside envelope wall height of 10.0 feet.

³Corridor temperature will generally never drop below 45°F, envelope wall height of 10.0 feet.

⁴Infiltration based on 60 CFM exhaust fan in bathroom with continuous operation for peak demand.

⁵This design heat load used to size equipment for the rooms.

Table 21.--Total Peak Heat Load Demand for 40 Motel Rooms

Description	Area (ft ²)	U (Btu/hr-°F-ft ²)	ΔT (°F)	Q (Btu/hr)
Net outside wall	9,996	0.237	81	191,893
Corridor wall	5,030	0.284	25	35,720
Doors	576	0.62	25	8,985
Windows	1,000	1.100	81	89,100
Ceiling	10,080	0.201	81	164,112
Floor	10,080	0.1	20	20,160
				509,970
Infiltration				174,960
Total				684,930

Table 22.--Total Peak Load Demand for Kitchen, Dining Room, Bar, Lobby, and Banquet Room.

Motel Area	Walls (Btu/hr)	Doors (Btu/hr)	Windows (Btu/hr)	Ceiling (Btu/hr)	Floor (Btu/hr)	Infiltration ¹ (Btu/hr)	Total (Btu/hr)
Dining	35,111	14,434	17,820	28,720	3,528		99,613
Kitchen	22,825	853	--	26,278	3,228	313,656	343,246
Bar	7,314	320	--	14,897	1,830		24,361
Lobby	5,164	3,412	4,455	14,816	1,820	232,232	261,899
Banquet	17,662	1,705	6,683	14,734	1,810	156,825	199,419
Total							928,538

¹Based on a maximum recycle air of 35 percent.

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Table 23.--Space Heating Demands for the
Baca Grande Inn.

Motel Area	Q (Btu/hr)
Motel rooms	684,930
Dining and kitchen	442,859
Bar and lobby	286,260
Banquet room	199,419
Total	1,613,468

Figure 23.--Peak heat load as a function of outside temperature.

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methods used to estimate hot water demand are: (1) fixture method; and (2) probable consumption per person per day.

To estimate the probable maximum demand and thus the peak load, the fixture method was used. Table 24 shows the number of Inn fixtures. For this analysis, 37 rooms were assumed available for occupancy while the other three rooms were assumed to be used for commercial purposes only.

Table 24 shows that a maximum flow rate of 50 gpm could be required. This peak demand will, in all likelihood, never be achieved since to realize this flow rate, all fixtures in the Inn would have to be utilized at the same time. ASHRAE suggests a motel demand factor of 0.25 which then brings the potable hot water demand down to 12.5 gpm (1). To heat this water from 55°F to 140°F, the heater must be sized at a 529,125 Btu/hour capacity.

It should be noted that certain cycles of dishwashers and laundry require 180°F water. Since the geothermal resource is not at high enough temperatures to reach these levels, the water heated to approximately 140°F will have to be boosted to the 180°F level through conventional means; existing water heaters will probably be the most economical for this purpose. Again, these loads are distributed throughout the day and do not occur simultaneously with the individual room hot water demand.

G. Swimming Pool

The swimming pool peak heating demand is a function of the pickup time period and the outside temperature. Pickup time is defined as the time required to raise the pool water from ambient to 80°F. The maximum pool heat load based on an 8-hour pickup period can be as high as 540,000 Btu/hour. The present system is currently sized at 560,000 Btu/hour.

The 1977 Colorado model energy code requires that swimming pools shall be equipped with controls to limit the water temperature to 80°F. The code also requires that electric or fossil fueled pool water heaters be inoperative whenever the outdoor air temperature is below 60°F. The geothermal retrofit for the pool system will be examined further in the geothermal design section.

H. Peak Heat Load for Space and Hot Water Heating

Table 25 summarizes the individual peak loads calculated for space heating, hot water heating, and pool heating at the Inn. The figures indicate that space heating at low outside temperature is the largest single demand.

Table 24.--Estimated Hot Water Demand¹.

Fixtures	Number of Fixtures	Demand per Fixture (gal/hr)	Total Demand (gal/hr)	Demand Factor	Design Rate Demand (gal/hr)
Public lavatories	8	8	64	0.25	16
Showers	37	75	2,775	0.25	694
Kitchen sinks	2	30	60	0.25	15
Private lavatories	40	2	80	0.25	20
			<u>2979</u>		<u>745</u>
Total			(or 50 gpm)		(or 12.5 gpm)

¹Based on ASHRAE, 1970, p. 557.

Table 25.--Summary of Peak Heat Loads,
Baca Grande Inn.

System	Required Energy (Btu/hr)
Space Heating (100% occupancy)	1,613,468
Hot water (public lavatories and individual rooms)	529,125
Hot water* (kitchen and laundry)	1,352,102
Swimming pool	540,000
*installed capacities assumed	

I. Projected and Actual Energy Consumption

The peak load calculations discussed previously are important in that they provide the data necessary for equipment sizing. However, to develop estimated cost savings, it is necessary to develop projections of monthly and annual energy consumption rates as compared to the very high peak load values which might occur only once or twice per year. As one might expect, the overall energy consumption is a function of both the occupancy rate and the degree days since space heating and hot water heating needs both increase with increasing numbers of guests and at lower temperatures. Historically, the Inn has experienced fairly high occupancy rates during the summer months but quite low usage during the off-peak winter season.

Figure 24 illustrates the Inn occupancy rates for the years 1976-78 showing a low of 5.3 percent in February 1978 and a high of 80.1 percent in August 1977. The actual monthly degree days occurring over that same time period are given in Figure 25. If the actual energy consumption of the Inn can be successfully fit to the projections of energy consumed for the same time period, confidence is established for being able to project energy usage rates in future years when occupancy rates are expected to rise.

The actual electrical billings for Inn usage are based on both the peak demand registered at any time during a particular month and also on the total kilowatt hours of electricity used for the entire month. Figure 26 illustrates the total use and the peak demand rates for the Inn for 1976-78. It is interesting to note that a substantial energy usage reduction is seen during the winter of 1977 as compared to the year previous. This is because of energy conservation measures which were instituted during that time period. These measures consisted principally of reducing the temperatures in unoccupied rooms to 40°F; this led to almost a 38-percent reduction in total electrical consumption.

The estimated space heating energy consumption is correspondingly related to peak loads for space heating by the equation:

$$EE = \frac{k(24)(PK)(DD)}{(Ti-To)}$$

where EE = Estimated energy consumption (kW)

PK = Peak load (kW)

DD = Degree days for the referenced time period

To = Outside design temperature (°F)

Ti = Inside design temperature (°F)

k = Constant accounting for solar penetration, heat from people, lighting, etc. Experientially derived and assumed to be 0.62 (source: Intermountain Rural Electric Association).

Likewise, hot water heating energy demands on a monthly basis can be calculated using an assumed usage rate of 40 gallons per guest per day at 140°F. The estimated space heating and hot water demand electrical consumption rates are summed and presented in Figure 27. A comparison to

Graph A, Figure 26, indicates only a fair agreement. The projected values which include air conditioning loads during summer months are low as compared to the actual values. For the winter months, the projected energy consumption values are significantly high when the full 35 percent fraction outside air is used in the heat load calculation for the lobby-kitchen-dining room areas. When that outside air fraction is reduced to 15 percent of the total recirculated air, as was done in the 1977 energy conservation effort, the projected versus the actual values give acceptable agreement. Figure 28 gives the relationship between occupancy rates and estimated annual electrical consumption. This is important to the overall economic evaluation in that the Inn is expected to gradually continue to increase its overall occupancy rate both due to its developing reputation and efforts to attract seminars and other group guests during off-peak months. Thus, the Figure 28 projection provides the basis for evaluating the economic savings at higher use rates. One last comment is noteworthy at this point. Present calculations indicate that hot water heating electrical consumption amounts to approximately 20 to 25 percent of the total electrical consumption depending on the occupancy rate. This fact also impacts the final economic analysis especially as related to the advisability of installing the equipment necessary to convert the domestic system to a geothermal source.

J. Feasibility Designs for Geothermal Heating of the Baca Grande Inn

The feasibility design effort for retrofitting the Inn to a geothermal source, focused on four basic design concepts. Descriptions of the basic process flow schematics are provided below; the estimated installed costs for these options is presented in the subsequent section. Discussions of the economic desirability of the proposed conversion is presented in Chapter VIII. The four separate alternatives are of two basic types. Two of the designs use the geothermal waters directly in the various heating systems; this is an advantage if the geothermal brine exhibits acceptable water chemistry, since no intermediate heat exchanger is required except for the potable domestic system. The second pair of systems assume the basic geothermal water chemistry is of such low quality that indirect heating is required.

The first design alternative, denoted as Inn Alternative 1 and described in Figure 29 utilizes the cascade approach which uses the highest available temperature geothermal waters for those applications demanding the highest temperature driving force. Subsequently, the water is then reused for uses with lesser temperature requirements. The net effect of this reuse is to extract greater amounts of heat from each pound of water, thereby demanding a lesser geothermal water supply. This is illustrated clearly in the material and energy balances accompanying the schematics for the four chosen cases. As seen in Figure 29, the direct heating-cascade system sends the hottest 150°F water from the supply tank to the individual motel guest rooms for use in the fan coil convection-type heating units. These fan coil units were chosen because of their flexibility to provide both heating and cooling services. All of the room supply lines are tied into this first system in parallel, i.e., all the rooms can obtain 150°F hot water on demand. Also, all rooms are individually thermostatically controlled, and as more heat is desired, the control valve

* Note: Each room has individual temperature controls

** Note: Each area has individual temperature controls

IDENTIFICATION		TEMP.	FLOW
		°F	GPM
1	Geothermal Supply	150	149.3
2	Supply Pipe	150	149.3
3	Motel Rooms Fan Coils Inlet	150	149.3
4	Fan Coil Outlet	141	149.3
5	Lennox Coils Inlet	141	149.3
6	Lennox Coils Outlet	129	149.3
7	Return Pipe	129	149.3
8	Hot Water Heat Exchanger Inlet	129	149.3
9	Hot Water Heat Exchanger Outlet	122	149.3
10	Domestic Cold Water Supply	55	16.5
11	Domestic Hot Water Supply	119	16.5
12	Geothermal Supply to Pool Ex.	122	149.3
13	Swimming Pool Outlet of Exchanger	80	80.0
14	Swimming Pool Inlet of Exchanger	66	80.0
15	Geothermal Discharge from Pool Exchanger	115	149.3
16	Geothermal Discharge	115	149.3
17	Geothermal Discharge from Tank	125	--

Figure 29. Direct Heating Cascade System--Alternative 1

regulating the influent water flow opens. After approximately a 90°F drop during that use, the water is then directed in series to the forced air system in the dining room-lobby area. Here the 141°F water is sent through coils located in the system ductwork; with a forced air system, a lower temperature water can be used, as compared to that required in the convection units located in the rooms. The geothermal brine, after this second use, is now at 129°F and is then sent to the domestic hot water heat exchange system. Here, domestic water is heated to 119°F; the geothermal brine temperature is lowered another 70°F in this step. If additional hot water is needed at any point, 150°F water from the source can be added to the cooled water via calling for additional flow by thermostat control. The final step in the cascade-direct use flow scheme is for hot water heating in the pool using a countercurrent exchanger. The exit geothermal water temperature, assuming a worst case peak demand, is 115°F. At temperatures less than 125°F the geothermal fluid in the holding tank is discharged and replaced with a new supply. For cooling during summer months, the water supply line to the individual fan coil units will be directly hooked to the existing potable water distribution system, thus eliminating the need for a separate cold water distribution line. This same cold water network is used for all design alternatives. Figure 30 illustrates Inn Alternative 2 which utilizes a direct heating parallel flow schematic. In this instance the geothermal brine is transferred from the surge tank to the various space heating systems such as the individual rooms, the lobby, etc. in parallel. Control valves, whose position is thermostatically controlled at the individual rooms, regulate the flow of water through the various heating systems. After hot water is used for space heating purposes, it is collected in a return piping system which then directs the water in series to the exchanger heating the domestic hot water system and finally to the pool heater exchanger. All hot water sent to the various space heating systems is at the 150°F temperature. The temperature of the return water to the domestic hot water exchanger is dependent on the heating loads experienced in the various parts of the building. The energy and material balances presented in the schematic indicate a geothermal flow rate of 215 gpm is required to meet peak demands; this is 44 percent higher than in the previous case.

The third and fourth alternatives as presented in Figures 31 and 32 utilize indirect heating via a central heat exchanger. These systems are similar in process flow to Inn Alternatives 1 and 2, respectively, except that the domestic hot water and the hot water supplying the various space heating systems are supplied through the same pipe. The domestic hot water would be sent to the currently existing hot water heaters which would maintain, but not heat, the hot water supply to approximately 140°F. Thus, the existing heaters would operate much as miniature insulated holding tanks. This dual distribution approach is limited basically to various motel rooms. A separate feed line serves the motel laundry needs and the restaurant hot water needs. The swimming pool exchanger is also tied into the system identically to the two direct system alternatives except that the heating source is high quality water as compared to geothermal brine. Also, it should be noted that no water from within the system is sent to waste except by domestic use. Rather, the fluid is pumped back through the central exchanger to be reheated and subsequently reused.

* NOTE: Each room has individual temperature controls

** NOTE: Each area has individual temperature controls

IDENTIFICATION		TEMP.	FLOW
		°F	GPM
1	Geothermal Supply	150	215.0
2	Supply Pipe	150	215.0
3	Motel Rooms Fan Coils Inlet	150	91.3
4	Fan Coil Outlet	135	91.3
5	Lennox Coils Inlet	150	123.7
6	Lennox Coils Outlet	135	123.7
7	Return Pipe	135	215.0
8	Hot Water Heat Exchanger Inlet	135	215.0
9	Hot Water Heat Exchanger Outlet	130	215.0
10	Domestic Cold Water Supply	55	15.1
11	Domestic Hot Water Supply	125	15.1
12	Geothermal Supply to Pool Ex.	130	215.0
13	Swimming Pool Outlet of Exchanger	80	80.0
14	Swimming Pool Inlet of Exchanger	66	80.0
15	Geothermal Discharge from Pool Exchanger	125	215.0
16	Geothermal Discharge	125	215.0
17	Geothermal Discharge From Tank	125	-

Figure 30. Direct Parallel Heating System--Alternative 2

* Note: Each room has individual temperature controls.

** Note: Each of the areas has its own temperature control.

Figure 31. Indirect Heating Cascade System--Alternative 3

Figure 32. Indirect Parallel Heating System--Alternative 4

K. Installed Cost Estimates

The capital cost analysis for the four alternatives is summarized in Tables 26 through 29. Piping materials of construction were insulated carbon steel for larger lines and non-insulated copper for short lines. Fan coil exchangers were of copper and the central plate type heat exchangers were of stainless steel.

To summarize these capital cost figures, the capital cost requirements for the various alternatives were relatively close--ranging between \$107,000 and \$117,000. The direct systems were somewhat cheaper, as expected; however, the overall cost differential was reduced because of lesser distribution piping requirements of the indirect cases. The indirect systems also retain the advantage of eliminating corrosion and scaling potential due to the high quality of water used in the heating loop. The Alternative 1, direct use cascade system, is the preferred alternate due to the expected high water quality, the low cost, and the more efficient use of the resource.

The charges for electrical consumption at the Inn from August 15, 1977 to August 15, 1978 were \$26,043.91. This billing consists of charges based on the single peak demand during each month and also on the total electrical energy consumption for that same month. By assuming that the elimination of electrical space heating, hot water heating, and air conditioning reduces the total electrical consumption and the peak demand both by 70 percent, one can calculate the potential electrical savings to be \$17,798 per year. In addition, \$3,850 can also be saved by eliminating the propane heating of the swimming pool. If the overall occupancy rate for the Inn improves, the total potential savings would be correspondingly greater.

L. Cooling System Conversion

In spite of the mild summers experienced at the study site, the motel has found it necessary to operate electric window air conditioners in the motel rooms and conventional freon systems in the lobby-dining area. The well water available at the Inn site is at temperatures of 40°F; fan-assisted convection coils were chosen for guest room temperature control since these units can be used not only for space heating but also for space cooling with the 40°F cold water directed through the coils. Likewise, with a relatively simple hydronic conversion to the existing lobby-dining area Lernox cooling systems, the 40°F water can be utilized as the cooling source here also, thereby further reducing the summer electrical loads. To summarize, the Alternative 1 direct-use cascade system is the preferred alternate due to the expected high water quality, the low cost, and the more efficient use of the resource.

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Table 26.--Cost Summary
Alternate 1--Direct Cascade System

Equipment	Cost (\$)
Space heating	
Room fan coils	22,060
Dining room, bar, lounge, sales, and kitchen coils	3,000
Central heat exchanger	0
Miscellaneous pumps, valves, storage tanks, expansion tanks	4,030
Hot water	
Heat exchanger, pumps, valves, storage tanks, and expansion tanks	3,460
Swimming pool	
Heat exchanger, controls, and valves	770
Distribution piping	20,780
Total material costs	54,100
Aesthetic control costs	2,700
Installation costs	40,600
Contingency @ 10%	9,740
TOTAL COSTS	107,140

Table 27.--Cost Summary
Alternate 2--Direct Parallel System

Equipment	Cost (\$)
Space heating	
Room fan coils	22,060
Dining room, bar, lounge, sales, and kitchen coils	3,000
Central heat exchanger	0
Miscellaneous pumps, valves, storage tanks, expansion tanks	4,140
Hot water	
Heat exchanger, pumps, valves, storage tanks, and expansion tanks	3,360
Swimming pool	
Heat exchanger, controls, and valves	620
Distribution piping	24,200
Total material costs	57,380
Aesthetic control costs	2,870
Installation costs	43,040
Contingency @ 10%	10,330
TOTAL COSTS	113,620

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Table 28.--Cost Summary
Alternate 3--Indirect Cascade System

Equipment	Cost (\$)
Space heating	
Room fan coils	22,060
Dining room, bar, lounge, sales and kitchen coils	3,000
Central heat exchanger	7,000
Miscellaneous pumps, valves, storage tanks, expansion tanks	5,630
Hot water	
Heat exchanger, pumps, valves, storage tanks, and expansion tanks	0
Swimming pool	
Heat exchanger, controls, and valves	770
Distribution piping	17,040
Total material costs	55,500
Aesthetic control costs	2,780
Installation costs	41,620
Contingency @ 10%	9,990
TOTAL COSTS	109,890

Table 29.--Cost Summary
Alternate 4--Indirect Parallel System

Equipment	Cost (\$)
Space heating	
Room fan coils	22,060
Dining room, bar, lounge, sales, and kitchen coils	3,000
Central heat exchanger	7,300
Miscellaneous pumps, valves, storage tanks, expansion tanks	5,740
Hot water	
Heat exchanger, pumps, valves, storage tanks, and expansion tanks	0
Swimming pool	
Heat exchanger, controls, and valves	670
Distribution piping	20,460
Total material costs	59,230
Aesthetic control	2,960
Installation costs	44,420
Contingency @ 10%	10,660
TOTAL COSTS	117,271

VIII. DESIGN AND ECONOMIC ANALYSIS OF THE COMMERCIAL AREA GEOTHERMAL HEATING SYSTEM

A. General Geothermal System Description

The geothermal system for the Commercial Area would serve the Baca Grande Inn, the mobile home subdivision, the light industrial area consisting of proposed greenhouse and aquaculture facilities, the administration building and finally the proposed small shopping center, herein referred to as the shopette. The Pro Shop is not part of the design since preliminary evaluations determined that its inclusion was not economic due to its small heating load. Although similar in theory, this basic system is greatly simplified when compared to the residential distribution system, due primarily to the close proximity of the production wells to the users, the small differences in elevation, and the higher energy demands at the utilization points. Figure 33 shows the location of the users relative to the production and reinjection well sites. As seen in this figure, the aquaculture facility is located adjacent to the reinjection site; this permits a reuse and final extraction of heat from the geothermal fluid immediately before ultimate disposal. Also shown in this figure is a pipeline from the production wells leading to the administration building and shopette. Preliminary calculations indicate that geothermal heating of the administration building and shopette may not be economical unless the shopette is built and both facilities are hooked into the system. This is because of the capital costs of the delivery and collection piping systems.

B. Greenhouse-Light Industrial Applications

An important portion of the overall work effort is to investigate applications of the geothermal potential to light industrial uses, the most prominent example of which is greenhouses. The significance of such development rests with the desired expansion of the local employment base and the associated demand for housing and local services. The greenhouse industry is typically a labor and energy intensive operation, thus lending itself optimally to geothermal applications.

Greenhouse operations obviously involve a significant capital commitment; therefore, it is necessary to carefully evaluate a broad range of factors affecting the viability of establishing such a development. These important factors include (1) product and market relationships; (2) climatic conditions; (3) energy, fuel, and power availability; (4) soil qualities; (5) water availability; (6) land availability, cost, and potential urbanization; (7) labor availability; and (8) capital availability and expected return on investment. The significance of these various factors for the proposed San Luis site are discussed in the following sections.

Figure 33. Major Pipelines in Commercial Area.

1. Potential Greenhouse Crops and Markets

An analysis of the Colorado greenhouse industry indicates that roses, green foliage plants, and tree seedling crops look to hold the greatest potential for a new facility. Carnations, which have been an important crop to the regional industry, are experiencing substantial competition from imports from Columbia and Israel. Thus, although they should not be discounted, carnations do not hold the potential of the other crops. Vegetable crops are not profitable due to competition from field-grown products from Florida, California, and imports from Mexico. The principal marketing areas for cut flowers and foliage plants are the Denver Metropolitan region and, more significantly, the broad Midwest region. Most of these products are shipped from Denver by air, truck, or by rail. Tree seedlings would likely be utilized within the Colorado-Western U.S. Geographical region. In this regard, the San Luis Valley transportation system is actually quite good. The Baca Grande Corporation has its own paved air strip located immediately adjacent to the development. Commercial flights fly in and out of the Valley daily from Alamosa, and good rail connections are also available through Alamosa via the Rio Grande, San Luis Central, and Southern San Luis Valley rail systems. Also, good truck service is provided by common carriers operating out of Denver and other Colorado cities. To summarize, marketing factors and transportation requirements would not appear to preclude the establishment of greenhouse operations in the Valley.

The minimum temperatures which these various crops can optimally accept are important to the establishing of the greenhouse design heating requirements. For the referenced crops, these are as follows:

Carnations-----	50°F
Roses-----	60°F
Bedding Plants and General Green Foliage----	60°F
Tree Seedlings-----	65°F
Tomatoes and Other Vegetables-----	65-70°F

In view of the above, a 65°F night time minimum temperature was chosen for use in the development of the design peak heat load determination. As discussed earlier in considerable detail, the general climatic conditions apparent in the Valley are somewhat more severe than noted in the Front Range area. The 30-year average for degree days is approximately 25 percent higher than, for example, Denver. However, solar gain should be excellent even on cold days and generally speaking, the importance of the increased degree day heating requirement is not as substantial in view of the proposed geothermal-based heating system.

Using National Greenhouse Manufacturer's Association criteria, an outside design temperature of -20°F was adopted. It is noted that the coldest temperatures practically always occur with no accompanied wind--which tends to balance the low minimum temperature requirement. This design information will be utilized in the greenhouse general design considerations presented later. Current annual front range

heating costs average $\$0.75/\text{ft}^2$ or approximately \$32,700 for a 1-acre facility.

To briefly address some of the other factors identified, reliable electrical service is provided by the San Luis Valley REA, and the Baca Grande Corporation along with AZL Resources have more than adequate rights to high-quality surface water supplies. The soil in the area is a sandy loam which should be adequate although some additional soil fortification may be necessary. Irrigated land in the San Luis Valley has proved exceptionally productive for a variety of agricultural crops. Land availability and cost should be good as compared to other more urban areas since the Baca Grande Corporation is actively trying to attract light industry and geothermal development. Local governmental support is also excellent, which is important to facilitate the permitting process. Finally, an adequate labor force is available and documented.

Whether it is viable to establish a greenhouse complex at the project site narrows to a focus of whether the overall cost savings associated with the proposed geothermal-based system, along with the favorable factors mentioned, are substantial enough to compensate for the higher geothermal heating system capital cost and the general inconvenience of the more remote Valley location.

2. Greenhouse Design

Project investigations, including discussions with greenhouse constructors and educators, indicate that greenhouse construction materials should consist of fiberglass walls with either a fiberglass or an air-inflated two-layer polyethylene roof. The latter exhibits superior heat loss characteristics; however, the fiberglass houses tend to provide a superior light transmittal for optimum growing conditions; this is especially important for the cut flower production of carnations and roses. One acre is recommended as the lowest economical size. A typical facility might thus consist of 8 units, each dimensioned at 36.75 feet by 150 feet with an arched roof of one of the two identified materials. Installed costs for the polyethylene type of facility approximates \$3.00-\$5.00/ft, exclusive of heating system and irrigation system costs. Fiberglass generally runs \$0.50 to \$0.75 per square foot higher capital; but the polyethylene has the continuing film replacement cost every two or three years. Conventional heating system costs are normally about 20 percent of the installed capital cost.

The general heating system design for the geothermal case is practically identical to that of a conventional hot water system except that the boiler is replaced by the underground geothermal source. For the specific case of the Baca Grande resource, the comparatively low 150°F water temperature will require approximately 1.7 times the overall heat transfer area and hence the cost of a conventionally fueled system. To finally quantify the apparent advantages of a

geothermal heat source, one must calculate a peak load design heating requirement, associated capital costs, probable annual geothermal heating costs, and the resultant energy costs in $\$/10^6$ Btu for the geothermal system. These can then be quantitatively compared to the costs seen in greenhouse operations, based on experience for the front range region.

The typical design used for our calculations is available competitively from various constructors with only minor modifications of dimensions. The proposed layout consisting of eight side-by-side units of arched roof design is pictured below.

Figure 34. Proposed Greenhouse Layout

The overall conductive-convective heat loss mechanism is described the fundamental heat transfer equation:

$$Q = U \times A \times \Delta T$$

where

Q = Required Design Heat Transfer (Btu/Hr).

U = Overall Heat Transfer Coefficient (Btu/Hr- $^{\circ}$ F-Ft 2)

A = Heat Transfer Area (Ft 2)

ΔT = Inside-Outside Design Temperature Driving Force ($^{\circ}$ F)

The overall heat transfer coefficient, of course, varies with the materials of construction. For fiberglass, U_0A ranges from 1.13 to 1.2; for air-inflated PE, $U_0A = 0.79$ to 0.84, thus illustrating the lesser needs for heating requirements. For each case, the larger number is used in all calculations for conservatism.

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Each 44,100 ft² fiberglass structure has an outside area of 58,918 ft². Using a ΔT of 85°F, and after adding 10 percent for infiltration losses, the total peak design heat loss is 6.61 million Btu/hr. For eight fiberglass structures, the design demand is, therefore, 52.9 million Btu/hr. A similar calculation assuming a polyethylene roof and fiberglass sides and ends gives a design heat load of 4.99 million Btu/hr for each structure.

For the fiberglass cases, the overall design heat load equals 150 Btu/hr-ft² and the polyethylene case represents 113 Btu/hr-ft². As compared to peak design rates, the annual heat consumption is based on a factor of 40 Btu/yr-ft²-degree day (49).

3. Greenhouse Heating System

The forced air heating system proposed for the above facility consists of 48 hot water heating units with aluminum finned copper coils rated at 138,900 Btu/hr at 150°F water and 65°F air. Thus, six of these units are required for each bay. The warmed air is distributed throughout the structure via 36-inch polyethylene tubing directly attached to the heater output and running the length of the building. For this design, 18.8 Btu/lb of water is extracted; thus, the return cooled water would average near 130°F. All temperature controls and installation is exactly the same as it would be in a conventional greenhouse structure. Estimated installed cost for the system is \$80,000 exclusive of well drilling costs.

C. Aquaculture-Light Industrial Applications

Geothermal aquaculture is a recently developing industry in which cold-blooded aquatic animals such as catfish and prawns are raised and sold at market values. The body temperature of these animals adjusts to that of the surrounding water and this is the major fact exploited in aquaculture facilities. The growth rate and a variety of other factors determining production efficiency are all greatly enhanced through the maintenance and control of warmer temperatures as possible through geothermal utilization. Four significant reasons for raising aquatic animals in controlled aquaculture facilities are:

- 1) To maintain a constant and optimal rearing environment.
- 2) To maximize growth and production by minimizing stress factors.
- 3) To facilitate control of breeding and also disease treatment.
- 4) To produce a large array of organisms in temperate climates.

Geothermal energy is readily adaptable to supplying the heating requirements of aquaculture facilities; however, the following engineering concerns must be addressed.

- Siting, including the cost and availability of the land, the availability of an economic geothermal resource, and the location of fresh processing water.

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- The reliability of the heat source.
- The variability of the energy resource.
- The proximity of food and marketing transportation.

All of these concerns are addressed affirmatively for an aquaculture facility located in the Baca Grande development; land availability is good, the resource is projected to be high quality, and the necessary transportation is available. For the Baca Grande case the geothermal fluid could be used directly, with appropriate cold water dilution, to raise the animals or indirectly by first heating a secondary fluid through an intermediate heat exchanger. This second alternative is preferable since the potential for contamination of the geothermal water, which could hinder reinjection efforts, is avoided. In a system as could be used in the San Luis Valley, the fresh water utilized to rear the aquatic animals is heated in plate-type exchangers using the spent geothermal fluid from the commercial area as the heating source. The water is heated from about 50°F to approximately 80°F, depending on the species raised. The geothermal heating fluid is supplied at a temperature of 120-150°F depending on the source and prior use. The existing temperatures will vary with the expected heat load. Reinjection is the ultimate means of disposal for the geothermal fluids. Disposal of the warm water used for rearing the animals can be accomplished in several ways: discharge to natural waterways, infiltration or agricultural irrigation, or possibly injection. Treatment of the water for removal of organics may be necessary if the fluids are to be discharged to surface waterways or if reinjection is the disposal scheme. Utilization of the spent water for irrigation purposes is the most practical disposal method during the spring and summer seasons.

Many different cold-blooded aquatic species can be grown in an aquaculture facility. However, based on experience from several existing operations, the most promising species include channel catfish, tilapia, and trout; also, significant interest has been expressed in the possibilities of raising prawns. On this basis, a brief description of each of these species is given below.

Channel Catfish: Ideal growth conditions occur at temperatures between 80° and 86°F. At temperatures above 86°F, the susceptibility of the fish to disease increases dramatically. Production yields of 325-1,000 lbs/acre of surface area can be achieved with pond or raceway (extensive or intensive) methods. The catfish market is well established at premium prices (\$2-3/lb).

Tilapia: A water temperature of 80°F is the optimum temperature for this genus. At temperatures below 55°F, the fish die. Some species of Tilapia (i.e., T. zillii) are primarily herbivorous and feed on algae, plants, etc. As such, they are ideally suited to clean and maintain canal systems. Additionally, this fish can be produced in ponds, downstream of the catfish, where they serve a waste treatment function by consuming uneaten food.

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Trout: Temperatures below 70°F are required for raising trout, with an optimum temperature being 59°F. Temperatures between 41°F and 55°F are necessary for spawning. At 59°F water temperatures, a marketable sized 12-ounce product is attained in 8 to 9 months, and a production rate of 8.2 lb/ft³ can be achieved. This species requires relatively high quality water and raceway water should be turned over often, i.e. every 30 minutes, to replenish oxygen and remove metabolic by-products.

Prawns: The preferred temperature for fresh water prawns ranges from 80°F to 83°F. Production yields range from 450 to 1,200 lbs/surface acre. The animals reach maturity in 8 to 9 months. Prawns are subject to depressed yields due to cannibalism and deaths of larvae in transit. Comparative profit margins can be high, however, with the current selling price of \$7.50-10.00/lb.

For this study area, it is not economical to drill geothermal wells for the single purpose of heating an aquaculture facility. Rather, the heat remaining in the cooled geothermal fluid from either the commercial or residential areas contains adequate heating value to operate a large facility. Energy balances are based on information obtained from a catfish farm located south of the Baca development. The temperature drop across raceways 30' x 200' is less than 10°F during the coldest winter season. This heat loss is within the temperature limitations of all species considered. With the available heating supply of 1,000 gpm at 120°F from prior uses in the commercial area, it is advantageous to first heat two raceways to 80°F for raising either prawns or catfish. The effluent from these ponds is at a minimum temperature of 72°F which is sufficient to produce tilapia. After heating the first two ponds to 80°F, there is sufficient heat remaining in the geothermal supply to heat two smaller raceways sized at 20' x 100' to 60° for trout production. Figure 33 presents a schematic of the potential aquaculture facility.

As noted above, the aquaculture business is not currently a high profit margin business and is heavily dependent on an inexpensive energy source. As such, the utilization of previously utilized warm waters can be economic. An aquaculture facility will have a positive effect on the overall economics of the geothermal development; to be certain, there is potential as is illustrated by currently existing, successfully operated facilities near the Baca Grande site. The final economic viability of this type of operation is not possible without a site specific marketing survey which is beyond the scope of this study.

D. Administrative Offices and Maintenance Shop

The administration building is a standard American metal building which is utilized for both administration and maintenance purposes. The total demensions are 60' x 105' with three open bays (60' x 60') for the shop having 15-foot ceilings and the remainder (45' x 60') for offices having an 8-foot hung ceiling. Currently, the shop is heated with electric space heaters and the offices with electric baseboard. Present insulation is 4-inch fiberglass in walls and ceilings.

The heat load for the administration building was determined from the utility bills for preceding years. The annual heating load was calculated by first summing the yearly kilowatt-hour used and then subtracting an appropriate value for nonheating purposes. The electricity for nonheating purposes was based on averaging electrical consumption

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during the three summer months. The annual heating requirement was thus calculated as 294×10^6 Btu/yr. The peak winter design load was calculated at 117,000 Btu/hr. For a 20°F water temperature drop, a geothermal flow rate of 12 gpm is required to meet that 117,000 Btu/hr value.

E. Proposed Shopette

The proposed shopette is a comparatively small shopping center of about 5,000 ft² floor area, which would meet the principal consumer needs for the area residents; its actual construction is dependent on future Baca Grande development construction activity, which will establish its necessary economic viability.

The structure would probably be single story, with the total floor space divided into 8 to 12 rented spaces of approximately equal size. The facility will be located on the east side of the commercial area as shown in Figure 33. A calculational procedure, similar to that presented in Chapter VI for the residential homes, was performed to determine the estimated peak heat design requirements; the results are summarized in Table 30.

Table 30

Projected Peak Heating Loads for Proposed Shopette

Component	Heat Loss Area (Sq. ft)	Heat Loss (Btu/hr)
Walls	2,070	12,072
Doors (glass)	210	11,056
Doors (metal)	210	4,933
Windows	1,470	77,400
Floor	5,000	40,500
Ceiling	5,000	22,275
Infiltration		192,000
Total-----		360,236

The design heat load for the shopette is 360,000 Btu/hr. The annual heating load is estimated at 900×10^6 Btu/hr.

F. Mobile Home Peak Heating System Design and Annual Energy Consumption

The peak heat demand of the mobile home subdivision, which represents the low to moderate priced housing area, was determined consistent with methods described in Chapter VI and through communications with home manufacturers. For a typical 14-foot x 70-foot coach and a -11°F design temperature, the peak demands were calculated and are presented in Table 31 which follows.

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Table 31

Mobile Home Heating Load

	Design (Btu/hr)	Annual (Btu/yr)
Space heating	39,300	100.0×10^6
Domestic hot water heating	<u>19,000</u>	<u>20.1×10^6</u>
Totals	58,300	120.1×10^6

The mobile homes currently on site are all propane forced-air systems and will be easy to retrofit to geothermal via the addition of coils in front of the furnace fan. The peak space heating and hot water heating demand represents a flow of 5.4 gpm of geothermal water.

G. Design of the Commercial Area Geothermal System

1. General Distribution System

The distribution systems for the Baca Grande Inn, the greenhouse, and mobile homes consists of low pressure pipelines leading from the production wells to each specific location. For the mobile home area a main trunkline leads to the subdivision area. From here the water is distributed to a backbone loop and finally through the branch system to individual user, similar to the design of the residential system.

The full production from one well rated at 1,000 gpm is sufficient to heat the existing mobile homes, motel, and 1-acre greenhouse, and the administration building and shopette if they are added to the system. Each well has a pumped capacity of 1000 gpm with a discharge pressure of 400 feet. The 400 feet of discharge pressure is required to lift the fluid 200 feet to surface, to overcome pipeline frictional losses in the distribution and collection systems, delivery pressure to the homes, and pressure for reinjection. A 125-hp motor is required for operation of the pump. The cost for each pump with a variable speed motor and associated surface valving is \$60,000.

2. Mobile Home Distribution System

The distribution layout in the mobile home area is very similar to that developed for Chalets I and II of the residential section. A main trunkline delivers the geothermal fluid from the well site to the backbone loop. From the backbone loop, which encircles the mobile home area, the geothermal waters are delivered to the individual homes through a branch network.

The main trunkline was designed to transport 2400 gpm. This flow represents the total flow requirements for the fully developed mobile home park, 2200 gpm, and the requirement of the motel, 150 gpm.

The 150-gpm flow for the motel is withdrawn from the approximate midpoint of the trunkline and piped to the motel, as shown in Figure 33. The pressure requirement of the trunk pipeline is 100 psi and is a result of all frictional losses throughout the piping system, slight increases in elevation, and a delivery pressure of 40 psi to the mobile homes. This low pressure requirement permits the use of concrete asbestos as the piping material.

At design conditions, the temperature loss through an uninsulated concrete asbestos trunkline is about 2.5°F . During periods of low demand on the geothermal system the temperature loss could be as high as 12°F . This large temperature loss renders the geothermal fluid inefficient as a heating source. Thus, to reduce heat loss an insulated concrete asbestos pipe must be used. The use of an insulated pipe reduces the temperature loss to 0.32°F and 1.7°F for peak and non-peak conditions, respectively.

The backbone loop in the motel area serves the same role as previously described for the residential area in that it transports large quantities of water throughout the service area. The backbone loop consists of 5,300 and 3,000 feet of 6-inch and 8-inch diameter pipe, respectively, as shown in Figure 33.

The pressure requirement of 100 psi on this piping segment is the same as that specified for the delivery line since the entire distribution system is pressurized via the well pump to this value. This once again permits the use of concrete asbestos; an insulation must be provided to maintain a viable geothermal heating media.

The branch feeder system is the last piping segment in the distribution of the geothermal resource to the mobile homes. In this segment the geothermal fluid is withdrawn from the backbone loop and branched through progressively smaller pipes to the individual mobile homes. Figure 18 is used to determine the piping distribution in the serviced area. Table 32 lists the necessary piping for the fully developed mobile home area of 403 homes.

Table 32

Piping Distribution Requirements for Mobile Homes

Pipe diameter (inches)	Length (feet)
3/4	28,200
1	2,600
1 1/4	2,600
1 1/2	2,600
2	7,500
2 1/2	7,000
3	6,600
4	5,100

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It is advantageous to use concrete asbestos piping for the 3-inch and 4-inch pipe sizes, and copper pipe for sizes smaller than 2 1/2 inch. Through the uninsulated branch system the temperature loss at design conditions is 8°F. During the warmer months when the system is not operating at design conditions, a temperature loss of about 25°F is possible. Thus, insulation is required to maintain the usability of the geothermal resource. Insulation on both the concrete asbestos and copper piping reduce the temperature loss to 4°F and 10°F for peak and non-peak periods, respectively. The economics of this piping segment were based on a pre-insulated concrete asbestos pipe and an insulated copper pipe with a PVC outer casing.

A pressure-regulating valve is installed at each home to ensure a constant supply pressure of 40 psi. As outlined for the residential distribution system, temperature control valves are located throughout the branch and backbone systems. These valves ensure an adequate temperature of the geothermal fluid particularly during non-peak demand periods. The valves discharge geothermal fluid to the collection system if the temperature drops below 135°F.

3. Motel

A flow of 150 gpm is required for heating purposes of the motel as discussed in detail in Chapter VII. This geothermal flow is distributed to the motel through a 3-inch diameter pipe leading from the mobile home trunkline. The short length, 200 feet, and low pressure specifications permit use of uninsulated concrete asbestos pipe. Throughout the design development effort, analyses were conducted comparing the costs of continually pumping larger flow rates of hot geothermal waters through the system even during periods of low heating demands to that of insulating the distribution piping. Except where stated, insulation coupled with the installation of variable speed pumping was economic.

4. Greenhouse

A flow rate of 700 gpm is needed to supply the design heat load of 6.62×10^6 Btu/hour for the greenhouse. This flow rate is supplied through a short 6-inch pipeline leading from the well site, shown in Figure 33. As was the case with the motel pipeline, the low pressure requirement and short distance permit the use of an inexpensive uninsulated concrete asbestos pipe. At design conditions the temperature loss is less than 0.5°F and during low utilization periods the temperature loss may increase to 1°F.

5. Collection System

The commercial area collection system carries the utilized geothermal fluid to reinjection site. The reinjection site is located about 3,000 feet southwest of the production field to minimize short circuiting potential. The aquaculture facility is located adjacent

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to this reinjection site to permit final heat extraction from the geothermal fluid.

The collection system also consists of several distinctive segments as required to service the user. Figure 33 shows the system used to collect the spent geothermal fluid. The collection system generally parallels the distribution system, although in some instances it is necessary to follow topographical contours to permit gravity flow. Thus, piping requirements are similar to those of the distribution system.

The collection system is designed for pressures and temperatures of 50 psi and 130°F, respectively. At these conditions cost is minimized by using concrete asbestos for all sizes greater than 3-inch; polyethylene is used for smaller pipe needs. All piping normally less than 3-inch are designated as a 3-inch pipe for simplicity of installation, reduction of friction, and small incremental costs of smaller sizes. Concrete asbestos is specified for pipe sizes larger than 3-inch and polyethylene for the remainder.

The spent geothermal fluid from the mobile home area is first collected in the 3-inch polyethylene pipe. It is then directed through progressively larger pipe sizes until a single 10-inch line carries the entire flow. This single 10-inch pipeline runs past the motel where up to 200 gpm is added to the return flow. This 10-inch pipeline continues to the greenhouse where the pipe size increases to 12 inch to accommodate an additional 700 gpm of cooled geothermal water flow from that source.

The 12-inch pipeline from the greenhouse then extends 3,000 feet to the southwest, to the aquaculture facility. At this location the fluid passes through a final set of heat exchangers prior to reinjection.

H. Economic Analysis

Thirty-year economic evaluations similar to those described in Chapter VI for the residential area were also prepared for the commercial area. Two base case alternatives were evaluated; the principal variant in these alternatives was the rate of mobile home activity and greenhouse construction. Commercial Alternative 1 assumed a moderate rate of five mobile homes per year for a total of 378 homes over thirty years. The Baca Grande Inn was retrofitted in the first year; one 44,100 square foot greenhouse unit was also constructed during that year, with four more units added during the fifth year. Commercial Alternative 2 supposes a mobile home addition rate of 12 units per year; greenhouse construction is similar to case 1 except that an additional 5 acres is added in the tenth year. The greenhouse is, of course, the principal energy consumer in this commercial system, accounting for 75-90% of the annual energy loads. Finally, Production Area II, located immediately adjacent to this service area, was used to determine piping lengths.

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The annualized cost analysis for the two base cases gives 30-year average costs of \$6.01 per million Btu for Alternative 1 and \$5.45 per million Btu for Alternative 2. Again, this is compared to current electrical costs of \$10.05 per million Btu. The economic breakdown is presented in Tables 33 and 34, which follow.

Table 33

Commercial Area Alternative 1

Total Mobile Home Development - 168 units
Total Greenhouse Development - 220,500 square feet
Geothermal System peak design capacity - 4,745 gpm
Distribution from Production Area II.

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10^9 Btu/yr	User Energy Cost \$/ 10^6 Btu
1	161.6	21.4	17.4	30-year average user cost \$6.01
5	336.6	62.5	76.4	
10	375.5	64.4	79.4	
15	391.2	66.2	82.4	
20	406.8	67.9	85.4	
25	422.5	69.7	88.4	
30	438.2	71.5	91.4	

Table 34

Commercial Area Alternative 2

Total Mobile Home Development - 378 units
Total Greenhouse Development - 441,000 square feet
Geothermal System peak design capacity - 9,267 gpm
Distribution from Production Area II

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10^9 Btu/yr	User Energy Cost \$/ 10^6 Btu
1	167.6	26.5	18.1	30-year average user cost \$5.45
5	395.7	65.2	81.8	
10	618.8	120.2	159.8	
15	690.8	133.8	167.0	
20	739.6	135.6	174.2	
25	788.3	138.2	181.4	
30	881.7	142.5	188.6	

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The computer-based analysis gives 30-year levelized costs of \$5.81 and \$5.44 for Alternative 1 and Alternative 2 respectively. A 5-percent inflation rate for 30 years increases these values by approximately 35 percent. The bases for these cost figures and for varying inflation rates are given in Appendix D.

Several important influences are seen in these results. First, the introduction of a major concentrated energy consumer in the form of greenhouses markedly improves the economics of this district system as compared to those of the low density residential system previously discussed. Piping costs to the greenhouses are minimal, thereby significantly reducing the capital distribution costs per marketed Btu. This point is clearly illustrated in both alternatives in that the average user cost gradually increases in the later years of the 30-year evaluation period due to the distribution costs of the mobile home subdivision area. Again, as noted in Chapter VI, the distribution piping system is complete in that no future tap fee will be required of mobile homeowners in future years. An additional positive factor improving these overall figures would be the establishment of an aquaculture facility which would effectively extract more heat from the previously utilized resource.

Since it was apparent that the greenhouse was, in effect, subsidizing the mobile home residential service area, one additional system was costed to evaluate the economics solely of the geothermal greenhouse heating system, to thereby more definitely highlight the potentials for future greenhouse operations at the Baca Grande. This case assumed 352,800 square feet of greenhouse capacity served by six 1,000 gpm production wells. One spare production well and one disposal well were provided for every three production wells. A levelized 30-year user cost of \$3.20-3.51 per million Btu results.

Since distribution piping costs are minimal, well costs become a much more significant factor; thus, if the resource is assumed to be at a 1,500-foot depth as compared to the deeper 2,000-foot depth, the user energy costs are reduced to \$2.99 per million Btu. This relates to an annual heating cost of \$0.96/ft² of greenhouse capacity per year. This is quite competitive with current Colorado front range costs of \$0.75/ft² per year. It is important to note that this comparison is conservative in that it assumes no escalation of conventional energy costs. If current conventional fuels escalate in the 7- to 10-percent range, as expected, the geothermal case will be very economic by comparison.

IX. INSTITUTIONAL FACTORS RELATED TO GEOTHERMAL DEVELOPMENT

An analysis has been made of the many non-technical factors that could affect the establishment of a geothermal system on the Baca Grant Ranch. The objective of this analysis was to assess the possibility that institutional elements may exist that could either provide an incentive for geothermal development or hinder that development. In this respect, both the San Luis Valley as a whole and Saguache County specifically were considered, despite their large size as compared to the smaller target project area, because of the relatively integrated nature of activities throughout the Valley. For instance, the working population in general does not object to commuting comparatively long distances to work; also, many Valley leaders have stated that beneficial development anywhere in the Valley is of general benefit to all concerned.

The conclusion of this analysis is that the institutional climate is favorable for a geothermal development of the type under study here. No severe environmental problems are apparent, as is discussed in Chapter XI. The general population, including government and business leaders and environmentalists, appear to be positively receptive towards the utilization of geothermal energy. There is currently a large utilization of expensive energy sources, such as electricity and propane for heating; new gas service is limited, and the electrical supply network is approaching present peak capacity; accordingly, a new and less expensive geothermal energy source would be welcome. Finally, the establishment of geothermal applications and a geothermal industry would provide an employment base that is recognized as necessary and is desired. Saguache County is experiencing a high 12.3 percent unemployment rate and a median family income of less than one-half of the Colorado State average. With respect to the latter factor, State agencies and local governments are equally anxious to create new jobs. To illustrate, the development of a large uranium mine by the Homestake Mining Company in the northern part of the County was very well received by the Saguache County Commissioners. They have been extremely cooperative and active in pushing that project through. Also, the construction permits for a geothermally heated hog farm to be located near Mineral Hot Springs, approximately 20 miles northwest of the Baca Grande, have recently been approved with very few problems. This latter development is important also since it represents an apparent acceptance of the fact that geothermal projects can be developed without detrimental effects to the current water use patterns.

Via the Colorado Geothermal Resources Act, the State Oil and Gas Conservation Commission is assigned the primary responsibility for approving the drilling permits required for geothermal wells. In its four-year history only one permit has been processed--that being the Colorado Geological Survey well drilled at Pagosa Springs. That permit was obtained without any unusual delays. Permits from the Water Quality Control Commission, the Air Quality Control Commission, and a determination from the State Water Engineer's office that a well will not infringe on already established water uses are also required. These regulatory agencies have been contacted and generally indicated that no unusual problems should be encountered. It is worth mentioning that due to the general lack of prior geothermal activity, these agencies are themselves "finding their own way."

The only potentially significant problem that has been identified relates to the effect of geothermal developments on non-geothermal waters. This is not a technical problem, however, since it appears that the geothermal system can be designed and managed so as not to affect the pressure or the productivity of nearby irrigation wells in the Valley. Rather, it is an institutional problem in that water is of primary economic importance in the Valley and as such, is a visible and sometimes emotional issue. If the public were not properly informed or the project not judiciously managed, it is conceivable that an adverse reaction could arise because of problems related to the geothermal system. To help avoid such a reaction, public information meetings should be useful.

An extensive report has been prepared that provides a data base for many of the institutional factors. Included are demographic data, socio-economic data, transportation systems, land use patterns, regulatory and permitting requirements, industrial patterns, and public opinion reviews. This report is lengthy and is presented in Appendix B.

With respect to electric power supplies in the Valley, both utility companies serving the region have needs for increased or new sources of supply. The San Luis Valley Rural Electric Cooperative Association is planning to meet its increased needs by constructing a new 230 KV transmission line that would bring in power generated outside the Valley. This line is expected to provide them with ample reserves for at least 5 years. Public Service Company of Colorado (PSC), which also services the area, can generate between 50 and 60 megawatts of electric power to meet the peak demand loads for Alamosa urban needs and for water pumping loads during periods of high irrigation water withdrawals. These generating facilities are a high cost, high maintenance system, consisting of gas turbines and an old steam generating plant which are fueled by natural gas and fuel oil. Appropriate PSC officials have expressed a strong interest in the geothermal alternative for local power generation, and have offered to support a promising geothermal electric project.

With respect to general geothermal developments, meetings were held in the San Luis Valley with representatives of several groups to assist in determining the probable local response to any geothermal development. A State official from the Department of Commerce and Development was present at all meetings. A meeting held at Alamosa was organized by the San Luis Valley Council of Governments, and was also attended by the Chamber of Commerce, a local banker, a local housing developer, and a local farmer. Separate meetings were held at Monte Vista with the City Manager, and with banking officials involved in the financing of new industrial ventures in the area. A meeting was also held at the Baca Grande Development with the Director of the Rio Grande Water Conservation District. The sentiments expressed at all these meetings were consistent with those summarized in this chapter, and favorable towards geothermal energy.

To repeat briefly, the participants believe that any non-polluting energy source such as geothermal, that brings with it the potential of providing an employment base, will be welcome in the Valley and will engender active support. The main concern with a geothermal development is related to the potential for infringement of existing water supplies; the need to adequately address this question as anticipated should not constitute a significant problem if reinjection

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and other good management are practiced. These sentiments complement and agree with responses obtained from others during the field surveys undertaken as part of the Institutional Analysis.

CHAPTER X. SUMMARY OF THE ENVIRONMENTAL REPORT

The objectives of the Environmental Report are to develop, collect, and organize information and technical data necessary for a preliminary evaluation of the environmental impacts of the project area. The report was structured in accordance with ERDA publication ERHQ-0001, "Guidelines to the Preparation of Environmental Reports for Geothermal Development Projects." As such, the report, which is included in its entirety as Appendix C, is organized into ten chapters consistent with the following outline.

Introduction--A general summary description of the proposed activity and its relationship to the overall geothermal program.

Description of the Proposed Activity--A detailed presentation of those aspects of the activity that could affect the environment.

Description of the Existing Environment--An accounting of the physical, biological, and socio-economic characteristics of the environment that could be affected by the proposed activity.

Environmental Effects of the Proposed Activity--A discussion of the effects on the environment that could result from conducting the proposed activity.

Effluent and Environmental Measurement and Monitoring Programs--A description of environmental data collection programs done both prior to the proposed activity and planned during the activity.

Reclamation and Restoration--A description of planned efforts to reclaim and restore the site of the proposed activity.

Alternatives to the Proposed Action--A summary analysis of feasible alternatives to the proposed activity and their potential environmental effects.

Irreversible and Irretrievable Commitments of Resources--An identification of resources that are lost due to performance of the proposed activity.

Trade-off Analysis--An analysis which weighs the benefits of the proposed activity against the environmental costs resulting from that activity.

Compliance with Regulations--A review of all environmental regulatory requirements that must be met to conduct the proposed activity.

The Baca Grande residential and recreational community is an existing commercial land development area which has acquired all necessary zoning permits and was platted and surveyed in the early 1970's. If alternative energy sources are not utilized, the residential and commercial participants will be served by either electricity or propane. The development of the geothermal resource would provide the option for an alternate and environmentally preferable energy source to meet these energy demands. In addition, the presence of an economically attractive geothermal energy source could encourage additional light industry to locate in the Valley. The principal conclusions of the report are summarized below.

Land Use

Environmental impacts can result from well drilling activities and pipeline construction. Drilling rigs, excavation equipment, support vehicle movement, and the associated dust and noise levels can all have short-term impacts on the physical terrain and aesthetics. These can be minimized through applications of the proper preventive and restorative efforts. Only one drill rig is anticipated to be on site at any one time and the drilling site will involve less than 5 acres. Immediately after drilling operations conclude, the drill site will be restored to its original condition. The pipeline routes also will be restored to their original contours and revegetated after installation. The short-term impact will be 90 percent mitigated within 3 years and there is no anticipated long-term impact.

Subsidence of the sediments due to consolidation caused by pressure declines in deep aquifers is not expected to be a problem. In the case at hand, irrigation pumpage has not caused notable subsidence. This pumpage appears greater than proposed for geothermal pumpage and this can be used as an indication of the magnitude of valid concern. In addition, the reinjection of the cooled brines should mitigate any potential subsidence. In other words, no problem is presently foreseen.

Modern means of waste disposal and human sanitation will be observed at the drilling and construction sites; no short- or long-term affect from these sources is anticipated.

Water Use

Effects on the area groundwater regime represent one of the most significant potential environmental impacts. Geothermal fluids will be produced from depths approximating 2,000 feet and could ultimately originate from depths of 5,000 to 11,000 feet. The majority of irrigation wells in the San Luis Valley are presently producing from depths less than 2,000 feet. Hydrogeological studies show that the deeper geothermal reservoirs are unrelated to the irrigation aquifers due to volcanic flows and clay lenses in the subsurface. In the immediate vicinity of the Baca Grande, there are only 13 irrigation wells which are estimated to be at depths approximating 1,000 feet or less. For these reasons and in view of the proposed reinjection system, it is anticipated that the production of geothermal fluids at the Baca Grande will have minimal impact to the present water use in the northeastern San Luis Valley.

Water Quality

There will be no impact to surface water quality and minimal impact to groundwater. All State and Federal water quality standards will be met; significant surface discharge to area waterways is not anticipated. Geothermal fluids should have total dissolved solids concentrations of less than 1,000 mg/l which is a very good quality water. If geothermal fluids are reinjected into the same or comparable aquifers from which they were produced, there will be no impact to the groundwaters.

Air Quality

Since the location of the Baca Grande is rather remote and not near present urban development, the air quality is virtually pristine. The only major pollutant constituent occurring does so naturally and is airborne dust. The geothermal development will have no residual impact on the air quality of the area. The reservoir water quality is high, and noncondensable gases are not present in the fluid and will not be released to the atmosphere.

Socio-Economic Environment

Lifestyle changes or changes in basic social structures, populations, economics, and services as a result of the proposed geothermal utilization are difficult to quantify since the major portions of the Baca Grande development have already been initiated. Increases in population certainly can have an impact on rural, economically depressed areas in terms of needs for expanding local services. For the case at hand, neither Crestone nor Moffat, Colorado, has centralized water or sewage treatment systems. Thus, any significant population increase in either of these two towns will create added pressure on the already marginal existing systems. On the other hand, more people mean a more stable tax base by which to increase this type of needed improvement. Since the Baca Grande community is geared towards a continuing growth, water, sewer, and utility provisions are adequate to meet any future projected needs. Impacts on the regional school systems should be positive rather than negative, since the local schools are seeking accreditation and need an increased number of pupils to successfully realize that goal.

In conclusion, the continuing development of geothermal services for the Baca Grande area is an environmentally acceptable and indeed preferable alternate for providing future energy supplies.

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APPENDIX A

A PRELIMINARY EVALUATION OF GEOTHERMAL PROSPECTS AT BACA GRANDE
DEVELOPMENT IN SAN LUIS VALLEY, COLORADO

A report by Richard W. Davis for Coury and Associates, Inc.

October 28, 1978

Coury and Associates, Inc.

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INTRODUCTION

This report is the second in a series on geothermal prospects in the San Luis Valley of south-central Colorado (Figures 1 and 2). The first report (Davis, 1977) discussed the whole valley, concentrating on the eastern portion, particularly the data from the #1-32 Mapco State (Mapco) well. This report draws extensively upon that initial submittal. It also relies heavily upon field and laboratory data collected by or under the direction of Coury and Associates. Other than that developed by Coury and Associates, no new field data is used in this report.

Study and analysis for 1978 have concentrated upon prospects for commercial geothermal development on the Luis Maria Baca Grant (Baca Grant) (Figures 2 and 3). The objectives of the hydrogeothermal evaluation discussed in this report have been to evaluate the geothermal resource in the vicinity of the Baca Grande Development (Baca Grande) which occupies a portion of the Baca Grant. A secondary objective has been to evaluate possible environmental impacts. Finally, using the data developed here, recommendations were to be made for the next phase of exploration and evaluation.

CONCLUSIONS

1. Geothermal prospects are probably best within the Baca Grande Graben (Figure 2). East of the graben near the mountain front, prospects of significant geothermal resources are not good.
2. For planning purposes, the thermal profile from the Mapco well is probably the best one to use. Although temperature gradients near the surface are quite high, they are expected to decrease sharply below depths of 1,000 feet.
3. Geothermal water in the reservoirs above depths of 2,000 feet probably contain 1000 mg/l or less of total dissolved solids.
4. Environmental problems associated with geothermal development are not expected to be serious.
5. One of the major unanswered questions still remaining pertains to the nature of the pattern of hydrologic circulation. Successful development of the geothermal resource will ultimately depend upon defining the system of circulation, for all but a negligible fraction of the geothermal water is derived from meteoric sources. An important objective of future efforts should be to provide the necessary answers.

Figure 1: Map of Colorado showing counties. Area encompassed by Figure 2 is hachured.

FIGURE 2
GEOTHERMAL STUDY
San Luis Valley, Colorado
LOCATION MAP

by
Richard W. Davis
Consulting Hydrogeologist
July, 1977

0 5 Miles 0 5 10 Kilometers

Explanation

Fault Trace
(dashed where
inferred)

BACA GRANT

BACA GRANDE GRABEN

#1-32 MAPCO
STATE WELL

38°00'

A-5

37°00'

106°00'

RECOMMENDATIONS

The evaluation program has proceeded about as far as it is feasible to proceed without more subsurface data. For this reason, a program of field data acquisition and exploration is strongly recommended for future work if the resource outlined here has economic potential.

A two-phased exploration program is recommended. In the first phase, more data from existing wells would be obtained. The most important cost item in an exploration program will be drilling and completing wells. Any data obtainable from existing wells will be economic by comparison and will enhance chances of success of a phase two drilling program. Static shut-in pressures, rates of pressure buildup, current production rates, temperature profiles, and downhole flow velocities should be measured in selected artesian wells. Probably four would suffice. Drawdown tests and temperature profiles should be run on non-flowing wells. The data so obtained would reveal zones of production, define aquifer parameters, and give more accurate temperature profiles. All of the tested wells into which a sonde can be inserted should be logged with gamma, gamma-gamma, and neutron gamma devices. These instruments are capable of revealing information on formation lithologies and porosities, even in cased wells.

Following evaluation of data from the first phase, final locations should be selected for two exploration test wells. The drilling and completion program should yield further information on temperature profiles, geology, and aquifer parameters under better controlled conditions and in areas where data is needed but lacking at present. A recommended hierarchy of criteria for locating the wells indicates the primary consideration should be to place them in the eastern half of the Baca Grande graben and within or near the Baca Grande Development area. The secondary consideration should be to place them where, if commercial production appears feasible, the production could be economically used. The tertiary consideration would be to place one well near and west of the eastern boundary of the Baca Grande Graben in order to see if fluids are being discharged upward along the fault zone. Such fluids could be expected to have much higher temperatures than the shallow water with which they mix.

Data from the two phases would be used to:

1. Establish lateral and vertical thermal gradients.
2. Establish lateral hydraulic head gradients.
3. Locate recharge areas for the shallow aquifers.
4. Determine production capabilities.
5. Measure water quality changes laterally and vertically.
6. Assess potential environmental problems.

A target depth of 2,000 feet is recommended for the first well. This should bottom within a sandy sequence near the top of the Santa Fe formation. The well should be drilled using the smallest practical bit size and logged in the uncased hole. If the open hole logs indicate a potential geothermal resource, the hole would then be reamed to a size sufficient to accommodate the casing needed and completed both as a test and as a production well.

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A design basis production well with 24-inch casing is recommended. This would require a hole reamed to 30 inches. Pending the results of an actual chemical analysis of the water, it is not anticipated that special corrosion-resistant steel will be needed for the casing. If the well appears to be of marginal value, 6-inch steel casing perforated in the most promising geothermal aquifer sequence might be installed rather than the 24-inch casing. This would permit extensive testing and evaluation with a smaller commitment of funds. Production capabilities of a 6-inch casing would be less than 200 gpm. The principle purpose of the well would be for aquifer testing, so low production rates would be acceptable. A perforated casing with gravel pack or a well screen will probably be needed through the interval of interest with the annulus between hole and well casing filled with cement above and below the perforated zone. For planning purposes, a total perforated interval of 200 feet seems reasonable. This well would be used to ascertain aquifer parameters using single-well methods of analysis such as drill stem tests and specific capacity tests.

When the results from the first test well are available, a final location and design for the second test hole could be selected. For design purposes, a well to 2,000 feet with a 24-inch steel casing should be used. It is assumed that a second well will not be needed if the results from the first well are not encouraging. If a second well is drilled, it should be preceded by a "slim hole" as on the first well and reamed to production size if preliminary evaluation indicates the hole warrants further work.

METHODOLOGY

Field Work

Coury and Associates arranged for the Baca Grande Corporation to conduct a survey of wells on and near the Baca Grant. The field surveys were intended to gather data on the depth and water temperatures of the wells. Locations of the wells are shown on Figure 3. The data collected are given in Attachment 1.

Following the initial survey, selected wells were revisited by Coury and Associates for the purpose of taking another measurement of water temperature, determining well yields, and collecting samples for analysis. The samples were sent to Colorado Analytical Laboratory in Brighton, Colorado, for analysis. Results of the field measurements and laboratory analysis are given in Attachments 2 and 3, respectively.

Geochemical Evaluation

The chemical data were analyzed by the methods of Fournier and Truesdell (1974) to estimate geothermal reservoir temperature and water quality. The discussions of Fournier and Truesdell have been expanded upon by Barrett and Pearl (1978). Fournier and Truesdell describe two methods for obtaining estimates of reservoir temperatures. Both were applied here. The results are given in Table 1. Where the data were unsuitable for the purposes of geothermal analysis, no reservoir temperatures are listed.

Table 1: Summary of geothermal analyses of Baca Grant wells. Well locations are indicated on Figure 1. "Reservoir temperatures" were calculated using geochemical techniques.

Well No.	Depth (ft.)	Artesian Flow Rate (gpm-est.)	Water Temp. °F	Reservoir Temp. °F	
				Na, Ca, K Method	Si (Mod. #1) Method
1	200	None	41		
2	180	?	41		
3	160	?	45		
4	210	?	51		
5	300	?	56		
6	625	50	70	---	220
7	625	150-200	74	---	220
8	690	900-1100	78	---	162
9	600	200-300	78	---	199
10	500	Flowing	67	---	225
11	400	20	61	---	217
12	400	25	63	---	225
12A	?(400+)	15-20	72	282	---
13	400	Flowing	62	---	---

Geophysical Analysis

Gaca and Karig (1965) have conducted a gravity survey of the San Luis Valley. The results of the survey were analyzed along a cross section whose location is shown on Figure 3. The analysis utilized a slight modification of the graticule method described by Heiland (1963, p. 153). Seismograph profile records published by Stoughton (1977) were also examined and analyzed. One of Stoughton's profiles (Line 5A, Figure 22) passes through the Mapco well. This well was the subject of intense analysis in last year's report (Davis, 1977). The seismic data from the Mapco well were used to determine seismic velocities for the various stratigraphic units. The seismic data were then used to modify the gravity interpretation along Stoughton's Profile No. 3. Figure 4 shows the geophysical interpretation along profile A-A' (Figure 3), which is close to Stoughton's Profile No. 3. Figure 3 shows the trends of concealed faults identified by the profile analysis.

Thermal Data

Thermal data listed in Powell (1958, Table 7) were used to obtain relative evaluations of different portions of the San Luis Valley. The water temperatures and well depths in various townships of the valley were subjected to a least squares trend analysis to define variations of well temperature with water depth.

Data listed in Attachments 1 and 2 were also used to estimate vertical thermal gradients for the deeper wells at Baca Grande (Figure 5). Based on data from Powell (1958, Table 7), the near surface water temperatures were assumed to be 41°F.

INTERPRETATION

General

The work of last year (Davis, 1977) verified the existence of high temperature water at depth in the graben, here called the Baca Grande Graben (Figure 2), along the west flank of the Sangre de Cristo Range. Figure 6 is from that report. A brief analysis of temperature gradients conducted during this year's study using temperature data from Powell (1958, Table 7) and from field surveys very definitely tends to indicate that the Baca Grande Graben is one of the two most favorable loci for geothermal prospecting. Another favorable area is in T. 36 N., R. 9 E., southwest of the town of Alamosa. No further work was done on evaluating this latter prospect as it was beyond the scope of this study to give more than cursory notice to the whole valley.

Geology

Geologic and geophysical cross sections along line A-A' (Figure 3) are shown in Figure 4. The geologic section indicates the probable thickness of the sediments. The uppermost unit is the Alamosa formation. This is the source of water for most existing irrigation wells.

Figure 4: Bouguer gravity anomaly, geophysical interpretation of depths to interfaces, and geologic cross section along A-A' (Figure 2).

Figure 6: Graphs of temperature and density versus depth in the #1-32 Mapco State well. Data are from geophysical logs. Solid squares in the temperature graph are water temperatures from other deep wells in the San Luis Valley plotted versus total depth of well.

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In the Baca Grande area the Alamosa formation consists of clastic debris derived from the Sangre de Cristo Mountains. The sediments are of fluvial origin, having been deposited as a series of coalescing alluvial fans. Transmissivities of the unit can be expected to vary a great deal in various depth ranges and from place to place, with the highest water yields coming from an occasional coarse, isolated channel deposit. These channel deposits are normally surrounded by relatively impermeable clays and silts. The ratio of coarse to fine units can be expected to increase toward the mountains.

Recharge to aquifer units in such alluvial fan deposits normally occurs along the mountain front where streams debouch onto the valley floor. Clement (1952, p.9) notes that streams flowing from the mountain front lose their flow by infiltration into the surface sediments within a very short distance. The ground water flows down-gradient toward the valley. Away from the mountain front, the coarse, aquiferous units become increasingly confined by silts and clays. The topographic gradient toward the valley is less than the hydraulic gradient in the deeper confined aquifers, so that at some point between the mountain front and the valley center, flowing wells can be constructed in the deeper aquifers. Yields from the Alamosa formation are quite high, ranging to in excess of 1000 gpm (gallons per minute) even from flowing artesian wells.

The Santa Fe formation underlies the Alamosa formation. Geophysical data and the Mapco well logs indicate that it is also about 2,000 feet thick. It is expected that it will have a much lower average permeability than the Alamosa formation. This statement is based on geophysical well log data from the Mapco well. At this time the best prospects for high yields from the Santa Fe are in sandy sequences near the top and near the middle of this formation (Figure 6). Water temperatures in the upper sandy sequence would probably be only a little higher than those at the base of the overlying Alamosa formation.

Below the Santa Fe formation the Mapco well data indicates a thick sequence of interbedded sands, shales, conglomerates, and volcanics. The average density of the sequence is very low (2.30 - 2.35 g/cm³). It is likely that much of the volcanic material is composed of tuffs, a form of volcanic ash. This sequence probably is present to the top of the crystalline basement complex at about 21,000 feet depth.

Figures 3 and 4 show the major structural elements at Baca Grande. The deepest part of the graben is bounded by major faults which do not seem to extend upward beyond the Santa Fe formation. East of the Baca Grande Graben crystalline basement occurs at shallow depths (about 4,400 feet). It is unlikely that significant geothermal resources occur here. This is because the most easterly conduit for significant thermal heat flux, either by fluid convection or by conduction, is the fault bounding the east side of the Baca Grande Graben (Figure 3). It is logical to assume that any thermal waters moving upward along this conduit will be offset westward, not eastward, by a westward water flow in the shallow aquifers. This is because the logical recharge area of the Alamosa and Santa Fe formations is along the mountain front.

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The apparent lack of faulting in the Alamosa and Santa Fe formations means that hydrologic continuity between recharge areas along the face of the Sangre de Cristo Range and the Rio Grande River is probably good. Potentiometric gradients in the shallow aquifer system are probably westward. This means that lateral ground water flow in the sediments above 4,400 feet, especially in the Alamosa formation, will be the dominant modifier of thermal flux patterns.

Thermal Regimes

The temperature data collected by field surveys during this study (Attachments 1 and 2) indicate a potential for abnormally high water temperatures at depth. Vertical thermal gradients calculated using well water sample temperatures measured at the surface versus total depth of the well are shown in Figure 5. Since the temperatures measured at the surface are probably from a mixture of waters, most of it likely from shallower, cooler waters, the temperatures measured at the surface would be less than bottomhole temperatures. This means the calculated thermal gradients are lower than would be measured if thermal profiles for the wells were available from downhole probes.

Analysis of hydrochemical data (Attachment 3) using the methods of Fournier et al. (1974) yielded the thermal reservoir temperatures in Table 1. The calculated reservoir temperatures average 219°F.

The methods of Fournier et al. (1974) implicitly require convective heat flow, that is, heat transport by upward moving ground water. Without convective flow there is no mass transfer of water and dissolved materials, only heat transfer. Hydrochemical analysis using the methods of Fournier and Truesdell (1974) inherently assumes a mass transfer mechanism. The temperatures are higher than any to be expected in the Alamosa formation without some form of circulation of water upward from deeper aquifers. However, there is no indication, other than Table 1, that such circulation is occurring. These two considerations are expanded upon below.

Figure 6 shows thermal data from the Mapco State well. The shallowest data point (5°C) has been added here. The profile is very straight between depths of 1,000 and 7,500 feet. It is reasonable to assume that the thermal parameters of the sediments in that interval are vertically homogeneous. The constant thermal gradient indicates that conductive heat transfer is the only mechanism operational in the interval. It is also reasonable to assume that the vertical homogeneity of thermal parameters extends from surface to 7,500 feet depth. Based on this assumption, the convex upward shape of the thermal profile above 1,000 feet depth indicates convective heat flow mechanisms in this interval. It is speculated here that the situation is analogous to the flow of water across a hot plate. The hot plate is the top of the Santa Fe formation. The flow is ground water movement through aquifers in the Alamosa formation. The ground water movement is assumed to be vigorous enough to render the conductive heat flow component negligible by comparison to the convective heat flow component in the Alamosa formation.

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There is an alternate or perhaps supplementary heat transfer mechanism which could be operational in the Baca Grande area. There is no data except that in Table 1 with which to evaluate this mechanism at present. It is quite possible that ground water moving upward from deeper aquifers along the faults bounding the graben is providing a convective heat flux mechanism extending to great depths. As pointed out in last year's report (Davis, 1977) the quality of water in the thermal reservoirs below 7,500 feet suggests good ground water circulation. In order to have such circulation, aquifer discharge and recharge are necessary. The bounding faults of the graben may be lines of recharge or discharge. If they provide recharge conduits, water temperatures will be lower along the faults. If, as seems more likely, they are lines of discharge, temperatures near the fault zones will be higher. This mechanism could explain the anomalously high temperatures calculated in Table 1.

Environmental Considerations

The major environmental topics to be addressed prior to beginning a geothermal development are:

1. Effects of development upon surrounding wells, springs and streams. Any adverse impacts upon water rights are likely to be met with strenuous objection in the arid San Luis Valley.
2. Potential subsidence effects caused by lowering of reservoir pressures.
3. Adverse environmental effects which might result from disposal of spent geothermal fluids. In the case at hand, it is understood that subsurface disposal is under consideration.

Data are lacking at present with which to do an adequate analysis of the three topics. However, it is possible to make reasonable preliminary judgements concerning environmental impacts. The source of geothermal water will probably be from sediments below or in the base of the Alamosa formation. Because of the nature of alluvial fan aquifers, this will probably involve other, separate aquifers from those presently in use for irrigation. It is assumed that the aquitard sequences will effectively isolate the deeper aquifers from those in shallow horizons so that negligible impact upon existing water rights is anticipated. This assumption should be verified during any future exploration program.

Subsidence of the sediments due to consolidation caused by pressure declines in deep aquifers normally has a potential for affecting a greater area than do such declines due to pumping shallow aquifers. At the same time, effects from deeper wells are less intense in any one area. In the case at hand, irrigation pumpage has not caused notable subsidence. This pumpage appears to be so much greater than the 2000 gpm proposed for near-term geothermal pumpage rates that it can be used as an indication of the magnitude of the problem. In other words, no problem is presently anticipated with initial pumpage rates. It also seems likely that subsid-

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ence would not be a problem at pumpage rates up to 10,000 gpm if the pumpage is properly distributed over a wide area. However, this statement needs corroboration. Test data on actual aquifer parameters along with well logs are necessary. The application of modeling techniques may also be necessary for analysis.

It is understood that reinjection of spent fluids into the subsurface and spreading ponds are being considered as methods of disposal. Permeabilities in the Alamosa formation should improve as the front of the Sangre de Cristo Range is approached. Provided the chemical quality of the water is compatible with the aquifer and water into which it will be injected, no problems are foreseen. It is quite likely that, instead of injection wells, spreading ponds may be feasible and more economical. Infiltration rates near the mountain front should be quite good. Freezing of the ponds would inhibit infiltration. It will probably be necessary to examine the thermal characteristics as well as the infiltration rates in such ponds. Precautionary measures such as ponds deeper than the expected freezing depth, artificial agitation and construction only in the most permeable areas may be necessary. If feasible, spreading ponds would be preferable to injection wells from almost all economic and engineering aspects. If subsidence effects become significant, pressure reinjection through wells would probably be necessary in order to alleviate the problem.

Water in the aquifers down to 2,000 feet depth is probably good. If later tests show it is too rich in undesirable chemicals, regulatory agencies will regard it as a pollutant and require treatment prior to discharge to surface or ground waters. On the positive side, good quality water recharged to the Alamosa formation would enhance supplies available for irrigation from the Alamosa. Water low in salinity, sodium adsorption ratio, boron, and toxic trace elements is required for agricultural use.

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ATTACHMENT 1

Results of Field Survey

by Baca Grande Corporation

SURVEY DATA
THIRTEEN WELLS VICINITY BACA GRANDE

June 21, 1978

Map Key Number	Estimated Depth (ft)	Approximate Temperature (^o F)	Remarks
1	200	41	Pump Well-Baca Grant Ranch Headquarters
2	180	41	BGWSO Well #17
3	160	45	BGWSO Pumphouse #2
4	210	51	BGWSO Pumphouse #1
5	300	56	D. Drawe irrigation well
6	625	68	H. Lamm artesian well drilled 1970
7	625	68	J. Moore artesian well drilled 1970
8	690	70	W. Wise-pasture north of main house
9	600	80	E. Clayton-artesian well
10	500	71	D. Blackwell-artesian well
11	400	62	Artesian stock well on BG airport road
12	400	70	B. Bunker
13	400	64	Gas well

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ATTACHMENT 2

Results of Field Survey by Coury and Associates, Inc.

July 11, 1978

WELL SUMMARIES

Note: All well numbers refer to appropriate numbers on the accompanying map of the area

WELL #6

Approximate Depth: 625 ft
Measured Temperature: 70°F
Estimated Flow Rate: 50 gal/min
Time Tested: 10:50 a.m.

Flowing

This is a private, one-family residence well, and it belongs to Mr. Henry Lamm. It was drilled in 1970.

WELL #7

Approximate Depth: 625 ft
Measured Temperature: 74°F
Estimated Flow Rate: 150-200 gal/min
Time Tested: 11:00 a.m.

Flowing

Most of this well was flowing into a ditch, while a small part (15 gal/min) was flowing into a trough to water cattle. The well was drilled in 1970, and belongs to J. Moore.

WELL #8

Approximate depth: 690 ft
Measured Temperature: 78°F
Estimated Flow Rate: 900-1100 gal/min
Time Tested: 11:30 a.m.

Flowing

This is used primarily for irrigation, although it is available as drinking water for the cattle. It is in the pasture to the north of the main house of the owner, W. Weiss.

WELL #9

Approximate depth: 600 ft
Measured Temperature: 78°F
Estimated Flow Rate: 200-300 gal/min
Time Tested: 9:25 a.m.

Flowing

This well seemed to be used to water a small family garden plot, as well as supply a house. It is owned by E. Clayton.

WELL #10

Approximate Depth: 500 ft
Measured Temperature: 67°F
Estimated Flow Rate: See below
Time Tested: 9:35 a.m.

Flowing

The well was emptying several places, and it wasn't practical to guess the flow rate. It flowed at least into two separate stock tanks. The well is owned by D. Blackwell.

WELL #11

Approximate Depth: 400 ft
Measured Temperature: 61-62°F
Estimated Flow Rate: 20 gal/min
Time Tested: 9:45 a.m.

Flowing

The well emptied into a watering tank. It is located on the Baca Grande airport road.

WELL #12

Approximate Depth: 400 ft
Measured Temperature: 63°F
Estimated flow rate: 25 gal/min
Time Tested: 10:10 a.m.

Flowing

The well flowed directly into a stock tank. The temperature was measured in the tank because the flow was too meager to adequately cover the thermometer bulb. The well belongs to B. Bunker.

WELL #12A

Approximate Depth: 400+ ft
Measured Temperature: 72°F
Estimated Flow Rate: 15-20 gal/min
Time Tested: 10:20 a.m.

Flowing

The temperature was measured from the stock tank into which the well emptied. There was some visible natural gas flowing out of the well, which is of high enough grade to be used directly for heating purposes.

WELL #13

Approximate Depth:	400 ft
Measured Temperature:	62°F
Estimated Flow Rate:	See below
Time Tested:	10:35 a.m.

Flowing

We only had access to a stock tank which the well fills, and it would be impossible to guess the overall flow rate of the system. Of particular interest in this well is the fact that natural gas flows out quite freely with the water. The gas used to be (still is?) collected over the tank and used for heating the house as well as the cow camp. The sample and the temperature both had to be obtained from the center of the stock tank. The sample will probably have accumulated some algae, as there was an abundance of it floating around.

ANALYSIS

All water samples were taken to Colorado Analytical Laboratories, in Brighton, Colorado, to be analyzed as follows:

- Concentrations of Na, K, Mg, Ca, SO₄, Cl, CO₃, HCO₃, Fe, SiO₂, and Nitrate will be determined.
- Specific conductivity, pH, total dissolved solids, and alkalinity will also be measured. The results of these analyses have been promised within a week, or July 19, 1978.

ADDITIONAL COMMENTS:

The guide indicated that Well #8, which flows at about 1000 gal/min at 78°F, is not necessarily as unique as it appears to be. He is of the opinion that almost any well in the general vicinity could produce similar flow rates and temperatures if it were drilled deep enough and of large enough diameter.

Apparently, many families in the Valley have their own wells which are used for small garden plots and as a family water supply. Water qualities and temperatures and well depths vary considerably from home to home, generally based on the finances involved in drilling the well. Depending on desired diameter, well-drilling costs can vary anywhere from \$20-\$25 up to and beyond \$40-\$45 per vertical foot.

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ATTACHMENT 3

Results of Laboratory Analysis of Water from Various Wells

(Well numbers correspond to those used in Attachments

1 and 2 and in Figure 2)

Well Number	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>	<u>12A</u>	<u>13</u>
pH (Units)	8.4	8.4	8.5	8.5	8.3	8.2	8.1	8.2	7.8
E.C. (mmhos/cm)	129	130	225	148	225	141	450	1330	425
<u>mg/Liter</u>									
Calcium	8	7	4	4	10	17	10	4	25
Magnesium	-1	-1	-1	-1	-1	-1	2	2	5
Sodium	24	26	54	33	44	16	109	345	73
Potassium	4	4	2	2	7	5	8	10	7
Iron	-.01	-.01	-.01	-.01	-.01	-.01	.05	-.01	.07
Silica	53	53	25	41	56	51	56	73	71
Alkalinity (CaCO ₃ Equiv)	47	49	88	57	99	55	236	723	219
Carbonates	0	0	0	0	0	0	0	0	0
Bicarbonates	58	61	107	67	118	66	293	883	260
Sulfate - S	9.0	8.8	13	9.0	10	9.0	12	17	11
Chloride	1.0	1.0	1.3	1.1	1.3	1.1	1.8	2.8	2.2
Nitrate - N	.80	.61	.83	1.2	.71	.70	.94	2.2	.39
Total Dissolved Salts	109	118	195	126	207	122	449	1270	391

Minus sign indicates less than reporting minimums.

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APPENDIX B

INSTITUTIONAL ANALYSIS

A report by Melvin Stuart and Associates, Inc.

February 1979

Coury and Associates, Inc.

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I. SUMMARY AND CONCLUSIONS

The overall picture of acceptance on a geothermal industry located on the Luis Maria Baca Grant No. 4 is optimistic. Although geographically isolated, the San Luis Valley has adequate air, rail and truck service. The climate is harsh and the construction season is brief but this also indicates a desperate need for additional heating energy (i.e., geothermal space heating or electrical energy).

The projected increases in population, along with existing and anticipated industrial activity, suggest that demand will definitely increase for home heating and industrial activity. This is especially true in the agricultural sector, which needs electricity for pivot sprinklers and product production. The employment situation and labor force pool available for construction appears more than adequate to handle new construction. The number of unskilled laborers and experienced construction workers is relatively high for the area.

The existing state of regulatory requirements in Saguache County is conducive to industrial growth and the procedures to be followed to receive State geothermal activity approval are straightforward and predictable. Local government and taxpayer attitudes reflect a positive attitude for industrial growth and development in Saguache County. Various environmental groups are generally in favor of this type of enterprises, but are concerned about the actual design and mechanics of the project.

The financial community is always conservative regarding what they consider "untried enterprises." There is a concern that there might not be enough residential activity to adequately test the project and make it worthwhile.

The impacts due to the project appear mild at worst and positive at best in regards to the human environment. None of these problems are insurmountable.

Public participation is the key to solving the problems which might occur in the area of public opposition. This opposition might come in the form of environmental groups, people concerned about community impacts and area agriculturalists concerned about impacts on water rights.

In conclusion, it looks like things are "go" in terms of public acceptance and political support. The work force and population dynamics also reflect the kind of growth that would help a project of this kind get off the ground and keep going.

II. INTRODUCTION

The purpose of the Institutional Analysis is to review those political and social factors that influence the local decision-making process of the project area. As such, the primary local life style forces that often determine the success or failure of new industrial endeavors will be identified. Impacts on social structures and the general man-made environment will also be discussed. For a more detailed assessment of environmental impacts, the reader should refer to the project environmental evaluation. For discussion purposes, the project area referred to will consist of the entire Luis Maria Baca Grant No. 4. It should be noted, however, that demographic data is given for both the San Luis Valley as a whole and also for Saguache County.

III. BACKGROUND DATA

A. Geography

1. Location

Location for the Baca Grant is in the San Luis Valley of south-central Colorado, in Saguache County. The San Luis Valley, in terms of its history and people, is more a part of New Mexico than Colorado. This large intermountain valley extends from the top of Poncha Pass in northern Saguache County to Taos, New Mexico. Poncha Pass (elevation 9,010 feet) is one of several passes that must be traveled to enter the San Luis Valley; others include North Cochetopa Pass (10,149 feet), Wolf Creek Pass (10,850 feet), Cumbres/La Manga Pass (10,022/10,230 feet), and La Veta Pass (9,382 feet). These passes have tended to isolate the San Luis Valley.

The Sangre de Cristo forms the eastern boundary of the San Luis Valley. The Sawatch Range forms the northern boundary and the San Juan Mountain Range forms the western side of the Valley.

Saguache County is located in the northernmost part of the San Luis Valley. The project area is nestled against the west side of the Sangre de Cristo Mountains, approximately 190 miles southwest of Denver, 150 miles from Pueblo and 210 miles from Grand Junction. The major highways entering the Valley are U.S. 285, U.S. 160, Colo. 14 and Colo. 17. Colo. 17 passes most closely to the project area (see Map 1).

2. Transportation

(The following information was compiled from Colorado Regional Profile, Region 8, December 1975.)

Colorado is located in the west-central portion of the United States, slightly west of the exact geographical center. National and international markets are easily accessible by jet air service to all parts of the world. Non-stop jets reach New York and Boston in 3 1/2 hours, Washington, D.C. in 3 hours, Chicago and Los Angeles in 2 hours. International direct flights are available to Canada, England and Mexico.

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Map 1. PROJECT STUDY AREA

The movement of highway traffic in Colorado is facilitated by the interstate highway system. Interstates 25, 70, and 76 provide rapid highway access to the rest of the nation. Truck service reaches the West Coast in two days and the East Coast in four days.

Colorado is served by seven Class I railroads which offer service to the West Coast in four days and the East Coast in five to six days.

The San Luis Valley Region is directly tied to the State's transportation network and to Statewide, national and international markets. Internally, the region is served by a good and improving network of highways.

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a. Air Transportation

The San Luis Valley is directly served by one commercial airport located in Alamosa. Rocky Mountain Airways offers daily flights between Alamosa and Denver and Durango, linking up with air transport services extending from intrastate to international. Air travel time between Alamosa and Denver is 1 hour. Commercial airline services to the San Luis Valley are listed in the Tables and Map 2 at the end of this section.

b. Truck Transportation

The San Luis Valley is served by common carriers operating out of Denver and other major Colorado cities. Trucklines serving the area include the Rio Grande Motor Way, Inc., and the Bill Clark Truck Line, Inc. For less-than-truckload shipments (LTL) into and out of the region, common carriers normally require docking of shipments at one of the major intersections for reloading and distribution. LTL shipments to and from the region are carried by intrastate carriers. United Parcel Service provides a delivery network for small articles and packages in the region. Scheduled truck delivery times from Colorado and the San Luis Valley to selected cities throughout the United States are shown on Map 3 of this section. Ordinarily, regional delivery times are one day longer from Denver.

c. Rail Transportation

The San Luis Valley is served by a network of interstate and regional railway transportation including the Rio Grande, San Luis Central, and Southern San Luis Valley railroads. The San Luis Central is used in shipping potatoes from Center to Monte Vista where the shipments are transferred to the Rio Grande Railroad. The Southern San Luis Valley is used in shipping lettuce to Blanca for connection with the Rio Grande Railroad. The Rio Grande Railroad serves many of the major communities in the region, connecting them with local, State and national markets. Scheduled rail delivery times from Colorado to selected cities and the network of railroads serving Colorado and the San Luis Valley are shown on Maps 4 and 5, respectively.

d. Bus Service

Continental Trailways serves all of the communities along U.S. Highways 160 and 285, as well as principal rural communities not located along these routes.

3. Climate

Saguache County has an average of 105 growing days, 8.10 inches of rainfall, 26.3 inches of snowfall, and has an annual mean temperature of 43.60. Winters are long and harsh and heating bills for the average home run between \$50.00 and \$100.00 per month from December to March.

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TABLE 1
COLORADO PLANNING AND MANAGEMENT REGION NO. 8
AIR TRANSPORTATION SERVICES

Origin-to-Destination	Hours	Daily Direct Flights	Airlines
<u>Alamosa to:</u>			
Denver	1	*NS	Rocky Mountain Airways
Durango	½ ^a	1	Frontier
Albuquerque, New Mexico	2 ^a	2	Frontier
Farmington, New Mexico	1 ^a	1	Frontier
Phoenix, Arizona	2	1	Frontier
<u>Durango to:</u>			
Alamosa	½ ^a	3	Frontier
Cortez	½ ^a	2	Frontier
Denver	1 ^a	5	Frontier
Albuquerque, New Mexico	2 ^a	2	Frontier
Farmington, New Mexico	½ ^a	4	Frontier
Gallup, New Mexico	1½	1	Frontier
Flagstaff, Arizona	1½	1	Frontier
<u>Denver to:</u>			
Alamosa	½	2	Frontier
Aspen	1	43 ^b	Aspen, Rocky Mountain
Colorado Springs	½	17	Braniff, Continental, Frontier
Cortez	1½	2	Frontier
Durango	1	3	Frontier
Eagle/Vail	1	4	Rocky Mountain
Grand Junction	1	6	Frontier, United
Gunnison	1	3	Frontier
Lamar	¾	1	Frontier
Leadville	½	1	Rocky Mountain
Montrose	1½ ^a	3	Frontier
Pueblo	½	5	Frontier
Steamboat Springs/Hayden	1	9 ^b	Frontier, Rocky Mountain
Albuquerque, New Mexico	1	8	Continental, Frontier
Atlanta, Georgia	3 ^a	2	Braniff
Boston, Massachusetts	3½	5	United, TWA
Casper, Wyoming	1	7	Frontier, Western
Chicago, Illinois	2	20	Continental, United, TWA, Ozark
Cleveland, Ohio	2½	2	United
Dallas/Fort Worth	1½	18	Braniff, Frontier
Detroit, Michigan	2½ ^a	2	United
El Paso, Texas	2 ^a	5	Continental, Frontier
Honolulu, Hawaii	8 ^a	6	Continental, United, Western
Houston, Texas	2	9	Texas International, Braniff, Continental
<u>Denver to:</u>			
Kansas City, Missouri	1½	13	Continental, Frontier
Los Angeles, California	2	20	Continental, United, Western
Minneapolis/St. Paul	1½	11	North Central, Western
New Orleans, Louisiana	2	4	Continental, Texas International
New York, New York	3½	11	Braniff, TWA, United
Oklahoma City, Oklahoma	1	8	Braniff, Continental, Frontier
Omaha, Nebraska	1	9	Frontier, United
Philadelphia, Pennsylvania	3	4	TWA, United
Phoenix, Arizona	1½	13	Frontier, Western
Portland, Oregon	2½	6	Continental, United
Salt Lake City, Utah	1	15	Frontier, Texas International
San Francisco, California	2½	14	United, Western
Seattle, Washington	2½	8	TWA, United, Western
St. Louis, Missouri	1½	10	Continental, United
Washington, D.C.	3	7	Frontier, TWA
Wichita, Kansas	1	7	Braniff, TWA, United
Calgary, Alberta	2	2	Continental, Air Midwest
Edmonton, Alberta	3 ^a	1	Western
Vancouver, B.C.	3½ ^a	1	Western
Winnipeg, Manitoba	2½ ^a	1	United
Mexico City, Mexico	4½ ^a	1	Frontier
London, England	11½ ^a	1	Mexicana
			TWA

^a One or more stops.

^b During ski season; fewer flights during the remainder of the year.

* Non-scheduled

Source: Colorado: A Regional Approach, 1974, Colorado Division of Commerce and Development, Community Development Section, Denver, Colorado.

MAP 2
SCHEDULED AIR TRAVEL TIMES FROM COLORADO TO SELECTED CITIES

MAP 3
SCHEDULED TRUCK DELIVERY TIMES FROM COLORADO TO SELECTED CITIES

MAP 4

SCHEDULED RAIL DELIVERY TIMES FROM COLORADO TO SELECTED CITIES

MAP 5

RAILROADS SERVING COLORADO

4. Population Distribution

The primary concentration of population in the San Luis Valley is along U.S. Highway-160 encompassing Alamosa, Monte Vista and Del Norte. The largest population concentration near the project area is Center, Colorado, located on the southern border of Saguache County and having a population of approximately 1,568. Saguache County itself averages 1 person per square mile. Crestone, which is the closest incorporated community to the project area, has a population of 61. The unincorporated community of the Baca Grande Development has approximately fifty year-round residents.

B. Demographic Data

Approximately 57 percent of the Valley's 42,013 residents live in Alamosa and Rio Grande Counties. Table 2 presents total population, the number of families, and the number of households by county in 1970 and 1974.

Table 3 lists the 1970 and 1973 population of each incorporated community in the San Luis Valley.

The San Luis Valley's population (16 years and over) is 47 percent male; the percentage of females for the Valley is 53 percent, with female percentages dominating every age bracket and increasing with age. The 1976 estimated Spanish surnamed population for age 16+ is 43.5 percent, which compares to 1970 census estimates of 41.5 percent. The balance of the population consists almost entirely of Anglo classified peoples. Only about 1 percent of this group is identified as Oriental, Black or Other ethnicities.

The 1973 birth rate of the San Luis Valley is estimated at 17.1 per 1,000 per year.

The mortality rate for the same area is estimated at 9.01 per 1,000 population per year.

The migration rate out of the Valley is considered high, by other standards, averaging 21 persons per 1,000 population per year.

1. Population Projections

Assuming:

- 1) no major cataclysmic intervention
- 2) present level or slight increases in Adams State College enrollment, and
- 3) no large-scale sudden change in "typical" economic activity.

then projected trends per major age groups indicate the following:

- 1) The median age of the population will increase slightly;
- 2) The proportion of young adults, children and retirement age persons will decline;
- 3) There will be relatively more women of childbearing age; and
- 4) The number of working age individuals will increase proportionately.

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TABLE 2

COLORADO PLANNING AND MANAGEMENT REGION NO. 8
ESTIMATED TOTAL POPULATION, HOUSEHOLDS AND FAMILIES
1970 AND 1974

County	Total Population			Number of Households			Number of Families		
	1970	1974	Change	1970	1974 ^a	Change	1970	1974 ^a	Change
Alamosa County	11,422	12,200	778	3,285	3,607	322	2,643	2,932	289
Conejos County	7,846	8,230	384	1,980	2,133	153	1,735	1,850	115
Costilla County	3,091	3,150	59	826	863	37	674	737	63
Mineral County	786	831	45	254	274	20	244	252	8
Rio Grande County	10,494	11,000	506	3,070	3,306	236	2,602	2,780	178
Saguache County	3,827	3,950	123	1,134	1,209	75	954	1,061	107
Region Total	37,466	39,361	1,895	10,549	11,392	843	8,852	9,552	700

^a Estimated by the Business Research Division based upon source data.

Source: "Regional and County Population Estimates--1973 and 1974," Colorado Population Trends, Vol. 4, No. 1, Winter 1975, Colorado Division of Planning, Denver, Colorado; and Housing in Colorado: Current Inventory and Needs, April 1, 1974, Colorado State Housing Board and Division of Housing, Department of Local Affairs, Denver, Colorado, June 1974.

TABLE 3

COLORADO PLANNING AND MANAGEMENT REGION NO. 8
ESTIMATED POPULATION BY REGION, COUNTY AND COMMUNITY
1970 AND 1973

Place of Residence	Total Population		Change	
	1970	1973	#	%
San Luis Valley Region	37,466	38,349	883	2.4%
Urban Community	10,894	10,527	-367	-3.4
Rural, Non-Farm Community	9,234	9,283	49	0.5
Alamosa County	11,422	11,807	385	3.4
Urban Community	6,985	6,950	-35	-0.5
Alamosa	6,985	6,950	-35	-0.5
Rural, Non-Farm Community	80	82	2	2.5
Hooper	80	82	2	2.5
Conejos County	7,846	8,009	163	2.1
Rural, Non-Farm Community	3,685	3,817	132	3.6
Antonito	1,113	1,179	66	5.9
La Jara	768	786	18	2.3
Manassa	814	835	21	2.6
Romeo	352	362	10	2.8
Sanford	638	655	17	2.7
Costilla County	3,091	3,225	134	4.3
Rural, Non-Farm Community	993	1,019	26	2.6
Blanca	212	218	6	2.8
San Luis	781	801	20	2.6
Mineral County	786	775	-11	-1.4
Rural, Non-Farm Community	653	646	-7	-1.1
Creede	653	646	-7	-1.1
Rio Grande County	10,494	10,608	114	1.1
Urban Community	3,909	3,577	-332	-8.5
Monte Vista	3,909	3,577	-332	-8.5
Rural, Non-Farm Community	1,569	1,571	2	0.1
Del Norte	1,569	1,571	2	0.1
Saguache County	3,827	3,925	98	2.6
Rural, Non-Farm Community	2,254	2,148	-106	-4.7
Bonanza	10	11	1	10.0
Center	1,470	1,357	-113	-7.7
Crestone	34	36	2	5.9
Moffat	98	98	0	0.0
Saguache	642	646	4	0.6

Source: 1970 Census of Population, Colorado, U.S. Department of Commerce, Bureau of the Census, Washington, D.C.; and 1973 Population and 1972 Per Capita Income Estimates for Counties and Incorporated Places in Colorado, U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, Washington, D.C.

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With the exception of working age persons, most of the proportional increases and decreases are small and would not indicate any serious exceptions to the present trends. See Table 4.

By the year 2000, it is expected that the Valley population will be approximately 57,800. Approximately 75 percent of that projected population will reside in Urban Communities. (1)

2. Saguache County Demographic Data

The population of Saguache County conservatively projected from 1970-1975 census data indicates a current figure of 4,221. (2) Last census estimates place the average age of the population at 26.2 years with 39.2 percent of the population under the age of 18 and 10.8 percent over the age of 65. The county population is 49.1 percent male.

The county's respective birth and mortality rates are 14.0 births and 9.2 deaths per 1,000 per year. Exclusive of migratory rates, this equates to a positive county growth of 4.8 per thousand population per year. (3).

Migratory rates for Saguache County indicate a net loss of 2 people per 1,000 per year.

Therefore, total county growth is projected to be a positive 2.8 per 1,000 per year when all factors are taken into consideration. (4)

Colorado Division of Planning Data for 1976 indicates an ethnicity configuration of 58 percent Anglo and 40.2 percent Spanish surnamed for the county. Aside from the migrant population of the area, there are no significant population sub-groups in the county. The migrant population in itself, 5 years of age and older, averages 16.8 percent of the total population, although this is a seasonal average. The racial and ethnic breakdown in Table 5 indicates that 40 percent of the county population is of Spanish heritage, while almost 60 percent are considered "Other White" or Anglo.

3. San Luis Valley Socio-Economic Data

The San Luis Valley ranks as one of the most economically and socially depressed regions in Colorado. Regardless of whether economic or social indicators are derived from income, employment, or educational data, a recognized pattern exists in the Valley. Mineral County generally ranks highest, and Saguache, Costilla, and Conejos Counties rank lowest.

An analysis of social indication generally reflects the seriousness of the situation, as evidenced primarily in the differences between the Anglo and Spanish surnamed populations of the area. Spanish surnamed individuals comprise approximately 40 percent of the total population. (1)

TABLE 4
PROJECTED TRENDS IN MAJOR AGE GROUPINGS

YEAR	YOUNG ADULT (15-29)		RETIREMENT (60-75+)		CHILDREN (0-14)		WOMEN IN CHILDBEARING AGE (15-44)		WORK FORCE (20-59)	
	No.	%	No.	%	No.	%	No.	%	No.	%
1970	9,365	25.0	5,280	14.1	12,025	32.1	7,530	20.1	15,885	42.4
1975	10,595	27.1	4,885	12.5	11,965	30.6	8,445	21.6	81,220	46.4
1980	11,140	27.3	5,465	13.4	11,875	29.1	9,180	22.5	18,930	46.4
1985	12,320	27.5	6,360	14.2	13,170	29.4	10,260	22.9	21,820	48.7
1990	12,530	27.5	6,855	14.0	14,245	29.1	11,310	23.1	23,935	48.9
1995	11,665	21.9	6,870	12.9	14,970	28.1	12,465	23.4	27,115	50.9
2000	12,140	21.0	6,995	12.1	15,720	27.2	14,390	24.9	30,810	53.3

TABLE 5
SAGUACHE COUNTY
ETHNIC GROUP POPULATION ESTIMATES
1960 - 1976

	1960	1970	1975	1976
American Indian	5	31	32	40
Negro	1	8	20	8
Oriental and other	2	31	13	13
Spanish	1,411	1,531	1,640	1,650
All Other White	3,054	2,226	2,395	2,389
TOTAL	4,473	3,827	4,100	4,100

Note: Data for 1960 and 1970 are taken from publications of the U.S. Bureau of the Census. Data for 1975 and 1976 are estimated. Ethnic group school enrollments for 1970, 1971, 1974 and 1975 were used as a basis for the 1975 and 1976 estimates.

Source: Colorado Division of Planning. 1976. Ethnic Group Population of Colorado Counties, 1960-1976. Denver, CO.

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Income.-- The average income of all families in the San Luis Valley is more than 30 percent below the mean for the State. About one out of every four families in the region has an annual income less than the United States poverty level set by the United States Department of Commerce. In addition, one out of every seven of these families falls within the lower 75 percent of the defined poverty group. Another one-third of the families make less than 25 percent above the poverty level. To further clarify a bleak situation, 60 percent of the families have incomes barely above the poverty level and less.

The most distinct income differences in the region exist between Spanish surnamed and Anglo families. The average income for non-Spanish families is 15 percent below the reported State average, while the Spanish family average is 50 percent below the same State figure. This eventually equates to two out of every three Valley families at or below poverty level, to be Spanish. It means that three out of every four of the poorest families are also Spanish surnamed. Of all families in the Valley, 41.4 percent are Spanish surnamed, and are representative of the hard-core poverty of the region.

Table 6 indicates that the per capita income of San Luis Valley residents in 1973 was estimated at \$2,490.

Employment Profiles.--Table 7 shows an estimated 15,260 persons or 35.3 percent of the population to be 16 years or older as of October 1976. Of this total, 5.8 percent are unemployed. As we shall note later, this is a much lower figure than seen in Saguache County wherein lies the specific study area. October generally reflects a seasonal low rate for unemployment. This is the result of the availability of extra jobs required for harvesting and the continuation of the construction season.

Comparison of October 1976 participation with 1970 Census reflects an increase of almost three percentage points during the six years. Even with this increase, the current civilian labor force participation rate of 55.3 percent is still slightly less than that reported for the State as a whole in 1970, and State participation has since climbed to well over 60 percent. The faster pace of participation at the State level reflects expanding job opportunities which have attracted large numbers of persons into the labor force.

Growth in labor force participation can also be attributed to greater female interest in work. Female participation in the San Luis Valley was estimated at 42 percent in October 1976, as compared with only 36 percent in 1970. Male participation held constant at 70 percent during this period. It is doubtful, however, that women will want to find and seek jobs at the same rate as men. Table 7 shows that 50 percent do not want or intend to look for work, as compared with only 26 percent of the men.

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TABLE 6

COLORADO PLANNING AND MANAGEMENT REGION NO. 8
TOTAL AND PER CAPITA PERSONAL INCOME
BY REGION, COUNTY AND COMMUNITY
1970^a AND 1973^b

Place of Residence	Total Personal Income			Per Capita Personal Income		
	1970	1973 ^c	% Increase	1970	1973	% Increase
San Luis Valley Region	\$73,470,106	\$100,133,945	36.3%	\$1,961	\$2,490	27.0%
Alamosa County	25,916,518	33,874,283	30.7	2,269	2,869	26.4
Alamosa	16,344,900	20,975,100	28.3	2,340	3,018	29.0
Hooper	119,760	234,684	96.0	1,497	2,862	91.2
Conejos County	10,341,028	15,000,857	45.1	1,218	1,873	42.1
Antonito	1,011,717	1,490,256	47.3	909	1,264	39.1
La Jara	1,329,408	1,893,474	42.4	1,731	2,409	39.2
Manassa	1,325,192	1,892,945	42.8	1,628	2,267	39.3
Romeo	339,328	670,424	97.6	964	1,852	92.1
Sanford	796,862	1,139,045	42.9	1,249	1,739	39.2
Costilla County	4,729,230	7,056,300	49.2	1,530	2,188	43.0
Blanca	418,064	479,164	14.6	1,972	2,198	11.5
San Luis	1,137,917	1,698,120	49.2	1,457	2,120	45.5
Mineral County	1,935,918	2,383,125	23.1	2,463	3,075	24.8
Creede	1,623,358	1,990,972	22.6	2,486	3,082	24.0
Rio Grande County	24,125,706	32,195,280	33.4	2,299	3,035	32.0
Del Norte	3,272,934	4,334,389	32.4	2,086	2,759	32.3
Monte Vista	8,783,523	10,434,109	18.8	2,247	2,917	29.8
Saguache County	6,421,706	9,624,100	49.9	1,678	2,452	46.1
Bonanza	N.A.	26,983	-	N.A.	2,453	-
Center	1,514,100	1,917,441	26.6	1,030	1,413	37.2
Crestone	N.A.	88,236	-	N.A.	2,451	-
Hoffat	165,718	240,198	44.9	1,691	2,451	44.9
Saguache	1,173,576	1,770,686	50.9	1,828	2,741	49.9

^a 1970 equals 1970 Census, which equals 1969 Annual Personal Income.

^b 1973 equals 1973 Census, which equals 1972 Annual Personal Income.

^c 1973 total personal income equals July 1, 1973 population times 1973 "Census" per capita personal income.

Source: 1970 Census of Population, Colorado, U.S. Department of Commerce, Bureau of the Census, Washington, D.C.; and 1973 Population and 1972 Per Capita Income Estimates for Counties and Incorporated Places in Colorado, U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census, Washington, D.C.

The effects of age on participation are also shown in Table 7. About 51 percent of the 16-21 year olds participate in the labor force, as contrasted to about 75 percent of persons in the 22-29 bracket. Participation holds at 75 percent until about 44 years of age, and declines to 11 percent at age 65. About 60 percent of the males have entered the labor force at the age of 16-21. By the time they reach 30-44, 93 percent have entered. Female participation in the area peaks at 64 percent in the 22-29 age bracket.

Data by age group shows a greater degree of difficulty for young in finding work than older persons. Over 96 percent of the persons in Table 7 above 22 years of age who have entered the labor force are employed, whereas this is true of only 80 percent of the 16-21 year olds. Males in the 16-21 bracket appear to have fared better in finding jobs with about 86 percent employed, as contrasted to

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TABLE 7

LABOR FORCE CLASSIFICATION OF POPULATION 16+ BY SEX, AGE, AND ETHNICITY

	Region 8 Total	Civilian Labor Force	Employed	Unemployed	Percent of L.F.	Persons Not in L.F.	Want Work Now	Intend to Look/Work	Do Not Want Work
Population 16+	27,600	15,260	14,381	879	5.8	12,340	855	822	10,663
Sex and Age									
Males	12,984	9,117	8,704			3,867			3,346
16-21	2,112	1,272	1,100			840			511
22-29	2,264	1,903	1,754			361			262
30-44	2,734	2,551	2,528			183			156
45-64	3,697	3,011	2,942			686			647
65+	2,177	380	380			1,797			1,770
Females	14,616	6,143	5,677			8,473			7,317
16-21	2,280	985	696			1,295			669
22-29	2,448	1,571	1,525			877			721
30-44	3,138	1,853	1,723			1,285			1,148
45-64	4,167	1,611	1,611			2,556			2,373
65+	2,583	123	122			2,460			2,406
Age Group Totals									
16-21	4,392	2,257	1,796			2,135			1,180
22-29	4,711	3,474	3,279			1,237			982
30-44	5,872	4,404	4,251			1,468			1,304
45-64	7,864	4,622	4,553			3,242			3,020
65+	4,761	503	502			4,258			4,177
Ethnicity and Sex									
Anglo and Other	15,588	8,768	8,408			6,820			6,104
Male	7,148	5,209	5,050			1,939			1,691
Female	8,440	3,559	3,358			4,881			4,413
Spanish-American	12,012	6,492	5,973			5,520			4,559
Male	4,836	3,908	3,654			1,928			
Female	6,176	2,584	2,319			3,522			

Source: San Luis Valley Labor Force Survey: October, 1976

only 71 percent of the females this age. Over the long run, however, about 93 percent of the women eventually find employment, as compared with about 96 percent of the men. (1)

The concept of underemployment provides information relating to problems encountered by the local population in finding jobs which pay sufficient wages to support the family economy above poverty levels of income, or to find full-time work. Underemployment may also reflect the lack of year-round jobs, and the fact that many of these persons may have experienced frequent or extended periods of unemployment and/or withdrawal from the labor force, after seasonal work has ended.

While underemployment is frequently discussed, estimates of the number of persons in this category are virtually nonexistent. This study attempted to measure the concept by counting as underemployed individuals and family members with income at or below poverty levels who were employed either full time or part time. By this method of measurement, all members of a poverty family

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who worked in October were counted as underemployed. The definition of underemployment in CETA legislation is different to the extent that persons working part time must also have been seeking full-time employment, but this would probably account for only a very small difference in the size of the estimate.

Table 8 shows underemployment estimated at 1,419, which is about 10 percent of the employed and nearly twice the size of unemployment. Unpublished survey results show a slightly higher proportion of males underemployed than females. Underemployment impacts most heavily upon the 16-21 age group, where the percentage reaches about 18 percent of employed workers. About 23 percent of female workers in this age group experience underemployment, as compared with about 14 percent of the males.

TABLE 8
LABOR FORCE CLASSIFICATION OF POPULATION 16+

	Region 8 Total
Population 16+	27,600
Labor Force Classification	
Civilian Labor Force	15,260
Employed	14,381
Underemployed	1,419
Other Employed	12,962
Persons not in Labor Force	12,340
Want Work Now	855
Intend to Look for Work	822
Do Not Want Work	10,663

Another indication of problems encountered in finding adequate employment is multiple jobholding. Unpublished data shows that approximately 5 percent of the employed labor force was made up of persons holding more than one job at the time of the survey. About 46 percent of these workers indicated they held an additional job in order to supplement income, and about 18 percent more did so because they could not find a full-time job.

It is commonly recognized that there are persons who do not meet the official definitions of employed and unemployed but who nevertheless are still interested in finding work. An estimated 855 persons were identified by the survey as wanting work now, but not actively seeking work. Many of these persons could be referred to as "discouraged workers" who sought work in the past, but were

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unable to find suitable employment and gave up the job search. Others are in this category because they have experienced child care, health and other problems preventing them from looking for work, or did not initiate the job search because of school activities. (1)

A similar type of situation exists with an estimated 822 persons who intend to look for work for similar reasons. Together these groups comprise about 14 percent of persons not in the labor force, which is nearly double the number of persons unemployed. (1)

The experiences of some persons in finding only seasonal or temporary work reflects a lack of year-round job opportunities in the area rather than worker preferences. Unpublished data indicate that about 79 percent of persons with job experience worked year-round, about 10 percent worked in regularly occurring seasonal jobs, and about 11 percent worked in jobs considered temporary.

Roughly half of those finding seasonal employment looked for other work or found other jobs in the off-season, while the remainder dropped out of the labor force. A large share of these persons worked in these jobs because they could find only seasonal employment, or did not believe year-round employment was available. Others felt they lacked the necessary skills, or were prevented from taking year-round employment due to school enrollment or family responsibilities. Less than one-fifth preferred seasonal work. About half the persons who had worked in temporary jobs did so because of school enrollment.

Ethnicity comparisons in Table 7 show some labor force differences between Anglo and other persons and Spanish-Americans. A noticeable difference in the labor force participation rates between males of the two ethnic groups exists, while between females there is practically no difference. Approximately 73 percent of the Anglo and other males participate in the labor force, as contrasted to 67 percent of the Spanish-American males.

The data show that Spanish-Americans, both men and women, are less successful in finding work in the San Luis Valley after they have entered the labor force than Anglo and other people. About 97 percent of Anglo and other males in the labor force are employed, as contrasted to 94 percent of the Spanish-American males. Employment for Anglo and other women is estimated at 94 percent, and only 90 percent for Spanish-American women.

A review of data not included in the tables indicates that unemployment is made up of about 60 percent Spanish-Americans, although this group comprises only about 44 percent of the area population 16 and over. Unemployment rates for Spanish-Americans, both male and female, are double those of their Anglo and other neighbors. Underemployment is about five times higher for Spanish-Americans than other persons. (1)

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The study of employed persons in terms of the industries where they work provides a better understanding of the area's labor market and factors which influence demand for workers. Employment demands are dependent to a large extent on the presence of "primary" industries, such as agriculture, manufacturing, mining and a few others, which bring money into the area from the outside to establish a necessary financial base upon which other employment can be supported. Trends in these economic sectors account for fluctuations in construction, retail trade, services, and other industries, although the primary industry work force in itself may not always comprise a large share of total employment.

Table 9 shows that the agriculture group, which includes crop and livestock production, leads primary industries in the San Luis Valley by providing 17.3 percent of total employment, which is about three times the State average. The extent of agriculture's influence is even greater than this, due to related activities which appear in the table under other industry classifications. For example, employment in the processing of agricultural products, such as starch from potatoes, shows up as part of food and kindred products manufacturing, while potato warehousing operations are classified with wholesale trade employment. Considering the relative size and importance of production activity, the processing of farm goods plays a surprisingly small part in local employment.

The second largest primary group, manufacturing, comprised 6.4 percent of the total. Statewide, manufacturing provides about twice as much employment. Production of durable goods accounted for over half of local manufacturing, which is unusual for a rural area. This is largely explained by a high level of employment generated from the production of turquoise jewelry, particularly in Conejos County. Lumber and wood products in the nondurable group, which includes sawmills, provides an important source of employment in Rio Grande County. Employment in apparel reflects outdoor garment production in Alamosa County.

Mining constitutes a primary industry showing a small share of the total at a regional level. Primary effects are also derived from an influx of outside income generated by the presence of Adams State College, which is included as part of the employment under educational services. Substantial expenditures in the area by college personnel and students support a much higher level of construction, retail trade, and service employment than would otherwise exist.

Another source of outside income is provided by tourist activity, which affects employment in eating and drinking places, hotels and motels, gasoline service stations, and various other retail trade establishments. The primary effects of tourism are harder to assess, due to the fact that it creates few year-round jobs.

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Table 9
EMPLOYMENT BY INDUSTRY

	Region 8 Total
Total Employed	14,381
Agriculture, Forestry and Fisheries	2,490
Agricultural Production, Crops	1,538
Agriculture Production, Livestock	533
Agricultural Services	284
Forestry and Other	135
Mining	248
Construction	812
Building Construction	268
Construction, other than Building Construction	347
Construction, Special Trade Contractors	197
Manufacturing	924
Durable Goods	498
Nondurable Goods	426
Food and Kindred Products	154
Apparel and Other Finished Products	105
Lumber and Wood Products	120
Transportation, Communications, Electric, Gas and Sanitary Services	699
Railroad, Motor Freight and Transportation Services	168
Communications, Utilities, Gas and Sanitary Services	340
Wholesale Trade	486
Wholesale Trade, Nondurable Goods	459
Retail Trade	3,013
Building Materials, Hardware, Garden Supply, and Mobile Home Dealers	225
General Merchandise Stores	427
Food Stores	405
Automotive Dealers and Gasoline Service Stations	685
Apparel and Accessory Stores	92
Furniture, Home Furnishings and Equipment Stores	168
Eating and Drinking Places	769
Other Retail	242
Services and Finance	4,891
Finance, Insurance, Real Estate, Business and Legal Services	503
Hotels, Rooming Houses, Camps, and Other Lodging Places	187
Personal Services	266
Automotive Repair, Services and Garages	111
Miscellaneous Repair Services	127
Health Services	726
Public and Private Educational Services	2,350
Social Services	235
Private Households	93
Other Services	293
Public Administration	818
Executive, Legislative and General Governments	450
Justice, Public Order and Safety	298

Source: San Luis Valley Labor Force Survey: October 1976

Construction, which absorbs 5 percent of employment, has some characteristics of primary industry. When construction expands, additional jobs are usually created in supply retailers such as hardware stores and lumber yards. Demand for construction, however, is highly dependent upon activity in other primary industries.

Transportation, communications, and utilities also account for 5 percent of employment. Similar to construction, employment growth is dependent on demand generated by primary industries, which in turn generates expansion in suppliers.

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Services and finance provide 34 percent of total employment, which is the largest industry group. The single largest source of employment in this group is education, which reflects local school systems and college personnel. Health services follow education as the next largest employer, although comprising less of services and finance locally than for the State as a whole.

Retail trade provides 21 percent of the area employment, with eating and drinking places and auto dealers and gas stations each making up one-fourth of the retail group. Wholesale trade contributed about 3 percent.

Private sector employment can be divided into self-employment and jobs dependent on wages and salaries. A distinction in government employment can be usefully made between Federal, State, and local levels. Information in this section is being presented from unpublished survey data.

A little over 70 percent of the population identifies the private sector as the source of their current or last job. Approximately one-third of these were self-employed, which is a significantly higher proportion than is generally found throughout Colorado. This could be partially explained by the local dominance of agriculture which has a high percentage of self-employed farmowners. Also, in an area with limited job opportunities, a small, self-owned business is often the only employment alternative.

Remaining employment totalling slightly less than 30 percent was provided by the public sector. Federal government employment in the region is a smaller share than its average in Colorado as a whole. State Government, however, is about the same share of employment as the Colorado average, which is largely explained by the presence of Adams State College personnel who are technically classified as State employees. The larger part of government employment results from local government activities, for which the school systems are an important segment.

The San Luis Valley appears to have somewhat more employment absorbed by government than the Colorado average. This might be partially explained by the large land area which normally necessitates more governing units, each of which must provide basic services requiring a minimum of employment regardless of the numbers being given these services. It is also likely that small governments tend to employ more labor intensive methods than areas with greater population density, although this does not necessarily result in proportionally higher expenditures.

Classifying employment by occupation shows the types of work the employed labor force performs. As such, it is an indication of skills that are presently available for performing the various kinds of work that exist. Analysis of occupations is important because it gives a feeling for the type and quantity of skills possessed by workers that may be transferable to new or growing job opportunities.

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Table 10 shows employment by occupation is more or less evenly distributed among six major classifications which provide over 80 percent of total employment. They include: Professional and Technical (16.8%), Operatives (14.9%), Nonfarm Managers and Administrators (13.9%), Clerical (12.2%), Service Workers (14.9%), and Crafts and Skilled Trades (10.6%).

Table 10
EMPLOYMENT BY OCCUPATION

	Region 8 Total
Total Employed	14,381
Professional and Technical	2,410
Health Professionals and Technologists	239
Engineering Professionals and Technologists	93
Teachers, College and University	158
Teachers, Elementary and Secondary Schools	936
Foresters and Conservationists	91
Vocational and Educational Counselors	156
Other Professional and Technical	737
Nonfarm Managers and Administrators	2,603
Sales	495
Salesmen and Sales Clerks	394
Insurance and Real Estate Agents and Other Sales	101
Clerical	1,763
Cashiers, Counter Clerks, and Food Store Checkers	175
Bookkeepers	402
Telephone Operators and Dispatchers	108
Receptionists, Secretaries, and Typists	666
Teacher Aides	115
Other Clerical	297
Crafts and Skilled Trades	1,531
Carpenters	219
Electricians	94
Excavating, Grading, and Road Machine Operators	230
Jewelers and Stonecutters	372
Mechanics and Repairmen	243
Plumbers and Pipefitters	91
Other Craftsmen and Skilled Workers	282
Operatives	2,138
Food Processing Examiners and Inspectors	101
Sewers, Stitchers, Dressmakers, and Seamstresses	156
Garage Workers and Gas Station Attendants	108
Produce Graders and Packers	461
Welders and Flamecutters	139
Deliverymen and Routemen	128
Truck Drivers	529
Other Operatives	516
Nonfarm Laborers	311
Farmers and Farm Managers	936
Farm Laborers and Farm Foremen	650
Farm Foremen	120
Farm Laborers	530
Service Workers	2,144
Janitors and Maintenancemen	237
Other Cleaning Service Workers	138
Cooks	293
Waiters and Waitresses	235
Other Food Service Workers	232
Practical Nurses and Nursing Aides	213
Personal Service Workers	302
Protective Service Workers	277
Private Household and Other Service Workers	217

Source: San Luis Valley Labor Force Survey, October 1976

College, elementary, and secondary teaching provide almost half of Professional and Technical employment. Health professionals comprise the next highest level of employment with the remainder being scattered fairly evenly among such professions as computer specialists, engineers,

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accountants, farm management advisors, vocational counselors, foresters and others.

Nonfarm Managers and Administrators comprise a pool of supervisory and skilled talent. This group contains craftsmen and skilled workers who manage their own enterprises as well as school administrators, officers of financial institutions, and other jobs thought of as being managerial. Many of the self-employed craftsmen have skills transferable to various manufacturing jobs and supervisory positions.

Crafts and Skilled Trades contain several important occupations. Predominating are turquoise jewelry makers, the extent of which was previously noted in the industry section. The fairly recent development of this occupation is important to the Valley because it provides an employment outlet for those with crafting skills, as well as a training ground for local people if assembly or semi-skilled jobs were to be developed.

Carpenters, electricians, plumbers, mechanics and repairmen generally exist in numbers somewhat proportional to local demand, but also comprise a pool which provides supportive services for the needs of expanding or new businesses. Many in these occupations could also be considered a potential source of highly skilled workers if jobs with equivalent skill requirements were to develop.

A sizable number of excavating and road machine operators exist in the area with job responsibilities and skills which could be transferable. Among the heading Other Craftsmen in order of magnitude are machinists, stationary engineers, non-classified craftsmen, masons and numerous skilled occupations each with small employment.

A large category of generally semi-skilled occupations is found in the Operatives group. Following truck drivers, the largest single occupation comprises workers who grade and pack produce. The seasonal nature of these jobs is an indication that many of these workers would likely seek other available job opportunities. The nature of the work implies that persons in this occupation would have acquired some skills transferable to assembly-type jobs.

About 7 percent of Operatives employment is found among those with welding as an occupation. Welders have generally had job experience and abilities needed for a wide variety of manufacturing situations. Many would probably be attracted to factory job opportunities if they were to develop. The significant number of students taking vocational training would also probably swell the pool of welders if jobs were to materialize.

Another fairly significant component of Operatives for the area is comprised of those in sewing occupations. The garment plant in Alamosa has been a particularly important source of employment opportunities for women. Sewing requires considerable manual dexterity and workers in this occupation would likely be attracted to a wide variety of somewhat similar jobs.

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Remaining Operatives possess the varying skills found in such occupations as mine work, gas station attendants, bus drivers, and deliverymen.

Although providing less than 10 percent of occupational employment, the combination of farmers, farm managers, farm foremen and farm laborers offer an interesting spectrum of skills and potential workers for a variety of jobs. Because of the nature of farming, it can be assumed that many of the workers in this occupational category have basic welding, machining handling and repair, and other related skills. Many of these would be transferable to semi-skilled manufacturing jobs, especially if accompanied with basic training which could be offered through the local area vocational school.

Trends toward increasing farm size will likely make small numbers of farm owners and managers potentially available employees. Non-farm Laborers comprise a very small part of total occupational employment. Included are such occupations as construction workers and freight handlers.

A rather large share of employment is provided by Clerical occupations. These are basically support personnel, and include a high percentage of receptionists, secretaries, and typists. There is also a large number of bookkeepers, followed by cashiers and store clerks. While possessing work habits and skills transferable to jobs requiring manual dexterity, a large pool of clerical workers also provides a critical source of supportive staff for new and expanding businesses.

The Service occupation group includes a wide variety of jobs with employment rather uniformly distributed. Relatively large percentages of employment are shown by janitors and other cleaning service workers, along with waiters, waitresses and other food service workers. Practical nurses, nurse aides, protective and other personal service workers round out employment in Services. While difficult to delineate specific skills, Services commonly furnishes employees for assembly-type jobs.

Various insurance agents, real estate agents, sales clerks and others comprise the small but important final occupations in the Sales category.

Commuting patterns indicate an acceptance on the part of workers to travel some distance to a job, and the extent to which employers can fill job needs by workers from outside the immediate area. The San Luis Valley covers a large land area, with well over half of its population living in small towns scattered throughout the region. Data in the study represent only commuting patterns between counties, which probably understate the total volume of commuting activity due to a substantial amount of travel which occurs between towns located within the same county.

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Table 11 shows that 63 percent of the jobs are located in Alamosa and Rio Grande Counties, a large portion of which exist in the growth center cities of Alamosa and Monte Vista, which are about 20 miles from each other and from many smaller towns. These counties experience a net inflow of workers to fill available jobs which exceed the supply of resident workers.

The reverse is true of Saguache and Conejos Counties, which are shown to have 164 and 109 net fewer jobs available than employed workers. Since these out-commuters are wage earners, they make a very important contribution to their county of residence by adding to its tax base and boosting local trade and service activity. If commuting possibilities were to be sharply reduced by factors such as high transportation costs, job deficit counties could lose substantial population needed for the future vitality of many small towns.

In the event that additional employment opportunities would become available, there is some indication from data in the table that workers could be drawn from fairly distant places in the valley to supplement workers living in the immediate area. On a regional basis, 10 percent of the employed persons commute to jobs located in a county other than where they live. Unpublished data reveal one-fourth travelled more than ten miles one way to work to their current or last jobs. Half of these traveled more than 20 miles.

The supply of potentially available workers in the San Luis Valley is approximately 8,000. Previous tables have estimated the unemployed at 879, persons not in the labor force who want work now at 855, and those who intend to look for work at 822. This indicates that over 70 percent, or about 5,000 workers, come from the ranks of the already employed who would be willing to change jobs to attain wage and work preferences. Unpublished survey results reveal a major percentage of the supply of potential workers will originate from Alamosa, Rio Grande and Conejos Counties.

TABLE 11
JOB COMMUTING PATTERNS OF EMPLOYED PERSONS

	Alamosa County	Conejos County	Costilla County	Mineral County	Rio Grande County	Saguache County
Total Employed						
Residents of County	5,010	2,422	901	559	3,790	1,699
Work in County	4,536	2,084	829	559	3,484	1,434
Work in Other Counties	474	338	72		306	265
Commuters From Other Counties	600	174	75		450	156
Total Work in County	5,136	2,258	904	559	3,934	1,590

Source: San Luis Valley Labor Force Survey: October 1976

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Shortly after the survey was completed, a large general merchandise retailer opened a store in Alamosa. For about 50 available jobs, there were between 650-700 applicants. This experience indicates that an estimate of about 8,000 potentially available workers is probably not too high.

Males comprise about 52 percent and females 48 percent of potential workers. With respect to age distribution, the table indicates about one-half is provided by workers in the 22-44 age bracket. About 30 percent comes from the 16-21 age category whose workers are typically testing and sampling the job market. A little over 15 percent can be expected to come from the 45-64 age group. The same table shows the composition to be about 53 percent Spanish-American and 47 percent Anglo and other ethnic groups.

Unpublished survey results indicated that almost one-half of the supply would take factory jobs and also preferred year-round work. This means that there are at least 4,000 people in the San Luis Valley who would be interested in factory-type work. Corresponding unpublished data indicates almost 90 percent of the above could be expected to originate in Alamosa, Conejos and Rio Grande Counties. For the other half of potential labor supply who did not indicate a willingness to accept factory work, a large percentage simply thought they would like their present line of work better. The rest generally preferred outdoor-type work or felt factory work would be too dull or repetitive. Only a small percentage felt they would not like a factory job because the hours were too long, they did not want to work by the clock, or other reasons.

The survey attempted to explore the feelings of potentially available rural workers toward aspects of a job other than wages. It was found in unpublished data that two out of three stated that other work conditions were as important or more important than wages. These conditions include type of work wanted; convenient working hours; paid sick leave, vacations and other fringe benefits; having a job nearby; interesting work; and people they work with. Almost eight out of ten felt the nature of supervision and treatment they received on the job was as, or more important, than wages.

The respondents were divided on the primacy of wages compared to other working conditions. Dominant identifiable concerns centered on safety and clean, well-heated working areas, with safety having the highest priority.

An attempt was made to measure how far workers were willing to travel if a job became available at the wages they were seeking. Table 11 shows that over 70 percent indicated a willingness to commute more than 10 miles one way, and 35 percent were willing to travel more than 20 miles. Since most of the potential labor supply is in Alamosa, Conejos and Rio Grande Counties, the above distances would be generally adequate to reach a job site in these counties.

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For wages even higher than those they were seeking, almost 50 percent indicated they would be willing to travel still further. The availability of reliable public transportation would apparently enhance willingness to commute and commute further.

In addition to commuting, approximately one-half the potential labor supply indicated a willingness to relocate to the major job centers of Alamosa and Monte Vista. Less than half, however, would move out of the San Luis Valley to find work they preferred at the same wages they were seeking.

Education.--Income, employment, and educational achievements are linked closely together and in the Valley this is especially true. The median level of education completed by the residents of the San Luis Valley is 12.0 years. Slightly more than 50 percent of the Valley residents are high school graduates. Of that total only 4,645 are of Spanish descent. Tables 12, 13, and 14 further analyze the levels of education of Valley residents.

Dependency Rates.--Information derived from Table 2 data shows that 1974 estimates place the average number of members per family at 4.1. The number of persons per San Luis Valley household calculated from the same information is 3.30.

TABLE 12
EDUCATION IN THE SAN LUIS VALLEY, 1970

	SAGUACHE		VALLEY	
No School	63			
Spanish	74			
Other				
8th Grade or Less	739		6075	
Spanish	526	(71.2)	4158	(68.4)
Other	213	(28.8)	1917	(31.6)
High School Graduation	874		9178	
Spanish	53	(6.1)	1803	(19.6)
Other	821	(93.9)	7375	(80.4)
Some College	294		2965	
Spanish	7	(7.8)	539	(18.2)
Other	287	(97.6)	2426	(81.8)
College Graduation	90		1926	
Spanish	7	(7.8)	216	(13.6)
Other	83	(92.2)	1665	(86.4)
Median Education	11.1		N.A.	
Spanish	6.7		N.A.	
Other	N.A.		N.A.	
% H.A. Graduates	44.4		50.4	
Spanish	8.1		24.6	
Other	62.7		70.9	

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TABLE 13
STUDENTS IN POPULATION 16+

	Region 8 Total
Population 16+	27,600
Students Status	
Students	3,605
High School	1,918
College	1,379
Vocational and Other	308
Non-Students	23,995

Source: San Luis Valley Labor Force Survey:
October 1976

TABLE 14
EDUCATION OF NON-STUDENT POPULATION 16+
BY SEX AND ETHNICITY

	Region 8 Total	Elementary		High School				College or University					
		0-7 yrs.	8 yrs.	1 yr.	2 yrs.	3 yrs.	4 yrs.	1 yr.	2 yrs.	3 yrs.	4 yrs.	5 yrs.	6 yrs. +
Non-Student Population 16+	23,995	3,456	2,155	926	1,790	1,340	7,792	1,347	1,411	289	1,959	442	1,080
Male	10,999	1,642	1,048	462	1,057	390	3,314	659	550	159	875	195	648
Female	12,996	1,814	1,107	464	733	958	4,478	688	861	130	1,084	247	432
Ethnicity													
Anglo and Other	13,990	581	708	278	646	712	5,554	991	1,113	289	1,717	402	999
Spanish-American	10,005	2,875	1,447	648	1,144	636	2,238	356	298	0	242	40	81

Source: San Luis Valley Labor Force Survey: October 1976

4. Saguache County Socio-Economic Data

Income Levels.--Saguache County, officially designated by the Federal Government as an "Economic Development Area," had as of 1975, 72.8 percent of its families reporting annual incomes of less than \$10,000. Table 15 distributes family percentage per designated income levels.

The median income of Saguache families is estimated to be \$5,770, using 1974 data. Based on the same information, the number of Saguache families below the United States defined poverty level is 32 percent. Only 5.2 percent (or 50) of the families that are headed by a female were reported to be at or below the poverty level. This information

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TABLE 15

SAGUACHE COUNTY

ESTIMATED ANNUAL INCOME

1975

(Percent of Family in Each Income Category)

\$0 - \$4,999	34.4
\$5,000 - \$7,999	29.8
\$8,000 - \$9,999	8.0
\$10,000+	27.8

Source: Colorado Department of Health, 1976. 1975 Demographic Profile.
Denver, Colorado.

shows that nearly 84 percent of those families at poverty level are headed by males. The implications of such information are clear. Either most of those male-headed families (255) are unemployed or underemployed.

For supplemental county information, refer to the Socioeconomic tables and charts for the San Luis Valley.

Employment Profile.--The Saguache County civilian labor force consists of 1,720 individuals. Of this total, 1,282 or 74.5 percent are males. The unemployment rate of the total county population is a very high 12.3 percent as compared to a lower overall rate of the Valley as a whole. Although minorities in Saguache County comprise 31.6 percent of the labor force, a slightly higher percentage, 36.5 percent of the unemployed are minority. There existed, and still exists, a non-worker to worker ratio of approximately 2/1.

Of the total employed population of Saguache County, 2.7 percent work in manufacture related industries and 24.3 percent are employed in white collar activities; 16.2 percent are Government employed. These statistics are still considered valid because of the lack of economic influx to the area from the time of the survey until the present.

Tables 16 through 18 provide further information pertaining to the employment profile of the county, especially in the areas of occupations and employment status. These charts are based on 1970 information, and illustrate the characteristics of the rural farm and rural non-farm populations.

Additional information pertaining to the Saguache County Employment Profile can be found in the San Luis Valley Employment Profile Tables.

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TABLE 16
COLORADO PLANNING AND MANAGEMENT REGION NO. 8
LABOR FORCE PARTICIPATION RATE BY AGE AND SEX
1970 CENSUS

Age (Years)	Total		Male		Female	
	Population	% in Labor Force	Population	% in Labor Force	Population	% in Labor Force
16-17	1,934	26.3%	997	30.1%	937	22.2%
18-19	1,797	46.6	874	54.5	923	39.1
20-21	1,197	53.9	537	70.4	660	40.5
22-24	1,443	60.4	708	77.5	735	43.9
25-34	3,766	64.9	1,949	90.8	1,817	37.1
35-44	3,781	67.5	1,728	92.7	2,053	46.2
45-64	<u>6,946</u>	63.9	<u>3,396</u>	84.6	<u>3,550</u>	44.1
16-64	20,864	58.9	10,189	78.0	10,675	40.7
65 and Older	<u>3,706</u>	16.2	<u>1,801</u>	25.5	<u>1,905</u>	7.5
16 and Older	24,570	52.5	11,990	70.1	12,580	35.7

Source: 1970 Census of Population, Colorado, U.S. Department of Commerce, Bureau of the Census, Washington, D.C.

TABLE 17
SAGUACHE COUNTY
WORK FORCE ESTIMATES
ANNUAL AVERAGE

	1968	1969	1970	1971
Total Work Force	1,401	1,435	1,455	1,458
Total Employment	1,301	1,282	1,314	1,279
Nonagricultural Employment	531	528	536	558
Agricultural Employment	770	754	778	721
Total Unemployment	100	153	141	179
Percent Unemployed	7.1	10.7	9.7	12.3

Source: Colorado Division of Employment. 1968, 1969, 1970, 1971.
County Work Force Estimates, Colorado. Research and Analysis Section, Denver, CO.

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TABLE 18
SAGUACHE COUNTY
ECONOMIC CHARACTERISTICS OF THE RURAL FARM POPULATION:
EMPLOYMENT STATUS
1970

Male, 16 Years Old and Over	393
Labor Force	331
Percent of Total	84.2
Civilian Labor Force	331
Employed	331
Unemployed	---
Percent of Civilian Labor Force	---
Not in Labor Force	62
Under 65 Years	55
65 Years and Over	7
Female, 16 Years and Over	334
Labor Force	49
Percent of Total	14.7
Civilian Labor Force	49
Employed	39
Unemployed	10
Percent of Civilian Labor Force	20.4
Not in Labor Force	285
Under 65 Years	267
65 Years and Over	18
Male, 14 and 15 Years Old	28
Labor Force	---
Female, 14 and 15 Years Old	26
Labor Force	---
Male, 16 to 21 Years Old	65
Not Enrolled in School	13
Not High School Graduate	6
Unemployed or Not in Labor Force	---

Source: U. S. Bureau of the Census. 1972. U. S. Census of Population, 1970. General Social and Economic Characteristics, Colorado. U. S. GPO, PC(1)-C7-COLO, Washington, D. C.

IV. LAND USE

Currently the area known as the Baca Grant consists of two major land uses. The first covers approximately 14,000 acres of the Grant and serves as the site for the Baca Grande Recreational/Residential Development.

The remaining acreage of the 140,000-acre Luis Maria Baca Grant is used primarily for agriculture. The area Land Use Map immediately following this section shows that the majority of the land is in unimproved grazing lands (082). Interspersed within the unimproved grazing lands are naturally irrigated lands (062) that generally follow intermittent streams and drainages in the area. Submarginal or casually grazed lands (088) occur in the southern part of the Grant as the soil conditions become sandier. Two center pivot sprinklers

Map 6. Land Use Map

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have been partially installed north of the Baca Grant and will probably go into grain or alfalfa when fully developed. The sprinklers cover approximately 80 acres.

The submarginal or casually grazed lands (088) are characterized by sandy soils and low growing brush. The unimproved grazing lands (082) are characterized by loamy to sandy soils with Indian rice grass and various forbs dominating the vegetation. The irrigated pasture and hay lands are characterized by deep medium to moderately fine textured dark colored soils, with native grasses and sedges as the dominant vegetation.

Adjacent land use to the east of the Grant is classified as low impact land use (091). Actually, this land is National Forest land that has been restrictively managed for several years to preserve wilderness characteristics.

South of the Grant the Great Sand Dunes National Monument provides recreational land use. West and north of the Grant is private land predominantly used for grazing.

Saguache County does not have county-wide zoning. A spot zoning regulation covers wildfire hazards, geological hazard and mineral resources. The master plan for the Baca Grande Development has reserved numerous park, school, church, commercial and greenbelt areas throughout the residential development. At this time there is one park in the Chalets plus the Restaurant/Inn complex with the golf course, rodeo grounds, and tennis courts. The other sites have been set aside for future use. Because of the lack of Euclidean type or traditional zoning, industrial developments may be located on any part of the Baca Grant itself. The site in the Baca Grande Development, although designated as commercial sites, could probably be put to light unobtrusive industrial development after review and approval by the Saguache County Commissioners as part of an amendment to the original subdivision master plan.

The location of suitable sites for industrial applications is limited only by existing development and the various hazard zones mentioned previously. It is anticipated that this situation will continue indefinitely into the future.

V. LOCAL GOVERNMENT STRUCTURE

The immediately effected project area is in the unincorporated rural area of Saguache County. As such, this property falls under the direct jurisdiction of the Saguache County Board of Commissioners.

Although the Saguache County Board of Commissioners have not been directly approached, outward indications seem to favor any type of economic development. The development of a large uranium mine by Homestake Mining Company in the northern part of the county was well received by the County Commissioners. They have been extremely cooperative and active in pushing the project through. If this is any indication of their acceptance and encouragement of industrial projects, a geothermal project should receive equal support and encouragement.

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The closest municipal jurisdictions to the Project Area are Crestone, 1/4 mile to the north, and Moffat, 12 miles to the west. Both towns are incorporated and have their own Town Boards. The town of Crestone is primarily a fixed income and seasonal community. There is a small element within the town that is against any growth. For many years the town has argued about the installation of a central sewer system. The two primary reasons for the opposition to this proposal is fear of economic hardship due to user charges and fear of unrepressed growth and new home construction. The town is currently reviewing a zoning plan for Crestone and this protection may inspire a reappraisal of central sewage treatment for Crestone.

Moffat is an extremely economically depressed town and would support and encourage any industrially related growth. Moffat has conducted a feasibility study for central sewage treatment but the estimated cost to fixed income residents put the project on the back burner.

The entire San Luis Valley is within Colorado State Planning Region 8. This region has an effective planning commission which reviews all Federally and State funded projects in Region 8. This review is accomplished under the A-95 review process. The commission has had a long history of support for industrial and clean energy developments. Various experimental projects for gasohol, wood chip fuel, solar housing, etc., have been recommended for approval by this organization.

VI. REGULATORY AGENCIES

A preliminary review of the Colorado Statutes does not reveal any applicable regulations to geothermal development or exploration. The Mined Land Reclamation Act (1976) specifically excludes geothermal from the definition of "mineral."

The Saguache County Zoning and Development Code may affect this phase of this project. The Zoning and Development Code applies to all new construction identified Natural Hazard or Mineral Resource Zones. These zones are outlined on the Official Saguache County Zoning and Development Code Maps. The zones include geologic and wildfire hazards. Wildfire Hazard Zones are common throughout the lower slopes of the Sangre de Cristo Mountain range due to the dense growth of pinion/juniper. However, even if construction were to be designated in a Wildfire Hazard Zone, this fact would not preclude construction. Additional expense might be incurred in order to mitigate the hazard enough to receive construction permission, which would be required from the Saguache County Planning Commission. Mitigation could include chemical treatment, thinning, or clearing. These techniques would easily satisfy the intent of the Code.

Via the Colorado Geothermal Resources Act, the State Oil and Gas Conservation Commission is assigned the primary responsibility for approving the drilling permits required for geothermal wells. In its 4-year history only one permit has been processed--that being the Colorado Geological Survey well currently being drilled in Pagosa Springs. That permit was obtained without any unusual delays. Permits from the Water Quality Control Commission, the Air Quality Control Commission, and a determination from the State Water

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Engineer's office that a well will not infringe on already established water uses are also required. These regulatory agencies have been contacted and generally indicated that no unusual problems should be encountered. It is worth mentioning that due to the general lack of prior geothermal activity, these agencies are themselves sort of "finding their own way."

VII. BASIC OPINION MOLDING GROUPS

Aside from the locally elected officials mentioned in Section 3 of Chapter III, there are several other active forces in Saguache County which start and control attitudes that affect Saguache County. These groups are water users (basically ranchers and farmers), environmental groups, and local residents (particularly Baca Grande Development residents).

The area of "Water" will probably be the most significant stumbling block and area of future problems. Nothing turned up so far has the potential to stop geothermal development in the San Luis Valley the way that water conflicts do. Proposed consumptive uses, other than domestic or agricultural, have already been heavily litigated in the San Luis Valley. So far, no case decisions have been made regarding this, but several cases are pending before district courts in the Valley.

In order to be adjudicated, new wells must be reviewed by district water courts. During this process, any individuals believing that his water right will be impaired by the new well, may file an objection to the adjudication. If the objection has even the hint of validity, the courts can require extensive data from the applicant, and the well drilling process becomes a long and involved one.

Because of this, it is vital that all individuals involved with this project should be careful to present a positive attitude toward non-consumptive, or at least augmented water use. The engineering and geological work being done by Davis and Coury should develop alternatives describing water augmentation plans, reinjection plans, and drilling depths.

The San Luis Valley Wilderness Society is the only significant locally based environmental group. Organizations such as the Colorado Open Space Council and the Environmental Defense Fund, however, are very active throughout the State and efforts should be made to communicate with these organizations whenever possible.

VIII. INDUSTRIAL EVALUATION

This section seeks to identify those industries that might be affected by or affect this project proposal. A review of existing energy intensive industries will be first, followed by an explanation of proposed industrial development in Saguache County.

1. Existing Industry

There are three power producing or marketing organizations in the San Luis Valley--Public Service Company (P.S.Co.) in Alamosa, S.L.V. Rural

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Electric Cooperative (SLV R.E.C.) near Monte Vista and the Town of Center Power and Light Department (C.P.L.D.) in Saguache County. These three companies purchase or generate in the case of P.S. Co. and C.P.L.D., their own power for distribution to individual customers. Major transmission lines for P.S.Co. and SLV R.E.C. travel north and south through Saguache County about 14 miles east of the project area. A new line (230 KV) is being proposed for construction in the spring of 1979 and will parallel the previously mentioned lines through Saguache County.

The biggest collective industry which uses the most power in the San Luis Valley is agriculture; specifically, pivot sprinklers for irrigation of crop lands. The Valley has received approximately 200 to 250 new center pivot sprinklers every year since 1975. It is this use of electrical power that has provided the excess demand requiring the new 230 K.V. transmission line.

The timber industry is another user of electrical power. There are several large sawmills in the South Fork area, the primary user being Douglas Studs, Inc. Three small sawmills operate near Saguache and one operates near La Garita in Saguache County.

2. Immediately Proposed Industrial Development

Two major industrial activities are proposed in the immediate future in Saguache County. First, Homestake Mining Company Pitch Project is planning a 600 ton/day uranium ore mining and milling operation. Currently 100 workers are on board doing preliminary overburden removal. Estimates indicate that approximately 70 percent of the labor force will come from Gunnison and 30 percent will come from Salida. One Saguache town resident is currently employed at the mine, and has to make a 200-mile round trip every day. It is not anticipated that the currently proposed Pitch Project activities will impact the project area at all.

Ten-year projections by the industry estimate that additional ore sources may have to be exploited to provide mill feed for the projected 25-year life of the mill. Ore is believed to exist near Middle Creek, which is located approximately ten miles west of the town of Saguache. This activity is almost 50 miles from the study area and impacts would be minimal. If an unusually rich ore source is found, residents from the Moffat and Crestone area may seek employment at these mines since many of these residents have previous mining experience.

Secondly, on July 3, 1978, the Saguache County Commissioners approved the necessary permits for M.M.G. Cattle Company to begin an Agri-Industrial business.

The project is located on Colorado Highway 17 north of Moffat (approximately 12 miles) at the platted City of Hot Springs. This unincorporated community is noted for its natural hot springs pools. The project will consist of a 700 farrow-to-finish Swine Farm, which will employ between 25 and 35 people. Once this phase of the project is

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on its feet, a fish farming operation will be initiated. The developer will use existing hot springs to provide a portion of the heat for the swine gestation and finishing buildings, and eventually use the cooled water for the fish raceways.

The total project will employ an estimated 50 people. Most of these individuals will live at the site. Many may also come from the town of Moffat, which is about twelve miles west of the Study Area.

IX. IMPACT

Lifestyle changes or changes in basic social structures, populations, economics, and services could very well occur as a result of this project.

Increases in population have a tremendous impact on rural, economically depressed areas. Even small increases may require new services or homes, and even if the changes are positive, often the more change itself is resisted by the people.

The following is an analysis of the potential positive and negative effects on basic services which may occur as a result of this project. The analysis will dwell on the towns of Crestone and Moffat, and exclude the Baca Grande Community. The reason for this omission is the fact that the Baca Grande is geared for growth. In fact, its very survival really depends on increasing numbers. Because of this, the Baca Grande has planned for growth well in advance of its occurrence. Water, sewer, and utility provisions currently exceed existing use. The only increases that are not accommodated by the developer in this case are impacts on schools. The impact on schools, however, should be positive, due to the fact that the local schools are seeking accreditation and need an increased number of pupils from what they presently have to pursue this.

1. Sewer Facilities

Adverse Impacts.--Neither Crestone or Moffat have central sewer systems. Each home is served by individual septic tanks. Both towns have small lots, and Moffat has a predominantly high water table. These factors create design problems for traditional septic tanks, which need one acre of ground and 4 to 7 feet of dry soil to effectively treat the effluent.

Cases of waterborne disease have already been noted in Moffat and it is expected that problems in Crestone and Moffat will increase in the future as more septic tanks are installed. Therefore, any additional housing in Crestone or Moffat, as a result of this project, could be considered to have an adverse impact.

Positive Impacts.--Ironically, it is additional housing that is needed in Moffat and Crestone in order to make central sewer facilities an acceptable solution. The town of Moffat recently had a private consultant do a feasibility study for the provision of a central sewage collection and treatment facility. The conclusion of the study estimated the per tap costs to be \$20.00 per month. Due to the depressed economy

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of Moffat and the tremendous number of low fixed-income people, citizens chose to reject this alternative. Additional employment and new homes due to the project proposal could make central sewer facilities possible for both towns.

2. Water Facilities

Adverse Impacts.--The problems described above under "Sewer Facilities," directly relate to water pollution and waterborne disease. Neither Moffat or Crestone are prepared to develop central water facilities, and any increase in population and housing due to the proposed project could create serious problems.

Positive Impacts.--Again, more homes to help finance water and sewer projects is really the only way out of the water and sewer dilemma. This project could provide the catalyst for the provision of central water facilities.

3. Public Utilities

Adverse Impacts.--Impacts to the provision of electricity as a result of this project should be minimal. Existing supplies are adequate for modern growth at this time. The San Luis Valley Rural Electric Cooperative is planning on constructing a new 230 KV transmission line into the San Luis Valley during 1978-79. Power from this project is expected to provide ample reserves for the next five to ten years.

Positive Impacts: This project has the very real possibility of adding to the Valley's electrical production. (According to information in the "Phase I, Project Report.")

4. Transportation

Neither positive or negative impacts will occur to existing transportation systems as a result of this project.

X. FINANCIAL COMMUNITY

Cautious is the best word to describe the financial community's attitude toward any experimental energy producing enterprise. As an example, homes with solar heating equipment, even if tremendously sophisticated, must have a conventional backup system to be able to qualify for most bank loans. The primary concern is one of design and application for geothermal energy in the project area. Because of the limited number of homes and potential users adjacent to the development, skepticism as to the financial soundness and cost/benefit relationship of this project would have to be resolved (private communication, January 1979, Bob Hagler, Vice-President of the Bank of Monte Vista).

A great deal more footwork needs to be done to specify and quantify the design and output parameters before the financial community will be too eager to get involved. However, the prospects of industrial development, employment and export of energy from the San Luis Valley are a major topic of discussion in economic development circles.

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XI. PARTICIPATION

Purpose.--Public participation is not only a popular endeavor, it is a useful tool in eliminating misconceptions about new activities. Because of the magnitude of this project, a public meeting would be extremely beneficial, the object being to inform all interested groups as to the overall concept of a local Geothermal Industry; the methods involved in determining feasibility and the results/benefits, etc., which may come of such a development.

An effort should be made to reach various and substantial interest groups such as ranchers/farmers, town residents, realtors, bankers, elected officials and community and industrial developers.

A location must be chosen which is comfortable to the particular individuals involved. The possibility of alienating certain groups due to the meeting location should be considered. Possible locations are Crestone firehall, Crestone Community Building, Baca Grande Administration Building or Fire Station, Baca Grande Inn, Moffat School, Saguache County Courthouse and any local Central Bank Office.

It is preferable to host these information exchange meetings after Phase I of this project is completed. By doing that, the hosts for the meetings will be in a better position to provide concrete data, as well as directly answer the multitude of questions that will surely come up at these meetings.

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APPENDIX C

ENVIRONMENTAL REPORT

RESIDENTIAL AND COMMERCIAL SPACE HEATING AND COOLING
WITH POSSIBLE GREENHOUSE OPERATION; BACA GRANDE DEVELOPMENT,
SAN LUIS VALLEY, COLORADO

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ENVIRONMENTAL REPORT

RESIDENTIAL AND COMMERCIAL SPACE HEATING AND COOLING WITH POSSIBLE GREENHOUSE OPERATION; BACA GRANDE DEVELOPMENT, SAN LUIS VALLEY, COLORADO

1. INTRODUCTION

1.1. Site Location

The Baca Grande recreational and residential development is located 200 miles southwest of Denver via highway 285 and 50 miles north of Alamosa in the San Luis Valley of south-central Colorado. Figure 1 illustrates that general location. The development is situated in the northeast corner of the former Luis Maria Baca Number 4 Spanish land grant in eastern Saguache County. If existing township and range survey lines were continued into the land grant, the Baca Grande would be within T. 24 S., Rs. 11-12 E. Latitude and longitude of the area is approximately 37°55'N, 105°35'W, and the approximate boundaries of the Baca Grande development are shown on Figure 2.

1.2. Activity Objectives

The activities of the current project are to perform a complete engineering study of a multi-purpose commercial application of moderate-temperature geothermal waters in the vicinity of the Baca Grande development project in the San Luis Valley. The study is specifically evaluating the application of geothermal waters for space heating and cooling, and for hot water for (1) residences, including a mobile home park; (2) an existing motel (retrofit); (3) a greenhouse complex; and (4) other small commercial uses, i.e. aquaculture, etc. This detailed analysis will permit an early decision on project feasibility and the possible initiation of the later construction phase. Several process designs based on standard technology are being developed to find the optimum energy utilization plan; capital and operating costs are being determined; environmental factors evaluated; and finally, an institutional analysis of the San Luis Valley region is being performed.

The Baca Grande residential and recreational community is a continuing commercial land development which has acquired all necessary zoning permits, with all lots platted and legally surveyed. If alternative energy sources are not forthcoming, the residential and commercial participants will be served by either electricity or propane. The development of a geothermal resource would simply provide an alternate, environmentally preferable energy source to meet these energy demands and any additional demands which may occur. Thus, the ultimate objectives of this project are to actually drill, construct pipelines, extract and utilize the geothermal resources at the Baca Grande. Tentatively this project will proceed in six steps as outlined herein:

Figure 1. Geographical location of the Baca Grande.

Figure 2. Boundaries of the Baca Grande Development

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- Step 1: A feasibility and engineering design study of potential geothermal utilization at the Baca Grande.
- Step 2: Geothermal exploration surveys and drilling of initial exploration and production wells. Flow testing of the wells and reservoir evaluation to define reservoir characteristics such as reservoir life, temperature, flow rates, capacity, etc.
- Step 3: Construction of pipelines, pumping stations, heat exchangers, and retrofitting existing structures.
- Step 4: Initial operation and troubleshooting of the system including performance testing.
- Step 5: Full-scale operation and production of the geothermal system.
- Step 6: Monitor the long-term effects on the geothermal reservoir and the performance of the pumping and distribution system.

1.3 Participants and Relationship to User

The land and half of the mineral rights at the proposed site are owned by AZL Resources, Inc., which is the parent company of the Baca Grande Corporation. The other 50 percent of the mineral rights are owned by the Newhall Land and Farming Company. The geothermal resources could be developed either by the Baca Grande or through other private investors with DOE cost-sharing as appropriate. The developer would in turn sell the energy to the Baca Grande Corporation, private residents, and light commercial operators through an entity similar to the existing sanitation district. Federal assistance may be sought from DOE/DGE in the form of Program Opportunity Notices, the Guaranteed Loan Program, or directly as cost-sharing. The geothermal resource may hold potential for electrical generation in which case Public Service Company or the local Rural Electric Cooperative could purchase the electricity and put it directly into their transmission grid. Other potential non-electric users are also being solicited.

1.4 Relationship to the National Geothermal Development Program

In ERDA publication, "Geothermal Energy Research, Development, and Demonstration Program" (ERDA-86), the Federal geothermal program goal is stated as to both perform and stimulate research, development, and demonstration which will lead to major utilization of geothermal resources by municipalities or industry, whether private or public. Because of the large low-temperature geothermal resources located in the West, the active utilization of these resources is a near-term priority in ERDA's development program.

The Baca Grande geothermal development project would serve as a model for direct use geothermal systems which would stimulate similar developments elsewhere in Colorado and the western United States. In

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regions of residential and commercial growth where conventional energy sources are unavailable or noneconomic, geothermal space conditioning systems and light commercial developments such as proposed for the Baca Grande may be utilized.

1.5 Activity Schedule

The projected development of the Baca Grande geothermal system is divided into the six steps as described in section 1.2 of this report. The preliminary time scheduling for each phase is given below.

Step 1: Engineering, 12 months, March 1978 to March 1979.

Step 2: Permitting/exploration/drilling, 6-12 months, 1979-1980.

Step 3: Installation, 12-36 months, dates not yet defined.

Step 4: Initial operation/troubleshooting, approximately 4 months, dates not yet defined.

Steps 5 and 6: Future dates not yet defined.

If geothermal development were to continue immediately following engineering design and feasibility, the geothermal system could be supplying hot water to residences and light commercial uses in the early 1980's.

1.6 Costs

The economics of the residential areas are dependent on the continued rate of housing construction. If essentially complete development occurs over a 30-year period, then the economics are favorable. For the Mobile Home, Baca Grande Inn, and the light industrial area, the economics of installing a geothermal system are good as compared to existing alternatives.

2. DESCRIPTION OF THE PROPOSED ACTIVITY

2.3.3 Reservoir Development and Operation

After the completion of the current feasibility study, the proposed development activity will proceed by conducting additional testing on existing wells. Static shut-in pressures, rates of pressure buildup, current production rates, temperature profiles and downhole flow velocities will be measured for selected artesian wells. Draw-down tests and temperature profiles will be run on non-flowing wells. Following evaluation of this first phase data, two exploration wells will be drilled to target depths of 2,000 feet. For economic and demonstrative purposes, one of these first wells drilled might be located near the Baca Grande Inn so as to provide space heating services for that facility. Drilling techniques for these wells will be conventional and will comply with all State drilling requirements. Drilling rigs with 2,000- to 3,000-foot capacities will be utilized and standard mud and air drilling will be utilized with additional blow-out prevention. The initial exploration wells will be slim-holes, so wildcat exploration costs will be kept to a minimum. When a geothermal resource has been found and proven it will then be necessary to redrill or ream these wells to 14-24-inch capacities. The drilling pads and mudpits associated with the wells will be constructed in normal fashions, and due to the relatively flat topography and arid semi-vegetated lands, this construction will pose no unusual problems. Storage ponds for water produced during drilling may also be constructed or this water may be turned to the surface for drainage disposal, with the proper disposal permits.

Existing roads will be used for the majority of all drilling and construction activities. When necessary, new roads will be developed in an environmentally acceptable manner. To control dust problems which might arise as the result of construction activities and additional vehicular movement, roads will be sprayed, as necessary, using water from the surrounding creeks or drilling operations.

Any pipeline construction in this phase will parallel existing roads in the Baca Grande whenever possible. Pipelines will be buried along the rights-of-way in a fashion similar to the installation of existing domestic water lines and buried utilities.

After drilling and construction activities are completed all disturbed areas will be returned to their original surface contours and re-vegetated. Since most construction will be along existing roads the construction impact is anticipated to be minimal.

The geothermal reservoir is probably limited to within the boundaries of the Baca Grande graben. As shown in Figure 3, the eastern limit may be the Sangre de Cristo Fault and the western limit may be the fault zone along the western boundary of the Luis Maria Baca land grant. The reservoir is probably at depths nearing 2,000 feet with reservoir temperatures of approximately 150°F. Anticipated flow rates are up to 1,000 gallons per minute (gpm), depending on well diameter and reservoir

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pressure, with total dissolved solids of less than 1,000 milligrams per liter (mg/l).

2.3 RESOURCE UTILIZATION

2.3.1 Construction

Major construction activities at the Baca Grande geothermal development will include drill site construction, pipeline construction, and the development of access roads and settling ponds. Drill site construction will include building a drilling pad for the drill rig and excavation of mud pits and settling ponds. To install pipelines a trench will be excavated along the rights-of-way of existing roads in a fashion similar to that for installing domestic water lines and utilities. New access roads will be built only when necessary. Any additional construction pertaining to the development of commercial facilities, i.e., greenhouses and fish farms, will be the responsibility of those owner/operators.

The duration of the environmental impact from drilling and pipeline laying activities will be temporary. After construction, the sites will be returned to their original surface contours and revegetated. After one year, 50 percent of the impact will be mitigated, and after three years, 90 percent will be mitigated.

From prior drilling and construction activity in similar topography and ecology there will be no anticipated impact on existing surface and groundwater supplies. When reviewing surface activities and reinjection techniques, in conjunction with groundwater aquifers and known stratigraphy, environmental impact is judged to be minimal as the result of this geothermal development.

2.3.2 Operation

When the proposed geothermal system is operational, it will supply hot waters to individual residences, the Baca Grande Inn, and the light commercial developments. Since the anticipated fluids are of a high quality, the waters will probably be used directly and not require heat exchangers. The hot waters will be pumped from the wellheads in Production Areas 1, 2, 3, and 4 to their ultimate utilization in the Residential and Commercial service areas (Fig. 4) and then to the disposal locations. Due to water rights constraints, the reinjection of spent fluids into the subsurface is the recommended disposal method. In that case, reinjection wells will put spent geothermal fluids directly back into the reservoir which would constitute non-consumptive water use and maintain the reservoir pressures. An alternative method of disposal may be settling or spreading ponds. This method may be more economical but it will operate differently than reinjection. Infiltration rates near the mountain front are quite good allowing geothermal waters to infiltrate into shallow sediments and aquifers and be disposed. This would augment water supplies in shallower aquifers. The good quality fluid chemistry will have minimal environmental impact. If the geothermal water chemistry proves to be poorer than anticipated, the spent fluids may have to be treated prior to such an infiltration step.

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Since all pipelines will be buried, the only external appearance of the geothermal system will be the wellheads and the pumping stations. Wellheads and pumps can be enclosed in soundproof sheds which will abate any noise impact as well as improving the overall visual impact. During very cold days, there may be visible steam releases from wellheads and bleeder valves, but this will have only minimal impact.

The only gaseous emissions from the system will be at the wellheads and bleeder valves; however, significant concentrations of hydrogen-sulphide and other noncondensable gases are not evident and the resulting emissions will be small. The chemical analyses of nearby irrigation wells indicate no unusual chemical incompatibilities.

Due to the nature of geothermal energy, it is anticipated that after the system is constructed and operational it will require minimal maintenance to keep the system operational. While production wells are being cleaned or repaired, backup wells will be utilized to supply geothermal fluids. If ruptures occur in the pipelines, cut-off valves will be closed and the necessary repairs made.

3. DESCRIPTION OF THE EXISTING SITE ENVIRONMENT

3.1 GEOGRAPHY AND DEMOGRAPHY

3.1.1 Site Plan

Figure 2 is a topographic map showing the regional terrain and approximate boundaries of the Baca Grande development. Figure 5 shows a more detailed plan of the proposed real estate development at the Baca Grande which covers an area of over 20 square miles. Although a substantial number of lots have been sold, the actual rate of residential construction has been moderate. Approximately 15 housing starts per year have been recorded at the site and as of July 1978, 75 homes had been constructed in addition to 18 mobile homes. One of the reasons the Baca Grande Corporation is interested in supporting geothermal development is to encourage future activity. If various light industries could be attracted to the area via this resource development, an employment base could be established in the northern part of the San Luis Valley to the benefit of both local residents and the Baca Grande.

The planned geothermal light commercial development will be located east of the Baca Grande Inn or south across County Road 62 from the Inn. The latter area is not currently platted for this use but could probably be made available to minimize geothermal piping runs. Presently there are no existing geothermal structures in the area.

3.1.2 Regional Demography

The Baca Grande is planned both as a residential and vacation community. About one-third of the residents are permanent inhabitants

the baca grande - colorado

Figure 5. Planned Residential Development of the Baca Grande

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with employment in the region. An equal number are retired people and about one-third are smaller summer and resort homes. The population density will be relatively high when compared to the whole San Luis Valley, as 4,475 lots have presently been sold in the Chalet I and II areas of the Baca Grande.

The population density outside the Baca Grande is decidedly rural. Within a ten-mile radius of the Baca Grande are scattered ranches and farms with large amounts of acreage under grazing and cultivation. The overall population of Saguache County is 3,925 within an area of 3,200 square miles. The nearest community to the Baca Grande is Crestone, Colorado, with a permanent population of 36, which increases to 200-300 during the summer months. The only other community near the area is Moffat, which is 12 miles west of the Baca Grande and has a population of 98.

3.2 LAND USE

The general land use at the Baca Grande is divided into two types. At the Baca Grande development itself the land use is predominantly residential. On the lands surrounding the Baca Grande the use is mostly grazing and agriculture.

Within the Baca Grande all lands are planned for residential development except those in the Casita Park area. Here the lands will be used for a mobile home park, the Baca Grande Inn, and the proposed light commercial development.

On adjacent lands outside the Baca Grande, which are also owned by AZL Resources, Inc., limited cattle grazing and alfalfa cultivation are practiced. To the north and west of the development on the valley floor, the land is semi-desert with sandy soils and scrub brush and sage vegetation. The land is gently rolling hills at the Baca Grande development on the flanks of the mountains and the vegetation here is predominantly pinon and juniper. Pines and Cottonwoods inhabit the creeks in this area. To the east of the development are the Sangre de Cristo Mountains with very rugged and steep topography and peaks ranging from elevations of 12,000 to 14,000 feet. This area is thickly vegetated with Ponderosa Pine and is a semi-pristine environment.

On the floor of the San Luis Valley, the land use is virtually all unimproved grazing or light agriculture. The development itself is planned for residential and light commercial use. To the east the mountains are used for recreational hiking and camping, with some jeeping on the few improved roads.

The Saguache County Zoning and Development Code may affect certain portions of any geothermal development. The Code applies to all new construction in identified Natural Hazard or Mineral Resource Zones and would be specifically applicable to new light industrial development. These zones include both geologic and wildfire hazards. Wildfire Hazard

Zones are common throughout the lower slopes of the Sangre de Cristo Mountain range due to dense growth of pinon and juniper. If construction were to be proposed in a Wildfire Hazard Zone, this fact would not preclude construction, although additional expense might be incurred in order to mitigate the hazard sufficiently to receive the construction permission required from the Saguache County Planning Commission. Mitigation techniques could include thinning or clearing; these techniques would easily satisfy the intent of the code. No other zoning or land use restrictions are apparent.

3.3 GEOLOGY

The San Luis Valley is a structural basin bordered by faults on the east and perhaps also on the west, although the structural relations on the west are largely obscured by tertiary volcanic rocks. This large basin is actually the northern extension of the Rio Grande rift which is a down-dropped graben.

The Sangre de Cristo Range on the east side of the Valley was subjected to at least two stages of glaciation that sculptured the sharp peaks and produced moraines that extended to the heads of large alluvial fans at elevations of 9,000 to 9,500 feet. Along the foot of the range and on the eastern side of the Valley, a deposit of windblown sands created by the prevailing winds blowing across the Valley floor has been designated the Great Sand Dunes National Monument.

The mountains on the west side of the Valley are a part of the San Juan group and are composed principally of Tertiary volcanic rocks, which have been subjected to at least three stages of glaciation.

With each uplift of the San Juan peneplain, subsidence apparently took place in the San Luis Valley. The bedrock surface is believed to have been depressed thousands of feet below the present floor of the Valley. The elevation of the floor of the Valley probably has not varied much, since the rate of filling and subsidence were probably nearly balanced.

The Baca Grande development is situated over the deepest portion of the San Luis Valley. Several faults have downdropped a portion of the Valley to depths of 21,000 feet, creating what is known as the Baca Grande graben. The basin fill in the graben is poorly consolidated clay, silt, and sands with a Precambrian crystalline basement of granites and gneiss. A large fault that trends through the Baca Grande is probably the eastern boundary of the Rio Grande rift which is the structural control of the entire San Luis Valley.

A geologic cross section through the San Luis Valley, Figure 6, shows that the faulting of the Baca Grande graben does not express itself at the surface. The faulting is masked by the basin fill deposits of the Alamosa and Santa Fe formations. These formations are composed of unconsolidated gravels, sands, silts, and clays which are interbedded with volcanic flows and tuffs of Oligocene to Holocene age.

Figure 6.-- Theorized cross-section through the San Luis Valley, south-central Colorado.

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The Alamosa Formation is the best water-bearing formation supporting many of the irrigation wells with discharge rates of up to 1,000 gpm. At the base of the Alamosa Formation, at 1,500-2,000 feet, geothermal temperatures may reach 150°F. The Santa Fe Formation is 2,000 feet thick with less permeability than the Alamosa Formation. The best water yields in the Santa Fe are in sand lenses near the top of the formation and near the middle.

A shallow geothermal reservoir is predicted at 1,500-2,000 feet with temperatures of 150°F. The reservoir fluids should be of high quality with total dissolved solids of less than 1,000 mg/l. A deeper geothermal reservoir with temperatures of 250°F to 300°F may be present at depths of 5,000 feet to 11,000 feet. This water still should be of a good quality with dissolved solids of less than 2,000 mg/l.

At the turn of the century the mineral resources development of the Sangre de Cristo Mountains were substantial. Gold and other precious metals were mined along the eastern boundary of the San Luis Valley in the vicinity of the Baca Grande. Strikes and mines around the Independence Mine and the camps of Crestone, Cottonwood, and Duncan produced over \$50,000,000 worth of precious metals.

The geologic hazards in the vicinity of the Baca Grande are minimal. Any tectonic activity would primarily be associated with the Sangre de Cristo Fault (Fig. 3), which has only minimal recorded tectonic activity in the past 10,000 years. Since the faults, as shown in Figure 6, do not dissect the upper sedimentary formations, the earthquake activity has been extremely minor since these formations were deposited thousands of years past. This is confirmed by the fact that significant seismic activity has not been noted in the region in the last 100 years (36).

Landslides pose very minimal to no danger at the Baca Grande. The slopes of the Sangre de Cristo Mountains are very competent plus the moisture content at the lower elevations is not enough to induce slope failure. The geothermal development will be in the lower portions of the Valley and if landslides were to occur, they would not reach these lower elevations.

Subsidence of the sediments due to consolidation caused by pressure declines in deep aquifers normally has a potential for affecting a greater area than do such declines due to pumping shallow aquifers. At the same time, effects from deeper wells are less noticeable in any one area. In the case at hand, irrigation pumpage has not caused notable subsidence. This pumpage appears to be so much greater than that proposed for geothermal development that it can be used as an indication of the magnitude of any concern. In other words, no problem is presently foreseen.

The only geologic hazard of any significance may be flash flooding along Crestone, Willow, Spanish, and Cottonwood Creeks. These creeks originate in the Sangre de Cristo Mountains and drop 1,500 feet within two miles down into the Baca Grande. Greenbelts have been established for 300 to 400 feet on either side of the creeks, thus minimizing flooding problems and at the same time creating aesthetically pleasing park areas.

3.4 HYDROLOGY

The proposed geothermal development at the Baca Grande will have minimal impact on the surface and groundwaters of the area. The surface waters flow through the eastern Baca Grande the year around. The streams flow intermittently by the time they reach the Valley floor and during the height of Spring runoff they do not flow as far west as to leave the Baca Grande. All of the irrigation wells in the immediate vicinity of the proposed geothermal development are into the Alamosa Formation at depths of generally less than 1,000 feet. The proposed geothermal development will likely be at depths of approximately 2,000 feet. Due to clay layers, volcanic lenses and local faulting which effectively isolate many of the confused aquifers, the geothermal development should not impact on the aquifers supplying the irrigation wells. The proposed reinjection of cooled geothermal waters will also insure that currently utilized aquifers will not be impacted.

3.4.1 Surface Water

Most of the surface waters at the Baca Grande are confined to mountain streams which flow from the Sangre de Cristo Mountains onto the Valley floor. The major creeks in the area are Crestone, Willow, Spanish, Cottonwood, and just to the south of the Baca Grande, Deadman's Creek. These creeks flow perennially in the eastern Baca Grande, but as they near the Valley floor they become intermittent. The surface water is typical of mountain streams with pure, clean water, highly aerated with rapid flow over stream gravels and boulders. The average gradients of the intermittent streams within the Baca Grande is 225 feet per mile, or 4.3%. The portions of the streams in the mountains which have perennial flow have gradients of 850 feet per mile, or 16.1%.

The principal source of recharge to the shallow groundwater aquifers is seepage from these mountain streams which flow across the alluvial fans flanking the floor of the San Luis Valley. At the edge of the Valley the basin fill clay series is absent, permitting recharge of the surface waters to the shallow groundwater aquifers. These mountain streams show significant losses as they cross the porous surface of the fans. For example, seepage measurements made on Deadman Creek show that the 7 cubic feet per second flow measured at the canyon mouth was completely dissipated within about eight miles; all but one cubic foot per second was lost in the first 3.7 miles. Evaporation also accounts for portions of the surface water loss. A moisture deficiency in the San Luis Valley can be identified by comparing evaporation rates to precipitation. For the years 1961-1967, average evaporation for the period April through September was 52.25 inches, but average precipitation for the period was only 5.02 inches (Emery and others, 1971).

The only other surface water at the Baca Grande besides the streams is a small 17.3-acre man-made lake known as Lago del Oro. This lake was built at the Baca Grande Inn in the Casita Park area for the recreational and aesthetic use of the hotel guests.

3.4.2 Groundwater

The water table at the Baca Grande is at a depth of only 120 to 150 feet (7,680 feet above sea level) in the Alamosa Formation. The groundwater in the Alamosa Formation is the source for most of the irrigation wells in the San Luis Valley, some of which have flows greater than 1,000 gpm. Below the Alamosa Formation the best water yields are found in the upper and middle sand sequences in the Santa Fe Formation. As described in section 3.4.1 of this report, the recharge of meteoric waters to these aquifers is from the Sangre de Cristo Mountains with groundwater movement from the east to the west. Transmissivity ranges in these shallow aquifers are from 4,000 to 300,000 gallons per day per foot with a storage coefficient of 0.0001 (Emery and others, 1971).

It is logical to assume that any thermal waters moving upward in the Baca Grande graben will be offset westward by the flow in the shallow aquifers. This is because the logical recharge area of the Alamosa and Santa Fe Formations is along the mountain front. Potentiometric gradients in the shallow aquifer system are westward.

Table 1 shows chemical analyses of several irrigation wells near the Baca Grande. The well numbers on Figure 7 correlate with the wells on Table 1. As can be seen from the chemical analyses, the water quality in the shallow aquifers is excellent. The geothermal fluids in these shallow aquifers should also have very good qualities and are expected to contribute no pollutants to the natural groundwater aquifers. The geothermal waters at depths of 5,000 feet and greater are projected to have less than 2,000 mg/l total dissolved solids.

The optimum sites for possible reinjection of spent fluids into the subsurface will be determined after preliminary exploration is completed. Permeabilities in the Alamosa Formation should improve as the front of the Sangre de Cristo Range is approached. Since the chemical quality of the water is compatible with the aquifer and the water into which it will be injected, no problems are foreseen.

3.4.3 Water Use

The major water use in the San Luis Valley is for irrigation and other agricultural purposes. The Valley is endowed with a plentiful supply of ground and surface waters. The surface water supply averages 1,500,000 acre-feet per year, and groundwater withdrawals have averaged 750,000 acre-feet per year in recent years (1962-1967). This annual supply is substantial but could be supplemented by additional development of the more than 2 billion acre-feet of groundwater stored in the deposits underlying the Valley (Emery and others, 1971). The stored water is sufficient to supply current consumptive use for 1,000 years. As of 1967, there were over 2,800 large capacity irrigation wells with flows of over 300 gpm each, throughout the 1.9 million acres of the San Luis Valley. Figure 8 shows the density of irrigation wells in the northeastern valley.

Table 1

Results of Well Sample Chemical Analyses

	6	7	8	9	10	11	12	12A	13
pH (Units)	8.4	8.4	8.5	8.5	8.3	8.2	8.1	8.2	7.8
E.C. (mmhos/cm)	129	130	225	148	225	141	450	1330	425
<u>mg/Liter</u>									
Calcium	8	7	4	4	10	17	10	4	25
Magnesium	-1	-1	-1	-1	-1	-1	2	2	5
Sodium	24	26	54	33	44	16	109	345	73
Potassium	4	4	2	2	7	5	8	10	7
Iron	-.01	-.01	-.01	-.01	-.01	-.01	-.05	-.01	.07
Silica SiO ₂ (mg/l)	53	53	25	41	56	51	56	73	71
Alkalinity (CaCO ₃ Equiv)	47	49	88	57	99	55	236	723	219
Carbonates	1	1	2	1	1	1	2	7	1
Bicarbonates	58	61	107	67	118	66	293	883	260
Sulfate - S	9.0	8.8	13	9.0	10	9.0	12	17	11
Chloride	1.0	1.0	1.3	1.1	1.3	1.1	1.8	2.8	2.2
Nitrate - N	.80	.61	.83	1.2	.71	.70	.94	2.2	.39
Total Dissolved salts	109	118	195	126	207	122	449	1270	391
Surface Temperature (°F)	70	74	78	78	67	62	63	72	62
Depth (ft)	625	625	690	600	500	400	400	400*	400
Flow Rates (gpm)	50	150-200	900-1100	200-300	?	20	25	15-20	?

* Well numbers correspond to those identified on Figure 8.

Minus sign indicates less than reporting minima.

Figure 8.--Density of irrigation wells in the northeastern San Luis Valley.

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Water use patterns and water rights in the State of Colorado are governed by the Appropriation Water Law. Essentially, the first party to utilize the water resource for beneficial use establishes a water right which is adjudicated in the State water court. Water rights established junior to that original use may not infringe upon the rights of those holding senior rights to continue to utilize the resource. Thus, water rights are considered property and as such can be purchased and/or traded.

As is the case in many areas of the Western United States, the surface waters of the San Luis Valley are already over appropriated, i.e., adjudicated rights exceed the natural stream flows. The regional water system as described leads to two basic problems. First, due to the continual increases in the amounts of water withdrawn from the Rio Grande River for irrigation and other uses, downstream inhabitants were suffering or in danger of suffering, severe water shortages in the early decades of this century. In 1929, the States of Texas, New Mexico, and Colorado signed the Rio Grande Compact on the management of Rio Grande waters. This pact delineated annual river flows which the several States would guarantee to cross their common borders. In actual practice, this limits the regional consumptive use affecting the residual volume of the Rio Grande flow. Under the terms of the Compact, Colorado is presently indebted for approximately one million acre-feet of water because of excessive withdrawals in past years. The present average amount of water flowing into New Mexico from the San Luis Valley is 445,000 acre-feet via the Rio Grande River and about 55,000 acre-feet from groundwater movement.

There are only around 13 irrigation wells in the immediate vicinity of the Baca Grande and these have flows ranging from 15 gpm to over 1,000 gpm. By studying the location of the geothermal development at the Baca Grande in relationship to the average flow rates and depths of existing irrigation wells, and also in view of the proposed reinjection, it is anticipated that withdrawal of geothermal fluids will have minimal effect on the present water use in the San Luis Valley.

3.5 METEOROLOGY

Precipitation within the confines of the Baca Grande averages only 10.6 inches annually. July through August are normally the months of greatest precipitation with around six inches; winter through early spring generally are dry, receiving less than one inch. Precipitation during the winter months is normally derived from Pacific fronts, while moisture during the summer originates from the Gulf of Mexico in convective-type occurrences. Variation, both in terms of monthly quantities and annual averages, is the rule rather than the exception.

Cool temperatures generally prevail in the Baca Grande since the area is at an elevation of around 8,000 feet. The mean annual temperature is between 40° and 45°F and varies annually in extremes from over 90° to more than -30°F. Table 2 shows the average monthly temperature and the average diurnal extremes near the Baca Grande at the Great Sand Dunes National Monument.

Table 2.--Temperature Data, Great Sand Dunes
National Monument Weather Station

	Monthly Average (°F)	Diurnal Extremes (°F)	
		Minimum	Maximum
January	21	-10	52
February	28	-2	53
March	33	2	61
April	43	9	68
May	52	24	78
June	62	35	86
July	65	45	88
August	63	41	87
September	57	32	82
October	45	16	73
November	35	-2	62
December	27	-3	51

Low level air inversions during the fall and winter months are relatively common in the Valley. Air movement within the Valley in terms of slope flow and valley flow is often observed. Cloudy days are relatively infrequent on an annual basis, and incoming solar radiation and outgoing reflected radiation are generally at a maximum. Large daily temperature variation results. The high altitude of the Valley and large daily temperature variation combine to produce a short growing season of about 100 days.

Winds in the Valley are excessive during late winter and early spring, and may approach 60 knots occasionally. Winds vary from a low of five miles per hour during the middle of winter to an average of 11 miles per hour during the spring and fluctuate between the north and south. The prevailing winds in the southern portion of the Valley are from the southwest; in the northern valley, the prevailing winds are from the west and north. The overall impact of winds in the San Luis Valley is demonstrated by the existence of the Great Sand Dunes National Monument.

Air pollutants in the San Luis Valley are the greatest near Alamosa, which is 50 miles southwest of the Baca Grande. The main pollutants are particulate matter, hydrocarbons, nitrogen, sulfur, and carbon oxides which are generally the result of human activity but are accentuated by the regional topography and air inversions. At the Baca Grande, the air quality is generally pristine with the most significant concern being associated with wind-generated dust particulate.

3.6 ECOLOGY

3.6.1 Terrestrial

Soils and soil associations in general are products of climate,

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parent material, topography, biota, and time. Each factor may exert a more dominating influence than any other factor. Most commonly, however, all of the factors combine to effectively result in the living medium named earth.

Soil associations are groupings of major and minor individual soils which, because of their particular combinations and complexity, are distinguishable in a specific area. Within the Baca Grande there are at least seven soil associations. These associations are described herein with their accompanying vegetation and are mapped on Figure 2.

A Cotopaxi Sand, hilly (deep sand): Soils in this area are deep, coarse textured sands. Moisture penetrates readily, but the ability to store moisture is poor. The present plant cover consists of Indian ricegrass, blowout grass, needle and thread grass, sand dropseed, thickspike and Western wheatgrass, blue grama, spiny muhly, beardless wildrye, and squirrel tail. The shrub species occurring are tall and low rabbitbrush, skunkbrush, current and traces of winterfat and smooth horsebrush. Forbs include cactus, yucca, scurfpea, golden pea, bee plant, groundsel, and several annuals.

B Space City, loamy sand (sandy bench): This area is characterized by moderately deep to deep loamy fine sands containing large amounts of coarse gravel and cobble. Moisture penetration is good, but storage capacity is low. Existing flora in this area is identical to that in area A with the addition of three-awn, pingus, four-wing saltbush, and yellow pea groundsel.

C Space City, loamy sand, saline (salt flats): The soils on this area are deep, moderately well drained loamy fine sands with strong alkali accumulations at about 24 inches. Moisture penetration is hindered by the presence of salt in the soil, and "puddling" of water is common. The existing watertable provides an excellent source of water for the native vegetation. The dominant plant cover consists of greasewood and tall rabbitbrush with an understory of alkali sacaton, alkali cordgrass, sand dropseed, salt grass, beardless wildrye, blue grass, Kochia weed, bee plant, and annuals.

C' Space City, loamy sand, saline (sandy bench): These soils are similar to those in area C but with only slight alkali accumulations in the root zone. The flora of this area is similar to that in area C but also has most of the same plants.

D Mt. Home, unnamed loam (foothill sand): Soils on this area are moderately deep to deep sands that contain 35% to 75% cobble. Moisture penetrates readily, but due to coarse texture and steep slopes, storage capacity of the soil is limited. The area is dominated with a cover of pinon pine and juniper. Understory shrubs are mountain mahogany, current, gooseberry, chokecherry, tall rabbitbrush, four-wing saltbush, and some winterfat. Ground cover is similar to other areas with the addition of lupine, pentstemon, and paintbrush.

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E Uraoca, cobbly loam (pinon-juniper woodland): Soils on this area consist of a very shallow (4 inch) fine sandy loam surface soil lying over a slightly heavier clay loam or sandy clay loam subsoil. Lower soils are high in lime. The soils are also very cobbly and rocky. This area, because of slope, is best suited for use as watershed, recreation, and for wildlife habitat. The plant community is dominated by a cover of pinon pine and juniper along with some ponderosa pine, Douglas fir, and Englemann Spruce. Understory plants are similar to those in area D with the addition of June grass, Arizona fescue, and geranium.

F Medano, sandy loam (wet meadow): The soils on this area are deep, rather poorly drained, coarse sandy textured soils overlying a gravelly subsoil. The surface soil is relatively high in organic matter. Moisture penetrates readily and the soil has a good capacity for storage. This area, more or less, occupies the flood plain of Crestone Creek, and as such, is subject to occasional flooding and a beneficial water table. This is evidenced by meadow-type plants such as Kentucky bluegrass, sedges, rushes, slender wheatgrass, Western wheatgrass, foxtail barley, Timothy, alsike clover, iris, and annual weeds.

Wildlife characteristic of the area are magpies, mourning doves, cottontail rabbits, jackrabbits, small mammals, shrub nesting nongame birds, coyotes, and wintering birds of prey. Also, portions of the Baca Grande are used by antelope (winter range), various ground nesting birds (horned lark and western meadowlark), and small burrowing mammals such as the prairie dog. Twenty miles south of the Baca Grande are wetlands and marshes. Habitat common to this area are waterfowl, including Canadian geese, gadwall, mallard and pintail, green- and blue-winged teal, cinnamon teal, and redhead.

Upland game birds that are found at least seasonally within the area include mourning dove and bad-tailed pigeon. Both species utilize the area primarily from late spring to early fall.

Raptors which occasionally utilize portions of the Baca Grande include the golden eagle, great-horned owl, prairie and peregrine falcons and marsh and red-tailed hawks. Winter residents include the northern bald eagle and rough-legged hawk. Swainson's hawk and American kestrel or sparrow hawk are common during the summers.

The common night hawk, common raven, and turkey vulture are nongame birds found in the area. Other nongame birds are the horned lark and western meadowlark, Brewer's sparrow, loggerhead shrike, and sage thrasher.

All available information indicates that mule deer and possibly elk use the eastern portions of the Baca Grande, and elk may also be present. The pronghorn antelope also occasionally utilizes portions of the area further from the mountains.

The presence of large predators such as mountain lions and black bear in the Baca Grande would be very rare. Coyotes, however, are found or observed quite commonly. The cottontail rabbit, a small game mammal, is found throughout the area, while furbearers such as muskrat and mink may inhabit ponds and lakes further east in the mountains.

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The deer mouse, long-tailed weasel, and the golden-mantled ground squirrel are nongame mammals that will be found throughout the study area. Also found in the area are white-tailed jackrabbit, chipmunk and Ord's kangaroo rat, white-tailed prairie dog, and the thirteen-lined ground squirrel. Reptiles living in the area are rare; however, a few garter snakes may be found near the Lago del Oro and the creeks.

3.6.2 Aquatic

The aquatic environment at the Baca Grande is limited. The only surface waters in the area are four mountain streams and a small man-made lake as described in section 3.4.1 of this report and shown on Figure 2. Lago del Oro is a 17.3-acre lake at the Baca Grande Inn which is used for recreation by tourists and contains varieties of bugs and Trout and typical aquatic ferns and flora associated with non-turbulent waters. The mountain streams are characterized by water ferns, mosses, lillies and other flora typical of turbulent aerated waters. The streams are artificially stocked with Rainbow Trout but naturally inhabited by Native Cutthroat.

3.6.3 Endangered Species and Habitat

There will be potential damage to the soils and vegetation of the area as a result of drilling and construction activity. However, 90% of this impact will be mitigated within three years and there will be no permanent or irreparable damage.

No threatened or endangered plant species are presently known to exist within the San Luis Valley or the Baca Grande. The only plant species that could possibly be found is a species of cress (*Rorippa coloradensis*); this species was collected only once in the Valley over 100 years ago. There are no ecologically unique areas, areas with unique wilderness values, roadless areas of 5,000 acres or more, or areas of critical environmental concern within the Baca Grande.

There are four threatened or endangered species of fauna that might potentially inhabit the regions near the Baca Grande. The peregrine falcon could use the area occasionally, but intensive use is not likely because of unsuitable habitat. The whooping crane may be found around 20 miles south of the Baca Grande; however, the Alamosa National Wildlife Area and BLM's Blanca Wildlife Habitat Area (near Alamosa) are undoubtedly much preferred over any specific location within the Baca Grande. Presence of and use of the area by the southern bald eagle and the black-footed ferret is unsubstantiated since neither species has been positively identified recently in the vicinity.

3.7 REGIONAL LANDMARKS

Around the turn of the century, boomtowns sprang up along the creeks transversing the Baca Grande; the neighboring town of Crestone reached its peak in 1900 with some 3,500 people supporting five stores, pool halls, a golf course, a school, a hotel, and a anbk, not to mention seven saloons and two newspapers. Gold had been discovered and the

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Independence Mine east of the Baca Grande and other strikes in the area are said to have produced an estimated \$50,000,000 worth of precious metals. A narrow-gauge railroad was even built from Moffat to Crestone and extended south to serve the mines and the boomtown communities of Cottonwood, Duncan, Liberty, and Freedom, all now ghost towns.

Current evidence of man's prehistoric presence in the San Luis Valley spans the period from the Folsom culture (10,800-10,200 B.C.) through the late Archaic early sedentary period (2500-1500 B. C.) with a hint of Pueblo use (post-500 A.D.). Within the boundaries of the Blanca Wildlife Refuge, 20 miles south of the Baca Grande, a total of 137 prehistoric sites are reported. Outside the refuge, in the general area, isolated sites have been reported of Folsom and Archaic age. At the Linger site, reported in 1941, a human *calva* (skullcap) of probable Folsom age was picked up in the early 1970's. Based on the historical review of the area, it is anticipated that no conflicts will arise between the proposed geothermal development and any sites of historical value.

3.8 SOCIAL PROFILE

Most of the present residents live in the Chalet I and Casita Park areas of the development. Initial drilling is planned to be to the south and southwest of these regions. Construction of pipelines will be similar to that already done for burying domestic water and sewage lines and utilities.

The community, recreational, cultural, and aesthetic characteristics of the Baca Grande may be changed by the influx of additional residents to the area. Certainly, as the Baca Grande development grows, the population density will increase. It is anticipated that geothermal energy could aid in developing cheap and clean energy for the Baca Grande residents. Some light commercial development is expected to be attracted to the area on the merits of the geothermal energy potential.

3.8.1 Community Characteristics

A continuing Baca Grande growth will distribute its socioeconomic impact both in the immediate region and on Saguache County as a whole. The statistics presented are for Saguache County and some of the highlights of the socioeconomic study presently being undertaken are:

1) The Saguache County region is entirely rural in character with a population of 3,827 persons. It is designated an official "Economic Development Area" by the U.S. Economic Development Administration, which means the county is in need of labor intensive industry or other means of boosting a depressed economy.

2) Ethnically, Saguache County is 58% Anglo, 40.2% Spanish sur-named, and 1.8% other.

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- 3) The unemployment rate is a high 12.3%.
- 4) The median family income is \$4,539 compared to \$9,555 in Colorado as a whole.
- 5) The average age in the county is 26 years with 39% of the people being under 18 and 11% over 65.

The nearest health care for Baca Grande residents is available in Alamosa or Saguache. Schools serving the area are in Moffat and Saguache and police protection is via the County Sheriff. Fire protection is via volunteer fire departments. At the Baca Grande, water and sewage facilities are provided through the locally organized water and sanitation district.

The principal significance of the above information lies in the fact that Saguache County and the San Luis Valley are receptive to an increased economic development which could help to establish a healthy base. For example, the development of a large uranium mine and geothermally heated hog farm were both well received by the County Commissioners who were helpful in the permitting process. The latter development is important also since it represents an apparent acceptance of the fact that geothermal projects can be developed without detrimental effects to the current water use patterns.

3.8.2 Aesthetic, Recreational, and Cultural Values

There are many areas of aesthetic beauty throughout the Baca Grande. Greenbelt areas, where no development is allowed, parallel the creeks for 300 to 400 feet on each side. These "greenbelts" are used for recreational and aesthetic values as well as for protecting the flood plains.

To the east of the Baca Grande are several thousand acres of semi-pristine wilderness area in the Sangre de Cristo Mountains. A large portion of this area is privately owned by AZL Resources, Inc. and is used for camping, hiking, fishing, jeeping, and other recreational purposes.

3.8.3 Ambient Noise

Drilling operations will, in most cases, likely be in excess of a mile from the nearest residences and, therefore, noise pollution will be minimal. Drilling operations have a noise level of 75 dBA at a distance of 30 feet and only 50 dBA of ambient noise level at 500 feet.

Noise levels for pipeline construction will be similar to that of burying domestic water supplies and utilities.

4. ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTIVITY

Environmental effects will result from the proposed drilling and pipeline construction activity. Drilling rigs, excavation equipment, pipeline rights-of-way and support vehicle movement will all have short-term impacts on the physical terrain, dust levels, noise levels, and aesthetics. These will constitute only minimal impact, however, since only one drill rig and one or two excavation crews will likely be working at the same time. There will be no residual effects to the terrain, air quality or aesthetics as the result of this geothermal development.

Though none are anticipated, effects on the groundwater regime may represent the most significant potential impact. This project will extract geothermal fluids from deep reservoirs, extract the heat content and either reinject them back into the strata or utilize surface disposal. Since the reservoir in question is unrelated to the various shallower confined aquifers and since the Baca Grande is situated away from the main irrigation pumping district of the San Luis Valley, the geothermal development should have no significant impact on the existing water use patterns in the Valley.

4.1 PHYSICAL ENVIRONMENT

4.1.1 Land Use

Environmental impact will result from the drilling activities and construction of the pipeline. However, each drilling site will involve less than five acres. Impact at the drill site will be the result of existing access roads, a drilling pad, narrow mud pits and possibly lined settling ponds. Immediately after drilling operations conclude, the drill site will be restored to its original condition.

Construction impact will be along existing road rights-of-way. Standard excavation equipment will be used to bury pipelines in a manner similar to the construction of existing domestic water supplies and buried utilities. The short-term impact will be localized defoliation, minimal dust generation and slight noise impact. Support vehicle movement along access roads will generate dust and to mitigate this impact roads will be sprinkled periodically as necessary.

Upon completion of drilling and construction activities, the drill site and pipeline routes will be restored to their original contours and revegetated. The short-term impact will be 90% mitigated within three years and there is no anticipated long-term impact.

Noise impact will result from drilling and construction operations, as well as from movement of support vehicles. Noise impact during drilling operations will be less than ambient levels over 500 feet from the rig. Noises from the wellheads and pumphouses will be mitigated by enclosure in sheds and soundproofed as necessary. Noise should not affect land use in the development area.

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Subsidence of the sediments due to consolidation caused by pressure declines in deep aquifers normally has a potential for affecting a greater area than do declines resulting from pumping shallow aquifers. At the same time, effects from deeper wells occur over a broad area and are less noticeable than are localized effects. In the case at hand, heavy local irrigation pumpage from shallow aquifers has not caused notable subsidence. This pumpage appears to be so much greater than the proposed for geothermal pumpage that it can be used as an indication of the magnitude of any concern. In other words, no problem is presently foreseen.

Modern means of waste disposal and human sanitation will be observed at the drilling and construction sites; no short- or long-term effect from these sources is anticipated.

4.1.2 Water Use

Geothermal fluids will be produced from depths approximating 2,000 feet and could ultimately originate from depths of 5,000 to 11,000 feet. The majority of irrigation wells in the San Luis Valley are presently producing from depths less than 2,000 feet. Hydrogeological studies show that the deeper geothermal reservoirs are unrelated to the irrigation aquifers due to volcanic flows and clay lenses in the sub-surface. In the immediate vicinity of the Baca Grande, there are only 13 irrigation wells (Fig. 8), all of which are estimated to be from depths of less than 700 feet. For these reasons and in view of the proposed reinjection it is anticipated that the production of geothermal fluids at the Baca Grande will have minimal impact to the present water use in the northeastern San Luis Valley.

AZL Resources, Inc. own some existing water rights at the Baca Grande. The potential for additional future water development and subsequent adjudication is excellent on lands owned by AZL Resources, Inc. If reinjection of spent fluids is chosen, water use would be considered nonconsumptive and current water use should not be affected. If a surface disposal is chosen, again current use should not be affected, for reasons previously stated; all geothermal development will comply with the water laws of the State of Colorado.

4.1.3 Water Quality

There will be no impact to surface water quality and minimal impact to groundwater. All State and Federal water quality standards will be met; surface discharge to area waterways is not anticipated. Geothermal fluids are expected to have total dissolved solids concentrations of less than 1,000 mg/l which is a very good quality water. If geothermal fluids are reinjected into the same or comparable aquifers from which they were produced, there will be no impact to the groundwaters. If surface discharge is considered, treatment may be required prior to discharge should geothermal water quality prove to be poorer than currently anticipated.

4.1.4 Natural Resources

There will be no effects on the exploration or production of minerals and other energy resources as the result of implementation of the proposed geothermal development.

4.1.5 Air Quality

Since the location of the Baca Grande is rather remote and not near present urban development, the air quality is extremely good and virtually pristine. Airborne dust is the only significant air pollutant in the region and it occurs naturally. The geothermal development will have no residual impact on the air quality of the area. No significant quantities of noncondensable gases are present in the fluid or will be released to the atmosphere.

The only potential short-term air impact is possible from dust generation due to drilling, construction, and vehicle movement. Dust generated on access roads will be abated by sprinkling with water trucks as necessary.

4.2 ECOLOGICAL ENVIRONMENT

4.2.1 Terrestrial

Some of the proposed geothermal activities will have a definite, albeit temporary, impact on soils at the specific drilling and construction locations. Well drilling, test pit excavation, wellhead vault installation, and drilling disposal areas could impact the soils of up to five acres in the immediate area. In areas where the existing vegetation is removed, soil erosion processes via both wind and water could be intensified; the affected areas will be small, however, and revegetative efforts should minimize any erosion tendencies.

Well drilling, settling and excavation, and pipeline construction activities could impact the wildlife of the localized site by altering normal patterns of use and movement. No lasting damage is expected since the cause of the pattern alteration will no longer exist once construction activities have been completed.

4.2.2 Aquatic

The geothermal development at the Baca Grande will have no anticipated impact on surface and groundwater aquatic environments. Extensive discharges to surface waterways are not anticipated and, therefore, the impact on that environment should be negligible. Groundwaters should also experience minimal impact. If reinjection is used as the preferred method of disposal, then the waters will be reinjected into aquifers similar to those from which they are produced. If geothermal fluids are chemically treated to reduce scaling tendencies, then these waters will be monitored while reinjection is taking place.

4.3 SOCIOECONOMIC ENVIRONMENT

Lifestyle changes or changes in basic social structures, populations, economics, and services as a result of this project are difficult to quantify since the major portions of the Baca Grande development have already been started.

Increases in population can have an impact on rural, economically depressed areas. Even small population increases may require new services, and even if the changes are positive, often the mere change itself is resisted by the people.

The following is an analysis of the potential positive and negative effects on basic services which may occur as a result of this project. The analysis will dwell on the towns of Crestone and Moffat and the Baca Grande Community. The Baca Grande Community is geared for growth. Because of this, the Baca Grande has planned for growth well in advance of its occurrence. Water, sewer, and utility provisions currently exceed existing use. The only increases that are not accommodated by the developer in this case are impacts on schools. The impact on schools, however, should be positive, since the local schools are seeking accreditation and need an increased number of pupils to successfully realize that goal.

4.3.1 Sewer Facilities

Adverse Impacts.--Neither Crestone or Moffat have central sewer systems. Each home is served by individual septic tanks. Both towns have small lots, and Moffat experiences a high water table. These factors create design problems for traditional septic tanks which typically need one acre of ground and four to seven feet of dry soil to effectively treat the effluent.

Cases of waterborne disease have already been noted in Moffat, and it is expected that problems in Crestone and Moffat will increase in the future as more septic tanks are installed. Though major additional housing in these areas is not anticipated, the adverse potential is none-the-less present. As noted earlier, the Baca Grande community has adequate collection and treatment systems.

Positive Impacts.--Ironically, additional housing is needed in both Moffat and Crestone to make central sewer facilities viable. The town of Moffat recently had a private consultant conduct a feasibility study for possible installation of central sewage collection and treatment systems. The study conclusions estimated the per tap costs to be \$20.00 per month. Due to the depressed economy of Moffat and the high number of fixed and low-income residents, citizens chose to reject this alternative. Additional employment and new homes possibly related to the project proposal might make central sewer facilities possible for both towns.

4.3.2 Water Facilities

Adverse Impacts.--The problems described above under 4.3.1, directly relate to water pollution and waterborne disease. Neither Moffat nor Crestone are prepared to develop central water facilities, and any increase in population and housing due to the proposed project could create serious problems if central facilities are not installed. The Baca Grande does have a centralized water supply with extra capacities for projected growth.

Positive Impacts.--Again, more homes to help finance water and sewer projects is the only long-term solution to the water supply dilemma. This project could possibly provide the catalyst for the provision of central water facilities in these two small towns.

4.3.3 Public Utilities

Adverse Impacts.--Adequacy of electrical supplies to the Valley region should not be impacted by the geothermal activities. Although existing supplies are tight, the San Luis Valley Rural Electric Cooperative is planning a new 230 Kv transmission line into the Valley during 1979. Power from this project is expected to provide ample reserves for the next five to ten years.

Positive Impact.--The geothermal resource holds the potential for eventual electrical production which could supplement existing electrical supplies.

4.4 POTENTIAL ACCIDENTS

Any accidents during drilling activities will likely result from human error. There are no unusual potentials for accidents that might result from geothermal energy development efforts. The shallow reservoir targeted is at 150°F, and the reservoir should not be under enough pressure to cause a blowout. Nonetheless, blowout preventers will be used during drilling operations. Fencing will be placed as necessary around drilling operations, including settling ponds, to minimize the potential of humans, livestock, or wildlife falling into mud pits or settling ponds.

As in drilling, accidents during pipeline construction will likely be from human or equipment failure. Hot water district distribution systems are similar in many respects to potable water systems and problems other than normal maintenance and repair are minimal. If, under worst case conditions, pipeline leakage or a rupture should occur, the worst case result would be the discharge of geothermal fluids to the surface. Since the fluids are anticipated to be of a high quality, no residual negative environmental effects would be apparent.

Accident potential from vehicle movement would be small. No development activities will take place near a major highway where traffic could be impaired. Vehicle movement generally will be on rural roads and sometimes through hilly and winding terrain. Appropriate safety precautions will be taken accordingly.

5. EFFLUENT AND ENVIRONMENTAL MEASUREMENT AND MONITORING PROGRAMS

5.1 PROGRAM UNDERTAKEN PRIOR TO THE START OF THE PROPOSED ACTIVITY

The preliminary environmental development work has been accomplished utilizing published reports and literature, private consulting reports, and open-file data of the USGS and the Bureau of Reclamation. On-site visits have been conducted at the Baca Grande to observe the environmental impact which could affect the land, water, aesthetics, and socioeconomics.

Surface waters have been observed so as to characterize potential impacts upon them as the result of the geothermal development. Since stream flow may be intermittent when it reaches the drilling sites, there should be no impact on the creeks. Existing roads and rights-of-way have been studied and determined adequate for the proposed geothermal development.

Groundwater supplies and geohydrology have been projected by reviewing public literature and private consulting reports. Some of the irrigation wells in the vicinity have been sampled and chemically analyzed (Table 1). The quality of these waters can be used as background data to monitor any short- and long-term effects of geothermal development on the groundwater supplies.

Geologic hazards which may affect the geothermal system, or result from its implementation have been observed and projected. Field projections indicate geologic hazards will only have minimum impact on the geothermal development.

5.2 PROGRAMS UNDERTAKEN DURING THE PROPOSED ACTIVITY

During the operation of the geothermal system, properties such as flow rates, temperature, pressure, and samples of the geothermal fluids will be measured at periodic intervals. These properties will be measured at the production wells, along the pipelines and at the reinjection wells or disposal facilities to monitor the system throughout and predict reservoir characteristics. In association with these measurements, the surrounding irrigation wells will also be monitored as necessary for similar properties. When this data is input into standard groundwater equations and computer models, the short and long-term effects on the geothermal reservoir can be predicted. These results will also be valuable to determine if the system can be expanded for additional residential and industrial uses.

Geothermal fluids will be sampled and analyzed to determine what mineral alteration is occurring in the reservoir and what, if any, impact geothermal fluids may be having on the groundwater aquifers.

Gas emissions at the wellheads and along the pipelines will be monitored and analyzed as necessary to determine what effects these vapors have on the ecology.

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The wellheads and pipelines will be periodically checked to verify the general condition of the system. Also revegetation rates and overall ecological impact will be observed throughout the geothermal system.

Though none are projected, subsidence rates and effects will be monitored and action will be taken as necessary to mitigate any occurrence.

5.3 OTHER ENVIRONMENTAL MEASUREMENT AND MONITORING PROGRAMS

There are several on-going or projected projects that will provide new data and in certain instances require environmental reports for areas in the northeastern San Luis Valley. These projects will not necessarily include the Baca Grande but they will encompass lands in the immediate vicinity. The Colorado School of Mines does geophysical research throughout the northeastern Valley every summer. The Colorado Geological Survey is planning to begin a geothermal exploration survey throughout portions of the Valley. Finally, the U.S. Bureau of Reclamation has been working for several years on the "Closed Basin Project" just to the south of the Baca Grande. The National Environmental Policy Act impact statement for this project will contain many items of interest applicable to future Baca Grande environmental work. The Closed Basin environmental statement is expected to be published in Spring 1979.

6. RECLAMATION AND RESTORATION

The first phase of actual geothermal reservoir development will be to drill and test geothermal exploration wells. Upon the termination of the drilling and flow-testing of these wells, all equipment and drilling apparatus will be removed from the site. All water left in the mud pits will be carefully drained or left to evaporate. The pits will then be earth-filled and the drill site restored to its prior contour.

When the geothermal system is no longer economical due to declining resource capability or distribution and collection system failure, it will be abandoned. The production and reinjection wells might be converted to irrigation use if the water quality is acceptable and if water rights allow that changeover. Pipelines will probably be left intact since it would be more environmentally damaging to excavate and remove pipelines than to leave them buried and intact.

Other protective, restoration, and reclamation procedures which will be used during and after the geothermal systems construction and operation include:

- 1) Existing roads and trails will be used whenever feasible.
- 2) In settling ponds, surface soil shall be removed down to a maximum depth of one foot and piled separately from the remainder of excavated material. At abandonment, the settling ponds shall be back-filled and the surface soil spread over the top of the backfill.

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- 3) Excavated material, not reused as backfill, will be smoothed and shaped to blend with surrounding area.
- 4) The settling pond areas will be reseeded with appropriate plant species as recommended by conservation agencies.
- 5) All new road or trail construction in the immediate area will be designed in such a manner as to minimize potential soil erosion and disturbance to overall landscape.
- 6) Drilling pits will be left open to dry and then filled and reseeded.
- 7) Equipment associated with the drilling activity will not be moved during wet periods if significant damage to the soil surface or existing vegetation will result.

7. ALTERNATIVES TO THE PROPOSED ACTIVITY

To slow or stop further efforts to utilize geothermal resources at the Baca Grande is a possible alternative and one that will result in no short-term, additional detrimental environmental effects to wildlife or to the land. However, it is one course of action that proponents of geothermal energy, including the Baca Grande Development Corporation, naturally do not consider to be a wise one because it effectively stops advancement in the field of geothermal energy. If geothermal resources are not utilized at the Baca Grande, alternative power sources would have to be utilized and these have greater environmental impact. Major electrical transmission lines, buried natural gas lines if ever available, and large solar collectors all have greater impact than a few geothermal wells and buried pipelines if one considers all aspects of those energy-producing alternatives. Presently, there is no natural gas available at the Baca Grande which leaves only propane and electricity as the predominant means of heat and power, and both are costly.

Alternatives within the framework of the geothermal system as proposed consist of the different locations of well sites and pipelines. With the present locations of pipelines along existing road rights-of-way and well sites situated away from populated areas, the impact to surface waters and agriculture lands will have the least environmental impact of any proposed system in the area. Alternate sites would result in new access roads, more difficult drilling terrain, and subsequently greater impact to the land and water uses. Also, well sites outside areas defined in this document may result in a less viable resource with less attractive economics.

Alternatives for disposal of cooled brines include reinjection, discharge to surface waterways, or infiltration to shallow unconfined aquifers.

Reinjection is the preferred alternative since this effectively mitigates water rights concerns; well drilling permits for consumptive use from the artesian aquifer have not been granted for several years due to potentials for decreasing recharge to the Rio Grande River. Ground-

water impact would be minimal since the basic water chemistry is unchanged by use. Infiltration systems are sound environmentally assuming a high quality geothermal water. This choice would tend to augment unconfined aquifers but would not replace water back to the original confined aquifer from where it was withdrawn. Discharge to surface waterways is in practice similar to the infiltration alternatives because of the intermittent nature of area streams which infiltrate and lose surface flows before leaving development properties. Thermal effects would have to be carefully considered for this alternate, however, to prevent damage to aquatic life. Also, the discharge of dissolved salts might also pose concerns depending on the final quality of the resource.

8. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Besides construction materials, manpower, and energy used during drilling and pipeline installation, the only irretrievable commitments of resources would be the consumptive use of thermal heat within the earth which is being transmitted via extraction and reinjection of geothermal fluids. However, thermal depletion of a measurable portion of the geothermal resources in this area is highly improbable. The main geothermal anomaly in the eastern San Luis Valley probably covers over 250 square miles of area which includes a large portion of the Baca Grande. The reservoir near the Baca Grande may be the main reservoir for this entire system. The geothermal system initially proposed for the Baca Grande will only utilize a shallow portion of this overall geothermal system which originates at depths significantly deeper than the 1,500-2,000-foot target depth.

The San Luis Valley is within the Rio Grande rift. A rift zone is a large tectonic feature where the earth is "cracking" apart and the internal heat of the earth is upwelling to the surface. It is physically impossible for the geothermal system at the Baca Grande to extract enough heat from local geothermal resources to even minutely effect the heat content within the Rio Grande rift.

The San Luis Valley encompasses a large amount of land, 1.9 million acres, exhibiting similar topography and ecology to that at the Baca Grande. Therefore, geothermal development at the Baca Grande will have virtually no impact to the overall ecology and environment of the Valley as a whole.

9. TRADE-OFF ANALYSIS

Trade-off analysis requires the consideration of both environmental and economic comparisons. Section 7 has previously discussed the alternatives to the proposed action in the environmental context. The economics of the residential areas are dependent on the continued rate of housing construction. If essentially complete development could occur over a 30-year period, then the economics are favorable. For the mobile home, Baca Grande Inn, and the light industrial area, the economics of installing a geothermal system are good as compared to the existing alternatives.

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10. COMPLIANCE WITH REGULATIONS AND OTHER CONTROLS

Prior to geothermal development at the Baca Grande, the following legal requirements, permits and bureaucracy will be adhered to:

10.1 FEDERAL

There will be no operations on public, acquired, or withdrawn Federal lands and, therefore, the regulations of the "Geothermal Steam Act of 1970" are not applicable as long as geothermal operations are restricted to the Baca Grant Ranch and do not effect any public lands. This environmental report is filed with DOE/DGE since the initial engineering study is being funded by DOE/DGE Contract Number ET-78-C-97-1703.

Water management practices will be consistent with all regulations developed under PL 92-500, the "Federal Water Pollution Control Act Amendments of 1972," and the Clean Water Act of 1977. Likewise, all provisions of the Clean Air Act and the Clean Air Act Amendments of 1977 will be met.

10.2 STATE (Coe, 1978)

All geothermal operations must comply with the rules and regulations set forth in Colorado HB 1165, "Geothermal Resources Act of 1974." This includes filing a permit to drill a geothermal well with the Colorado Oil and Gas Conservation Commission (HB 1165, section 34-70-102). An application must also be filed to recompleat or abandon a well. After review by the Oil and Gas Commission the permit is sent to the Colorado State Engineer's Office where it is reviewed for adverse impact on existing groundwater rights. The State Engineer must act upon the permit within 60 days or it is denied.

If a developer wishes to discharge geothermal fluid into a stream or an injection well, he must obtain a permit from the Colorado Department of Health, Water Quality Control Division. This permit should be applied for at least 180 days in advance of operations so a public hearing can be held if necessary.

Though no formal permit is required it is advisable to file a letter of intent with the Colorado Department of Health, Air Pollution Control Commission. They have the authority to monitor all point-source emissions and ambient air quality throughout the State. If any operation is in violation of the Federal Clean Air Act or the Colorado Air Pollution Control Act of 1970, the State Department of Health has the authority to intervene.

10.3 LOCAL

The Saguache County Land Use Zoning and Development Code authorizes five steps which must be adhered to prior to any geothermal development in the county. They are as follows:

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- Step 1. The applicant must file a letter of intent with the Saguache County Land Use Administration.
- Step 2. The Land Use Administration will submit the letter of intent to the County Planning Commission and all parties will meet to review the proposed geothermal development.
- Step 3. The County Planning Commission submits the letter of intent, with their recommendations, to the County Commissioners for review. If the Commissioners determine that there will be no adverse impact, the application will be approved and the project may go on with no further authority of Saguache County.
- Step 4. If the County Commissioners determine that there may be appreciable impact from the geothermal development, an application for a Permit to Develop must be filed with the Land Use Administration. If it is determined that a major impact may occur, then a series of public meetings will be scheduled to solicit public response.
- Step 5. After the public hearings the County Commissioners will again review the project and designate it as approved or denied (or a portion thereof).

The anticipated time to meet all of the requirements of Saguache County is 60 to 90 days, which would include two public hearings. The Saguache County Land Use Zoning and Development Code also includes stipulations pertaining to Wildfire Hazard Zones. These requirements are outlined in section 3.2 of this report.

10.4 OTHER

As long as a geothermal space heating utility is constructed totally on private lands there are no laws governing public utilities. If the system crosses public access or leaves one-party ownership, then the Colorado Public Utilities Commission may require permitting. The proposed geothermal development should be reviewed by the Fixed Utilities Section of the Public Utilities Commission. This procedure may take up to three to four months.

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APPENDIX D

ECONOMIC ANALYSIS OF GEOTHERMAL ENERGY OPTIONS
FOR THE BACA GRANDE DEVELOPMENT

A report by Dr. Richard T. Meyer, Western Energy Planners, Ltd.,
and Steven G. Roberts, Science Applications, Inc.

December 14, 1979

Coury and Associates, Inc.

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ECONOMIC ANALYSIS OF GEOTHERMAL ENERGY OPTIONS
FOR THE BACA GRANDE DEVELOPMENT

A. Introduction

This report provides an economic analysis of municipal utility operations of five separate geothermal energy production facilities for the Baca Grande Corporation community land development in Southern Colorado. The economic analyses have been performed by Western Energy Planners, Ltd. under subcontract to Coury and Associates, Inc. The analyses are an extension and expansion of cost of delivered energy calculations provided by Coury and Associates, Inc., as part of a U.S. Department of Energy PRDA project. Western Energy Planners, Ltd. has utilized the System for Economic Evaluation under Risk (SEER)¹ computer program of Science Applications, Inc. for evaluations of revenue requirements, profitability measures, and cash flow requirements.

B. Objectives

The primary objective of this economic analysis has been to refine and expand the original calculations of the cost of delivered energy performed by Coury and Associates, Inc. (C&A). The refinements permitted by use of the SEER computer program include integration of yearly investments, annual operating costs, municipal bond interest rates and pay-off schedules, and inflation factors into a more comprehensive thirty-year life-cycle cost analysis. In addition, sensitivity analyses have been conducted to examine the effects of inflation rates and municipal bond interest rates on revenue requirements. Both constant 1979 dollar and current (inflated) dollar values of the costs of delivered energy have been evaluated to provide cost perspectives for comparison with alternative fuel forms. The constant dollar costs are the applicable charges to the consumer for future years if the investments and construction were carried out at 1979 costs and if no inflation or deflation occurred in future years. The current dollar costs are the energy charges to the consumer in future years projected at assumed inflation rates on equipment, construction costs, operating and maintenance costs.

C. Methodology, Data and Assumptions

1. SEER Computer Program Capabilities

The SAI "System for Economic Evaluation Under Risk" (SEER) computer program has been utilized for the economic analyses because of its specific formulation for energy and mineral resource development projects and because of its flexibility to examine several measures of business profitability. The full capability of SEER to account for the several Federal, State and local tax classifications of investments and expenses has not had to be applied to the

¹ For the purposes of this study, the "Risk" aspects of the SEER program were not extensively utilized.

present case of an energy development by a municipal utility. However, the program has provided exact calculations of revenue requirements and the associated cash flow projections for five separate geothermal energy utility systems. Business profitability measures include discounted cash flow rate of return, minimum rate of return, net present value, payback period and discounted payback period. For more details on the SEER program, the reader is referred to the SAI SEER Users Manual and to the text Economic Evaluation and Investment Decision Methods by F. J. Stermole (Investment Evaluations Corporation, Golden, Colorado, 1974).

2. Geothermal Utility Base Cases

The PRDA study of the Baca Grande Development has addressed the design engineering, operations and economics of five separate geothermal energy production facilities, each scaled to supply space heating and domestic hot water heating to five different energy consuming systems. The energy consuming systems included two cases of residential district heating systems, two cases of commercial space heating, and one case of a medium- to large-size greenhouse operation. The two cases each for the residential and commercial systems represent two different rates of growth and ultimate sizes at the end of thirty years for the residential and commercial sectors of the Baca Grande Development.

The base case physical parameters and economic data for the five energy production facilities are given in Tables 1 to 5. It is to be noted that the total annual operating costs for the SEER computations are the sum of the annual operating costs as tabulated in Tables 1 to 5 and of the annual maintenance and insurance costs, calculated at 3.5% and 0.5%, respectively, of the fixed capital each year. The yearly royalties listed in Tables 1 to 4 are already included in the tabulated annual operating costs, but are listed to indicate their magnitudes.

A royalty rate of 10% of a \$15.00 per barrel of oil equivalent wellhead price, which amounts to \$0.25 per million Btu, has been assumed.

a. Residential Area Alternatives

The residential development by the Baca Grande Corporation includes 72 existing residences and new residential units to be constructed over future years. The present economic analysis addresses two alternative growth rates for the residential area and for construction of the geothermal energy system.

Residential Alternative 1 (RA1) assumes a continuing housing construction rate of 20 homes per year for a 30-year total of 672 homes. The peak design capacity of the geothermal production system is 4,300 gpm, based upon a peak demand rate of 6.4 gpm per house. The production system is constructed incrementally over the entire 30 years with major equipment additions in the first, sixth, and nineteenth years.

Table 1

BACA GRANDE ECONOMIC DATA*

Residential Alternative 1

Housing Construction - 20 Units per year

Total Development -- 672 Housing Units

CASE 1 -- RESIDENTIAL

YEAR	Annual Capital Expenditures (\$1,000)	Royalties (\$1,000)	Annual ** Operating Costs (\$1,000)	Heat Utilized 10 ⁹ Btu/year
0				
1	3,148.9	3.2	170.2	12.9
2	82.3	3.9	176.6	15.7
3	69.2	4.6	184.4	18.5
4	251.4	5.3	204.7	21.3
5	69.2	6.0	213.3	24.1
6	1,354.0	6.7	273.2	26.9
7	69.2	7.4	281.4	29.7
8	95.8	8.1	291.4	32.5
9	69.2	8.8	299.4	35.3
10	69.2	9.5	322.3	38.1
11	69.2	10.2	327.4	40.9
12	224.8	10.9	338.7	43.7
13	69.2	11.6	344.4	46.5
14	69.2	12.3	352.9	49.3
15	69.2	13.0	361.1	52.1
16	69.2	13.7	369.8	54.9
17	69.2	14.4	377.9	57.7
18	69.2	15.1	386.4	60.5
19	906.5	15.8	428.6	63.3
20	69.2	16.5	436.8	66.1
21	69.2	17.2	450.0	68.9
22	69.2	17.9	458.7	71.7
23	82.3	18.6	468.4	74.5
24	69.2	19.3	493.3	77.3
25	69.2	20.0	496.8	80.1
26	69.2	20.7	500.3	82.9
27	237.9	21.4	511.8	85.7
28	69.2	22.1	518.9	88.5
29	69.2	22.8	525.3	91.3
30	69.2	23.5	533.3	94.1

* All data are presented in constant 1979 dollars.

** Annual Operating Costs include royalties, auxiliary energy costs, administration, and annual maintenance and insurance costs; annual maintenance is 3.5% of fixed capital; annual insurance cost is 0.5% of fixed capital. Working capital is 2.5% of fixed capital.

Table 2

BACA GRANDE ECONOMIC DATA*

Residential Alternative 2

Housing Construction -- 139 Units per year

Total Development -- 4,242 Units

YEAR	Annual Capital Expenditure (\$1,000)	Royalties (\$1,000)	Annual ** Operating Costs (\$1,000)	Heat Utilized 10 ⁹ Btu/yr
0				
1	5,297.0	7.4	291.4	29.6
2	636.5	12.3	355.6	49.0
3	2,667.0	17.1	502.8	68.5
4	480.9	22.0	563.3	88.0
5	676.2	26.9	605.1	107.5
6	636.5	31.7	674.1	126.9
7	1,382.2	36.6	768.5	146.4
8	663.1	41.5	836.4	165.9
9	649.6	46.4	899.9	185.4
10	1,382.2	51.2	994.2	204.8
11	663.1	56.1	1064.9	224.3
12	649.6	61.0	1109.2	243.8
13	1,382.2	65.8	1202.2	263.2
14	1,317.4	70.7	1294.1	282.7
15	494.0	75.6	1353.3	302.2
16	1,382.2	80.4	1448.5	321.7
17	663.1	85.3	1496.5	341.1
18	649.6	90.2	1556.5	360.6
19	1,382.2	95.0	1650.2	380.1
20	663.1	99.9	1726.8	399.6
21	636.5	104.8	1791.3	419.0
22	494.0	109.6	1850.5	438.5
23	1,382.2	114.5	1944.9	458.0
24	663.1	119.4	1987.8	477.5
25	649.6	124.2	2053.2	496.9
26	1,382.9	129.1	2148.0	516.4
27	636.5	134.0	2212.6	535.9
28	494.0	138.9	2272.0	555.4
29	636.5	143.7	2336.1	574.8
30	636.5	148.6	2378.5	594.3

* All data are presented in constant 1979 dollars.

** Annual Operating Costs include royalties, auxiliary energy costs, administration, and annual maintenance and insurance costs; annual maintenance is 3.5% of fixed capital; annual insurance cost is 0.5% of fixed capital. Working capital is 2.5% of fixed capital.

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Residential Alternative 2 (RA2) assumes a full housing development rate of 139 homes per year over 30 years for a total of 4,242 homes. Peak design capacity for the geothermal well system is 27,100 gpm.

b. Commercial Area Alternatives

The existing commercial area consists of the Baca Grande Inn, 18 mobile homes, and the Corporate administration building. The geothermal system design and economic analysis includes the adaptation of these existing units during the first year and then two alternative growth rates for the future development of the commercial area.

Commercial Alternative 1 (CA1) assumes a moderate growth rate of 5 mobile homes per year for a total of 168 homes over 30 years. The Baca Grande Inn is retrofitted in the first year. One 44,100 square foot greenhouse unit is also constructed in the first year, with four more units added during the fifth year. Total peak capacity for the geothermal system is 4,745 gpm.

Commercial Alternative 2 (CA2) assumes a mobile home addition rate of 12 homes per year for a total of 378 homes over 30 years. Greenhouse construction is similar to CA1, except that an additional 5 acres is added in the tenth year for a total greenhouse development of 441,000 square feet. The geothermal system peak capacity is 9,267 gpm.

c. Greenhouse

The Greenhouse only alternative (GH) has been analyzed because of its prospective dominance of the energy consumption requirements for the commercial or residential area alternatives. The greenhouse case assumes a 352,800 square foot facility served by six 1,000 gpm production wells. One spare production well and one disposal well were provided for every three production wells.

3. Base Case Assumptions of Economic Parameters

The leading assumption for the economic analyses is that the geothermal energy utility systems would be established and operated as a municipal or possibly a special district utility. Municipalities are authorized by Colorado State Statutes to own and operate utility systems and are exempted from regulation by the State Public Service Commission. Therefore, the municipal geothermal utility would not be subject to Federal, State or local taxes. Factors which then must be addressed are the issuance of municipal bonds to provide the investment capital, the time schedule of capital investments, the interest rate for the municipal bonds, and the rate of reserve capital accumulation to the municipal utility.

Table 3

BACA GRANDE ECONOMIC DATA *

Commercial Area Alternative 1

Total Mobile Home Development -- 168 Units

Total Greenhouse Development - 220,500 square feet

YEAR	Annual Capital Expenditure (\$1,000)	Royalties (\$1,000)	Annual ^{**} Operating Costs (\$1,000)	Heat Utilized 10 ⁹ Btu/year
0				
1	1,077.6	4.4	64.5	17.4
2	175.9	4.5	72.7	17.9
3	20.9	4.6	74.0	18.5
4	20.9	4.8	75.2	19.1
5	948.5	19.1	152.3	76.4
6	20.9	19.3	153.6	77.0
7	20.9	19.4	154.7	77.6
8	20.9	19.6	156.0	78.2
9	175.9	19.7	163.3	78.8
10	20.9	19.9	164.5	79.4
11	20.9	20.0	165.7	80.0
12	20.9	20.2	166.9	80.6
13	20.9	20.3	168.1	81.2
14	20.9	20.5	169.4	81.8
15	20.9	20.6	170.5	82.4
16	20.9	20.8	171.7	83.0
17	20.9	20.9	172.9	83.6
18	20.9	21.0	174.0	84.2
19	20.9	21.2	175.2	84.8
20	20.9	21.3	176.4	85.4
21	20.9	21.5	177.6	86.0
22	20.9	21.6	178.8	86.6
23	20.9	21.8	180.0	87.2
24	20.9	22.0	181.2	87.8
25	20.9	22.1	182.4	88.4
26	20.9	22.3	183.6	89.0
27	20.9	22.4	184.7	89.6
28	20.9	22.6	186.0	90.2
29	20.9	22.7	187.1	90.8
30	20.9	22.9	188.3	91.4

* All data are presented in constant 1979 dollars.

* * Annual Operating Costs include royalties, auxiliary energy costs, administration, and annual maintenance and insurance costs; annual maintenance is 3.5% of fixed capital; annual insurance cost is 0.5% of fixed capital. Working capital is 2.5% of fixed capital.

Table 4

BACA GRANDE ECONOMIC DATA *

Commercial Area Alternative 2

Total Mobile Home Development -- 378 Units

Total Greenhouse Development -- 441,000 Square Feet

YEAR	Annual Operating Expenditure (\$1,000)	Royalties (\$1,000)	Annual ** Operating Costs (\$1,000)	Heat Utilized 10 ⁹ Btu/year
0				
1	1,117.6	4.5	71.6	18.1
2	215.0	4.9	81.5	19.5
3	65.0	5.3	85.4	21.0
4	65.0	5.6	88.9	22.4
5	1,175.2	20.2	170.7	81.8
6	65.0	20.5	184.1	83.2
7	65.0	20.9	187.1	84.7
8	65.0	21.2	190.0	86.1
9	65.0	21.6	193.0	87.5
10	1,227.6	39.7	285.2	159.8
11	220.0	40.0	294.8	161.2
12	65.0	40.4	298.4	162.6
13	65.0	40.7	307.0	164.1
14	65.0	41.1	310.0	165.5
15	65.0	41.5	318.0	167.0
16	65.0	41.8	320.9	168.4
17	65.0	42.2	323.9	169.9
18	65.0	42.5	326.8	171.3
19	65.0	42.9	329.8	172.7
20	65.0	43.3	332.8	174.2
21	65.0	43.6	335.7	175.6
22	65.0	44.0	338.7	176.1
23	65.0	44.3	341.6	178.5
24	65.0	44.7	344.8	179.9
25	65.0	45.0	348.4	181.4
26	362.6	45.4	363.7	182.8
27	65.0	45.8	367.2	184.3
28	65.0	46.1	370.7	185.6
29	65.0	46.5	374.2	187.2
30	65.0	46.9	377.6	188.6

* All data are presented in constant 1979 dollars.

** Annual Operating Costs include royalties, auxiliary energy costs, administration, and annual maintenance and insurance costs; annual maintenance is 3.5% of fixed capital; annual insurance cost is 0.5% of fixed capital. Working capital is 2.5% of fixed capital.

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Table 5
BACA GRANDE ECONOMIC DATA*

Commercial Area Alternative 3
Greenhouse Only
Capacity - 352,800 Square Feet

Initial Capital -- \$2,180,000
Total Annual Operating Cost -- \$158,200
Royalties -- \$28,300/year, included in Annual Operating Cost
Heat Utilized -- 113.3×10^9 Btu/year
Working Capital: Assume 2.5% of Fixed Capital
Annual Maintenance Cost: Assume 3.5% of Fixed Capital
Annual Insurance Cost: Assume 0.5% of Fixed Capital

* All data are given in constant 1979 dollars.

The capital investment and municipal bond issuance schedules assumed for the present evaluations are given in Tables 6 to 10. These schedules reflect certain real municipal financing considerations, including prospective utilization of the DOE Geothermal Loan Guaranty Program, and a minor constraint of the SEER program.

First, it must be recognized that the total capital investments over thirty years are individually small for four of the five systems; the exception is RA2 at a total investment of \$31,329,500. Second, the incremental annual investments are even smaller, except for two to three investments per case, RA2 excepted, each of which approximates \$1 million. Since municipal bond issuances in the marketplace are only practical for values in excess of \$1 million and since it would be costly due to interest charges to issue bonds for the total thirty-year investment at the beginning of year 1 (unless the municipality is able to reinvest the borrowed money at higher interest rates), it has been assumed that municipal bonds would be issued only at those times when capital investments (for a two-year minimum period) were of the order of \$1 million or greater. For Case RA2, five bond issuances, each covering investments for four years, are utilized. The total values of the bond issuances per case constitute the following percentages of the total thirty-year investments: RA1 - 72%; RA2 - 75%; CA1 - 76%; CA2 - 68%; GH - 100%. The bond issuances are designated as A-Bonds, B-Bonds, C-Bonds, etc., in Tables 6-10. The balance of the remaining incremental investments are assumed to be derived from the cash flow of the utility operations and/or the treasury of the municipality or special district.

Table 6

Schedule of Investments, Bond Issuances and Costs: Residential Alternative 1

Year	Biannual Capital Expenditures (\$1,000)	Bond Issuances (\$1,000)	Aggregated Fixed Capital (\$1,000)	Total Annual Operating Costs (\$1,000)
0				
1	3,231.2	3,231.2 (A)	3,231.2	173.4
2	-----		3,231.2	176.6
3	320.6		3,551.8	194.5
4	-----		3,551.8	204.7
5	1,423.2	1,423.2 (B)	4,975.0	267.5
6	-----		4,975.0	273.2
7	165.0		5,140.0	285.3
8	-----		5,140.0	291.4
9	138.4		5,278.4	302.1
10	-----		5,278.4	322.3
11	294.0		5,572.4	336.4
12	-----		5,572.4	338.7
13	138.4		5,710.8	347.1
14	-----		5,710.8	352.9
15	138.4		5,849.2	363.9
16	-----		5,849.2	369.8
17	138.4		5,987.6	380.7
18	-----		5,987.6	386.4
19	975.7	975.7 (C)	6,963.3	431.3
20	-----		6,963.3	436.8
21	138.4		7,101.7	452.8
22	-----		7,101.7	458.7
23	151.5		7,253.2	471.1
24	-----		7,253.2	493.3
25	138.4		7,391.6	499.6
26	-----		7,391.6	500.3
27	307.1		7,698.7	514.6
28	-----		7,698.7	518.9
29	138.4		7,837.1	528.1
30	-----		7,837.1	533.3

A - Bonds: 30 years

B - Bonds: 26 years

C - Bonds: 12 years

Table 7

Schedule of Investments, Bond Issuances and Costs: Residential Alternative 2

Year	Biannual Capital Expenditures (\$1,000)	Bond Issuances (\$1,000)	Aggregated Fixed Capital (\$1,000)	Total Annual Operating Costs (\$1,000)
0				
1	5,933.5	9,081.4 (A)	5,933.5	316.8
2	-----		5,933.5	355.6
3	3,147.9		9,081.4	522.1
4	-----		9,081.4	563.3
5	1,312.7	3,358.0 (B)	10,394.1	630.6
6	-----		10,394.1	674.1
7	2,045.3		12,439.4	795.0
8	-----		12,439.4	836.4
9	2,031.8	3,344.5 (C)	14,471.2	955.1
10	-----		14,471.2	994.2
11	1,312.7		15,783.9	1,090.9
12	-----		15,783.9	1,109.2
13	2,699.6	4,575.8 (D)	18,483.5	1,254.9
14	-----		18,483.5	1,294.1
15	1,876.2		20,359.7	1,408.6
16	-----		20,359.7	1,448.5
17	1,312.7	3,358.0 (E)	21,672.4	1,522.5
18	-----		21,672.4	1,556.5
19	2,045.3		23,717.7	1,672.2
20	-----		23,717.7	1,726.8
21	1,130.5		24,848.2	1,811.0
22	-----		24,848.2	1,850.5
23	2,045.3		26,893.5	1,971.4
24	-----		26,893.5	1,987.8
25	2,032.5		28,926.0	2,108.5
26	-----		28,926.0	2,148.0
27	1,130.5		30,056.5	2,232.4
28	-----		30,056.5	2,272.0
29	1,273.0		31,329.5	2,361.1
30	-----		31,329.5	2,378.5

A-Bonds: 30 years

B-Bonds: 26 years

C-Bonds: 22 years

D-Bonds: 18 years

E-Bonds: 14 years

Table 8

Schedule of Investments, Bond Issuances and Costs: Commercial Area Alternative 1

Year	Biannual Capital Expenditures (\$1,000)	Bond Issuances (\$1,000)	Aggregated Fixed Capital (\$1,000)	Total Annual Operating Costs (\$1,000)
0				
1	1,253.9	1,253.5 (A)	1,253.5	71.5
2	-----		1,253.5	72.7
3	41.8		1,295.3	74.8
4	-----		1,295.3	75.2
5	969.4	969.4 (B)	2,264.7	153.1
6	-----		2,264.7	153.6
7	41.8		2,306.5	155.6
8	-----		2,306.5	156.0
9	196.8		2,503.3	164.1
10	-----		2,503.3	164.5
11	41.8		2,545.1	166.5
12	-----		2,545.1	166.9
13	41.8		2,586.9	169.0
14	-----		2,586.9	169.4
15	41.8		2,628.7	171.3
16	-----		2,628.7	171.7
17	41.8		2,670.5	173.7
18	-----		2,670.5	174.0
19	41.8		2,712.3	176.1
20	-----		2,712.3	176.4
21	41.8		2,754.1	178.5
22	-----		2,754.1	178.8
23	41.8		2,795.9	180.8
24	-----		2,795.9	181.2
25	41.8		2,837.7	183.2
26	-----		2,837.7	183.6
27	41.8		2,879.5	185.6
28	-----		2,879.5	186.0
29	41.8		2,921.3	188.0
30	-----		2,921.3	188.4

A - Bonds: 30 years, 8% interest, 100% debt

B - Bonds: 26 years, 8% interest, 100% debt

Table 9

Schedule of Investments, Bond Issuances and Costs: Commercial Area Alternative 2

Year	Biannual * Capital Expenditures (\$1,000)	Bond Issuances (\$1,000)	Aggregated Fixed Capital (\$1,000)	Total Annual Operating Costs (\$1,000)
0				
1	1,332.6	1,332.6 (A)	1,332.6	80.2
2	-----		1,332.6	81.5
3	130.0		1,462.6	88.0
4	-----		1,462.6	88.9
5	1,240.2	1,240.2 (B)	2,702.8	173.3
6	-----		2,702.8	184.1
7	130.0		2,832.8	189.7
8	-----		2,832.8	190.0
9	65.0		2,897.8	193.0
10	1,447.6	1,447.6 (C)	4,345.4	294.0
11	-----		4,345.4	294.8
12	65.0		4,410.4	298.4
13	130.0		4,540.4	309.6
14	-----		4,540.4	310.0
15	130.0		4,670.4	320.6
16	-----		4,670.4	320.9
17	130.0		4,800.4	326.5
18	-----		4,800.4	326.8
19	130.0		4,930.4	332.4
20	-----		4,930.4	332.8
21	130.0		5,060.4	338.3
22	-----		5,060.4	338.7
23	130.0		5,190.4	344.2
24	-----		5,190.4	344.8
25	427.6		5,618.0	362.9
26	-----		5,618.0	363.7
27	130.0		5,748.0	369.8
28	-----		5,748.0	370.7
29	130.0		5,878.0	376.8
30	-----		5,878.0	377.6

* See departures from biannual schedule in years 9-12; total of 16 investments.

A - Bonds: 30 years

B - Bonds: 26 years

C - Bonds: 21 years

Table 10

Schedule of Investments, Bond Issuances and Costs: Greenhouse

Capital Investment: \$2,180,000 in Year 0

Bond Issuances:

A - Bonds (Revenue): \$1,635,000 in Year 1, 30 Years

B - Bonds (General Obligation): \$545,000 in Year 1, 10 Years

Total Annual Operating Costs: \$158,200

The 100 percent financing of the greenhouse was assumed to consist of 75 percent from revenue bonds and 25 percent from general obligation bonds. Whereas the greenhouse revenue bonds were extended over 30 years, the general obligation bonds were scheduled for only 10 years in order to release bonding capacity for other municipal requirements.

The computer program does permit a life-cycle cost analysis for a thirty-year investment period, but it is restricted to 20 separate investments and to five separate borrowings during that 30 years. Therefore, the annual investments for the present analysis were paired into 15 two-year investments, with each investment made at the beginning of the two-year interval. Similarly, the bond issuances were set in value equal to the corresponding required two-year capital investments, except for Case RA2 where the five bond issuances were set equal in value to the sum of four-year capital investments.

Another adaptation of the SEER program was made to accommodate the present analysis. Since new incremental capital investments are made all the way out through thirty years, it is desirable to allow a payback of the later investments from revenues derived in years of utility operation beyond thirty years. Therefore, utility operations for an additional fifteen years at the same levels as existed in the 30th year were projected. The costs and revenues were projected for the succeeding fifteen years and then discounted back at a 9 percent rate of return to obtain a net present value in the 30th year; these net present values of costs and revenues were added to the values for the 30th year; consequently, the revenues and operating costs were assumed to remain fixed. However, this approximation does provide an additional 15 years of revenues out of which to pay for the capital investments for which no bonds were issued.

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The municipal bond interest rate for the base cases was assumed to be 8 percent. This rate was selected after a survey of current issuances as reported in the Wall Street Journal, contacts with bond experts of financial institutions, and a discussion with one Colorado municipal comptroller. Interest rates for bonds issued in the past year have generally been in the 6-7 percent range, but have increased in recent months to 7-7.5 percent. Consensus for the current and future market seems to be for an interest rate around 8 percent. Some parties expressed a viewpoint that a rate higher than 8 percent might apply to a geothermal energy utility because of the technical risk and the lack of knowledge by investors. In addition, a higher rate is likely to apply to a newly created municipality which has no established bond rating in the municipal bonding markets. It must indeed be recognized that at this time no municipality exists for the Baca Grande Development site, no tax base has been established, and no revenue flow created. Hence, the assumed rate of 8 percent is highly optimistic; the sensitivity analysis includes an interest rate of 11 percent to show the effect on the consumer energy price.

The maximum life of the bonds was assumed to be the remaining number of years after year of issuance out to the 30-year life of the project. A repayment schedule of equal annual principal payments plus interest was selected. The implications of these assumptions on the results are discussed in Section E.

A utility reserve fund was assumed to be created from proceeds of the utility operation over the 30-year project life. A 9 percent rate of accumulation was assumed. This figure was derived from the aforementioned contacts with financial houses and municipal authorities. It is lower than the 15-16 percent "rate of return" typical of regulated investor-owned utilities, but it provides a municipal utility with income for future capital investments and/or for an in-lieu-of-tax payment to the municipality.

An additional factor in assuming an 8 percent bond interest rate for the base case calculations was the prospect of the municipality qualifying for a DOE Geothermal Loan Guaranty. The Geothermal Loan Guaranty Program (GLGP) does provide for loan guaranties to municipalities for the financing of geothermal energy systems, either electrical or direct thermal. The municipality has to obtain its financing in any of the usual ways (e.g., revenue bonds), but the feasibility of a Federal loan guaranty can facilitate the marketing of bonds and can impact the magnitude of the interest rate. Basic provisions of the present GLGP are that the loan guaranties are limited to a maximum of 75 percent of the estimated cost of a project and that at least 25 percent of the project cost must be in the borrower's equity. Therefore, a municipality would have to obtain 25 percent of the capital investments from general obligation or revenue bonds that would not be guaranteed by the GLGP; these bonds are likely to bear an interest rate higher than the guaranteed bonds.

4. Sensitivity Analyses

Sensitivity analyses have been performed on the variations of required revenue (cost of delivered energy) with inflation rate and bond interest rate. The base case for inflation rate was 0 percent, with analyses carried out for 5, 10, and 15 percent. All investment costs and all operating and maintenance costs were increased from the 1979 base-year costs, as tabulated in Tables 1 to 10, by the prescribed inflation rates. The electrical energy costs for system pumping, therefore, were escalated at these same rates. Likewise, the royalty payments were escalated but always from the base dollar value calculated at 10 percent of \$15.00 per barrel of oil equivalent.

The bond interest rates were varied from the 8 percent base case to include 6 percent and 11 percent rates. This sensitivity analysis was applied only to the base case with an inflation rate of 0 percent.

5. Calculational Procedures

The SEER analyses were first applied to the two residential and two commercial alternatives using base case parameters. The "average 30-year user costs" derived in the original calculations were utilized as input data for approximating the actual revenue requirements. The SEER analysis generated not only the actual 30-year revenue requirement for each case but also the business profitability measures for the utility operations based upon revenues equal to the assumed "average 30-year user costs." The same procedure was then followed to generate the actual revenue requirements for the sensitivity analyses in which the inflation rates and bond interest rates were varied.

Once the revenue requirements were obtained, then SEER was rerun using these revenue requirements to generate the cash flow projections over 30 years for all cases.

Finally, the calculated revenue requirements were transformed from 1979 (year 1) constant dollar values to levelized current dollar values over the 30-year period, using the following equation:

$$\text{Levelized Current Dollar Revenue} = \left(\left[\frac{(1+d)^n - (1+i)^n}{(1+d)^n - 1} \right] \cdot \frac{d-i}{1+i} \right) \times \text{Constant Dollar (1) Revenue}$$

Where: d = discount rate,
 i = inflation rate,
 n = years of project,

and $\frac{d}{1+i}$ = inflation adjusted discount factor.

6. Definition of Revenue Requirement Price (Constant and Current Dollars)

SEER calculates a revenue requirement price, or cost of delivered energy to the consumer, which will yield a specified rate of return

to the utility or energy producer. For cases in which the project costs, both capital and operating costs, are constant throughout the life of the project, the calculated revenue requirement price is a constant price charged to the consumer over the life of the project. If real cost increases are experienced by the utility during its operation, the utility will adjust upward its rate of charge to the consumer in order to assure that its rate of return is maintained.

When inflation occurs, both capital and operating costs are increased and, as a consequence, the utility must charge its customers more for the energy delivered. Future prices of delivered energy can be calculated assuming certain rates of inflation on the capital and operating costs that are identified at the beginning of a project (year 1979 in the present case). The calculated future energy prices can be expressed, for purposes of analysis and comparison, either in terms of an incrementally increasing price in each and every future year (the "current" year dollar charge to the consumer) or in terms of a levelized annual price. The current dollar price starts at a certain dollar amount in the first year and then incrementally increases each year at the assumed rate of inflation; the consumer would pay the increased rate beginning with each year after the first. The levelized annual price for a given assumed inflation rate is the fixed price the utility would charge its consumers from beginning to end of the project, if it adopted a fixed rate of inflation and made no changes in its investments or operations during the project life; application of the levelized annual price would guarantee the utility the assumed rate of return if indeed the investment costs, operating costs, and rate of inflation remained as specified at the outset of the project.

D. Results of SEER Economic Analyses

1. Geothermal Utility Base Cases

Table 11 presents a comparison of the 1979 energy costs to the consumer calculated for the base cases of the five geothermal utility systems. Base case assumptions include 0 percent inflation rate, 8 percent bond interest rate, and 9 percent rate of capital accumulation to the municipal utility.

The results for the two residential alternatives confirm the major impact that residential growth rates have on the cost of delivered energy to the consumer. The RA2 case yields a consumer cost that is almost one-half of that for case RA1. Even so, the absolute 1979 dollar cost of \$11.90/MMBtu associated with the full rate development of the residential area remains higher than the existing electrical energy cost of \$10.05/MMBtu equivalent.

The commercial alternatives and the greenhouse alone all have 1979 geothermal energy costs that are significantly lower than the existing electrical energy cost. The difference between CA1 and CA2 is not so great as to preclude development at the slower pace of CA1 or to dictate that a full-paced development must occur to be economical.

Table 11

Comparison of Calculated 1979 Energy Cost to the Consumer
(Constant Dollar Revenue Requirements (Dollars/MMBTU)) for Base Case Assumptions *

Case	Coury and Associates Results	Western Energy Planners Results
RA1 -- Residential Low Growth Rate	18.40	20.839
RA2 -- Residential Full Growth Rate	10.94	11.900
CA1 -- Commercial Low Growth Rate	6.01	5.809
CA2 -- Commercial Full Growth Rate	5.45	5.440
GH -- Greenhouse	3.51	3.20

* Bond interest rate = 8%; rate of capital accumulation = 9%; zero inflation rate.

The 1979 constant dollar cost of geothermal energy for the greenhouse must be regarded as highly attractive, even with respect to natural gas, if it were available in the area. A price of \$3.20/MMBtu must be considered cost competitive with natural gas at this time in many parts of the country.

2. Business Profitability Measures

Inasmuch as the C&A calculated values of "average 30-year user cost" were used as input revenue values for the SEER analyses, it may be informative to report and examine the business profitability factors that were calculated based upon those values and the other base case assumptions. Table 12 presents the results for the two residential and two commercial cases.

The target minimum rate of return for the evaluations was 9 percent, so the discounted cash flow rate of return (DCFROR) and the net present values (NPV) shown in Table 12 reflect the departures from 9 percent and zero NPV which the input revenues generate. An energy price of \$18.40/MMBtu for case RA1 yields a DCFROR of 5.664 percent and a NPV of negative \$1,076,809. If that energy price were cost competitive and if the utility were willing to settle for a rate of return of 5-6 percent, then the utility system for RA1 would be a reasonable investment.

The original calculated energy prices for Cases CA1 and CA2 are reasonably close to a target value for the rate of return of 9 percent. The DCFROR of 10.963 percent for CA1 indicates that the price to the consumer can be lowered.

Table 12

Business Profitability Measures Calculated for Assumed Constant Dollar Energy Price

(Inflation Rate = 0%, Bond Interest Rate = 8%)

Case	Constant 30-Year Energy Price (Dollars/Constant MMBTU)	DCFROR (%)	Net Present Value at 9% MINROR	Payback Period (Years)	Discounted Payback Period (Years)
RA 1	18.40	5.664	- 1,076,809	29.01	>30
RA 2	10.94	8.982	- 10,141	29.03	>30
CA 1	6.01	10.963	141,644	19.05	29.25
CA 2	5.45	9.132	16,031	23.31	29.95
GH	3.51	N.C.	N.C.	N.C.	N.C.

N.C. = Not Calculated

3. Results of Inflation Rate (Sensitivity) Analyses

Since inflation impacts the dollar values of future capital investments and total operating costs, it is necessary to examine the associated inflationary effects on the costs of delivered geothermal energy to the consumer. Therefore, sensitivity analyses have been performed for assumed inflation rates of 5, 10, and 15 percent.

The results of the inflation analyses are presented in Tables 13 and 14. Table 13 presents the revenue requirements for the first year (1979), and Table 14 lists the levelized consumer costs over the 30-year period. The result that the absolute numbers for the non-zero inflation rates are less than the zero-inflation values is a consequence of the fact that the real value of the interest payments by the utility is increasing as inflation increases; that is, the borrowing by the utility at fixed interest rates early in the project life provides a reduction of the impact of inflation on costs in future years.

The first year revenue prices in Table 13 would be escalated by the utility each year at the assumed inflation rate to obtain the required revenue in the current year for the amount of energy to be delivered in that year:

$$R_{t,i} = P_{0,i} (1 + i)^t \cdot H_t, \quad (2)$$

Where $P_{0,i}$ = base year price

i = inflation rate

t = year t

H_t = heat energy delivered in year t

$R_{t,i}$ = revenue in year t .

Table 13

First Year (1979) Energy Cost to Consumer (Dollars/MMBTU) as a Function of Inflation Rate (Bond Interest Rate = 8%)

Case	Inflation Rate			
	0%	5%	10%	15%
RA 1	20.839	15.00	11.585	9.920
RA 2	11.900	9.250	7.675	6.850
CA 1	5.809	4.507	3.710	3.290
CA 2	5.440	4.301	3.621	3.266
GH	3.20	2.450	1.900	1.625

Table 14

Levelized Energy Cost to Consumer (Dollars/MMBTU) as a Function of Inflation Rate (Bond Interest Rate = 8%)

Case	Inflation Rate			
	0%	5%	10%	15%
RA 1	20.839	25.841	39.095	73.850
RA 2	11.900	15.936	25.900	50.996
CA 1	5.809	7.764	12.520	24.490
CA 2	5.440	7.410	12.220	24.310
GH	3.20	4.220	6.412	12.098

Table 14 presents the levelized energy costs to the consumer, calculated from Equation 1. These are the prices the utility would apply at the start of the first year and maintain throughout the life of the project in order to compensate at the outset for a fixed inflation rate and to assure a minimum rate of return of 9 percent. These current dollar prices may be compared with inflation-adjusted discounted prices for other competing fuels.

4. Results of Bond Interest Rate (Sensitivity) Analyses

The effects of varying the interest rate on the municipal bond issuances is presented in Table 15. Interest rates of 6, 8, and 11 percent were applied to the other base case assumptions.

Table 15

Energy Cost to the Consumer (Dollars/MMBTU) as a Function of Bond Interest Rate (Inflation Rate = 0%)

Case	Bond Interest Rate		
	6%	8%	11%
RA 1	19.577	20.839	N.C.
RA 2	11.100	11.900	13.125
CA 1	5.445	5.809	N.C.
CA 2	5.123	5.440	5.990
GH	N.C.	3.20	N.C.

N.C. = Not Calculated

A reduction in the bond rate from 8 percent to 6 percent naturally makes all geothermal utility cases more favorable. Case RA1 at \$19.577/MMBtu, however, remains noncompetitive with existing electrical energy. Case RA2 at \$11.100/MMBtu also is higher than the \$10.05/MMBtu for the existing electrical energy source, but can be considered competitive. An 11 percent bond rate would keep the geothermal systems for the commercial cases substantially competitive.

A municipal bond interest rate of 11 percent is considerably greater than anything being experienced today in the marketing of municipal securities. While it can readily be incorporated into a parametric analysis, the implications of the other economic factors that would be associated with the real world of an 11 percent municipal bond rate cannot be evaluated within the scope of this project. Therefore, the validity of the calculated energy costs for the 11 percent rate must be held in question.

5. Cash Flow Requirements

As stated in Section C, the SEER-computed base year revenue requirements (those contained in Table 13) were subsequently provided as input to SEER in order to generate the cash flow projections for the assumed geothermal utility systems. A comparison of the net cash flow requirements for each year over the 30 years is given in Table 16 for the base cases. However, no attempt has been made to structure an optimum cash flow environment for the municipal utility.

In all cases, heavy deficits in net cash flow are projected for the early years of the utility operations. Since the capital investments were generally prescribed for the odd numbered years, i.e., the odd year of an odd-even pair of years, one must really look at the sum of the net cash flows for the odd-even pairs rather than the

Table 16

Comparison of Net Cash Flow Requirements for
Inflation Rate of 0% and Bond Interest Rate of 8%

Year	C A S E				
	RA1	RA2	CA1	CA2	GH
0					54,500 CR
1	21,423	3,671,540	13,197	2,714	79,040 CR
2	300,144 CR	1,586,525 CR	143,569 CR	161,280 CR	70,320 CR
3	558,622 CR	3,605,959 CR	179,894 CR	283,874 CR	61,600 CR
4	201,719 CR	1,204,791 CR	133,280 CR	148,851 CR	52,880 CR
5	121,056 CR	2,113,976	102,665	67,931	44,160 CR
6	342,077 CR	1,395,707 CR	8,949 CR	85,771 CR	35,440 CR
7	443,550 CR	2,046,395 CR	42,072 CR	203,396 CR	26,720 CR
8	220,743 CR	1,101,682 CR	7,644	63,806 CR	18,000 CR
9	295,806 CR	2,353,831	190,379 CR	118,145 CR	9,280 CR
10	111,509 CR	1,923,368 CR	14,337	228,782	560 CR
11	223,031 CR	1,054,015 CR	18,686 CR	29,115 CR	62,660
12	10,726	779,061 CR	31,030	52,636	67,020
13	61,437 CR	3,129,503	2,193 CR	64,799 CR	71,380
14	140,160	1,176,173 CR	47,523	80,482	75,740
15	64,497	812,886 CR	14,600	36,453 CR	80,100
16	263,594	1,439,699 CR	64,316	108,929	84,460
17	187,831	2,830,699	31,193	2,906 CR	88,820
18	386,928	774,463 CR	81,009	142,475	93,180
19	395,355	1,350,911 CR	47,886	29,996	97,540
20	288,806	364,460 CR	97,702	175,821	101,900
21	220,539	129,598 CR	64,579	63,542	106,260
22	421,733	295,353	114,395	203,927	110,620
23	352,265	442,895 CR	81,272	96,989	114,980
24	557,459	581,756	130,988	242,070	119,340
25	472,392	744,417	97,965	162,695 CR	123,700
26	682,585	293,567	147,682	255,216	128,060
27	438,108	1,249,319	114,558	142,781	132,420
28	814,111	1,674,170	164,275	287,019	136,780
29	747,744	1,731,532	131,251	175,128	141,140
30	10,883,330	33,256,488	2,353,725	4,361,628	200,000

CR = Credit = Negative Cash Flow

individual years. Even so, paired-year deficits are projected for Case RA1 through the 12th year, and for Cases CA1 and CA2 through the 10th year; deficits for the greenhouse are also projected through the 10th year. Case RA2 has negative cash flows for the odd-even year pairs starting in years 2, 7, 11, 15, and 19.

More important, the cumulative net cash flows remain negative out to 20 or more years for the assumed financial operations. The immediate implications of these results are that the municipal utility would have to draw heavily upon the municipal treasury for cash, that the utility would have to issue more revenue bonds at the outset of the operations, or that the utility would have to charge higher rates to its consumers to provide for its cash flow requirements.

In the former case, the municipality might consider the overall 9 percent rate of capital accumulation from the utility to be fair compensation for use of its cash reserve. However, municipalities are often restricted by State law from using general revenues to operate municipal utility systems; that is, some State laws provide that the municipal utility operations must be self-sufficient. In Colorado, municipalities cannot use property tax revenues to pay for the operations of utilities, but they can draw upon other general revenues.

Another option available to the utility is to structure the pay-offs of the revenue bonds on a different schedule than the one assumed. The assumed schedule is one of equal annual principal payments plus interest. An alternative schedule would be equal annual "mortgage" (principal + interest) payments. In this schedule, the total interest costs would be higher but the annual payments would be lower. A third alternative is to establish a bond payoff schedule that is specially designed to solve the cash flow problems of the early years; an example would be to delay principal payments for the first several years. This is often done in the issuance of municipal revenue bonds.

In order to approach a determination of the effect that the above options would have on the cash flow, a special SEER analysis was carried out for Case RA2. It was assumed that the municipal utility would borrow the total capital requirements for the 30-year project in the first year and would issue bonds in that amount, namely \$31,329,500. Secondly, a repayment schedule of equal annual mortgage payments was assumed. The analysis was applied only for the base case assumptions (0% inflation, 8% bond interest).

The calculated energy cost to the consumer is \$11.250/MMBtu, which is less than the \$11.900/MMBtu value calculated for the RA2 base case. The basic reason for the decrease is that the assumed interest rate of 8 percent is less than the 9 percent rate of capital accumulation that is assumed for the utility; it is implicitly assumed in the SEER computation that the utility can derive a 9 percent effective return on the use of the borrowed money before

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it is spent on the year-to-year capital investments. Therefore, the energy price difference reflects a "1% net gain" for the utility. If the rate of capital accumulation were reduced below 8 percent (the bond interest rate), then the calculated energy cost would go up.

The time occurrence of the impact of changes in the rate of capital accumulation is extended by the fact that regular positive cash flows only occur near and after the 3-year mark for the cases analyzed. It is largely the revenue generation and accumulation in the later years that produces the implicit investment or use value of the reserve funds and which influences the revenue requirement for the total project life. A reduction in the specified rate of capital accumulation first reduces the gain in value of the reserve funds and then increases the revenue requirement or energy cost to the consumer.

The revised borrowing and payback schedule for the special case of RA2 does indeed alter the cash flow picture for the utility during the early years. The yearly cash flow requirements are presented in Table 17. The excess funds borrowed in the first year provide coverage for the cash flow requirements through the 7th to 8th years, without allowance for the reinvestment or value of use at 9 percent of that money to the utility; with allowance for a 9 percent annual accumulated value for the excess funds, the cash flows would remain positive for additional years. Refinancing of the outstanding debt in later years then might be instituted to address the cash flow requirements remaining in those years.

The determination of acceptable and practical cash flow solutions for the prospective geothermal utility systems was not the primary objective of this expanded economic analysis. More extensive sets of analyses would be required to optimize the borrowing, investment, and payback schedules so as to achieve satisfactory cash flows for the preferred parametric values of interest rates and rate of capital accumulation. The additional SEER analysis described above can only serve to indicate the magnitude of change in energy costs to the consumer that will occur.

E. Findings and Conclusions

The SEER procedure for economic evaluations is based upon long established and proven economic principles. However, it must be recognized that practicing economists utilize many different and varying analytical tools and criteria for evaluating investments, rates of return, cash flow requirements, and taxation. Private utilities in particular have evolved many unique approaches to determining revenue requirements for their rate hearings before State public utility commissions. The U.S. Internal Revenue Service and the several State bureaus of revenue also have devised specific ways of computing taxable income of investor-owned utilities. Hence, the SEER method cannot be construed to be the one and only proper analytical method for evaluating energy and mineral investments. However, for private investments it does offer the special capability of evaluating several business profitability measures simultaneously or selectively.

Table 17

Net Cash Flow Requirements for Special SEER Analysis of Residential
Alternative RA2 (Inflation Rate of 0%, Bond Interest Rate of 8%)

<u>Year</u>	<u>Case RA2 - Special</u>
1	\$ 25,900,396
2	3,372,070 CR
3	5,428,396 CR
4	3,064,121 CR
5	3,140,246 CR
6	2,925,796 CR
7	3,624,121 CR
8	2,727,046 CR
9	2,663,671 CR
10	3,217,121 CR
11	2,408,146 CR
12	2,193,571 CR
13	2,921,121 CR
14	2,676,146 CR
15	1,794,771 CR
16	2,503,496 CR
17	1,672,946 CR
18	1,475,071 CR
19	2,154,096 CR
20	1,270,221 CR
21	1,137,870 CR
22	815,496 CR
23	1,656,320 CR
24	734,246 CR
25	674,096 CR
26	1,227,523 CR
27	374,348 CR
28	52,072 CR
29	97,221
30	25,937,424

CR = Credit = Negative Cash Flow

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The results of SEER analyses have the greatest meaning and value when the SEER methodology is applied to all alternative investments or to all competitive energy supply systems. Therefore, there is considerably greater value in the internal comparison of the five geothermal utility systems treated in this study than in the comparison of the present results with the original calculations for the project or the energy prices for competing utilities.

The original pricing calculations developed by Coury and Associates, Inc., are a fully acceptable method for estimating yearly energy costs and average costs over the life of a project. The major differences are in the presentation of the numerical results and in the accounting of specific costs. The C&A method both prescribes and implies very high energy prices to the consumer for the early years of a project; see Tables 18 and 21. In addition, the annualized capital costs are based upon a single percentage estimate of the aggregate payments for principal, interest, insurance, and maintenance. Finally, the C&A results have assumed a zero inflation rate for capital investments and all operating costs over the next 30 years.

Major objectives of the present study, therefore, have been to introduce more specific accounting of costs, to determine the impacts of inflation on future energy prices, and to calculate energy costs to the consumer in terms of first-year and levelized current dollar values.

1. Comparisons of the Five Geothermal Utility Systems

It is clear from the SEER analyses that a nearly full development rate for the residential area would be required to make the geothermal system cost-effective. The energy price difference between Cases RA1 and RA2 is substantial. It is apparent that the low heat demand for Case RA1 is a significant factor in the high energy price. Only a more uniform, higher demand for energy will reduce the price per million Btu to the residential consumer for Case RA1.

The economics for the two commercial area alternatives are both favorable. Undoubtedly the continual demand for a substantial fraction of the total energy by the greenhouses contributes both to the lower energy prices relative to the residential systems and to the small difference in prices for the two commercial development rates. This conclusion is justified by the findings for the greenhouse only case. The projected energy prices for the greenhouse are highly favorable under base case assumptions as well as under the variations in inflation rate and bond interest rate that were evaluated.

Integration of all energy-consuming components of Cases RA2, CA2, and GH into one geothermal utility system with equal rates to all consumers would yield an intermediate energy price that would be cost-effective and cost-competitive with the existing electrical energy rates.

Table 18
Economic Summary

Residential Alternative 1

Housing construction - 20 units per year
 Total development - 672 housing units
 Geothermal System peak design capacity - 4,300 gpm
 Distribution from Production Area III

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10^9 Btu/yr	User Energy Cost \$/ 10^6 Btu
1	472.3	44.2	12.9	40.03
5	543.2	68.5	24.1	25.38
10	791.8	111.2	38.1	23.70
15	867.0	129.9	52.1	19.13
20	1,044.5	158.3	66.1	18.19
25	1,098.4	203.9	80.1	16.25
30	1,175.6	219.8	94.1	14.83

Average 30-year user cost \$18.40 per million Btu

Table 19
Economic Summary
Residential Alternative 2

Housing construction - 139 units per year
 Total development - 4,242 units per year
 Geothermal system peak design capacity - 27,100 gpm
 Distribution from Production Area III
 Annualized costs @ 15%

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10^9 Btu/yr	User Energy Cost \$/ 10^6 Btu
1	794.6	79.5	29.6	29.53
5	1,463.6	214.8	107.5	15.61
10	2,170.7	415.4	204.8	12.63
15	2,846.6	594.2	302.2	11.38
20	3,557.6	778.1	399.6	10.85
25	4,131.5	951.5	496.9	10.23
30	4,699.4	1,125.3	594.3	9.80

Average 30-year user cost: \$10.94 per million Btu

Table 20

Commercial Area Alternative 1

Total Mobile Home Development - 168 units
Total Greenhouse Development - 220,500 square feet
Geothermal System peak design capacity - 4,745 gpm
Distribution from Production Area II.

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10^9 Btu/yr	User Energy Cost \$/ 10^6 Btu
1	161.6	21.4	17.4	10.51
5	336.6	62.5	76.4	5.22
10	375.5	64.4	79.4	5.54
15	391.2	66.2	82.4	5.55
20	406.8	67.9	85.4	5.56
25	422.5	69.7	88.4	5.57
30	438.2	71.5	91.4	5.58

Average 30-year user cost: \$6.01 per million Btu.

Table 21

Commercial Area Alternative 2

Total Mobile Home Development - 378 units
Total Greenhouse Development - 441,000 square feet
Geothermal System peak design capacity - 9,267 gpm
Distribution from Production Area II

Year	Annualized Capital Costs (\$1,000)	Total Operating Costs (\$1,000)	Heat Utilized 10^9 Btu/yr	User Energy Cost \$/ 10^6 Btu
1	167.6	26.5	18.1	10.72
5	395.7	65.2	81.8	5.63
10	618.8	120.2	159.8	4.62
15	690.8	133.8	167.0	4.90
20	739.6	135.6	174.2	5.02
25	788.3	138.2	181.4	5.11
30	881.7	142.5	188.6	5.43

Average 30-year user cost: \$5.45 per million Btu

The economics for the two commercial area alternatives are both favorable. Undoubtedly the continual demand for a substantial fraction of the total energy by the greenhouses contributes both to the lower energy prices relative to the residential systems and to the small difference in prices for the two commercial development rates. This conclusion is justified by the findings for the greenhouse only case. The projected energy prices for the greenhouse are highly favorable under base case assumptions as well as under the variations in inflation rate and bond interest rate that were evaluated.

Integration of all energy-consuming components of Cases RA2, CA2, and GH into one geothermal utility system with equal rates to all consumers would yield an intermediate energy price that would be cost-effective and cost-competitive with the existing electrical energy rates.

The impacts of non-zero inflation rates on the geothermal energy prices have been determined and are significant, as one would expect. The advantage that geothermal systems generally have over conventional energy supply systems is that of low and fixed "fuel source" costs. Fuel price escalation for oil, gas, coal, and uranium caused by crude oil price increases and inflation leads to continuing increases in the delivered energy prices. The price differences between conventional energy systems and the geothermal systems considered in this study are moderated by the fact that the capital investments for the geothermal systems are spread out over 30 years. Inflation impacts not only the annual operating costs, but also the incremental capital investments. This consequence is more significant under the general assumption of a municipal utility when the bond interest rates and rate of capital accumulation are less than the rate of inflation. The prospect of drawing more of the capital investments and system construction into the first year deserves consideration by the developer.

The effects of different bond interest rates are important but are not as great as changes in the inflation rate. This is a consequence again of the fact that the inflationary impacts on capital investments and operating costs are cumulative over the entire 30 years whereas the bonds are issued at only a few times with fixed interest rates and are paid off incrementally over the years. Overall, changes in the bond interest rate do affect the energy prices to the consumer but do not preclude the economic feasibility of the geothermal systems, except for Case RA1.

2. Comparison of SEER Results with Original Calculations

The "average 30-year user costs" calculated by C&A compare very well with the SEER values of constant dollar revenue requirements for Cases RA2, CA2, and GH under a zero inflation rate assumption; in addition, the prices for Case RA1 agree within 10 percent.

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The favorable comparison of energy costs is remarkable in view of the differences in methodologies and in assumptions. The original calculations were based upon an annualized costing procedure. The user energy cost for a given year was determined by taking 15 percent of the aggregated capital investment through that year, adding the total operating costs for the year and dividing the sum by the heat energy utilized in the year. The thirty-one energy costs were then averaged to obtain the "average 30-year user cost." The 15 percent rate applied to the aggregated capital investment was based upon a 30-year payback period of equal mortgage payments for each annual capital investment and an interest rate of 10.5 percent on the borrowed money.

For the SEER computations, the number of bond issuances was restricted to five or less, the overall debt was held to the 65-75 percent range, the payback periods on the bonds were reduced from a 30-year maximum to the number of years between the year of issuance and the 30th year of the project, and a bond payoff schedule of equal annual principal payments plus interest was used. The effect of each of these variables on the energy cost to the consumer has not been determined in this analysis. While qualitative statements can be ventured as to the direction of impact of changes in these variables on the energy cost, quantitative specification would require a separate set of parametric evaluations for each variable.

Perhaps the most valuable results of the SEER analyses in relation to the original calculations are the determinations of the first-year energy costs to the consumer and the levelized current dollar revenue requirements for the three assumed inflation rates. These numbers allow calculation of the geothermal energy prices for future years and comparison with inflation-adjusted discounted rates for competitive energy systems.

3. Competitiveness of a Geothermal Energy Utility

A full examination of the competitive position of the five geothermal utilities relative to conventional energy systems requires either an application of the SEER methodology to the conventional systems or more detailed information on the present and future energy prices for the conventional systems. However, the single value for the existing electrical energy cost of \$10.05/MMBtu equivalent is useful for specifying the present competitive position of the prospective geothermal utility systems. It can be clearly stated that the geothermal systems for Case CA1, CA2, and GH are clearly cost-effective and competitive with the available electrical energy supply system and that Case RA2 is almost cost-competitive. Furthermore, it is highly likely that the four geothermal systems would remain competitive for at least the near-term under conditions of inflation approaching 10 percent. Based on limited knowledge of projected electrical energy costs, it can be speculated that the geothermal systems would continue to be cost-competitive over the entire 30 years.

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4. Additional Considerations

Two additional topics deserve further discussion here. One concerns the municipal debt and equity assumptions used in the present analyses and the other concerns the prospective applicability of the DOE Geothermal Loan Guaranty Program (see Attachment I for a brief description of this program). The assumption of debt to equity ratios approximating 75 to 25 for the two residential and two commercial alternatives was made both to represent what a new municipal utility might be faced with in the financial marketplace and to qualify the revenue bonds for a Geothermal Loan Guaranty.

The net cash flow requirements analysis revealed, however, that the municipal utility would experience severe cash flow difficulties for many years unless the utility could draw upon the municipal treasury. In Colorado, it appears that State law would permit a transfer of funds between municipally owned enterprises, except for property tax revenues. However, a 100 percent debt financial plan with a specially structured repayment schedule might be necessary to resolve the cash flow problem. The net cash flow analysis for Case GH, which did assume 100 percent financing with equal annual principal payments, suggests that a specially structured repayment schedule would be necessary.

At the outset of the present evaluations, it was assumed that 25 percent equity computed for the total aggregated capital investment requirement would qualify the municipal utility for a Geothermal Loan Guaranty. The Geothermal Loan Guaranty Program regulations require, however, that the equity fraction must be equal to or greater than 25 percent at every time point over the life of the loan guaranty. This provision limits applicability of the Federal guaranty only to 75 percent of the bond values issued in year 1, and subsequent years until a 25 percent equity is established. If the municipality has bonding capacity and credit to issue general obligation bonds for the remaining 25 percent of the capital investment, that capital can qualify for the Loan Guaranty equity requirement.

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ATTACHMENT I

A. The Geothermal Loan Guaranty Program

Development of our nation's Geothermal Energy Potential is an important goal. Fast, efficient geothermal commercialization will help lessen the impact of rapidly rising petroleum prices and will aid in the effort to decrease our dependence on external energy supplies. Development of the resource and resource utilization technologies will also add to the economic base of those regions where the resources are located by attracting new industries.

The key to these benefits is the early and rapid development of the resource and its uses. As with any new industry, accelerated development is accompanied initially by high financial risks to investment capital. In an effort to promote geothermal development during the high risk period, the Department of Energy (DOE) has been granted the authority to undertake loan risks that exceed levels acceptable in the private marketplace. For geothermal energy development the vehicle by which the DOE accepts these risks is the Geothermal Loan Guaranty Program (GLGP).

The purpose of the GLGP is to stimulate the commercialization of geothermal energy by minimizing the financial risk incurred by development capital lenders. Under the program the United States government pledges its full faith and credit to the lender to guarantee the repayment of principal and interest on geothermal development loans. The GLGP objective is to provide financial incentives for the early and rapid development of the geothermal alternative while helping to establish the resources and technologies necessary for a self-sustaining industry. As the industry develops, normal financial relationships between borrowers and lenders will also develop, eliminating the need for the GLGP. In addition, the opportunities afforded by the GLGP should help to stimulate new entrants into the field helping to foster competition in the industry.

The range of projects for which the GLGP is applicable is very broad. Any project that falls into one or more of the following categories is eligible for a loan guaranty.

- Determination and evaluation of the commercial potential of geothermal resources
- Research and development in geothermal extraction and utilization technologies
- Obtaining rights to geothermal resources
- Development, construction, and operation of equipment or facilities for the commercial production of electrical energy from geothermal resources
- Development, construction, and operation of equipment or facilities for nonelectric application of geothermal resources.

Any organization, public or private, can be granted a geothermal loan guaranty. According to the GLGP regulations, preferential consideration is given

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to those projects that are to be carried out by small independently owned and operated businesses and small utilities. In addition, priority consideration is given to projects that show promise of quickly resulting in geothermal applications, projects that use new technological advances, and projects that exploit the development of new geothermal resource areas.

Loan guaranties of up to 75% of the estimated cost of a project may be granted for up to 30 years. At least 25% of the project cost must be in borrower's equity. The maximum loan guaranty for a single project is set up at \$50,000,000 with allowances for larger amounts for projects considered to be in the national interest. The maximum loan guaranty amount that any single borrower may have outstanding is \$200,000,000. The granting of a geothermal loan guaranty does not prohibit the borrower from qualifying for or obtaining other Federal financial assistance.

Application for a geothermal loan guaranty is made to the DOE San Francisco (SAN) Office, which has national responsibility for administration of the program. The SAN Office evaluates GLGP applications and monitors ongoing GLGP projects.

The SAN Office works closely with the GLGP applicant to ensure that the application is complete and contains all information necessary for evaluation. The primary objective in evaluating an application is determining that a reasonable assurance of revenue exists for the payment of principal and interest on the loan. The GLGP applicant supplies project information in seven key areas: geothermal resource, engineering feasibility, product marketability, project financial projections, project management, environmental aspects, and legal requirements. The application evaluation process reviews the potential of the geothermal resource, the technical feasibility of the project, and the evidence of a market or potential market for the project's product or results. The evaluation determines whether sufficient financing has been arranged to carry out the project (including contingencies), whether projected cash flows are sufficient to repay the loan, and whether the borrower has a plan of operations for the timely and efficient completion of the project using environmentally acceptable processes. Finally, a review is made to determine that all Federal, State, and local legal requirements are met for both the project and the guaranteed loan.

At present, DOE Headquarters in Washington has approval authority based on the recommendations of the SAN Office.

As the Geothermal Loan Guaranty Program progresses, experience has been gained and the program has been modified to make it more attractive and viable for the potential applicant. Through policy and procedural changes, the supporting information for the GLGP application has been shortened and simplified. More flexibility has been added to the requirements for the borrowers' 25% equity. Further, it is not necessary for the borrower to have an established lender prior to submitting his application.

Expedient evaluation and approval procedures have been established to facilitate review and approval of the application. Normal evaluation and approval time have been established at approximately 4 months in the SAN Office and 2 months in the Washington-DOE Headquarters.

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Recent legislative changes have increased the upper limit for loan guarantees from \$25,000,000 to \$100,000,000--the loan limit is currently set at \$50,000,000 until community impact assistance regulations are issued. Principal and interest assistance can be made available for certain projects, and special interest differential assistance is now allowed for those public projects that are partially financed through tax-exempt bonds. Additional changes have also been made to facilitate the marketability of guaranteed securities. Other regulatory changes now make it possible for the Department of Energy to borrow funds from the treasury if default payment is demanded and the geothermal resource development fund balance is depleted. These and other changes are currently being documented. Revised regulations and procedural documents will be made available in the near future.

For additional information on the GLGP and the application requirements and processes, contact the Manager of the DOE San Francisco Operations Office, at the address below:

Geothermal Loan Guaranty Office
San Francisco Operations Office--DOE
1333 Broadway
Oakland, California 94612

Area Code (415) 273-7151

B. Status of the Geothermal Loan Guaranty Program

To date, DOE has approved four guarantees under the Geothermal Loan Guaranty Program with total project costs of approximately \$43,000,000. Follow-on commitments to these projects total another \$102,000,000. Four additional applications are under review with guarantee requests totaling another \$88,000,000. In total, the Geothermal Loan Guaranty Program has approved, committed, or has under review, projects valued at \$233,000,000. Following are examples of Geothermal Loan Guaranty Projects/Applications.

1. Vegetable Dehydration Plant--Geothermal Food Processors of Fernley, Nevada, has constructed a vegetable dehydration plant at Brady's Hot Springs Nevada, using geothermal energy as a heat source. This plant is capable of processing 18,000,000 pounds of raw onions per year as well as other vegetables such as carrots, celery, bell peppers, chilli peppers, and potatoes. Geothermal fluids are used as process water and heat for the plant operations. It is estimated that the Company will save \$1.8 million in fuel costs over the next 15 years.

Delayed completion of the plant resulted in the Company experiencing some financial difficulties. However, additional equity capital has been acquired and DOE has increased the loan guaranty to provide the additional financing to complete the plant and start operations.

2. East Mesa Field Exploration Project--Republic Geothermal Inc. of Santa Fe Springs, California, has a loan guaranty to demonstrate the economic feasibility of producing electricity from the hot water underlining the East Mesa area. The first phase of the project provides for drilling eight

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production wells, seven of which have now been completed. Two supplementary applications are expected in the near future: one to build a 64 gross megawatt, double-flash power plant at East Mesa and the other for an expanded field to support the plant.

At the present time it appears that the East Mesa project will result in the first hydrothermal power plant in the country over 10 megawatts. This project will be a significant demonstration of the feasibility of a moderate temperature hot water resource for producing electricity since the East Mesa temperature and flow rates are both at the low end of the commercial range.

The Bank of America, Los Angeles, California, is providing the financing for this project.

3. Geysers Power Plant--The Northern California Power Agency of Santa Clara, California, has proposed the building of an electrical generating plant in The Geysers in California. The proposed project provides for 110 megawatt plant to be located in the Castle Rock Springs area of The Geysers. The Bank of Montreal (California) will provide the financing. The estimated costs are approximately \$60,000,000, of which \$45,000,000 will be guaranteed. DOE has signed a memorandum of understanding with the State of California and other Federal agencies to conduct a joint environmental review. This joint review approach is a first, and hopefully will set precedence for more effective and efficient environmental reviews.

4. Exploratory Drilling Project--Geothermal Kenetics, Inc., and the McCulloch Geothermal Corp. of Los Angeles have completed a drilling project at South Brawley, in the Imperial Valley of California. The project is financed by the Bank of Montreal. After completing the first well, a collapsed casing cut the well tests short. DOE agreed to increase its risk by allowing the borrowers to draw upon the balance of the guaranteed dollars to clean out the well and complete the well tests. The well tests were completed, and the well was tested at 75,000 pounds of steam per hour. From draw-down tests, the borrower believes that the well may be capable of delivering at or above 200,000 pounds of steam per hour. Wellhead temperatures were measured at 422°F. The borrower has submitted an application for full development of the resource for a 55-megawatt power plant.