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A DIRECT APPLICATION OF GEOTHERMAL ENERGY AT
THE L'EGGS PRODUCT PLANT, LAS CRUCES, NEW MEXICO

Final Report
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ABSTRACT

The study program to determine the feasibility of interfacing a potential geothermal resource of Dona Ana County, New Mexico L'eggs Products industrial process is discussed in this final report. Five separate sites were evaluated initially as to geothermal potential and technical feasibility. Preliminary analysis revealed that three sites were considered normal, but that two sites (about three miles from the L'eggs Plant) had very high shallow subsurface temperature gradients (up to $14.85^{\circ}\text{F}/100\text{ ft}$). An initial engineering analysis showed that to meet the L'eggs plant temperature and energy requirements a geothermal fluid temperature of about 250°F and 200 gpm flow rate would be necessary. A brief economic comparison indicated that the L'eggs plant site and a geothermal site approximately four miles from the plant did merit further investigation. Detailed engineering and economic design and analysis of these two sites (including the drilling of an 1873 feet deep temperature gradient test hole at the L'eggs Plant) showed that development of the four mile distant site was technically feasible and was the more economic option. It was determined that a single-stage flash system interface design would be most appropriate for the L'eggs Plant. Approximately 39 billion Btu/yr of fossil fuel could be replaced with geothermal energy at the L'eggs facility for a total installed system cost of slightly over \$2 million. The projected economic payback period was calculated to be 9.2 years before taxes. This payback was not considered acceptable by L'eggs Products, Inc., to merit additional design or construction work at this time.

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Introduction

This is the third and final report submitted to the U.S. Department of Energy by Energetics Corporation for the one year program "A Direct Application of Geothermal Energy at the L'eggs Products Plant, Las Cruces, New Mexico." The previous two interim technical reports were completed in March and June of this year. This report presents a summary of the previous work to provide clarity and continuity. Also, a more detailed discussion of the engineering work completed to date is provided along with a presentation of the final system design and projected economics.

Geothermal Sites Description

The L'eggs Products Hosiery Plant in Las Cruces, New Mexico, is located about 50 miles north of El Paso, Texas, in Dona Ana County of south-central New Mexico. Considerable geothermal assessment of this region indicates significantly higher than normal subsurface temperatures, which are exceeded in New Mexico only by the Valles Caldera area of north-central New Mexico (Ref. 1, 2, and 3).

Five locations were initially available to be evaluated for their geothermal potential and technical feasibility in providing process heat to the L'eggs Plant. These sites were designated Sites A through E as shown in Figure 1. Site A was the L'eggs Plant property and lies within the Rio Grande River basin. Site B was an abandoned gas well on Bureau of Land Management property approximately twelve miles south-southwest of the L'eggs facility. The geothermal rights for this site were held by Energetics Corporation. Site C was at an existing 860 ft deep geothermal test well on property owned by New Mexico State University. This site was 3.5 miles northeast of the L'eggs Plant. Site D was 3 miles northeast of the L'eggs Plant near a shallow temperature gradient test hole drilled by New Mexico State University. Site E was about 3 miles south of the L'eggs Plant within the river basin. Both Sites D and E were owned by private individuals. The elevations of the five sites are shown in Figure 2 along with the elevation profile for a straight line from each site to the L'eggs Plant. Sites B, C, and D were out of the Rio Grande River basin at elevations approximately 300 to 350 feet above this basin. Site E was within the basin area about 10 feet below the L'eggs Plant site.

FIGURE 1. SITE LOCATIONS FOR L'EGGS GEOTHERMAL STUDY PROGRAM,
LAS CRUCES, NEW MEXICO

FIGURE 2. ELEVATION PROFILES

During the course of the program an additional potential geothermal site was identified as an area about two miles due east of the L'eggs facility (shown as Site A' on Figure 1). It was expected that this area would have the same geothermal potential as Site D while having the advantage of being closer to the L'eggs Plant. Another advantage to this possible geothermal development site was that it was on Bureau of Land Management (BLM) property. Thus, geothermal lease rights could be obtained from the State of New Mexico Energy and Minerals Department by L'eggs Products. As discussed later, the lack of ownership of geothermal rights can deter potential development for a particular site. Site A' was not investigated further, however, due to a lack of funds (the available funds were used instead to drill a deep temperature gradient test hole at Site A, the L'eggs Plant property).

Geothermal Sites Analysis

Only Site C had a proven low temperature geothermal potential. But since significantly higher temperatures were required by the L'eggs process it was necessary to research the deeper geothermal potentials of all sites. The data used in evaluation of the five sites included temperatures of water wells, temperature gradients measured in existing wells, reconnaissance and detailed electrical resistivity, reconnaissance gravity, magnetic, heat flow and geologic data, and the available drilling logs of deep oil and gas wells. The available data are summarized in Table 1. The measured temperatures reflect the top of the water table (less than 650 feet) except for Sites A and C which were measured below the water table at depths of 1870 feet and 985 feet, respectively.

TABLE 1. SUMMARY OF GEOTHERMAL DATA

<u>ITEM</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>
Geochemical Temperatures($^{\circ}\text{C}$)					
NaKCa	62	147	184	179	66
SiO ₂	77	97	110	109	77
Average	70	122	147	144	71
Measured Temperatures($^{\circ}\text{C}$)					
Maximum	32	31	62	43	24
Average	19	26	53	39	20
Shallow Temperature Gradient ($^{\circ}\text{C}/\text{km}$)	26	70	270	215	25
Electrical Resistivity Anomaly	No	No	Yes	Yes	No

Other data including the temperatures of producing water wells located at or adjacent to each site and detailed temperature/depth measurements (temperature gradients) in abandoned water wells or other suitable boreholes located at each site were also utilized. Also, the technique of chemical geothermometry which utilizes the chemical constituents dissolved in the geothermal fluid (or any groundwater) to predict the subsurface temperatures below the sampling point was employed (Ref. 4).

The two most common methods of estimating subsurface temperatures chemical geothermometry and extrapolation of near surface temperature gradients, unfortunately, are subject to large uncertainties and potentially serious misinterpretation. Geochemical temperatures require water rock equilibrium and subsequent metastable conditions which may not exist in a given geologic environment. Furthermore, geochemical methods yield a subsurface temperature without providing information on which depth those temperatures exist. Since deep circulation as well as lateral migration of groundwaters are possible, geochemical temperatures may not reflect the true geothermal regime beneath a particular site. On the contrary, extrapolation of near surface temperature gradients require steady-state conductive conditions and knowledge of subsurface thermal conductivity. Steady-state conditions rarely exist in geothermal areas below a few hundred meters making this technique as hazardous as the geochemical methods.

Since estimating subsurface temperatures is an imprecise science the following three step approach was adopted in this program: First, only the temperatures actually measured were considered; next the temperatures estimated by extrapolation of "normal" temperature gradients were determined; and finally, a best guess estimate was made

on the basis of whatever data was available. Subsurface temperatures obtained by extrapolation of "normal" temperature gradients were thought to be reliable although they were suspected to be too low. Thus, the final step involved both a conservative and optimistic temperature estimate as given in Table 2 at several depths for each site. It should be noted that these temperature estimates were intended for preliminary design and engineering feasibility studies only. True subsurface temperatures can only be determined from actual measurements in drilled holes.

Examination of Tables 1 and 2 reveal that Sites C and D clearly showed the presence of a geothermal resource. Sites A and E, however, provided expected temperatures that were normal. Site B was estimated to have subsurface temperatures in between these conditions but only slightly above normal.

Site A was of specific interest in this study since it would obviously be advantageous to have the geothermal well at the point of use of the geothermal energy. However, "thermal masking" due to underflow from the Rio Grande River with the river basin area was expected. "Thermal masking" occurs when groundwater, circulating in high yield aquifers, sweeps away thermally heated water at a faster rate than it can be supplied from depth. In order to verify this theory and provide additional lithological data, a test hole (6 inch diameter) was drilled to a total depth of 1873 feet in hopes that an impermeable strata would be penetrated and allow the deep geothermal gradient to be measured. After drilling of the test hole, it was found that thermal sweeping was, in fact, occurring as indicated in the temperature log for the L'eggs test well (Site A) in Figure 3.

TABLE 2. ESTIMATED TEMPERATURES FOR ENGINEERING FEASIBILITY STUDIES AND ECONOMIC ANALYSIS

<u>Depth (m)</u>	<u>Conservative Estimates °C</u>				
	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>
500	29	35	65	50	20
1000	38	50	75	60	38
2000	60	85	100	85	60
3000	120	120	120	120	120
<u>Depth (m)</u>	<u>Optimistic Estimates °C</u>				
	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>
500	29	40	75	60	30
1000	48	60	85	70	45
2000	93	100	130	110	100
3000	138	140	185	150	130

Figure 3. GEOTHERMAL GRADIENT IN L'EGGS WELL
SITE A, LAS CRUCES, NEW MEXICO

The temperature gradient in the upper 360 feet was effected by shallow groundwater circulation. Below this depth a quasi-conductive gradient of about $1.46^{\circ}\text{F}/100$ feet extended down to a depth of slightly over 1650 feet where a lithologic change occurred. Based on cutting samples and geophysical well logs, this change was the impermeable strata referred to above. Thus, the region between 360 and 1650 feet is probably effected by "thermal masking" which caused the less than normal temperature gradient. However, below about 1650 feet a higher temperature gradient of about $2.46^{\circ}\text{F}/100$ feet was experienced. This higher temperature gradient was extrapolated to obtain the optimistic temperature estimates for Site A in Table 2.

Flow rates were even more difficult to predict than subsurface temperatures because the requisite data on aquifer transmissivity was not available. However, a general rule of thumb is that flow rates will decrease with depth (due to overburden pressure) and also decrease with increasing temperature (impermeable beds are requisite to the buildup of high subsurface temperatures). Thus, although shallow aquifers were expected to produce roughly 200 to 300 gpm per well from intergranular porosity, deeper aquifers were known to possibly not produce at all unless fracture permeability or porous limestones or dolomites were present. This uncertainty in well flows accompanies all geothermal development programs where little or no production drilling activity has been completed. In this study program, the probability of obtaining the required well production rate for the process was considered similar for all sites. The absolute value of this probability was not identified in this work.

L'eggs Process Description and Thermal Energy Use

The L'eggs Products plant in Las Cruces, New Mexico, produces the well known L'eggs brand of pantyhose with an output of about forty-eight million pair annually. The plant utilizes both electrical and thermal energy in its operation. Electrical energy provides the power for cooling the plant, compressing air, knitting, sewing, and lighting. Thermal energy (steam generated from fossil fuels) was used in the plant for domestic hot water, process heat for dyeing of the hosiery, building heat for temperature and humidity control, and for deaerating the condensate supplied to the boilers.

The steam is generated by a pair of fire tube boilers that fire No. 2 fuel oil, LPG, or natural gas to generate 110 psig and 344°F saturated steam. Table 3 shows the approximate annual thermal energy consumption of the L'eggs Plant. In addition to the end uses mentioned above, the thermal energy losses associated with the system operation are shown. These losses include boiler blowdown losses, boiler stack hot gas losses, deaerator blowdown losses, miscellaneous steam and condensate leaks, and pipe heat losses.

Table 3 shows the actual thermal energy use of the L'eggs Plant for the one year period of July 1978 to June 1979. As shown, the significant thermal energy uses are process dyeing and building HVAC (heating, ventilation, and air-conditioning). The 1978-79 energy usage was about 47% higher than the projected 1980-81 energy use due to the expected startup of an energy conservation project in 1980. This conservation project, the dye house heat reclaim project shown in Figure 4, was recently completed by L'eggs and had a significant impact on the program's geothermal system design requirements in terms of temperature and economics.

TABLE 3. ANNUAL THERMAL ENERGY REQUIREMENTS AT THE
L'EGGS PRODUCTS, LAS CRUCES, NEW MEXICO PLANT
(Billion Btu/yr)

	<u>Projected 1980-81</u>	<u>Actual 1978-79</u>
Fuel Input	<u>38.98</u>	<u>57.37</u>
Boiler Losses		
Stack Losses	7.99	11.76
Miscellaneous losses	.78	1.15
Blow down losses	<u>2.89</u>	<u>2.89</u>
Total Boiler Losses	11.66	15.80
Useful Steam Generated	<u>27.32</u>	<u>41.57</u>
Dyeing Eenergy Requirement	9.95	18.34
Drying Energy Requirement	-0-	4.76
Drying Condensate losses	-0-	1.68
Deaerator blow down losses	.58	.58
Domestic Hot Water	.25	.25
Miscellaneous Losses	4.02	4.02
Building HVAC	<u>12.52</u>	<u>12.52</u>
Total of all Uses	27.32 <u>27.32</u>	41.57 <u>41.57</u>

Projected 1980-81 Usage Based on Operation of Dye House Heat Reclaim Project.

FIGURE 4. DYE HOUSE - HEAT RECLAIM PROJECT

The dye process is a batch process where warm water at 122°F in a dye tank is heated at a controlled rate (approximately 3°F/min) by direct steam injection up to the dye set temperature (typically 212°F), then stirred for several minutes, and finally dumped. This dumped hot water is then used at the L'eggs Plant to preheat incoming cold water and to heat air used for hosiery drying (see Figure 4). The cooled dye water is subsequently discharged from the plant. Steam is used in the building HVAC system for space heating in the winter and for reheat throughout the year. The knitting and inspection areas of the L'eggs Plant are controlled to both temperature and humidity conditions and thereby require steam for reheat of the delivered air stream. It was estimated, based on calculated and derived heating loads, that the average steam demand for dyeing and HVAC use was 1600 lb_m/hr and 1400 lb_m/hr, respectively. Peak steam loads (which could be simultaneous) were estimated to be 3800 lb_m/hr and 3500 lb_m/hr for the corresponding dye process and HVAC heating requirements.

Although these thermal energy uses were provided by steam generated at 110 psig/344°F, the steam was regulated to 35 psig and 281°F at the point of use. In addition, the actual processes required a much lower temperature (212°F for dyeing and about 95°F for space heating). However, this temperature difference enhanced heat transfer capability and thereby required smaller heat exchange equipment than would be necessary otherwise. This information provided the rationale necessary to interface a potential geothermal resource with the L'eggs process and identified the two temperature ranges and peak energy delivery rates required to satisfy the plant needs.

Engineering Aspects of Geothermal Energy Usage

Engineering investigations necessary to define a preliminary system design and to provide budgetary cost estimates were also com-

pleted during this program. Well drilling and completion costs were estimated based on drilling times and equipment and material costs. Geothermal fluid pumps were evaluated and their resulting cost determined. The transport of the geothermal energy via pipe line was studied, including material requirements, fluid pressure drop, pipe line heat loss, and construction cost. Also the heat loss from a geothermal well bore was studied with an analytical closed-form solution derived by Energetics for the steady-state temperature of homogeneous flow in a well bore. Finally, a conceptual interface design between a geothermal resource and the L'eggs plant was proposed with preliminary cost and operating parameters determined. These investigations are discussed in the following paragraphs of this section.

Well Drilling

Well drilling and completion costs were particularly difficult to predict due to the many unknowns associated with this type of work. While drilling contractors quote an hourly or daily drilling rate, they do not quote how fast they will drill. Also, if an area is relatively unexplored, which was the case for this area (for the depths required), an additional unknown is involved. Therefore, drilling costs were, at best, only budgetary costs that could be loosely correlated with well depth or drilling time. Geothermal well drilling and completion costs were estimated from previous Department of Energy geothermal projects (Ref. 5) and other geothermal project well costs (Ref. 6). In addition, separate estimates based on drilling equipment rental rates, projected drilling times, casing and

cementing costs, and drill bit and drilling mud expenses were completed by Energetics Corporation. The results of this cost study revealed that well cost could be roughly correlated by the following equation where well cost is in 1980 dollars:

$$\text{Well Cost} = 1.21 \times 10^{(\text{depth}/7450 + 5.161)} \quad (\text{Eq. 1})$$

In Equation 1 the completed well depth is expressed in feet. Also, Equation 1 should be applied only in the depth range of 1,000 to 10,000 feet. The exponential trend indicated in Equation 1 can be attributed to the lower rates of penetration (ROP) and the increased trip time in and out of the hole for deeper wells.

Geothermal Well Pumps

Since none of the well sites in this program were expected to be artesian, well pumps were needed to supply the geothermal fluid to the surface. The two basic types of pumps which could be used for this service were submersible centrifugal pumps and vertical line shaft centrifugal "turbine" pumps. Submersible pumps are fully self contained pump and water proof motor units that are set in the well on the end of the discharge pipe. The electric supply lines are extended down the hole and connected to the submersible pump. This type of pump can be used in crooked wells but is limited in its service to handle fluids at temperatures of about 250°F to prevent damage to the electric motor windings. However, as long as this temperature requirement is met, a submersible pump should be able to operate at virtually any well hole depth. Shaft driven, deep well centrifugal "turbine" pumps are the most commonly used pumps for geothermal wells.

This type of pump consists of impellers and casing assembly mounted down hole at the pumping level and connected by a vertical shaft to an electric motor positioned on the surface. The advantage to this configuration is that almost any temperature of fluid can be handled since the electric motor is not immersed in the fluid. However, line shaft pumps are normally not used at depths greater than 400 feet due to shaft line stretch and require special design consideration for deeper settings. This limitation contributed considerably to the increased cost of vertical line shaft pumps in this program since pump setting was expected to be about 1000 feet. The pumping water level was projected to be 550 feet deep. The cost for a 100 gpm pump with a 700 feet head was found to be about \$52,300 for a vertical line shaft pump and \$19,200 for the submersible design. For double this flow with a pump head of 1350 feet the corresponding costs were determined to be \$86,700 and \$35,100 for line shaft and submersible pumps, respectively. These costs included pump motor, cable, transformer, switch board, and the column pipe to the surface. It was obvious from these figures that as long as the submersible pump motor could operate at the fluid temperature that it was the more economical selection. Final system cost estimates were based on utilizing the submersible pump design in the geothermal well.

Geothermal Pipe Line

The geothermal pipeline design and cost estimate for each of the potential sites was based on pre-insulated, direct-burial piping components. All systems were capable of transporting approximately 250°F fluid to the L'eggs Plant. It was found that of the four types of carrier pipe investigated for geothermal use (carbon steel,

epoxy lined asbestos cement, fiberglass reinforced plastic (FRP), and polymer concrete) only carbon steel and FRP pipe were applicable to these temperatures. Detailed cost studies revealed that FRP pipe could provide a lower installed piping system cost when compared to carbon steel by about 15% for a four-inch pipe size. The main reason for this lower cost was due to decreased material cost by the elimination of expansion loops and the decrease in skilled labor cost resulting from the assembly by epoxy adhesive on the bell and spigot end connections rather than by welding. In addition, FRP had no corrosion problems and had a long-life smooth interior surface with less pressure drop than a carbon steel system. Thus, with exception of Site B which used carbon steel pipe because of higher pressures and temperatures than was required from the other sites, FRP was the carrier pipe used for all sites in the final economic comparison. Several types of insulation were also considered for the buried pipeline. Based on a cost-effectiveness study, it was found that urethane insulation with a maximum temperature rating of 300°F was the most appropriate selection from cellular glass, fiberglass, urethane, calcium silicate, and mineral powder. Installed costs of the FRP pipe system, pre-insulated with urethane insulation, and covered with a PVC jacket was determined to be about \$19.60 per foot for a four-inch carrier pipe with a 2.75-inch insulation thickness. For the same size carbon steel carrier pipe, the installed cost was found to be nearly \$23.50 per foot (including expansion loops). Based on the projected flow rates required to satisfy the L'eggs plant thermal energy needs (with a delivered temperature of about 250°F), a four-inch FRP carrier pipe was selected. Engineering studies revealed that this was the most cost-effective pipe size selection when pipeline heat loss, pump power, and construction cost were accounted for.

The steady-state heat loss from a fluid flowing in a pipeline was calculated from the following equation derived from the principle of conservation of energy:

$$T = T_a + (T_i - T_a) \exp \left[\frac{-L}{\dot{m} C_p \frac{\ln (D_o / D_i)}{2 \pi k}} \right] \quad (\text{Eq. 2})$$

In Equation 2, "T" is the temperature of the pipeline fluid at a distance "L" from the geothermal well, "T_a" is the ambient temperature of the ground in which the pipe is buried, "T_i" is the fluid initial temperature (well head geothermal fluid temperature), "m" is the mass flow rate of the fluid, "C_p" is the specific heat of the pipeline fluid, "k" is the thermal conductivity of the pipeline insulation, and "D_o" and "D_i" are the outer and inner pipeline insulation diameters, respectively. In the derivation of Equation 2, the inside heat transfer coefficient and the thermal resistance due to the pipe wall were neglected. Also, no insulating value was given to the surrounding soil, therefore, the temperatures calculated by Equation 2 should provide conservative values.

It was found that for a flow of 200 gpm the geothermal fluid would lose only about 6°F in temperature between the well head and the L'eggs plant for Sites D and E, while Site B as a special case, had nearly a 60°F temperature drop for this flow rate.

Well Head Temperature Calculation

The fluid temperature available at the well head of a geothermal well is of paramount importance in determining system design and performance. This temperature has been previously calculated for several

wells (Ref. 7 and 8) based on a computer numerical well bore model (Ref. 9). However, a closed-form analytical solution of the steady-state fluid temperature profile for homogeneous flow in a well bore has been developed by Energetics. This analytical solution was used to determine the well head temperature for the various flow conditions at Sites A and C in this study. The condition for homogeneous flow in the well bore (no flashing) for these two sites was assured in that both wells were assumed to be pumped flow with the fluid pressure maintained above saturation pressure.

The simple analytical model developed by Energetics considers heat loss from the well bore in the form of conduction through the soil and accounts for the temperature gradient, S (measured in units of $^{\circ}\text{F}/\text{ft}$), which exists over a length of well bore. It can be shown that for a given inlet fluid temperature (T_1) to a section of well bore (where T_1 could also be the bottom hole temperature for the bottom section of well bore), the fluid temperature (T) at a distance (X) from the section inlet is given by the equation:

$$T = S(X-G) + T_b + (T_1 - T_b + SG) \exp(-X/G) \quad (\text{Eq. 3})$$

where:

$T [^{\circ}\text{F}]$ = temperature of fluid at X

$S [^{\circ}\text{F}/\text{ft}]$ = temperature gradient of soil
(negative number since T decreases as X increases)

$X [\text{ft}]$ = distance from bottom hole

$G [\text{ft}]$ = effective resistance of wellbore = $m \text{ cp} \ln \frac{D_o/D_i}{2 \pi k}$

$m [\text{lbm}/\text{hr}]$ = mass flow rate of liquid in wellbore

$\text{Cp} [\frac{\text{Btu}}{\text{lbm}/\text{hr}}]$ = specific heat of fluid

$D_o [\text{ft}]$ = effective diametral distance from the wellbore for which the flow has an appreciable effect on the temperature distribution in the soil.

D_i [ft] = wellbore diameter

k [$\frac{\text{Btu}}{\text{ft}^\circ\text{Fhr}}$] = conductivity of the soil

T_b [$^\circ\text{F}$] = temperature of soil at $X = 0$

T_1 [$^\circ\text{F}$] = temperature of fluid at the inlet of the wellbore section under consideration

As can be seen above, an estimate need only be made of the well bore flow rate (production rate), soil thermal conductivity, and the effective soil insulating distance (D_o) to be able to calculate well head fluid temperature. Of these three parameters, D_o is most difficult to determine (since the production rate is normally specified for a given well). However, work done by Nathenson (Ref. 10) for flow up a fault indicates that the distance to which the flow has an appreciable effect on the temperature distribution in the soil is about 15% of the depth of the fault. Thus, using the relation $D_o = 0.15 X_{\text{max}}$ and a value of soil thermal conductivity of 1.2 Btu/hr-ft- $^\circ\text{F}$ (Ref. 7, pg 83) approximate well head temperatures can be calculated. Results of this calculation are plotted in Figure 5 for Site C. As indicated, the well bore heat loss causes a 6 $^\circ\text{F}$ temperature drop from bottom hole to well head.

System Interface Design

The proposed geothermal interface design for the L'eggs Plant is shown in Figure 6. The incoming geothermal fluid flashes in a flash vessel to provide steam to the dye process by direct steam injection into the dye tanks for heating. The remaining fluid at about 220 $^\circ\text{F}$ passes through a heat exchanger which provides heat to the plant heating system. This scheme requires that the L'eggs plant

FIGURE 5. SITE C TEMPERATURE GRADIENT

FIGURE 6. GEOTHERMAL INTERFACE DESIGN

steam heating system be modified to a hydronic heating system. Preliminary calculations suggested that this modification could be accomplished by utilizing the existing steam and condensate piping as the hydronic piping. However, the tube and finned single row steam coils would need to be replaced with similar sized (same frontal surface area) hydronic finned coils of three-row construction. It was estimated that these changes to the L'eggs facility would cost approximately \$335,000 with slightly over half this cost associated with the HVAC modification.

For a geothermal well flow of 200 gpm delivered at a temperature of 250°F the peak energy delivery rates are about 2960 lb_m/hr of steam to the dye process and the energy equivalent of about 3840 lb_m/hr of steam simultaneously delivered to the plant HVAC system (see Figure 6).

This design flow meets the peak heating rate for the HVAC requirement of the L'eggs plant but falls short of meeting the dye process heating requirement. However, two additional effects can occur to increase steam production for the dye process while having negligible effect on the energy available to the HVAC system. First, as the steam usage increases in the dye house, the flash tank pressure could be allowed to drop, thereby providing an increase in the production of steam (although at a lower temperature and pressure) from the flash vessel. This effect is represented in Figure 7. This drop in flash tank operating pressure caused by the increased steam demand would also cause a secondary increase in the flash tank steam flow by allowing a drop in the delivery pressure to the L'eggs plant, since the drop in delivery pressure would cause a corresponding slight increase

FIGURE 7. FLASH TANK STEAM PRODUCTION VS TANK PRESSURE FOR 250°F GEOTHERMAL WATER

in the pipeline geothermal fluid flow. This hydraulic effect is represented in Figure 8 for Site C where the system and pump head-capacity curves are plotted. As can be seen, a flow increase of about 8 gpm (or about 4%) would occur in the present system design. Thus, by careful examination of Figures 7 and 8, it can be determined that nearly 3500 lb_m/hr of 216°F steam can be supplied to the dye process from 250°F geothermal fluid. However, the peak steam requirement of the dye process (based on four dye tanks being heated simultaneously) can not be totally met with 200 gpm of geothermal fluid at 250°F so an additional investigation was completed to show the effect of the plant inlet geothermal fluid temperature on steam production from the flash tank. The result of these calculations is shown in Figure 9 for the nominal 200 gpm flow rate. To meet the peak dye process steam demand of 3800 lb_m/hr a geothermal fluid temperature of about 258°F would be necessary at the L'eggs plant for 220°F saturated steam production, from the flash tank. But to lower this geothermal fluid temperature would require either to lower the required steam temperature (Figure 7), to increase the design system flow (Figure 8), or to reduce the design peak steam flow. All of these options have drawbacks, however, which tend to favor slightly higher geothermal temperatures (and thus a deeper well) than the original nominal 250°F case.

To meet the dye process peak steam demand both flash tank temperature and geothermal fluid temperature were varied slightly from the nominal design case. The design flow rate of 200 gpm was not changed except that the hydraulic system "runout" condition shown in Figure 8 was accounted for. It was determined that the peak steam flow could be provided by dropping the flash tank temperature to 218°F

Figure 8. Site C System Hydraulics

FIGURE 9. FLASH TANK STEAM PRODUCTION VS GEOTHERMAL WATER TEMPERATURE FOR 220°F STEAM

if the plant geothermal supply temperature were maintained at about 254°F. These temperatures and flows were selected as the final system design conditions.

Geothermal Site Economic Comparisons

Preliminary cost analysis of the available five sites is shown in Table 4. This data does account for pipeline heat loss but does not allow for well bore heat loss. Thus, the well temperature indicated is the bottom hole temperature and also the well head temperature. Site A is favored in this simplified comparison since it is located at the L'eggs plant and is not penalized for pipeline heat loss. Table 4 is further based on a temperature entering the L'eggs plant of 240°F which is lower than the nominal design temperature of 250°F selected later in the program. This lower temperature also favors the economics of Site A since this site had a lower temperature gradient than Sites B, C, and D.

The payback periods shown in Table 4 were based on the fossil fuel usage of the L'eggs plant. While these paybacks are too long to interest private industry, it should be realized that additional thermal energy could be removed from the geothermal fluid before re-injection if there were an appropriate use for this energy near the L'eggs plant. That is, the geothermal fluid discharge from the L'eggs plant at 180°F could be dropped in temperature to around 100°F if an appropriate user were available with a doubling in the amount of energy provided at little additional system cost. If this could be accomplished, the payback periods shown in Table 4 could be cut approximately in half to a more respectable 5 to 7 years.

Table 4. Site Comparison For L'eggs Geothermal Program

<u>SITE</u>	<u>WELL DEPTH (ft)</u>	<u>WELL TEMP (F°)</u>	<u>WELL COST \$10⁶</u>	<u>PIPELINE COST \$10³</u>	<u>TOTAL COST \$10⁶</u>	<u>PUMP POWER \$/YR</u>	<u>PAYBACK (YEARS)</u>
A	8120	240	2.16	-0-	2.56	12,000	11.4
B	10500	298	4.0	1,782	6.18	20,100	28.5
C	6250	254	1.21	441	2.08	13,400	9.3
D	7500	251	1.78	397	2.58	12,000	11.5
E	9000	251	2.83	293	3.52	13,700	15.8

NOTES: 200 GPM at 240°F delivered to L'eggs Plant. Well bore heat loss neglected. Total Cost includes \$335,000 plant modification cost and \$65,000 injection well and pump cost. Well depths based on optimistic temperatures of Table 2. Fuel savings based on 85¢/gal. fuel oil for \$236,700/yr savings. Pump power cost based on 4¢/KWH electricity cost.

One other item of special interest, but which is not shown in Table 4, is the probability of finding a production well at the stated temperature and depth. While these projections are the best currently available, the total cost for a L'eggs plant geothermal system development program can hardly be justified without more drilling data becoming available.

Analysis of Table 4 does indicate, however, that Site B, due to the long pipeline and corresponding heat loss, is not competitive with other sites. Also, Site E is not sufficiently distinct from Site A to merit selection of the former since it requires an approximate three mile pipeline. Sites A and D are very close, based on economics, but since Site D was similar in nature to the more desirable Site C and since it was also about three miles from the L'eggs Plant, Site D was also dropped from further consideration.

Sites A and C were then given a more careful review. This more detailed economic study included all technical aspects covered in this program such as pipeline heat loss, pump power and pipeline sizing, drilling costs, well bore heat loss, and a minimum plant interface temperature of 250°F. Table 5 tabulates this information and the associated cost for interface temperatures of 250°F and 259°F. As can be readily seen Site C is a significantly better site economically than Site A (L'eggs Plant).

It should be noted that the economic comparison of Table 5 does not include pipeline right-of-way costs, geothermal well lease costs, or royalty payments. The costs in Table 5 are based purely on technical merits and geothermal potential. These other concerns would be resolved for an economically viable project on a site specific basis.

Table 5. Detailed Comparison of Sites A and C for L'eggs Geothermal Program

<u>SITE</u>	<u>WELL DEPTH (ft)</u>	<u>WELL COST (\$10⁶)</u>	<u>PIPELINE COST (\$10³)</u>	<u>PUMP COST (\$10³)</u>	<u>TOTAL COST (\$10⁶)</u>	<u>L'EGGS PLANT TEMP. (F⁰)</u>	<u>PUMP POWER \$</u>	<u>PAYBACK (YEARS)</u>
A	9,600	3.41	-0-	27	3.84	259	12,000	17.1
A	9,200	3.01	-0-	27	3.44	250	12,000	15.3
C	6,500	1.31	441	28	2.18	259	13,400	9.8
C	6,200	1.19	441	28	2.06	250	13,400	9.2

NOTES: Well bore heat loss included. L'eggs plant temperature as specified. Other items as for Table 4. Total cost includes \$335,000 L'eggs modification costs and \$65,000 injection well and pump cost.

Selected Geothermal System Design Criteria

Site C was selected as the most appropriate geothermal development site for the L'eggs Plant based on technical and geothermal potential feasibility. Site C, the L'eggs Products plant site, and the proposed interconnecting pipeline is represented in Figure 10. This pipeline route was selected from three possible routings. It has minimum private property interference, no building interference, and was the shortest of the three routes studied. The elevation profile for this pipeline route is shown in Figure 11.

Detailed engineering investigations revealed that the most economic, long life, and lowest maintenance pipeline was fiberglass reinforced plastic (FRP) pipe. For the 200 gpm design geothermal fluid flow a four inch (inside diameter) pipe size was selected. The pipe would be pre-insulated with closed cell urethane insulation 2-3/4 inches thick with a PVC protective jacket. The pipe would be assembled with bell and spigot end connections with adhesive and buried about four feet deep. No expansion loops would be required. The installed cost of this 4-1/4 mile long pipeline was estimated to be \$441,000 including cased road crossings, freight, and all installation labor.

The proposed well design for Site C was a 10-3/4 inch production casing diameter to a depth of 6300 feet as shown in Figure 12. The casing depths were designed to the specifications of the State of New Mexico Oil Conservation Commission Rules and Regulations for Geothermal Resources (Ref. 11). These regulations state that the maximum and minimum casing depths for conductor pipe are 200 feet and 90 feet respectively, and 1500 feet and 200 feet for surface casing, respectively. The surface casing is set to a depth of 1000 feet to anchor it on an

FIGURE 10. GEOTHERMAL PIPELINE ROUTE FROM SITE C TO THE L'EGGS PRODUCE PLANT

Figure 11. Elevation Profile of Site C Pipeline Route

Set casing with API Class G Cement 30% Silica Flour
to production zone depth.

FIGURE 12. GEOTHERMAL WELL DESIGN AT SITE C

impermeable rhyolite layer which is known from previous drilling to be at that depth (Ref. 12). The production casing was designed from extrapolated temperature gradients for a depth of 6300 feet to provide the required process temperature at the L'eggs Plant of 254°F. At the design flow of 200 gpm, well head fluid temperature was projected to be 259°F based on the predicted bottom hole temperature of 265°F.

Other significant equipment required in the geothermal system design (Figure 6) includes the well production pump, injection pump, HVAC circulation pump, HVAC heat exchanger, backup steam heat exchanger, air handler and air washer hydronic heat exchangers, and the geothermal fluid flash tank. Pertinent design and cost information for this equipment is listed in Table 6.

Conclusion

The economic payback for interfacing potential geothermal resources of Dona Ana County with the L'eggs Plant industrial process are not presently attractive to the industry based on current fuel costs. However, future fuel cost increases or fuel unavailability may make such a proposal look much more promising. Also, if industrial or commercial end users were available which could combine with the L'eggs facility and utilize the still warm geothermal fluid discharged from L'eggs then the economic payback period could be cut approximately in half. This could result in four to five year paybacks. Also, possible future tax credits or reservoir depletion allowances could further improve system development economics.

Geothermal development was shown to be technically feasible even

Table 6. Geothermal System Equipment Design Information

Geothermal Well Production Pump

Type: Submersible Centrifugal
 Specifications: 800 ft. Head at 200 gpm; 68% efficiency; 3475 RPM; 75 Hp motor; 32 stages
 Manufacturer: Centrillift Model 32S-175-513-GP
 Cost: \$28,000 (includes pump, motor, cable, transformer, switchboard, and discharge pipe)

Geothermal Injection Pump

Type: Horizontal Split Case Centrifugal
 Specifications: 485 ft. Head at 200 gpm; 67% efficiency; 3500 RPM; 50 Hp motor; 2 stages
 Manufacturer: Peerless Model #2TU-10
 Cost: \$5,300

HVAC Circulation Pump

Type: End Suction, Close Coupled Centrifugal
 Specifications: 58 ft. Head at 100 gpm; 72% efficiency; 3500 RPM; 2 Hp motor; single stage
 Manufacturer: Allis Chalmers Model C-1
 Cost: \$500

HVAC Heat Exchanger

Type: Shell and Tube, Single Pass
 Specifications: Geothermal fluid tube side; tube design pressure/temperature 500 psi/260°F; Shell Design pressure/temperature 100 psi/260°F
 Design Code: TEMA Standards
 Approximate Cost: \$5,000

Backup Steam Heat Exchanger

Type: Shell and Tube, Single Pass
 Specifications: Steam Tube Side; Tube Design pressure/temperature 100 psi/340°F; Shell Design pressure/temperature 100 psi/260°F
 Design Code: TEMA Standards or HEI Standards
 Approximate Cost: \$2,500

Hydronic Heat Exchangers

Type: Tube and Fin, Multipass Coil
 Specifications: 3 rows; 8 fins/inch; 5/8" Copper tube; copper or aluminum fins; Design pressure/temperature 100 psig/220°F
 Design Code: ARI Rated
 Approximate Cost: \$17,000 (16 air handler and 4 air washer coils)

Geothermal Fluid Flash Tank

Specifications: Vertical Tank with mist eliminator; design pressure/temperature of 150 psi/260°F; carbon steel ASTM A 285 Gr. C
 Design Code: ASME Boiler and Pressure Vessel Code Sec. VIII, Div. I.
 Approximate Cost: \$18,000

for geothermal sites three to four miles from the end user, provided the distant sites had sufficiently higher subsurface temperatures to merit a pipeline. However, it seems unlikely that significant geothermal energy use will occur in a region that is relatively unexplored due to the high initial investment required for production drilling and to the associated risk in obtaining the required fluid production and/or temperature to interface with an industrial process.

References

1. Harder, Vicki, P. Morgan, and C. A. Swanberg, "Geothermal Resources in the Rio Grande Rift: Origins and Potential." To be published in Geothermal Energy for the Eighties, Geothermal Resources Council Transactions, Vol. IV, 1980.
2. Stone, William J., N. B. Mizell, Geothermal Resources of New Mexico--A Survey of Work to Date, New Mexico Bureau of Mines and Mineral Resources, March 1977, pp. 53-57.
3. Lohse, Richard L., "Geothermal Assessment of Dona Ana County, New Mexico." To be published in Geothermal: Energy for the Eighties, Geothermal Resources Council Transactions, Vol IV, 1980.
4. Truesdell, A.H., Summary of Section III, Geochemical Techniques in Exploration, 1975, in Proc. 2nd U.N. Symposium on the development and use of geothermal resources, San Francisco, California, Vol. 1, p. LIII - LXXXIX.
5. Chappell, Robert N., Prestwich, Susan J., Miller, Lowell G., Ross, Howard P., "Geothermal Well Drilling Estimates Based on Pase Well Costs," Expanding the Geothermal Frontier, Geothermal Resources Council Transactions, Vol. III, 1979.
6. Lund, John W., et al, "Klamath Falls Geothermal Heating District", Expanding the Geothermal Frontier, Geothermal Resources Council Transactions, Vol. III, 1979, p. 387.
7. Howard, J.H., et.al., "Geothermal Resource and Reservoir Investigations of U.S. Bureau of Reclamation Leaseholds at East Mesa, Imperial Valley, California, Lawrence Berkely Laboratory, LBL-7094 UC-66a, Berkely, California, October 1978.
8. Longyear, A.B., et.al., "Mountain Home Geothermal Project," Energetics Marketing & Management Associates, Ltd., DOE/ET/28442-1, San Francisco, Calif., Feb. 1979.
9. Juprasert, S., and S.K. Sanyal, "A Numerical Simulator for Flow in Geothermal Wellbores," Geothermal Resources Council, Transactions, Vol. 1, pp. 159-161, San Diego, California, May 1977.
10. Natherson, Manuel, et.al., "Approximate Solution for the Temperature Distribution Caused by Flow Up a Fault and Its Application to Temperatures Measured in a Drillhole at Raft River Geothermal Area, Cassia County, Idaho," Geothermal Resources Council, Transactions, Vol 3, pp. 477-480, Reno, Nevada, September 1979.

References (Continued)

11. "State of New Mexico, Oil Conservation Commission Rules and Regulations for Geothermal Resources," 1979.
12. Chaturvedi, Lokesh, "Analysis of Geological and Geophysical Log of Two Geothermal Exploration Wells Drilled on New Mexico State University Land, Las Cruces, New Mexico," April, 1979.

APPENDIX A

Extracts From the First Technical Progress Report

Note: The Technical Progress Report page numbers are maintained for clarity with the addition of "A" indicating Appendix A.

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Application Description

The L'Eggs Product hosiery plant is located in Mesilla, New Mexico, immediately south of Las Cruces. The plant produces the well-known L'Eggs brand "pantyhose" with an output of about four million dozen pair annually. The plant utilizes both electrical and thermal (fossil fuel) energies in its operation. Electrical energy provides the power for cooling the plant, compressing air, knitting and sewing, and lighting. The thermal energy is provided within the plant by a pair of fire-tube boilers that fire No. 2 fuel oil or natural gas to generate 110 psig (344°F) saturated steam which is utilized within the plant for process dyeing and drying and for building heat. This program is concerned with supplementing or replacing the fossil fuel used at the L'Eggs facility and is not particularly interested in electric power generation from the geothermal resource. However,

if especially high geothermal temperatures are determined to be present, this option could always be investigated. Thus, the thermal energy utilized at the L'Eggs plant was specifically studied to determine the quantity of energy used within the plant or process, where it was used, and at what temperature.

The L'Eggs facility utilizes 110 psig saturated steam throughout the plant for domestic hot water (not for cafeteria, however, as this is supplied by an electric hot water heater), process heat for dyeing and drying of the hosiery, building heat for temperature and humidity control, and for deaerating the condensate supplied to the boilers. The basic steam condensate and thermal energy flow schematic is represented in Figure 2. In addition to the end uses mentioned above, the thermal energy losses associated with the system operation are shown. These include such losses as boiler blowdown, boiler stack, deaerator blowdown, miscellaneous steam and condensate leaks, and pipe heat losses. The approximate amount of energy required annually for each process or energy loss at the plant is listed in Table 1.

<u>ITEM</u>	<u>AMOUNT</u>
Fuel Input	57.37 x 10 ⁹ Btu/yr
Boiler Stack Losses	11.76 x 10 ⁹ Btu/yr
Miscellaneous Boiler Losses	1.15 x 10 ⁹ Btu/yr
Boiler Blow Down Losses	2.89 x 10 ⁹ Btu/yr
110 psig Saturated Steam	41.57 x 10 ⁹ Btu/yr
Dyeing Energy Requirement	18.34 x 10 ⁹ Btu/yr
Drying Energy Requirement	1.51 x 10 ⁹ Btu/yr
Drying Waste Condensate Losses	0.35 x 10 ⁹ Btu/yr
Deaerator Blow Down Losses	0.58 x 10 ⁹ Btu/yr
Domestic Hot Water	0.25 x 10 ⁹ Btu/yr
Miscellaneous Energy Losses	4.02 x 10 ⁹ Btu/yr
Building HVAC (Heat & Reheat)	16.52 x 10 ⁹ Btu/yr

TABLE 1. L'EGGS FACILITY THERMAL ENERGY ACCOUNTING

FIGURE 2. DETERMINATION OF L'EGGS PLANT ENERGY CONSUMPTION

It should be noted that these energy quantities are approximate and based on the best available information and/or engineering judgement, but are not measured quantities (except for the total energy consumption amount). However, the L'Eggs plant is currently installing steam, water, compressed air, and electricity meters that will provide data later in this program to substantiate or refine these energy figures. It is felt, however, that the energy quantities listed in Table 1 are realistic and account for the actual process energy use within 10 to 15 percent.

Based on the annual energy consumption represented in Table 1, the plant steam and condensate process flow diagram shown in Figure 3 was derived. The flow rates indicated are average flows based on 6 day per week continuous operation. It would be expected that actual instantaneous flows could be up to $1\frac{1}{2}$ times greater than these average flows. As can be seen from Table 1 and Figure 3, the dyeing process and building HVAC (heating, ventilating and air-conditioning) require over 75% of the generated steam.

The potential for energy conservation at the L'Eggs plant is readily apparent upon examination of Table 1 and Figure 3. This potential would include waste heat recovery from the boiler stack gases (installation of an economizer), reduction of steam leaks, heat recovery from the boiler blowdown, and re-use of the thermal energy discharged from the dyeing process. The L'Eggs personnel are currently investigating both heat recovery from the boiler stack gases and from the waste water of the dye process. However, the first segment of this geothermal program has only dealt with interfacing of the geothermal resource with the process such that use of the plants steam

FIGURE 3. L'EGGS PLANT LAS CRUCES, NEW MEXICO STEAM & CONDENSATE FLOW DIAGRAM
49 (A-11)

was reduced. Potential modifications or process changes that could provide energy conservation as well (while also modifying the geothermal interface design) will be further studied during the remainder of this program.

It should also be noted that the dyeing process is a batch process where cold water in a dye tank is heated to a given temperature by steam, stirred, and then dumped. Therefore, the actual steam flow varies from zero to some maximum rate during this cycle with the rate given in Figure 3 representing the time averaged steam flow rate for a complete dye cycle. Also, the waste water flow from the dye process is time averaged. The impact of this batch process as it effects a geothermal interface design will be clarified at a later date.

Although all the thermal energy uses within the L'Eggs facility are provided by 110 psig/344°F steam (with the minor exception of the electric hot water heater for the cafeteria) the actual processes require a much lower temperature. This temperature difference enhances heat transfer capability thereby requiring smaller heat exchange equipment. Table 2 lists the actual processes with their corresponding temperature. Also indicated is the temperature of a modified process

PROCESS	PRESENT PROCESS TEMPERATURE	MODIFIED PROCESS TEMPERATURE	MODIFIED EQUIPMENT TEMPERATURE	PRESENT EQUIP. TEMP.
PROCESS DRYING	130-140°F	90-110°F	130-150°F	281°F
DOMESTIC HOT WATER	67-105°F	67-105°F	92-130°F	281°F
BUILDING HVAC	50-75°F	50-75°F	90-115°F	281°F
PROCESS DYEING/ DYE CYCLE	67-212°F	67-212°F	92-237°F	281°F
FINISH CYCLE	67-110°F	67-110°F	92-135°F	281°F

TABLE 2. L'EGGS PLANT PROCESS AND EQUIPMENT TEMPERATURES

that could be obtained with sufficient equipment redesign. However, these process temperatures can only be obtained with geothermal fluids at a higher temperature when operated with actual equipment. Thus, this higher temperature is required to provide energy to a process. This latter temperature is listed in Table 2 as the modified equipment temperature. For comparison, the present equipment temperature is listed in Table 2 as the temperature of saturated steam at a regulated pressure of 35 psig (281°F). This is the steam pressure regulated for these processes and closely approaches the actual equipment operating temperature.

To determine the potential for energy savings due to the utilization of geothermal energy at the L'Eggs plant, Figure 4 was derived from the information of Figure 3 and Table 2. As indicated, this figure shows the amount of useful energy required by the plant at or below a specified temperature for various equipment modifications. For instance, 100% of the process energy needs are at or below 212°F, but a geothermal fluid at the same temperature could only provide 94% of the plants energy needs if major equipment modifications were completed within the plant. Further, minor modifications (which would effect only the dye process) would result in only about 44% of the plants energy requirements being met by the same temperature geothermal resource. These percentages are based on the total useful energy used by the L'Eggs plant which is defined as the useful thermal output of the plants boilers less the deaerator blowdown losses, drying waste condensate losses, and miscellaneous energy losses (see Table 1).

FIGURE 4. L'EGGS PLANT ENERGY CONSUMPTION

Plant Process/Geothermal Interface

The L'Eggs plant interface with a potential geothermal source is discussed in this section. Three source temperatures were identified, but not necessarily as to which site or depth they could be obtained. These potential geothermal resources were then interfaced with the L'Eggs processes in two ways - one which required minimal plant or equipment modification and another which could involve substantial (or major) equipment or facility redesign and modification. It was found that, depending on temperature, the fuel oil (or thermal energy) usage could be reduced by 20% or more or even eliminated by the use of a suitable geothermal resource. In addition, it was determined that only moderate geothermal fluid flow rates of 50 to 120 gpm (depending again on source temperature or plant modification) would need to be provided. Engineering or design details related to the L'Eggs plant modification were not completed, nor was any cost information on the plant modifications compiled. However, this data will be provided later in the program.

The three geothermal fluid temperatures investigated for the conceptual plant interface designs were 135°F, 240°F and >280°F. These temperatures would hopefully be obtained at depths of approximately 1000 feet, 6000 feet, and 10000 feet, respectively (depending on the site - see the geothermal evaluation later in this report) and demonstrate the maximum variation in interface design.

Both major and minor plant modifications were investigated with the amount of useful energy provided to the facility dependent on the geothermal fluid temperature and as shown previously in Figure 4. As discussed earlier in conjunction with Figure 4, a minor plant modification

was considered to involve only the dye process (both cycle and finish cycle) while a major modification to the plant would involve all end uses that presently use thermal energy. The most substantial change required for a major plant modification would be in the building HVAC system. Currently this system utilizes 35 psig steam at 281°F within the heat exchangers for effective heat transfer to the air that is at temperatures of about 50° to 75°F. Thus, much lower temperatures could be provided in a geothermal interface design but only at the expense of this major modification. As can be determined in Table 2, the geothermal fluid interface is expected to have a 25°F minimum temperature difference for water interfaces and a 40°F temperature difference in air interfaces (building HVAC).

The results of the geothermal fluid/L'Eggs plant interface conceptual design study is given in Figures 6 through 15. Figures 6 through 10 show the actual plant interface with the geothermal resource and provide the expected average flows and temperatures. Figures 11 through 15 indicate the geothermal energy allocation for the corresponding interface design case. Where possible and advantageous the geothermal fluid was cascaded through the plant process to extract the maximum amount of thermal energy. The results of this interface study were used to determine geothermal fluid flow rates, required temperatures, the annual energy provided to the processes, and the expected annual fuel savings for each interface design. This information was then used in the site comparisons to assist in the selection of the best two sites for further study during the remainder of this program.

FIGURE 6. GEOTHERMAL PLANT INTERFACE CASE 1
(135°F with minor modifications)

Figure 7. Geothermal Plant Interface Case 2
(135°F with major modifications)

FIGURE 8. GEOTHERMAL PLANT INTERFACE CASE 3
(240°F with minor modifications)

FIGURE 9. GEOTHERMAL PLANT INTERFACE CASE 4
(240°F with major plant modifications)

FIGURE 10. GEOTHERMAL PLANT INTERFACE CASE 5
 ($>280^{\circ}\text{F}$ with minor plant modifications)

FIGURE 11. GEOTHERMAL ENERGY ALLOCATION - CASE 1

FIGURE 12. GEOTHERMAL ENERGY ALLOCATION - CASE 2

FIGURE 13. GEOTHERMAL ENERGY ALLOCATION - CASE 3

FIGURE 14. GEOTHERMAL ENERGY ALLOCATION - CASE 4

FIGURE 15. GEOTHERMAL ENERGY ALLOCATION - CASE 5

Geothermal Site Evaluation - Summary

The two best sites for continued geothermal evaluation are Site C and an expanded version of Site A. Site C is the New Mexico State University property and Site A is the L'Eggs property expanded to include federal lands (BLM) to the east. Temperatures in the 50°-70°C (125°-160°F) have already been demonstrated in shallow aquifers (100-400 meters, 300-1200 feet) at Site C and the expanded version of Site A should encounter similar conditions, albeit the lower end. Production from these shallow aquifers should exceed 800-1200 l/m (200-300 gpm) per well. Geochemical evidence indicated the presence of deeper aquifers in excess of 150°C (300°F) at both sites although the depth cannot be predicted. Production from the deeper aquifers could well require fracture permeability (i.e., good production only if fractures are encountered). Brackish waters of roughly 2000 mg/l (total dissolved solids) are to be expected at both sites. Problems are not to be expected from silica scaling or hydrogen sulphide corrosion and precipitation of calcium carbonate can be easily controlled. Flouride and boron may be present in slightly elevated amounts. Reinjection will be required as both sites lie adjacent to the populated valley of the Rio Grande. Sites B, D, and E can be rejected on the grounds that they are located further from the L'Eggs site than are the recommended sites while exhibiting lower geothermal potential.

Since this project did not include funds for geothermal exploration, it was required to utilize information obtained from published and unpublished literature. Fortunately, southcentral New Mexico has been well studied and a rather large body of geothermal related data are available for interpretation. Specific geothermal

studies include Swanberg (1,2) Morgan et al. (3), Jiracek et al. (4), and Lohse (5). A wealth of geothermal related information is available from over 50 publications included in two compendiums dealing with the geology of southcentral New Mexico (6,7). Finally, New Mexico State University has actively explored for geothermal resources (at Site C) in conjunction with their program to utilize geothermal fluids for space heating and direct use applications at the main campus.

The data used in evaluation of the five sites include temperatures of water wells, temperatures estimated by chemical geothermometry, temperature gradients measured in existing wells, reconnaissance and detailed electrical resistivity, reconnaissance gravity, magnetic, heat flow and geologic data, and well logs of deep oil tests. These data are summarized in Table 1 of the Final Report. In ranking of the five sites, other data including the temperatures of producing water wells located at or adjacent to each site and detailed temperature/depth measurements (temperature gradients) in abandoned water wells or other suitable boreholes located at each site were also utilized. Also, the technique of chemical geothermometry, a technique which utilizes the chemical constituents dissolved in the geothermal fluid (or any groundwater) to predict the subsurface temperatures below the sampling point (8) was employed. The results can be summarized as follows:

1. The hottest wells are at Site C. Temperatures at Site D also show the presence of a geothermal resource while temperatures at Site B are only slightly above normal. Temperatures at Sites A and E are normal.
2. Temperature gradients at Sites C and D clearly reflect geothermal activity. Gradients at Site B are slightly above normal while gradients at Sites A and E are normal

3. Estimated subsurface temperatures (by chemical geothermometry) are very high at Sites D, C, and B but normal at Sites A and E.

On the basis of these data, the two best sites are C and D. However, the expansion of Site A to include federal lands immediately to the east, would bring Site A to the same geothermal potential as Site D. Thus, Site A would be preferred over Site D since it would be closer to the L'Eggs plant. Site B does appear to have geothermal potential, particularly in deep aquifers as evidenced by the geochemical data. However, none of the data for Site B are as promising as Site D and since Site B is further from the L'Eggs plant, this site can also be rejected. In summary, the two best sites are D and the expanded Site A.

The two most common methods of estimating subsurface temperatures are by chemical geothermometry and by extrapolation of near surface temperature gradients. Unfortunately, both are subject to large uncertainties and potentially serious misinterpretation. Geochemical temperatures require water rock equilibrium and subsequent metastable conditions which may not exist in a given geologic environment. Further, geochemical methods yield a subsurface temperature without providing information on where those temperatures exist. Since deep circulation as well as lateral migration of groundwaters are possible, geochemical temperatures may not reflect the true geothermal regime beneath a particular site. Extrapolation of near surface temperature gradients require steady-state conductive conditions and knowledge of subsurface thermal conductivity. Steady-state conditions rarely exist in geothermal areas below a few hundred meters making this technique as hazardous as the geochemical methods.

Because of the restrictions noted above, estimating subsurface temperatures is an imprecise science. Thus, the following three-step approach was adopted:

- 1) Consider first, only the temperatures actually measured.
- 2) Consider second, the temperatures estimated by extrapolation of "normal" temperature gradients. These temperatures should be reliable although they will generally be too low to make a geothermal project economically feasible.
- 3) Finally, make a best-guess estimate on the basis of whatever data are available.

Table 3 shows the maximum temperatures measured for each site. All of these measurements reflect the top of the water table (<200 meters) except for Site C which is at a depth of 300 meters. Figure 16 shows the normal temperature gradient which exists in southcentral New Mexico. Table 4 gives conservative and optimistic temperature estimates at several depths. It should be noted that these latter figures are intended for design and feasibility studies only and are not intended to represent true subsurface temperatures.

Flow rates are more difficult to predict than subsurface temperatures because the requisite data on aquifer transmissivity are not available. A general rule of thumb is that flow rates will decrease with depth (due to overburden pressure) and also decrease with increasing temperature (impermeable beds are requisite to the buildup of high subsurface temperatures). Shallow aquifers can be expected to produce roughly 800-1200 ℓ/m (200-300 gpm) from intergranular

FIGURE 16. COMPARISON OF TEMPERATURE GRADIENTS AND GROUND TEMPERATURES

CONSERVATIVE ESTIMATES °C

DEPTH(m)	A	B	C	D	E	ALTERNATE A
500	30	35	65	50	30	50
1000	38	50	75	60	38	60
2000	60	85	100	85	60	85
3000	120	120	120	120	120	120

OPTIMISTIC ESTIMATES °C

500	35	40	75	60	35	60
1000	45	60	85	70	45	70
2000	100	100	130	110	100	110
3000	130	140	185	150	130	150

These are not predicted subsurface temperatures. They are best-guess numbers upon which to base engineering design and feasibility studies.

TABLE 4. SUGGESTED TEMPERATURES FOR ECONOMIC ANALYSIS

porosity. Deeper aquifers may not produce at all unless fracture permeability or competent, but porous limestones or dolomites are encountered. A single geothermal well at Site C was flow tested in February 1980 and yielded roughly 1000 l/m (250 gpm).

The relation between flow and temperature and the resulting geothermal dilemma is exhibited at Sites A and E. There is a possibility (perhaps a good possibility) that thermal water exists beneath these sites. However, their presence is masked by the underflow from the Rio Grande. That is groundwater, circulating in high yield aquifers, is sweeping away the thermal water at a faster rate than it can be supplied from depth. A program to drill beneath the disturbed zone may well encounter geothermal fluids but such wells by necessity will penetrate impermeable strata. For these reasons, an expansion of Site A is proposed to include the lands immediately east (2 miles) of the L'Eggs plant. This area will not be affected by the Rio Grande underflow and geothermal fluids can be expected at shallow depths (<300 meters).

If the economic evaluation required geothermal production from shallow aquifers then the optimum production sites are C and A (alternate). At greater depths, the differences among the sites becomes less pronounced although Site C is probably still the best. Site A is a suitable only if it is possible to drill below the disturbed zone.

Piping Evaluation

In order to be able to choose the most cost effective insulation to use on a system, it must be pointed out that it is desired to get the greatest amount of thermal resistance (not the greatest amount of weight, volume, thickness or other property) for each dollar that is invested. For slabs, the amount of thermal resistance is dependent upon the thickness and the conductivity of the material. For pipes, the amount of thermal resistance is dependent upon the conductivity of the material and the natural logarithm of the ratio of outside to inside radii. It can be shown that two materials, A and B, with thermal conductivities k_A and k_B , will have the same thermal resistance if the thickness of material A, (t_A), is chosen such that:

$$t_A = r_i \left(\frac{r_i + t_B}{r_i} \right)^{k_A/k_B} - r_i \quad (18)$$

Material A

Material B

FIGURE 21
EQUIVALENT THERMAL RESISTANCE THICKNESS

As can be seen in Figure 21, material B has a lower thermal conductivity than material A thus allowing smaller insulating thickness to provide the same thermal resistance as material A. If both materials A & B can be purchased on a \$/volume basis, then the cost per foot length of insulation can be calculated for equivalent thermal resistances of different materials.

Consider the following example which compares foam glass and fiberglass insulation.

Material B - (foam glass)

$$k_B = 0.45 \frac{\text{btu in}}{\text{ft}^2 \text{hr}^\circ\text{F}}$$

$$t_B = 4.0''$$

$$r_i = 1.5''$$

$$$/\text{in}^2\text{-ft} = 0.1268$$

$$$/\text{ft} = 87.97 \text{ in}^2 \frac{\$0.1268}{\text{in}^2 \text{ ft}} = \$11.15/\text{ft}$$

Material A - (fiberglass)

$$k_A = 0.29 \frac{\text{btu in}}{\text{ft}^2 \text{hr}^\circ\text{F}}$$

$$t_A = ? \text{ (to be found)}$$

$$r_i = 1.5''$$

$$$/\text{in}^2\text{-ft} = 0.1512$$

From equation (18):

$$t_A = 1.5 \left(\frac{1.5 + 4.0}{1.5} \right) \frac{0.29}{0.45} - 1.5 = 1.965''$$

$$$/\text{ft} = 30.65 \text{ in}^2 \frac{\$0.1512}{\text{in}^2\text{-ft}} = \$4.63/\text{ft}$$

Thus, it can be seen that even though the foam glass is not as expensive as the fiberglass on a per unit volume basis, the fiberglass is much cheaper than the foam glass on an equivalent thermal resistance basis and would be a better insulation for that reason. However, other requirements such as vapor barrier characteristics, structural strength and moisture resistance would also have to be considered in the selection of insulation. Table 5 shows the different insulating materials and their relative insulation values compared to the base case of foam glass cited above.

MATERIAL	CONDUCTIVITY $\frac{\text{btu in}}{\text{hr}^\circ\text{F ft}^2}$	PRICE PER VOLUME \$/in ² -ft	PRICE/FT OF EQUIVALENT RESISTANCE \$/ft	% CHANGE FROM BASE CASE (4" FOAM GLASS) %
foam glass	0.45	0.1268	11.15	-0-
fiberglass	0.29	0.1512	4.63	-58
urethane	0.16	0.090	0.97	-91.
calcium silicate	0.40	0.085	5.45	-51
mineral powder	0.75	0.064	33.80	+203

TABLE 5. COST OF EQUIVALENT THERMAL THICKNESS OF INSULATORS

While urethane is seen to be the most cost effective insulator, it is restricted in its uses because of the maximum temperature limit of 250°F. Other general properties of several types of insulation are shown in Table 6.

MANUFACTURER	MATERIAL	CONDUCTIVITY $\frac{\text{btu in}}{\text{ft}^2 \text{hr}^\circ \text{F}}$ @ 200°F	DENSITY {lbm/ft ³ }	MAX TEMP {°F}	JACKET NEEDED	LENGTH OF JOINT {ft}	PRE-INSULATED	MAX. PRESS. OF CARRIER PIPE {psi}	AVERAGE PRICE PER VOLUME {\$/in ² -ft}	MOISTURE RESIST- ANCE
<u>Pittsburg- Corning</u>	foam glass	0.45	8.5	900	yes	2	no	---	0.1268	Closed cell impervious to water. Must seal joints.
<u>Thermocore</u> ^C	urethane	0.22	2.2	250	no	40	yes	FRP-150	0.090	Closed cell. Absorbes water. Must protect
<u>Johns-Man- ville</u>										
Thermo 12	cal. silicate	0.40	13.0	1500	yes	3	no	---	0.085	
Flame-Safe	fiberglass	0.29	1.5	400	yes	4	no	---	0.1512	
Temptite	urethane	0.16	2.2	210	no	13	yes	Asbestos Cement-150	0.090	Closed Cell.
<u>Heat-tite</u>	urethane	0.16	2.2	210	no	10	yes	> 500	0.090	Closed cell.
<u>Owens Corning</u> P2	urethane	0.16	2.2	225	yes	4	no	---	0.090	Closed cell.
<u>Rovanco</u> Insul-8	urethane	0.19	2.0	250	no	30	yes	O-ring-250	0.090	Closed cell.
<u>Protexu- late</u>	Mineral Powder	0.75	60.0	480	no	---	no	---	0.064	Water repellant.

TABLE 6. GENERAL PROPERTIES OF INSULATION

In addition to the type of insulation, the choice of carrier pipe is very important in a geothermal system. Depending on the type of carrier pipe, expansion joints and welding may be required. Basically there are two different types of piping systems, i.e., field insulated and pre-insulated. In field insulated systems, the carrier pipe is assembled at the site and insulation is then strapped around the pipe with a protective weather jacket if required. In pre-insulated systems, each carrier pipe comes with a layer of insulation attached to the pipe and surrounded by a vapor barrier to protect the insulation from the elements. The more common pre-insulated pipe is that with the inner fluid carrier pipe made from steel, copper, PVC, fiberglass reinforced pipe (FRP) or asbestos cement; the outer vapor barrier made from PVC or asbestos cement (AC); and the annulus filled with the insulator (usually urethane). Either pre-molded urethane or catalyst-reactant urethane field molding kits are available with heat shrinkable protective sleeves to insulate all joints. Pre-insulated systems have the advantages over field insulation systems in that they are easier to install and do not require the added labor of installing the insulation. Also, due to the method of fabrication, the insulation on pre-insulated pipe is in little danger of being damaged or diminishing in its insulating properties due to the protective water tight vapor barrier. On the other hand, while field insulated pipe may have the same type of carrier pipe as pre-insulated systems, field applied protective coverings don't form as secure a vapor barrier as the pre-insulated pipe and may require concrete tunnelling as illustrated in Figure 22 for protection. This type of installation allows for easy access for repairs or future development but may cause installation to be 3 times that of

FIGURE 22. SUBSURFACE TRANSMISSION TUNNEL

a pre-insulated system. However, field insulated systems are not restricted to using urethane insulation with its low temperature limitation.

Most geothermal fluid transmission lines are installed underground because of environmental and aesthetic reasons. If the system is high temperature ($T > 200^{\circ}\text{F}$) and substantially pressurized ($P > 200 \text{ psi}$), then a metallic carrier pipe is required. If this is the case, a welded carbon steel system is normally used with the required expansion loops. The maximum straight-line length between a defined size U-shape expansion loop is defined in common engineering practice. Less footage of pipe is required for long straight line distances between expansion loops than shorter distances. This suggests that cost for pipe and elbow-couplings will be minimum if long distances (on the order of 300 ft) are used between expansion loops.

If the system is low temperature ($T < 200^{\circ}\text{F}$) and low pressure ($P < 200$ psi), welded joints are not required. Instead, slip joints with O-rings may be used. These are designed to allow for thermal expansion and contraction, thus eliminating the need for expansion loops. In either of these two types of systems (welded or slip joints) thrust blocks are required at any change of direction or pipe size. These thrust blocks, along with the pipe anchors in welded systems, confine the pipe from moving except within specified limits.

Since in geothermal systems the pipe must survive many years of being exposed to hot, brackish water, the choice of carrier pipe to be used is very important. Four types of carrier pipe recommended for use with geothermal fluids are as follows: 1) low carbon steel, 2) epoxy lined asbestos cement (AC), 3) fiberglass reinforced plastic (FRP) and 4) polymer concrete (PC).

The most common and aggressive corrosive species in geothermal waters for metal carrier pipes are given as follows: (9)

- o Oxygen
- o Hydrogen ion (ph)
- o Chloride ion
- o Hydrogen sulfide
- o Carbon dioxide, carbonate & bicarbonate ion
- o Ammonia, ammonium ion
- o Sulfate ion

A case study based on weight loss of low carbon steel exposed to geothermal fluid at Raft Rivers for 109 days shows that the average

corrosion rate is 1.9 mills/year. In Table 7, the chemical composition of a Raft River geothermal well and data from the production hole at Site C are shown for comparison. This data would support

PARTS PER MILLION (PPM)		
	RAFT RIVER RRGE - 2(10)	SITE C (11)
Na	331	372
K	31	41.4
Ca	32	124
Mg	0.7	25.4
HCO ₃ ⁻	42	579.7
CO ₃	--	-0-
CL ⁻	701	571.1
SO ₄ ⁼	29	52.0
F ⁻	7.9	1.22
SiO ₂	155	59.5
B	--	0.34
Fe	--	<u>0.10</u>
Total Dissolved Solids (TDS)	1161	1820

TABLE 7. SALINITY OF GEOTHERMAL WELLS

the use of low carbon steel as a carrier pipe of geothermal fluids in the Las Cruces, New Mexico area based on corrosion considerations.

Besides not being susceptible to galvanic corrosion, FRP, AC, and PC carrier pipes have their own advantages over the conventional carbon-steel system. Low cost asbestos cement (sewer-type) pipe has a 12 mil thick epoxy lining which is centrifugally cast, then cured to the inner wall. This gives the pipe a hard, chemical resistant, protective coating with a smooth finish that is advantageous for fluid flow. Thermal expansion is accounted for in the design of the O-ring slip joints, thus eliminating the need for expansion loops. Fiberglass reinforced plastic (FRP) pipe also has no need of expansion loops because of the flexibility of its helically wound glass fibers. FRP pipe is virtually inert to any geothermal constituent, very lightweight, and easily assembled using an epoxy on the bell and spigot end connections. The use of polymer concrete pipes with geothermal fluids seem to show much promise in the present developmental stage as new processes for mass manufacturing are conceived. However, the primary disadvantage of all three of these non-metallic systems is their limits on temperature ($T < 200^{\circ}\text{F}$) and pressure ($P < 200 \text{ psi}$).

Trenching, backfill, and tunneling are all involved in installing a subsurface piping system. For common terrain and soil of the Las Cruces area, a continuous bucket trenching machine should be adequate to dig an 18 inch wide, 3 foot deep ditch. Machine and labor costs would result in approximately \$0.60/ft trenching cost. Should the excavated soil not be useable as backfill because of rock and debris content, refined sand would have to be used. This may cost an additional \$0.40/ft for a selective backfill. Thus, trenching and backfilling cost would be about \$0.60 - \$1 per foot.

Inherent to each of the five geothermal sites is the number of asphalt topped roads, railroads, and rivers needed to be crossed in connecting a pipeline from each well to the L'Eggs Plant. These require special subsurface tunnels lines with steel casing for structural support. Installed costs for these are approximately \$60-\$100/ft.

Geothermal Site Budgetary Analysis

Using the projected data for Sites C, D, and B, a budgetary analysis of an installed insulated piping system was made. The results are summarized in Table 8 for different percentages of the L'Eggs Plant thermal requirements being met. Note that for pre-insulated systems, the cost of the jacket and carrier pipe are included under the insulation column and Site B is a composite system made from a 5 in. and 4 in. pipeline for reasons which are explained later in this report.

Several geothermal production wells have been drilled in the Las Cruces area for New Mexico State University (NMSU) by local companies. Site C is one such example where a geothermal production well is no more than a deep (850 ft) water well. Quoted costs from local drilling companies in Las Cruces of \$15-\$20/ft for drilling a 6 in. well at a depth less than 600 ft are consistent with the suggested rates in Figure 23. The exponential trend indicated in Figure 23 can also be seen in another source of Figure 24. The reason for this trend is the lower rates of penetration (ROP) and the increased trip time in and out of the holes for deeper wells. Table 9 shows the total cost and breakdown of several geothermal wells.

COST BREAKDOWN OF SITE 'C' $T_{\text{well}} = 140^{\circ}\text{F}$

% L'eggs Demand m(lbm/hr)	Diameter Type * (Inches)	Insulation \$	Jacket \$	Expansion Elbows \$	Pipe \$	Couplings \$	Weld Labor \$	Trench ** \$	Insulation Labor \$	Jacket Labor \$	Adhesive \$	Total \$	Pump Power (\$/yr)	Heat Loss (10 ³ btu/hr)	Exit Temp. (°F)
75%															
51,809	4 #40	59,515	38,475	36,796	125,622	19,647	21,546	34,628 C	38,475	28,856	-0-	403,600	-0-	207	136
	4 FRP	240,240	-0-	-0-	-0-	-0-	-0-	11,088	36,960	-0-	1,848	290,136	-0-	207	136
	4 T	175,560	-0-	-0-	-0-	-0-	-0-	11,088	36,960	-0-	-0-	223,608	-0-	259	136
	4 P	206,808	-0-	36,796	-0-	19,647	21,546	11,543	38,476	-0-	-0-	334,815	-0-	207	136
	3 #40	35,830	28,723	14,938	88,085	10,761	18,384	34,468 C	23,936	28,723	-0-	283,848	2,993	207	136
50%															
34,540	3 #40	35,200	28,221	14,677	86,544	10,573	18,061	33,865 C	23,518	28,221	-0-	278,880	-0-	207	134
	3 T	134,904	-0-	-0-	-0-	-0-	-0-	11,088	32,340	-0-	-0-	178,332	-0-	276	132
	2½ #40	24,110	33,422	9,246	71,236	7,553	18,334	34,376	38,196	28,647	-0-	265,120	1,463	207	134
25%															
17,270	3 #40	35,846	33,527	14,946	88,127	10,537	18,392	34,484 C	38,316	38,316	-0-	312,491	-0-	190	129
	3 P	161,885	-0-	14,946	-0-	10,537	18,392	11,495	38,316	-0-	-0-	255,571	-0-	190	129
	3 T	134,904	-0-	-0-	-0-	-0-	-0-	11,088	36,960	-0-	-0-	182,952	-0-	259	125
	2½ #40	24,109	33,422	9,246	71,235	7,553	18,334	34,376 C	38,196	38,196	-0-	274,669	165	190	129
	2 FRP	184,985	-0-	-0-	-0-	-0-	-0-	11,088	36,960	-0-	1,848	234,881	1,026	173	130

COST BREAKDOWN OF SITE 'D' $T_{\text{well}} = 120^{\circ}\text{F}$

25%	3 T	116,800	-0-	-0-	-0-	-0-	-0-	9,600	28,000	-0-	-0-	154,400	-0-	167	113
23,789	2½ #40	20,776	24,680	7,965	61,371	6,581	15,795	29,616 C	20,567	24,680	-0-	212,031	13	119	115
	2 #40	14,142	24,624	3,278	45,308	3,316	10,506	29,549 C	20,520	24,624	-0-	175,867	1,721	119	115
	2 P	96,854	-0-	3,278	-0-	3,316	10,506	9,850	513	-0-	-0-	124,317	1,721	143	114
15%	2½ #40	20,776	24,680	7,965	61,371	6,581	15,795	29,616 C	20,567	24,680	-0-	212,031	203	114	112
14,274	2 P	96,854	-0-	3,278	-0-	3,316	10,506	9,850	513	-0-	-0-	124,317	203	128	111

COST BREAKDOWN OF SITE 'B' $T_{\text{well}} = 300^{\circ}\text{F}$

100%															
68,940	5 4 ****	476,952	-0-	177,471	438,796	88,735	56,791	26,620	88,735	-0-	-0-	1,176,630	1,658	3,584	
		225,511	-0-	48,683	166,206	25,994	28,507	15,272	50,906	-0-	-0-	561,077	2,655	1,724	223
												1,737,707	4,313	5,308	

* #40 - Schedule 40, FRP - Fiberglass reinforced plastic, T - temtite, P - preinsulated #40 **** Composite system

** C - concrete lined tunnel

*** at \$0.04/kw -hr

TABLE 8. INSTALLED PIPELINE COST FOR PERCENTAGES OF L'EGGS THERMAL DEMAND

FIGURE 23. WELL COSTS VERSUS DEPTH (1978 \$)⁽¹²⁾

FIGURE 24. PROJECTED AVERAGE WELL COSTS (13)

TOTAL WELL COSTS
(Corrected to 1978 Prices)

Description	Year Drilled	Depth (feet)	Casing Diameter (inches)/Depth (feet)	Cost (1000's)	Inflation Factor	Costs Corrected to 1978 (1000's)
Raft River #1	75	5007	13-3/8 to 3634	810	1.38	1,118
Raft River #2	76	6561	13-3/8 to 4227	800	1.26	1,008
Raft River #3	76	*5917 *5532 *5853	13-3/8 to 1385: 9-5/8 to 4255	662	1.26	834
Raft River #4A	77	2840	13-3/8 to 1820	305	1.12	342
Raft River #4B	78	*5427 *5115	13-3/8 to 1820: 9-5/8 to 3457	830	----	----
Raft River #5	78	4925	13-3/8 to 1500: 9-5/8 to 3408	995	----	----
Raft River #6	78	3888	13-3/8 to 1698	325	----	----
Raft River #7	78	3858	13-3/8 to 2044	275	----	----
Industry Coupled #1	74	4300		385	1.63	628
Industry Coupled #2	76	5100		370	1.26	466
Industry Coupled #3	75	4000		290	1.38	400
Industry Coupled #4	78	5400		550	----	----
Industry Coupled #5	78	6000	Bore diameter at surface was	800	----	----
Industry Coupled #6	78	7735	17-1/2 inches narrowing to	2,079	----	----
Industry Coupled #7	78	5200	8-3/4 inches at target depth.	1,232	----	----
Project Applications #1	79	1500	16 to 700: 7-7/8 to 1300	214	.93	199
Project Applications #2	79	2176	10-3/4 to 800: 7, 500 to 2176 (perforated)	296	.93	275
Project Applications #3	78	4266	10-3/4 to 1000: 7-5/8 to 3722: 5 to 3900	452	----	----
INEL #1	79	10356	13-3/8 to 3359: 9-3/8 to 6796	2,960	.93	2,753

• Multilegged wells.

COST BREAK DOWN
(Not Corrected to 1978 Prices)

Well Identification	Project Applications #2	Industry Coupled #6	Industry Coupled #7	Raft River #1	Raft River #3	Raft River #5	INEL #1
Well Depth	2176	7735	5200	5007	5917	4925	10356
<u>Item Description</u>							
Location Preparation	491	67,044	81,888	16,600	14,300	11,400	227,800
Mobilization and Demolition	36,000	----	----	37,700	45,700	9,000	350,000
Drilling	72,910	687,131	404,201	319,600	185,400	418,800	749,750
Drill Bits	6,938	107,755	46,400	23,200	59,100	35,200	70,592
Drilling Fluid	26,958	181,643	104,149	3,500	4,000	----	92,710
Cementing	28,904	554,149	329,066	95,000	74,800	52,500	252,301
Equipment Rentals	5,208	111,321	70,467	56,900	69,900	72,700	89,168
Transportation	----	102,635	70,363	9,300	----	----	1,810
Supervision	26,260	36,400	24,600	In Drilling Cost	In Drilling Cost	21,900	71,400
Logging	12,510	----	----	58,200	58,000	123,000	51,330
Casing	23,435	159,481	72,780	91,400	83,600	45,700	339,585
Well Head	15,664	25,878	12,466	41,000	37,000	44,000	74,304
Miscellaneous	40,984	45,964	15,270	57,600	30,400	160,500	589,544
TOTAL	296,262	2,079,401	1,232,150	810,000	662,200	994,700	2,960,294

TABLE 9. BREAKDOWN OF WELL COSTS (14)

Of the five sites considered to supply geothermal fluid to the L'Eggs Plant, two have existing wells. Site C has a 6 in. 800 ft deep geothermal well that was drilled by New Mexico State University (NMSU) to provide heat for the campus and Site B has an 8 in.-22,000 ft abandoned gas well. The water table is 250 ft at Site C and the water temperature is 140°F at 800 ft. The well was drilled in 8 days by a local firm in Las Cruces and cost approximately \$15,000 (\$19/ft). The well at Site B is one of the deepest gas wells on record. A temperature of over 390°F was encountered at 20,000 ft according to the drill bit record for the well. It took 8 months to drill the well and when abandoned, it was cement plugged from 10,650 to 10,950 ft. Logs of the well exist but have not been assessed. If Site B is chosen as a geothermal source, there would be little advantage (except in the existing well logs) to have the existing 22,000 ft well since reopening the well would cost more than drilling a new one.⁽¹⁵⁾

Down-hole centrifugal well pumps are needed to pump the geothermal fluid to the surface since none of the wells are expected to be artesian. The two basic types of pumps which can be used are submersible and shaft turbine pumps. A submersible pump is a fully self contained pump and motor that is set at a desired level in the well. The discharge pipe, electric supply lines, and safety rope are extended down the hole and are connected to the submersible pump. This type of pump can be used in crooked wells but is limited in its service to handle fluids at temperatures less than 150°F so that the windings

of the electric motor will not be damaged. As long as this temperature requirement is met, a submersible pump should be able to operate at any well hole depth. A typical 6 in.-15 hp submersible pump that can provide 400 ft of head at 110 gpm will cost about \$3,000. A control panel and magnetic starter should cost another \$1200. The most commonly used pumps for geothermal wells are shaft driven, deep-well pumps. This type consists of impellers mounted down-hole that are connected by a shaft to an electric motor mounted on the surface. The advantage to this configuration is that almost any temperature of fluid can be handled since the electric motor is not submersed in the fluid. However, shaft turbines are normally not used at depths greater than 400 ft because of clearance problems due to shaft line stretch. A fluid driven, down-hole pump that, in theory, could operate at depths greater than 1100 ft is in the developmental stage. A high pressure hydraulic turbine on the surface drives the down-hole pump. This type of pump is not restricted by temperature limits or well depths as are the submersible and shaft pumps, respectively.⁽¹⁶⁾

In order to size the pump for a geothermal system; the depth to water table, feet of drawn-down, vapor pressure of the fluid, frictional pressure drop of the pipeline, elevation change, required working pressure at the L'Eggs Plant, and the required flow rate must all be considered. The depth to the water table depends on the elevation at the site but for the Las Cruces area is about 3900 ft above sea level. The feet of draw-down varies from site to site and depends on the porosity of the well formation. The vapor pressure of the geothermal fluids depends on the temperature of the fluid. It is important to maintain a pressure greater than the vapor pressure in order

to have single phase liquid flow. If this is not maintained, serious problems may arise from cavitation in the pumps and water hammer in the pipeline.

To complete a geothermal system, a method for waste fluid disposal must be determined. Some suggested methods of waste disposal are as follows(17):

- o direct surface discharge,
- o treatment and surface discharge,
- o ponding,
- o secondary use of effluents,
- o reinjection,
- o reinjection with pretreatment.

When using direct surface discharge to streams, compatibility with surface waters in the following areas must be considered:

- o Salinity: > 300 ppm is undesirable
>1000 ppm is not potable
- o Temperature: Stream temperature plus a few degrees F is allowable
- o Gas Content: H_2S , high CO_2 , low oxygen content are undesirable.

Because the salinity of the geothermal fluid is considered high (Site C, 1800 ppm), discharge to the Rio Grande River is undesirable. At the present, the L'Eggs Plant has approximately 37,500 gallons of dyeing effluent and 175,000 gallons of rinse and cooling water that is daily discharged to either a holding pond for evaporation or an alfalfa field for irrigation and percolation. Because this is an abnormally large quantity of water to dispose of on a daily basis, the L'Eggs Plant is almost saturated in its present means of fluid disposal. Should the use of a geothermal well be integrated at the plant, then a new means of fluid disposal would be required. The use of a reinjection well seems to be a practical solution. If the reinjection well is located at the site of the production well, the following advantages and disadvantages apply.⁽¹⁸⁾

Advantages to production site reinjection:

- o helps to maintain fluid pressure in the producing reservoir,
- o helps to prevent subsidence,
- o eliminates surface disposal concerns,
- o improves the recoverable heat reserves by applying a sweep.

Disadvantages to production site reinjection are:

- o cost of well and return pipelines,

- o cost of pump and motor power,
- o possibility of activating faults,
- o possibility of cooling the production well,
- o possibility of blocking pores of the formation in the reinjection region of the well.

Because of the cost of a return pipeline and the other disadvantages stated above, it is recommended that a reinjection well at the L'Eggs Plant be used. The cost of this well should be comparable to a shallow production well or \$15-\$20/ft.

Geothermal Site Comparison and Selection

The five geothermal sites were reviewed in terms of the geophysical and engineering data obtained to date during the program. This data was then evaluated and conceptual system designs completed such that rough cost estimates and fuel savings could be determined. In this way, all five sites were economically compared on an equivalent basis of payback period to help in the selection of the best two sites.

Table 10 lists the five geothermal sites with their corresponding technical and economic data. Based on this information it can be seen that, independent of the L'Eggs plant modifications, Sites A and C provide the best geothermal site selections when compared by payback period. It should be indicated that while the absolute economics of Table 10 are based on only conceptual designs the relative standings of the individual sites are expected to vary only little. In addition, the sites well depth, temperature, and flows were projected as if they would be equally probable (which is difficult to determine without site specific drilling data).

SITE	FLOW (lbm/hr)	WELL DEPTH (ft)	USEFUL TEMP (°F)	PIPELINE COST \$	PRODUCTION WELL COST \$	OTHER COSTS \$	TOTAL CAPITAL INVESTMENT \$	PUMP POWER \$/yr	OPERATION & MAINTAINENCE \$/yr	FUEL SAVING \$/yr	PAY BACK PERIOD yr
Minor Modifications to L'Eggs Plant											
A	18,000	7,000	240	-0-	1,200,000	224,000	1,424,000	3,545	28,500	158,000	11.3
B	68,000	10,000	225	1,737,700	3,200,000	403,600	5,341,300	26,637	103,400	158,000	191.2
C	29,000	1,000	135	178,300	50,000	307,800	536,100	2,539	9,100	72,600	8.8
D	29,000	1,000	115	155,100	50,000	307,800	512,900	2,539	8,700	38,700	18.6
E	18,000	7,000	240	201,400	1,200,000	264,000	1,665,400	1,575	32,500	158,000	13.4
Major Modifications to L'Eggs Plant											
A	32,400	7,000	240	-0-	1,200,000	227,200	1,427,200	6,381	28,500	344,200	4.6
B	68,000	10,000	225	1,737,700	3,200,000	405,000	5,342,700	26,637	103,500	344,200	25.0
C	78,500	1,000	135	295,000	50,000	310,000	655,000	6,872	11,500	205,300	3.5
D	78,500	1,000	115	256,500	50,000	310,000	616,500	6,872	10,700	110,000	6.7
E	32,400	7,000	240	201,400	1,200,000	265,000	1,666,400	7,800	32,500	344,200	5.5

- NOTES:
- 1) Other costs include reinjection well, pump, and pipeline road or river crossings. Right-of-way costs are not included
 - 2) Total capital investment is exclusive of L'Eggs Plant modification costs.
 - 3) Fuel cost savings are based on 85¢/gallon fuel oil and 77.5% boiler efficiency.
 - 4) Operation and maintainence costs based on 2% of the total investment cost.

TABLE 10. SITE COMPARISON FOR L'EGGS GEOTHERMAL PROGRAM

However, the data of Table 10 does present some interesting conclusions. For instance, Site C provides the least payback period even though it is projected to supply a relatively moderate temperature (135°F) geothermal fluid. Also, Site A, while not as promising geothermally due to the deeper well expected to be required, has the advantage of not requiring a delivery pipeline. The effects of a longer pipeline are readily seen by analysis of Site B. At this site, it would be expected to obtain approximately 280-300°F geothermal fluids, but after transportation to the L'Eggs facility it would only be available at about 225°F. Also, the associated pipeline cost helps to make development of Site B nearly four times more expensive than Site A which is the next most expensive proposal.

As indicated previously, all costs listed in Table 10 are considered conceptual or budgetary costs in nature. More refined cost figures will be determined for the selected Sites A and C in the remainder of the program. Specifically, well costs are actually charged based on drilling time rather than depth and can only be accurately projected in areas which have considerable previous drilling experience. Also, pump costs at this time are only tentative although the costs have been determined to be a relatively small part of a geothermal supply system (less than 1% of the total investment).

REGULATORY ANALYSIS

Geothermal development at the L'Eggs Plant is subject to a large number of rules and regulations which are administered by several agencies. All four sites are located on either state or private land and are subject to the rules and regulations of the various state agencies. Some Federal laws have requirements to be met relating to environmental and cultural properties. Federal lands will become involved with the project only if Site B is selected for development. Site B itself is located on New Mexico State land and is not subject to Federal regulations governing geothermal development. However, to use geothermal resources from Site B at L'Eggs, would necessitate that a pipeline traverse Federal lands and consequently be subject to the Bureau of Land Managements Rule and Regulations concerning right-of-ways.

Once a definite site has been selected for development, there are four main steps leading from the feasibility study phase to actual usage of geothermal energy at the L'Eggs plant. These are as follows:

- o Leasing,
- o Drilling,
- o Construction,
- o Usage.

Each of these activities are affected by the rules and regulations of some agency. At this time, there are no apparent regulations which would drastically hinder geothermal development at L'Eggs.

LEASING

The first step in actual development of geothermal resources for use by L'Eggs, is to secure the right to use those resources from the party which has control. Site A (T24S:R 2E:S9) is owned by the Hanes Corporation. There would be no problem obtaining geothermal rights. Sites D and E are both owned by individuals. Leases for a time period equal to or greater than the expected life of the program must be secured from those individuals. Site C is on University property (New Mexico State University) and rights for that site would come from the Institution.

Site B is located on state-owned land, of which the geothermal lease is held by a corporation. The geothermal rights to this property would be secured from that corporation.

In all of the locations, except A, it is highly probable that royalties would be paid to the lessor. The legal terms and conditions would be worked out by those parties involved.

DRILLING

Drilling is the next phase of development which can be broken down into two sub-phases: exploratory and development drilling.

Exploratory drilling is that activity associated with the effort to attempt to define the boundaries of a geothermal reservoir. The Oil Conservation Commission defines an exploratory well as a "well drilled for the discovery or evaluation of geothermal resources one mile or more beyond the established limits of a designated geothermal field."

The same agency regulates all drilling activities and its permitting process must be followed in order to develop geothermal resources at the L'Eggs Plant.

The first step to drilling is designating an agent (OCC Rule 100). The agent is responsible for holding all well records. OCC Rule 101 mandates that a plugging bond be posted next. This ensures that no well will be left open if non-productive or when abandoned. The number of bonds varies in number and amounts depending on the exact number of wells to be drilled. The bond shall be posted until the well is plugged and abandoned.

Once bonding is in order, an application for a drilling permit* must be filed (OCC Rule 102). This activity is standard for any drilling operation in the state which is to take place on state or private land. Other drilling requirements are too numerous to mention. Installation and safety regulations relative to casing, mud, blowout prevention equipment, cementing, etc., are included in the regulations of the Oil Conservation Commission.

Given that a drilling permit has been obtained from the Oil Conservation Commission, the next agency to contact is the Museum Division of New Mexico. This agency administers the State Cultural Properties Act. This agency issues permits for the use of earth moving equipment on private land involving archeological sites. The agency also issues permits for archeological survey work on state lands. Due to the known development of the Las Cruces area and past actual development on each site, this agency does not appear to offer any slow downs in construction.

* Applicant must be licensed by New Mexico State Corporation Commission prior to filing application.

CONSTRUCTION

Construction of this project, would require interfacing with the New Mexico Constructions Industries Board. The normal building permits would have to be obtained and the New Mexico Building Codes followed. The corporation must be licensed by and have a Certificate of Good Standing from the State Corporation Commission. Since this project is not for power generation then the New Mexico Public Service Commission would have no bearing on this project.

USAGE

Once the project is underway and operating, there is continuous interfacing with several government agencies.

The OCC requires monthly reports of production, injection and purchasing. These reports are for monitoring the activity of the wells.

OCC Rule #211 requires an annual temperature and pressure test of each well. The OCC publishes a testing schedule to be used for this report.

The Taxation and Revenue Department would be dealt with on a monthly basis also. The State imposes taxes of various kinds as listed below:

- o Oil and Gas Conservation Tax,
- o Gross Receipts Tax,
- o Compensating Tax,
- o Property Tax,
- o Income Tax.

FEDERAL LAWS

The Federal Laws which are pertinent to geothermal projects in general are listed below. Those under the heading of "Land Use" if applicable, are applicable to Site B only since its development for L'Eggs would necessitate a pipeline crossing Federal land. Each is evaluated as it relates to geothermal development at the L'Eggs Plant.

LAND USE

P.L. 91-581

Geothermal Steam Act of 1970.

This law is to authorize "the Secretary of the Interior to make disposition of geothermal steam and associated geothermal resources and for other purposes." The Secretary may issue geothermal leases on lands administered by him and in any national forest or other land administered by the Department of Agriculture through the Forest Service. None of the sites associated with L'Eggs falls under this law and consequently does not effect this project.

P.L. 94-579

Federal Land Policy and Management Act

This law gives the Secretary of the Interior the authority to grant right-of-ways across Federal land. Section 501 applies to pipeline crossing Federal land.

P.L. 88-577

The Wilderness Act of 1964

This act was established to protect Federal lands which are identified as wilderness. In part, a wilderness is described as an area of 5,000 acres or more that is "undeveloped Federal land in a natural condition, without permanent improvements or human habitation." None of the 4 sites fall on Federal land and is not included.

P.L. 86-517

Multiple Use Sustained Yield Act of 1960

P.L. 93-378

Forest & Rangeland Renewable Resources Planning Act of 1974

P.L. 94-588

National Forest Management Act of 1976

All of the above laws related to Federal land. These laws deal with the management of Forest and other land use on Federal lands.

Of the land use laws, only F.L. P.M.A. appears to have any potential bearing on this project. If Site B is chosen for development, then right-of-ways would have to be secured from the Bureau of Land Management. That agency publishes regulations on right-of-way policy.

ENVIRONMENTAL LAWS

P.L. 91-190

National Environmental Policy Act of 1969

P.L. 91-224

Environmental Quality Improvement Act of 1970

N.E.P.A. was the first piece of legislation that was aimed at the establishment of environmental requirements. E.Q.I.A. followed N.E.P.A. and established the Council on Environment Quality. C.E.Q. issues guidelines for the preparation of N.E.P.A. relevent regulations by each Federal agency.

P.L. 88-206

Clean Air Act

This act is designed to protect the quality of air. The E.P.A. has issued regulations relative to this act which requires permits if a project will discharge pollutants above an established level. For geothermal projects, the primary concern is usually H₂S. However, in the Las Cruces areas, this is not a problem. The chemical analysis of all sites show no measurable concentrations of H₂S.

P.L. 92-500

Federal Water Pollution Control Act

The purpose of this act "is to restore and maintain the chemical physical and biological integrity of the Nation's waters." Since

there is no discharge into water way's, the L'Eggs project is not subject to this particular law. However, if underground injection is utilized, then, the Safe Drinking Water Act will be applicable (see below).

P.L. 43-523

Safe Drinking Water Act

This act is designed to protect the drinking water supplies. This act applies to the program in that underground injection is controlled by the E.P.A. regulations. The E.P.A. regulations are not finalized as of yet. Discussions with E.P.A. indicate that waters of less than 10K ppm are the ones to be protected. The regulations anticipate that jurisdiction over discharge plans will be given to the Oil Conservation Division as it now is with the New Mexico version of this act.

Regulations: Not available.

P.L. 92-574

Noise Control Act of 1972

This law establishes the need for noise standards in order to judge those activities which may be harmful to the general population. This act authorizes the Administration of the EPA to establish regulations governing noise. The L'Eggs project is not expected to create any problems in this area.

P.L. 89-272

Solid Waste Disposal Act

LIST OF AGENCIES AND LAWS PERTAINING TO GEOTHERMAL DEVELOPMENT

STATE LAND OFFICE

Laws: Geothermal Resources Act

Regulations: Rules and Regulations Relating to Geothermal Resources Leases.

OIL CONSERVATION DIVISION

Laws: Geothermal Resources Conservation Act

Regulations: Geothermal Resources, Rules and Regulations

LABORATORY OF ANTHROPOLOGY (STATE ARCHAEOLOGIST)

Laws: 1) State: New Mexico Cultural Properties Act
2) Federal: Federal Antiquities Act (P.L. 34-209)
National Historic Preservation Act (P.L. 89665)
Archaeological & Historic Preservation Act
(P.L. 93291)

NEW MEXICO HERITAGE PROGRAM

Laws: New Mexico Endangered Species Act

ENVIRONMENTAL IMPROVEMENT DIVISION

Laws: New Mexico Air Quality Control Act

Environmental Improvement Act

Other laws relative to environment (i.e., solid waste, radiation, hazardous materials)

NEW MEXICO STATE CORPORATION COMMISSION

CONSTRUCTION INDUSTRIES DIVISION

Laws: Construction Industries Licensing Act

APPENDIX A

REFERENCES

1. Swanberg, C.A., 1975, Detection of geothermal components in groundwaters of Doña Ana County, Southern Rio Grande Rift, New Mexico, New Mexico Geol. Soc. Guidebook, 26th field conf., p. 175-180.
2. Swanberg, C.A., 1978, Chemistry, origin and potential of geothermal resources in southwestern New Mexico and southeastern Arizona, New Mexico Geol. Soc. Guidebook, 29th field conf., p. 349-352.
3. Morgan, P., Swanberg, C.A., and Lohse, R.L., 1979, Borehole temperature studies of the Las Alturas Geothermal Anomaly, New Mexico, Geothermal Res. Co. Trans., vol. 3, p. 469-472.
4. Jiracek, G.R., and Gerety, M.T., 1978, Comparison of surface and downhole resistivity mapping of geothermal reservoirs in New Mexico, Geothermal Res. Co. Trans., vol. 2, p. 335-336.
5. Lohse, R.L., 1980, Heat flow study of Doña Ana County, southern Rio Grande Rift, New Mexico, unpl. M.S. thesis, New Mexico State University, Las Cruces, N.M.
6. Riecker, R.E., ed., 1979, Rio Grande Rift: Tectonics and Magmatism, Am. Geophys. Union, Washington, D.C.
7. New Mexico Geological Society, 1975, 26th Annual Field Conf. Guidebook, Las Cruces, Country.
8. Truesdell, A.H., 1975, Summary of section III, Geochemical techniques in exploration, in Proc. 2nd U.N. Symposium on the development and use of geothermal resources, San Francisco, vol 1, p. LIII-LXXXIX.
9. Expanding the Geothermal Frontier (EGF), Geothermal Resources Council, Volume III, 1979, "Materials Selection Guidelines for Geothermal Energy Systems", Marshall F. Conover, P.E. and Peter F. Ellis, p. 125.
10. EFG, "Geochemical Modeling at Raft River", C.A Allen, R.E. Chaney and R.E. McAtee, p. 1.
11. Swanberg, Chandler A., Site "D" Evalauation, November 1979.
12. EGF, "Geothermal Well Drilling Estimates Based on Past Well Costs", Robert N. Chappell, Susan J. Prestwich, Lowell G. Miller, Howard P. Ross, p. 99.
13. EGF, "Klamath Falls Geothermal Heating District", John W. Lund, Paul J. Lienau, G. Gene Culver, Charles V. Higbee, p. 387.

14. EGF, "Geothermal Well Drilling Estimates Based on Past Well Costs", Robert N. Chappell, Susan J. Prestwich, Lowell G. Miller, Howard P. Ross, p. 99.
15. EGF, "The Madison Formation - Problems of Direct Use", Keith E. Brown, p. 78.
16. Present Status and Future Prospects for Nonelectrical Uses of Geothermal Resources, Lawrence Livermore Laboratory (LLL), October 1975, p. 7.
17. EGF, "Limiting Factors on Geothermal Development, Imperial County, California, U.S.A.", James B. Pick and Edgar W. Butler, p. 538.
18. LLL, October 1975, p. 33.

APPENDIX B

Extracts From the Second Technical Progress Report

Note: The Technical Progress Report page numbers are maintained for clarity with the addition of "B" indicating Appendix B.

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CHAPTER II

SITE C PIPELINE DESIGN

Considerable effort was expended to fully define the engineering aspects of the geothermal pipeline from Site C to the L'Eggs plant. This work involved selection of pipeline routing, calculation of pressure drop and heat loss for various flow conditions, specification of pipeline material and construction, and detailed cost estimates. This work was deemed necessary in order to better understand and compare the geothermal attributes of Site C to those at Site A.

As indicated in Figure II-1, three potential pipeline routes were identified between Site C and the L'Eggs plant. These routes were preliminarily identified from aerial photographs, topographic maps, and property identification maps of Doña Anna County. The pipelines were then traversed to obtain detailed engineering information on road crossings, potential land use conflicts (i.e., pecan orchards), canal crossings, exact locations of structures and topography.

All three routes avoid the Las Alturas housing subdivision by running parallel to existing roads. Aerial photographs (February 1979) clearly show that a straight pipeline would pass directly under several buildings. Since a pipeline cannot be laid beneath an existing structure, the cost to purchase and demolish those houses, in order to construct a pipeline, is assumed to be too prohibitive for consideration. Alternatively, a pipeline could possibly be "snaked" through the development in an attempt to maintain as straight a line as possible, but this consideration was eliminated also. Property identification maps show that the area is divided into housing sized lots. Crossing lots which are undeveloped at this time could prevent future building.

Consequently, there would be a cost associated with the purchase of the lot since no building could be placed over the pipeline.

In light of the above thought, it was decided to run the pipeline westerly from the well site to the highway. This route follows an existing dirt road leading to Highway 25. It has been determined from the New Mexico Highway Department that a pipeline may be installed parallel to the highway at no right of way cost (See Appendix I: Application for Parallel Installation). At Interstate 25, however, three separate routes were investigated. Route 1 in Figure II-1 was selected such that it would cross as little agricultural land as possible, then parallel the main highway to L'eggs. This route had the added advantage of coming within 1/4 mile of Sandyland Nursery, the only other large natural gas user in the area. It was felt that the possibility of utilizing geothermal energy at this location should not be overlooked if the L'eggs development program were carried through. Route 1 was 4.74 miles in length. Route 2 was identified as the easiest route in which to gain right-of-ways. This route parallels the existing freeway for over half the total distance, then cuts through non-agricultural areas to the L'eggs plant. An added advantage is that this route crosses only one interstate freeway. The principal disadvantage of this pipeline routing is that it is the longest (5.21 miles) of the three possible routes. The final route identified, Route 3, was the most direct. This route took the shortest practical path from Site C to the L'Eggs plant while avoiding potential interference problems. This route was 4.25 miles in length.

To determine requirements of road, railroad, and canal crossings, the New Mexico Highway Department, the Atchison, Topeka and Santa Fe Railway Company and the Elephant Butte Irrigation District, respectively,

Figure II-1. Possible Geothermal Pipeline Routes from Site C to the L'EGGS Product Plant.

were contacted. Basically, all crossings involve boring under the obstacle, pulling through a casing (metal pipe), then pulling through the insulated carrier pipe. Typically, the minimum buried depth is three feet to the top of the pipe (either casing or carrier pipe).

The pipeline design was based on pre-insulated, direct burial piping components that are commercially available. The geothermal fluid carrier pipe was selected to be carbon steel based on its higher pressure and temperature ratings over FRP pipe. Also, no internal corrosion problem is anticipated at this time. However, once well head temperature and pressure are finalized (dependent upon plant interface design), FRP will be investigated as to its applicability since FRP offers a 10 to 20% cost savings over carbon steel.

The pipeline insulation is polyurethane with a moisture proof PVC jacket. Material specifications, design details, and construction techniques for two manufacturers, Rovanco Corporation and Thermacore Process Incorporated, are provided in Appendix III.

A detailed engineering investigation was completed for the Site C geothermal pipeline to determine system performance and cost. The results of this investigation are presented in Tables II-1 through II-4. For each of the three potential routes, two flow rates (100 gpm and 200 gpm) from two different well depths (6,000 ft and 6,500 ft) were considered. In addition, two pipe sizes (4 inch and 5 inch) each with two different insulation thicknesses were studied. The required pumping head, pipeline heat loss, fluid temperature at the L'Eggs plant, and total pipeline cost were determined for each case. The required well depth was based on providing approximately 240°F water

Table II-1. Performance and Cost Data for Site C Geothermal Pipeline

<u>Pipeline Route</u>	<u>Pump Head (ft)</u>	<u>Nominal Pipe Size (in)</u>	<u>Insulation Thickness (in)</u>	<u>L'eggs Temp ($^{\circ}$F)</u>	<u>Pipe Heat Loss (10^3 Btu/hr)</u>	<u>Pipeline Cost (\$1000)</u>
1	679	4	1.75	231	651	590
2	693	4	1.75	229	744	662
3	648	4	1.75	232	605	532
1	679	4	2.75	234.6	490	624
2	693	4	2.75	233.6	537	700
3	648	4	2.75	235.6	440	562
1	599	5	2.21	231	651	676
2	604	5	2.21	230	698	757
3	593	5	2.21	232	605	609

Well depth = 6,000 ft

Bottom hole temp. = 255° F

Flow rate = 100 gpm

Well head temp. = 245° F

Table II-2. Performance and Cost Data for Site C Geothermal Pipeline

Pipeline Route	Pump Head (ft)	Nominal Pipe Size (in)	Insulation Thickness (in)	L'eggs Temp ($^{\circ}$ F)	Pipe Heat Loss (10^3 Btu/hr)	Pipeline Cost. (\$1000)
1	1335	4	1.75	243	651	590
2	1397	4	1.75	241	837	662
3	1270	4	1.75	243	651	532
1	1335	4	2.75	245	465	624
2	1397	4	2.75	244	558	700
3	1270	4	2.75	245	465	562
110 (B-2.6)						
1	921	5	1.21	238	1116	649
2	938	5	1.21	237	1209	727
3	893	5	1.21	239	1023	585
1	921	5	2.21	243	651	676
2	938	5	2.21	242	744	757
3	893	5	2.21	243	651	609

Well depth = 6,000 ft

Bottom hole temp. = 255° F

Flow rate = 200 gpm

Well head temp. = 250° F

Table II-3. Performance and Cost Data for Site C Geothermal Pipeline

<u>Pipeline Route</u>	<u>Pump Head (ft)</u>	<u>Nominal Pipe Size (in)</u>	<u>Insulation Thickness (in)</u>	<u>L'eggs Temp (°F)</u>	<u>Pipe Heat Loss (10³ Btu/hr)</u>	<u>Pipeline Cost (\$1000)</u>
1	679	4	1.75	243	698	590
2	693	4	1.75	241	791	662
3	648	4	1.75	244	651	532
1	679	4	2.75	247	512	624
2	693	4	2.75	246	558	700
3	648	4	2.75	248	465	562
1	599	5	1.21	234	1116	649
2	604	5	1.21	231	1256	727
3	593	5	1.21	236	1023	585
1	599	5	2.21	243	698	676
2	604	5	2.21	242	744	757
3	593	5	2.21	244	651	609

Well depth = 6,500 ft

Bottom hole temp. = 270°F

Flow rate = 100 gpm

Well head temp. = 258°F

Table II-4. Performance and Cost Data for Site C Geothermal Pipeline

Pipeline Route	Pump Head (ft)	Nominal Pipe Size (in)	Insulation Thickness (in)	L'eggs Temp ($^{\circ}$ F)	Pipe Heat Loss (10^3 Btu/hr)	Pipeline Cost (\$1000)
1	1335	4	1.75	256	744	590
2	1397	4	1.75	255	837	662
3	1270	4	1.75	257	651	532
1	1335	4	2.75	258	558	624
2	1397	4	2.75	257	651	700
3	1270	4	2.75	259	465	562
1	921	5	1.21	251	1209	649
2	938	5	1.21	250	1302	727
3	893	5	1.21	252	1116	585
1	921	5	2.21	256	744	676
2	938	5	2.21	255	837	757
3	893	5	2.21	257	651	609

Well depth = 6,500 ft

Bottom hole temp. = 270° F

Flow rate = 200 gpm

Well head temp. = 264° F

to the L'Eggs plant. This was accomplished in all cases except for the 6,000 ft well with 100 gpm production rate which could provide only 230°F to 235°F water. The deeper well at the higher flow (6,500 ft at 200 gpm) could provide 250°F to 260°F water, however.

FIGURE IV-3. LITHOLOGY OF SITE A TO A DEPTH OF 1770 FEET

	Lithology	Density	NEUTRON	Caliper	Resistivity	SP	GAMMA
0		High porosity (unconsolidated)	ERRATIC				
100				Rugged Wall	Variable to ERRATIC		
200		Variable 310-400 cps	Fairly STEADY 190-220 cps	Washout	MODERATE RESIST.		
300				WASHOUT	STEADY MODERATE RESIST.		
400		Variable w/ several high porosity zones	170-200 cps porosity indicated		SEVERAL ZONES OF LOW RESIST.		FEATURELESS TRACE w/ few definable peaks
500		350-450 cps					
600					Variable		
700		Variable 270-370 cps	Variable 200-250 cps		Generally higher RESIST.	ENTIRE CURVE VERY ERRATIC AND	
800				WASHOUT	SEVERAL ZONES OF LOW RESIST.	WANDERING	
900			ERRATIC 160-270 cps			Difficult TO INTERPRET	
1000							
1100		Fairly STEADY 260-330 cps	Fairly STEADY 220-250 cps		Generally STEADY		
1200					Low to MODERATE RESIST.		EVEN MORE FEATURELESS THAN ABOVE SECTION
1300							
1400							
1500		Variable 280-370 cps		WASHOUT			
1600		STEADY 250-280 cps		WASHOUT			
1700		Variable 200-350 cps	ERRATIC 180-300 cps	WASHOUT	VERY ERRATIC AND Variable RESIST. Readings		ONLY MINOR POSITIVE FEATURES
1800		Large Porosity	VERY ERRATIC	WASHOUT			
1900		ERRATIC 200-340 cps	ERRATIC 180-250 cps				FEATURELESS TRACE
2000							

Brief Summary of the Cuttings and Geophysical Logs from
L'Eggs Product Plant Geothermal Well - Site A, Las Cruces, NM

Borehole cuttings and a suite of geophysical logs from a geothermal test hole near Las Cruces, NM have recently been examined by LASL personnel. The cuttings have been examined in detail over the interval 1000 to 1870 ft and also for a limited zone in the upper part of the hole (400 to 500 ft). This information has been summarized in the lithologic column of Figure IV-3. Detailed descriptions of the lithologies in the closely examined intervals follow:

400 to 500 ft -

Sandy gravels to gravelly sands of heterogeneous composition. The gravels are generally subangular to subrounded and are up to 15 mm in diameter. Compositionally they include rhyolite, granite, limestone and other misc. rock fragments. The sand is poorly sorted, angular to subangular, probably of granitic origin, and is calcite cemented.

1000 to 1660 ft -

Buff to tan, poorly sorted, angular-to-subrounded sand, probably of granitic origin. Consists mostly of quartz and feldspar, with minor and variable amounts of amphibole, biotite, chlorite, epidote, magnetite and traces of zircon and sphene. The sand appears to have been cemented with calcite.

1660 to 1870 ft -

Dark grey to black volcanic rock fragments. The chips range in size from 1.0 to 10.0 mm (ave. about 2-3 mm) and are all angular. Extensive alteration of the primary phenocrysts has occurred. From the crystal pseudomorphs remaining and the assemblage of alteration minerals, the rock could probably be termed a basalt. Lath-shaped plag. pseudomorphs are still preserved, the plag. being replaced by light yellowish to greenish material, probably saussurite (epidote). Original ferromagnesian (pyroxene?) have also been replaced by a deeper greenish mineral, probably chlorite. The most prominent and abundant alteration mineral appears as greenish blue, fine-grained botryoidal material (prehnite?) found in the numerous vugs and cavities present in the rock. Other alteration minerals present include calcite, quartz and hematite. The groundmass appears vitreous and chocolate brown under the binocular scope.

Also found associated with the basaltic rock samples, but in minor amounts, are off-white, non-volcanic, fine-to-medium grained clumps that are flecked with a dark material. These clumps probably represent secondary alteration veins in the basalt (possibly zeolites). Angular to sub-angular sand, very similar to the sand in the overlying section, is also present. Some of this sand could be due to spallation from the upper sand section. However, in the interval 1800 to 1830 ft significant amounts of sand with minor amounts of gravel are present. From 1830 to 1870 ft, the cuttings are again mostly basaltic rock fragments. There is a possibility then for several separate flows to exist.

Near the top of the upper flow (1660 to 1670 ft) the volcanic fragments take on a much lighter grey, earthy color and the amount of alteration material also increases, with the greenish blue prehnite as a very abundant vug and cavity filler.

The exact stratigraphic position of the rocks penetrated by this bore hole is uncertain. According to Chaturvedi (ref.4) two geothermal test holes on New Mexico State University property just north of the Las Alturas Estate penetrated sediments of the Santa Fe Group but bottomed in "rhyolite gravel" at a depth of about 1200 ft. No indication of the stratigraphic age of these gravels was given. Chaturvedi (ref.5) mentions the possibility of encountering sedimentary rocks of Upper Paleozoic Age at a depth of 1000 to 2000 ft in the Las Cruces area.

Geophysical Log Summary

Logging performed in this bore hole included: (1) density, (2) neutron, (3) caliper, (4) resistivity (type of tool not specified), (5) SP, and (6) gamma ray. Tool responses over the intervals described in the lithologic section are discussed below and are summarized in Figure IV-3. It must be mentioned however, that the tool readings were not calibrated in standard API units. Therefore, information concerning absolute porosity can not be extracted from these logs. Only information on relative changes in porosity can be given.

Density -

Over the interval 340 to 490 ft, the density log indicates several zones of high porosity (high counts per second-cps). These zones correspond to the sandy gravels observed in the cuttings.

Very uniform trace with little deviation from 1000 to 1440 ft. Apparent small increase in porosity at 1440 to 1450 ft. At approximately 1550 to 1650 ft, the trace is mildly erratic and generally appears to have slightly lower porosity than the section 1000 to 1440 ft.

An abrupt decrease in the density reading occurs at 1605 ft and is apparently related to a hole washout at this depth. Base of the sand section (at about 1660 ft) is marked by a large increase in porosity and is probably due to poorly consolidated sand (an aquifer?). From 1670 to 1760 ft (total depth logged), the erratic trace could be due to rugged hole conditions or possibly fracturing in the basalt.

Neutron -

The neutron log readings over the interval 420 to 480 ft are low, indicating relatively higher porosity for this section. Again this probably corresponds to water saturated sandy gravels.

Very uniform trace in the sand section from 1000 to 1550 ft. From 1550 to 1657 ft the readings are mildly erratic and this corresponds in a general way to the density log values over the same interval.

The increase in the neutron log reading at 1657 ft apparently records the base of the sand (as did the density log) and may indicate the presence of water.

From 1660 to 1760 ft, the neutron log records lower values than in the sand section (as would be expected).

Caliper -

The hole is in fairly good gage in the sand section from 1000 to 1660 ft. Minor washouts do occur at 1550 to 1560 ft and 1605 to 1615 ft. At the top of the basalt section the hole enlarges by several inches (at approx. 1670 ft) possibly due to the weathered or fractured nature of the flow top. From 1675 to 1760 ft, the hole is a little rugged (more so than in the sand section).

Resistivity -

Type of resistivity tool is not indicated. In the interval 420 to 500 ft, several zones of low resistivity (indicating water-filled porosity) are present. This tool response corresponds to the readings of the density and neutron devices in the same interval.

The resistivity values are fairly uniform over the interval from 1000 to 1570 ft. From 1570 ft to the base of the sand the trace is quite erratic. The

basalt section gives widely varying readings, and is therefore difficult to interpret.

The resistivity value at the base of the sand is not distinctive as would be expected if water were present (as was presumably indicated by both the density and neutron logs).

SP-

The reading of the SP log is difficult to interpret. For the relatively homogeneous sand section from 1000 to 1660 ft, the SP gives widely fluctuating excursions. Such variable values would (and should) not be expected from such a sandstone section as this. Possibly indicates tool malfunction.

Gamma Ray -

From 1000 to 1620 ft the log is featureless. From 1620 to 1655 ft there is a slight and variable increase in the gamma ray count. The largest excursion occurs at 1650 to 1655 ft (the base of the sand). From 1655 to 1760 ft the log is again featureless with readings similar to that of the sand section. It appears that the sensitivity control was set at too low of a value.

NMSU-DG-2 (NMSU DEEP GEOTHERMAL WELL NO. 2)

INTERPRETED SUBSURFACE CONDITIONS BASED ON ALL LOGS

DEPTH (FEET)	GRAPHIC LOG	DESCRIPTION
0		SAND AND GRAVEL. ROUNDED TO SUBROUNDED GRAVEL PIECES CONSIST OF QUARTZ, FELDSPARS, RHYOLITE, ASH FLOW TUFFS, A VARIETY OF IGNEOUS ROCKS, ETC.
50		HIGH RESISTIVITY, UNIFORM CALIPER WITH MINOR FLUCTUATIONS, UNIFORM GAMMA RAY AND
100		UNIFORM LOW POROSITY DENSIOLOG AND NEUTRON.
150		PROBABLY SANTA FE GROUP BASIN FILL. DRY.
200		ABOVE THE WATER TABLE.
250		WATER TABLE CLEARLY INDICATED BY ALL LOGS AT 265FT BELOW SURFACE. FROM 265FT. DOWN TO ABOUT 420FT, THERE APPEAR TO BE LAYERS OF SAND AND GRAVEL ALTERNATING WITH LAYERS OF CLAY. LOW
300		RESISTIVITY, CAVED ZONES, FLUCTUATING GAMMA RAY, HIGH
350		POROSITY VALUES AND LITHOLOGY ALL INDICATE THIS.
400		
450		BETWEEN 420 AND 450FT. BELOW SURFACE DOWN TO 720FT, THERE IS A ZONE OF SUBANGULAR TO SUBROUNDED FRAGMENTS OF RHYOLITE, RHYOLITIC ASH FLOW TUFF, ANDESITE AND ANDESITE ASH FLOW TUFF - APPROX. 1/4 INCH DIAMETER PIECES OR FINER.
500		UNIFORM RESISTIVITY AND HIGH GAMMA RAY FOR THIS ZONE.
550		
600		
650		
700		FROM 720FT. TO 850FT, THERE ARE GRAVEL AND SAND OF MORE HETEROGENEOUS COMPOSITION WITH SOME FLATTENED, ROUNDED GRAVELS OF ANDESITE.
750		
800		
850		FROM 850FT TO THE BOTTOM OF THE WELL, THE ZONE IS CHARACTERIZED BY VERY UNIFORM PROFILES OF RESISTIVITY, GAMMA RAY, NEUTRON AND DENSIOLOG.
900		LITHOLOGY SHOWS FINE CHIPS OF RHYOLITE AND MINOR
950		AMOUNTS OF QUARTZ, FELDSPARS, ETC.
1000		

Figure IV-4. Lithology of Site C to a Depth of 1000 Feet

CHAPTER VI

L'EGGS ENERGY USAGE

The L'eggs plant processes and energy uses were covered in the Part 1 Technical Progress Report but will be covered here briefly, with clarifying figures and pictures provided in this chapter.

Thermal energy in the form of 110 psig saturated steam is used at the L'eggs plant for domestic hot water production, process dyeing, process drying, and heating in the building HVAC. However, because of the recently completed Dye House Heat Reclaim Project steam will no longer be used for process drying and will be reduced by about 45% for process dyeing. This conservation project is based on the recycling of the hot dye bath at 212°F which was identified in the Part 1 Technical Progress Report. Based on completion of this conservation project the predicted plant energy consumption is provided in Table VI-1. As can be seen in this table, significant energy reduction should be accomplished with this energy conservation project.

The L'eggs plant chilled water piping schematic and plant steam piping schematic are represented in Figures VI-2 and VI-3, respectively. Detailed representatives of a typical air handler and spray air washer are shown in Figures VI-4 and VI-5, respectively. A photograph of a spray air washer is shown in Figure VI-6. As can be readily determined by examination of these figures, the steam is used in a reheat mode, with the return air temperature varying from about 55°F (during summer cooling) up to about 65°F (during winter heating). Thus, a hydronic HVAC coil could readily be utilized at liquid temperatures as low as 95°F to 105°F in this application.

FIGURE VI-3. L'EGGS PLANT STEAM PIPING SCHEMATIC
121 (B-6.4)

FIGURE VI-4. AIR HANDLER DETAIL

FIGURE VI-5. AIR WASHER DETAIL

FIGURE VI-6. SPRAY AIR WASHER IN L'EGGS HVAC SYSTEM

TABLE VI-1. PREDICTED THERMAL ENERGY REQUIREMENTS AT L'EGGS, LAS CRUCES,
NEW MEXICO PLANT

		<u>10⁹ Btu/yr</u>
Fuel Input		<u>38.98</u>
Boiler Losses		
Stack losses	7.99	
Miscellaneous losses	.78	
Blow Down losses	<u>2.89</u>	
Total Losses	11.66	
Useful 110 psig Saturated Steam		<u>27.32</u>
Dyeing Energy Requirement	9.95	
Drying Energy Requirement	-0-	
Drying Waste Condensate Losses	-0-	
Deaerator blow down losses	.58	
Domestic hot water	.25	
Misc. energy losses	4.02	
Building HVAC(Heat & Reheat)	<u>12.52</u>	
Total	27.32	<u>27.32</u>

CHAPTER IX

ECONOMIC ANALYSIS AND SITE COMPARISON

An economic analysis on twelve cases of varying well depths, pipeline costs, and pumping power requirements for Sites A and C was performed to fully define the recommended geothermal system design. The twelve potential geothermal systems are listed in Table IX-1 along with their appropriate economic factors.

The net energy delivered in Btu/yr was calculated by subtracting annual operating power from the gross energy delivered based on the estimate that each electrical Btu was worth three thermal Btu's. The capital costs were calculated on the basis of a unit of capacity of 10^6 Btu/yr. Operating costs were approximated at 1% of capital costs per year. Using the economic required methodology developed in "The Cost of Energy from Utility Owned Solar Electrical Systems," JPL report #5040-29 dated June 1976, and making the necessary adjustments to thermal energy, the levelized* cost of energy in units of million Btu was calculated for each of the twelve cases. The economic factors used are shown in Table IX-2. Table IX-3 shows the capital cost and the levelized cost of energy for each of the twelve systems for an annual fuel escalation rate of 10%.

The importance of Table IX-3 is in it providing a means of directly comparing alternatives. Thus, as can be seen in Tables IX-1 and IX-3, those systems with the lowest levelized

* Levelized cost is the charge per unit of energy that must be applied to break even on the cost of all capital and operating expenses when they are brought for the life of the system to the first year of operation.

CASE #	SITE	WELL DEPTH	* WELL COST (10 ⁶ \$)	** PIPE LINE COST	*** PUMP COST	FLOW GPM	TEMP. AT L'EGGS °F	ANNUAL OPERATING POWER (KWH)	GEO THERMAL ENERGY EQUIVALENT IN GALLONS OF FUEL OIL
1	C	6500'	1.31	\$562K	\$19K	100	248	1.65 x 10 ⁵	175,000 gal.
2	C	6500'	1.31	\$609K	\$19K	100	244	1.51 x 10 ⁵	175,000 gal.
3	C	6000'	1.12	\$562K	\$35K	200	245	6.85 x 10 ⁵	350,000 gal.
4	C	6000'	1.12	\$609K	\$34K	200	243	4.82 x 10 ⁵	350,000 gal.
5	C	6500'	1.31	\$532K	\$35K	200	257	6.85 x 10 ⁵	350,000 gal.
6	C	6500'	1.31	\$585K	\$34K	200	252	4.82 x 10 ⁵	350,000 gal.
7	A	10300'	4.23	-0-	\$19K	100	~245	1.51 x 10 ⁵	175,000 gal.
8	A	10000'	3.85	-0-	\$34K	200	~248	3.0 x 10 ⁵	350,000 gal.
9	C	8000'	2.08	\$562K	\$19K	100	248	1.65 x 10 ⁵	175,000 gal.
10	C	8000'	2.08	\$609K	\$19K	100	244	1.51 x 10 ⁵	175,000 gal.
11	C	7360'	1.70	\$562K	\$35K	200	245	6.85 x 10 ⁵	350,000 gal.
12	C	7360'	1.70	\$609K	\$34K	200	243	4.82 x 10 ⁵	350,000 gal.

TABLE IX-1. ECONOMIC ANALYSIS PARAMETERS

*References: A Direct Application of Geothermal Energy at the
L'eggs Product Plant," Technical Progress Report #1, page 56.

**See text Chapter II

***See text Chapter III

TABLE IX-2. ECONOMIC FACTORS FOR LEVELIZED ENERGY COST CALCULATION

General Inflation	5%
Cost of Capital	10%
Income Tax	50%
Insurance	0.25% of Capital Cost
Operating Cost	1.0 % of Capital Cost
Year of Design	1980
First Year of Operation	1982
Plant Life	20 years
Fuel Escalation	8,10 & 12%

TABLE IX-3. LEVELIZED ENERGY COST OF SEVERAL GEOTHERMAL SYSTEMS

<u>CASE</u>	<u>CAPITAL*</u> <u>COST 10⁶\$</u>	<u>NET ENERGY</u> <u>REPLACED (10¹⁰ Btu/yr)</u>	<u>CAPITAL COST</u> <u>PER 10⁶ Btu/yr</u>	<u>LEVELIZED COST</u> <u>\$/10⁶ Btu</u>
1	1.891	2.33	81.11	16.53
2	1.938	2.35	82.82	16.75
3	1.717	4.33	39.65	8.01
4	1.763	4.51	39.09	7.89
5	1.877	4.33	43.34	8.76
6	1.929	4.51	42.77	8.65
7	4.249	2.35	180.81	36.57
8	3.884	4.70	82.11	16.61
9	2.661	2.33	114.06	23.07
10	2.708	2.35	115.23	23.31
11	2.297	4.33	53.05	10.73
12	2.343	4.51	51.95	10.50

*Does not include injection well and pump, modification to the L'eggs facility, or Site C piping right-of-ways, land leases, and geothermal resource royalties.

cost are for Site C. Case #1 through #6 are based on the optimistic temperature profile provided by Swanberg in the Part 1 Technical Progress Report for Site C. Case #9 through #12 are from his conservative estimates. The greater depths were required for the lesser flows in order to account for the increased temperature loss within the wellbore and pipeline. Thus, all cases except #5 and #6 were based on delivering approximately 243°F to 248°F geothermal fluid to the L'eggs Plant. As can be seen in Figure IX-3, at the same flow rate, both the optimistic and conservative Site C case is more economically viable than drilling the much deeper well at Site A. Thus, Site C is recommended as the more viable geothermal development site. This is based on 1) the site temperature gradients as discussed in Appendix II and estimated by Swanberg in the Part 1 report; 2) the pipeline cost, pump cost, and pumping energy requirements as discussed in Chapter II and III of this report; and 3) the well costs identified in the Part 1 report and presented in Table IX-1.

In addition to making a direct comparison of various options as was done here, a meaningful comparison can also be made with the levelized cost of fossil fuel over the life of the system. Thus, for annual fuel escalation rates of 8, 10, and 12% for 20 years, the levelized cost of #2 fuel oil is \$15.90, \$16.44, and \$25.05 per gallon, respectively, if it cost \$1.00 per gallon in 1980. Correspondingly, with the same escalation factors natural gas costing \$4/mcf in 1980 would have a levelized fuel cost of \$9.09, \$9.39, and \$14.32/mcf.

With this comparison in mind, the Site C systems with 200ggpm flow look very favorable (even against natural gas) over the life of the system.

However, the total system cost (including the L'eggs plant modifications of about \$400,000) would increase the levelized costs of the geothermal systems by about \$1.80 per MM Btu (nearly \$3.50 per MM Btu for those systems with only 100 gpm flow).

Right-of-way costs were investigated for both private and public land. Both areas produce insignificant costs and are not included in the overall system cost.

For reporting purposes an average cost for right-of-ways in the oil industry is considered appropriate. Discussions with individuals, active in the oil business, revealed that \$10-\$15 per rod is a representative average for obtaining pipe line right-of-ways. The actual figure depends on location, land use, and other factors. The cost is normally a one-time occurrence paid directly to the land owner.

The only public right-of-ways to be encountered are those which parallel public highways. As discussed in Chapter II, there is no cost for this capability.