



DOE/ET/27256--T30

DE82 015119

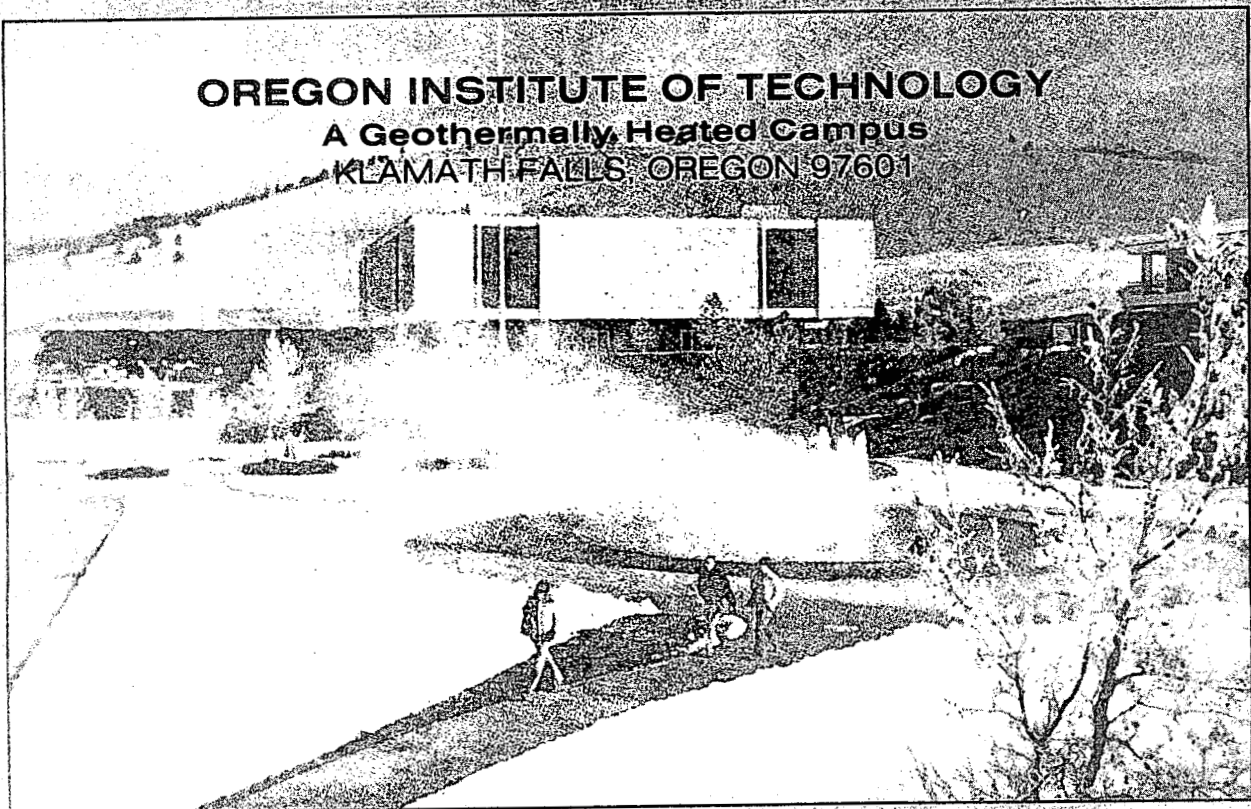
**MASTER**

# GEO-HEAT CENTER

SONOMA STATE HOSPITAL  
GEOTHERMAL-HEATING SYSTEM  
CONCEPTUAL DESIGN & ECONOMIC  
FEASIBILITY REPORT

FEBRUARY 1982

**OREGON INSTITUTE OF TECHNOLOGY**  
A Geothermally Heated Campus  
KLAMATH FALLS, OREGON 97601



## **DISCLAIMER**

**This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.**

## **DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

SONOMA STATE HOSPITAL  
GEOHERMAL-HEATING SYSTEM  
CONCEPTUAL DESIGN & ECONOMIC  
FEASIBILITY REPORT

FEBRUARY 1982

## DISCLAIMER

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, expressed or implied, or assumes any legal responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights.

SONOMA STATE HOSPITAL,  
ELDRIDGE, CALIFORNIA  
GEOTHERMAL-HEATING SYSTEM:

CONCEPTUAL DESIGN AND ECONOMIC  
FEASIBILITY REPORT

FEBRUARY, 1982

PREPARED FOR: Geo-Heat Center  
Oregon Institute of Technology

Contract No. TA 6-81 (West of Arnold Ave.)  
Contract No. TA 7-81 (East of Arnold Ave.)

BY: Gennis and Associates, Engineers  
a division of  
George S. Nolte and Associates

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

*fy*



TABLE OF CONTENTS

	<u>Page</u>
SUMMARY	1
A. INTRODUCTION	2
B. BUILDINGS SELECTED FOR RETROFIT	3
C. EXISTING HEATING AND HOT WATER SYSTEMS	4
1. Steam Generation and Distribution	4
2. Space Heating Systems	4
3. Domestic Hot Water Heating Systems	5
4. Steam Services that Cannot be Converted	5
D. SPACE HEATING AND HOT WATER REQUIREMENTS	7
1. Space Heating	7
A. Climatological Data	7
B. Theoretical Building Heating Requirements	10
C. Steam Production Records	10
D. Existing Installed Capacities	12
2. Hot Water Requirements	14
3. Steam Consumption Summary	15
4. Gas Consumption Summary	18
E. GEOTHERMAL HEATING CONCEPT	19
F. RELIABILITY EVALUATION	25
G. GEOTHERMAL HEATING SYSTEM DESIGN	26
1. Heating System Retrofits	26
2. Distribution System	29
3. Cost Summary	31
H. ESTIMATED ENERGY SAVINGS	33
I. ECONOMIC ANALYSIS AND CONCLUSIONS	37
1. Payback Period	37
2. Benefit/Cost Ratio	38
3. Conclusions	38
J. REFERENCES	43

TABLE OF CONTENTS - Continued



APPENDICES

- A. Energy Profiles for Sonoma State Hospital taken from the Cogeneration Feasibility Study prepared by Kaiser Engineers
- B. Geothermal Fluid Distribution and Return System - Detailed Quantity Take Off and Cost Estimate.
- C. Life Cycle Cost Analysis Performed by Geo-Heat Center, Oregon Institute of Technology
- D. Revised Project Cost Amortization Schedules and Benefit/Cost Ratios Based on Modified Projections of Natural Gas Prices



## LIST OF FIGURES

	<u>Page</u>
1. Location Map	8
2. Monthly Steam Demand and Degree-Day Relationship	11
3. Typical Annual Steam Consumption	17
4. Cascade Heating Concept - Typical Temperature Profile	22
5. Derating Curve for Existing Hydronic Heating Coils	23
6. Geothermal Heating System Retrofit Schematic	27
7. Geothermal Retrofit for Laundry Hot Water	28
8. Geothermal Fluid Distribution and Collection System	30
9. Forecasted PG&E Natural Gas Prices	35

## LIST OF TABLES

1. Monthly Heating Degree-Days: 1977-81 for Napa, Santa Rosa, and Sonoma	9
2. Existing Heating System Installed Capacities	13
3. Project Cost Amortization Over Payback Period	39
4. Project Cost Amortization Over Payback Period Including Geothermal Resource Development Costs	40
5. Benefit/Cost Ratios and Net Savings	41

## SUMMARY



The Sonoma State Mental Hospital, located in Eldridge, California, is presently equipped with a central gas-fired steam system that meets the space heating, domestic hot water, and other heating needs of the hospital. This system is a major consumer of natural gas - estimated at 259,994,000 cubic feet per year under average conditions. At the 1981 unit gas rate of \$0.4608 per therm, an average of \$1,258,000 per year is required to operate the steam heating system.

The hospital is located in an area with considerable geothermal resources as evidenced by a number of nearby hot springs resorts. A private developer is currently investigating the feasibility of utilizing geothermally heated steam to generate electricity for sale to the Pacific Gas and Electric Company. The developer has proposed to sell the byproduct condensed steam to the hospital, which would use the heat energy remaining in the condensate for its own heating needs and thereby reduce the fossil fuel energy demand of the existing steam heating system.

The geothermal heating system developed in this report is capable of displacing an estimated 70 percent of the existing natural gas consumption of the steam heating system. Construction of the geothermal fluid distribution and collection system and the retrofits required within the buildings are estimated to cost \$1,777,000. Annual expenses (operation and maintenance, insurance, and geothermal fluid purchase) have been estimated to be \$40,380 per year in 1981 dollars. The proposed geothermal heating system could then be completely paid for in 32 months by the savings in natural gas purchases that would result.

Based on the technical feasibility and the rapid payback that can be achieved, the use of geothermal energy from the proposed electrical generation facility for heating needs at the hospital is highly cost-effective. Even if the geothermal resource should not prove sufficient for the generation of electricity, heating by direct use of geothermal fluid would still remain an attractive alternative for the hospital.



## A. INTRODUCTION

This report presents the findings of an engineering conceptual design and feasibility study of the use of geothermal fluid produced as a byproduct of geothermal power production for space heating and domestic hot water services for the Sonoma State Hospital at Eldridge, California. The study was performed by Gennis and Associates Engineers, a Division of George S. Nolte and Associates, under contract to the Geo-Heat Center of the Oregon Institute of Technology.

The specific work involved included: evaluation of the existing heating and hot water systems; conceptual determination of the retrofits required to those systems to utilize a geothermal fluid heat supply; preliminary layout of a geothermal fluid distribution and return piping system; estimation of the reduction in natural gas consumption as a result of the conversion to a geothermal energy source; cost estimates of the work required; and an economic analysis of the cost effectiveness of the geothermally heated system vs. the existing gas-fired central steam system.

## B. BUILDINGS SELECTED FOR RETROFIT



Sonoma State Hospital is comprised of some 77 different buildings distributed throughout an area of about 200 acres. The buildings were constructed over a period of time extending from the 1890's to the 1960's. For this reason, the buildings represent a variety of different construction types, design features, quality of workmanship and condition of repair.

Forty of these buildings were screened out of the retrofit evaluation because they fell into one or more of the following categories:

1. The building is not currently served by the existing central steam heating system. Its exclusion from the steam heating system was considered to be an indication that its energy requirements for heating and hot water services are too low to make any form of centralized heat supply (steam, geothermal, or otherwise) cost effective.
2. The building is currently heated by steam convection radiators scattered throughout the structure. Costs for retrofitting such buildings to a hydronic system were assumed to exceed the savings to be derived from a reduction in the steam demands.
3. The building is not currently heated.
4. The building is nearing the end of its useful life and the remaining use of the building will require only small amounts of heat energy.

Although less than half of the buildings were included in this study, the included buildings represent over two-thirds of the total floor area of all buildings. And, more importantly, the included buildings utilize over 90 percent of the total heat energy required by the hospital. A more detailed analysis of those buildings excluded from this study can be made during the preliminary design stage and may be able to demonstrate that conversion of the systems in some of those buildings would be cost effective, particularly if major rehabilitation of the existing heating systems will be required in the near future.



## C. EXISTING HEATING AND HOT WATER SYSTEMS

### 1. STEAM GENERATION AND DISTRIBUTION

The heat source for nearly all of the space heating and hot water needs of the hospital is the central steam generating plant located in the powerhouse on the southwest side of the buildings area. Four boilers have been provided with the following characteristics:

<u>Make and Model</u>	<u>Date Installed</u>	<u>Capacity lbs./hr.</u>	<u>Pressures, psig</u>	
			<u>Design</u>	<u>Operating</u>
Erie City Iron Works Natural Draft	1938	15,000	160	110
Babcock and Wilcox F-1714	1949	50,000	160	110
Bros Water Tube Boiler	1959	32,000	160	110
Murray Iron Works M64-D195	1960	30,000	150	105

(Data taken from Reference 1).

A recent study prepared by Kaiser Engineers (Reference 1) estimated the thermal efficiency of the boilers to range from 70 to 80 percent.

An underground distribution system of steel and transite pipe transports the steam to the individual buildings. Heat extraction from the steam results in its condensation back to the liquid phase. The condensate flows through a pipe drainage system where several condensate return pump stations are used to return the water to the boilers. Some of the distribution and return piping is located in tunnels to allow for access and for the thermal expansion of the pipe.

### 2. SPACE HEATING SYSTEMS

Building space heating systems utilizing steam use the steam directly (in convection radiators or unit heaters) or indirectly by transferring the heat to a water (hydronic) system with shell and tube type heat exchangers. Those buildings which utilize the steam in a centralized heating system were included in the feasibility study. However, those buildings with decentralized convection or unit heaters that directly utilize the steam were not included because it was assumed that the cost to install a



decentralized hot water system or to provide a centralized system would not be recoverable through energy savings in a reasonable period of time.

Most of the hospital's space heating needs are met with hot water systems. These systems utilize 200°F hot water obtained from shell and tube type heat exchangers. Heat is then transferred to the air with either central hot decks or unit zone heaters installed at various points in the ventilation system. The design water temperature drop across the coils ranges from 20°F to 26°F. These buildings are readily and in expensively convertible to geothermal fluid supplied heat.

The Nelsen Treatment Center also has hot water coils located in the flooring as well as a centralized hot deck. However, the hot decks have been capable of meeting the heating needs of the building and hospital maintenance staff are of the opinion that the floor coils have leaks. Consequently, the floor coils are seldom used -- if at all. Geothermal fluid could be used as the heat source for the floor coil system if it is desired by the hospital.

### 3. DOMESTIC HOT WATER HEATING SYSTEMS

Hot water is produced at each building by steam to water heat exchangers. There are two main types. One utilizes a shell and tube type exchanger with storage provided by an oversized expansion tank. The other type consists of an integral storage unit with steam coils inside.

The laundry hot water system differs from the others in that no storage of hot water is provided. Instead, four instantaneous steam to hot water heaters are used, each rated at 79 gpm with a temperature rise from 40°F to 180°F. The peak demand on the steam system that these heaters can exert is then 18,975,000 BTUH or 17,250 lbs/hr. of steam. The magnitude of the peak demand that this system exerts has caused operational problems with the steam system when only one boiler is in use. Two boilers are often used in the mornings to meet this demand. A shell and tube heat exchanger was installed to recover the heat in the used laundry water and preheat the incoming water to as much as 90°F. However, no storage was provided with this system either, and it requires frequent cleaning due to scum deposits from the use of wash water as the heat source.

The final type of water heaters in use is a small number of electric unit heaters. These represent a very small portion of the domestic hot water consumption.

### 4. STEAM SERVICES THAT CANNOT BE CONVERTED

In addition to the steam uses that were considered not cost effective to convert to a geothermal fluid heat source, a number of existing services



will need to retain the use of steam because the temperatures in the geothermal fluid are not high enough to meet the needs of those services. These are the steamers in the kitchens, the laundry dryers and pressing machines, sterilizers, and booster heaters installed with the dishwashers to raise the water temperature from 140°F to 180°F needed for disinfection purposes. (This latter practice will largely be discontinued as part of the Fire Life Safety and Environmental Improvements program now being implemented. Chemical disinfection is being provided in these cases to eliminate the burn hazards associated with high temperature water.)



## D. SPACE HEATING AND HOT WATER REQUIREMENTS

The key element of the feasibility analysis is the determination of the space heating and domestic hot water requirements of the hospital. Peak demand information is needed to adequately size the geothermal heating system. Average demands are needed to determine the savings in energy costs that can be achieved through the use of geothermal heating.

### 1. SPACE HEATING

A number of methods were used to determine the space heating design requirements and demands at the hospital.

#### A. Climatological Data

Climatological data were obtained for a number of nearby communities since no data exists at the hospital itself. Design outdoor air temperatures were obtained from the ASHRAE Fundamentals Handbook as follows:

<u>Location</u>	<u>Elevation</u>	<u>Design Dry-Bulb Temperatures, °F</u>	
		<u>99%</u>	<u>97.5%</u>
Napa	16	30	32
Petaluma	27	26	29
Santa Rosa	167	27	29

The locations of these communities relative to Sonoma State Hospital can be seen on Figure 1.

Degree-day information for Napa State Hospital (Napa), Santa Rosa, and Sonoma was obtained for the period between July, 1977 and June, 1981 from publications issued by the U. S. Weather Service. These data are shown in Table 1. Analysis of this information shows that the climate at Sonoma to be more closely related to Napa than to Santa Rosa even though Napa is considered to be a "heat island," with a warmer climate than other communities in the area. (Reference 13.) For this reason, design dry-bulb temperatures for Napa were used as the basis for determining the heating needs at Sonoma State Hospital since this data was not obtained for Sonoma or at the hospital. The 99th percentile value (30°F) was selected since the importance of maintaining indoor temperatures in a hospital is greater than for most other buildings. This gives a temperature gradient ( $\Delta T$ ) of  $70 - 30 = 40^\circ\text{F}$  for use in heating local calculations.

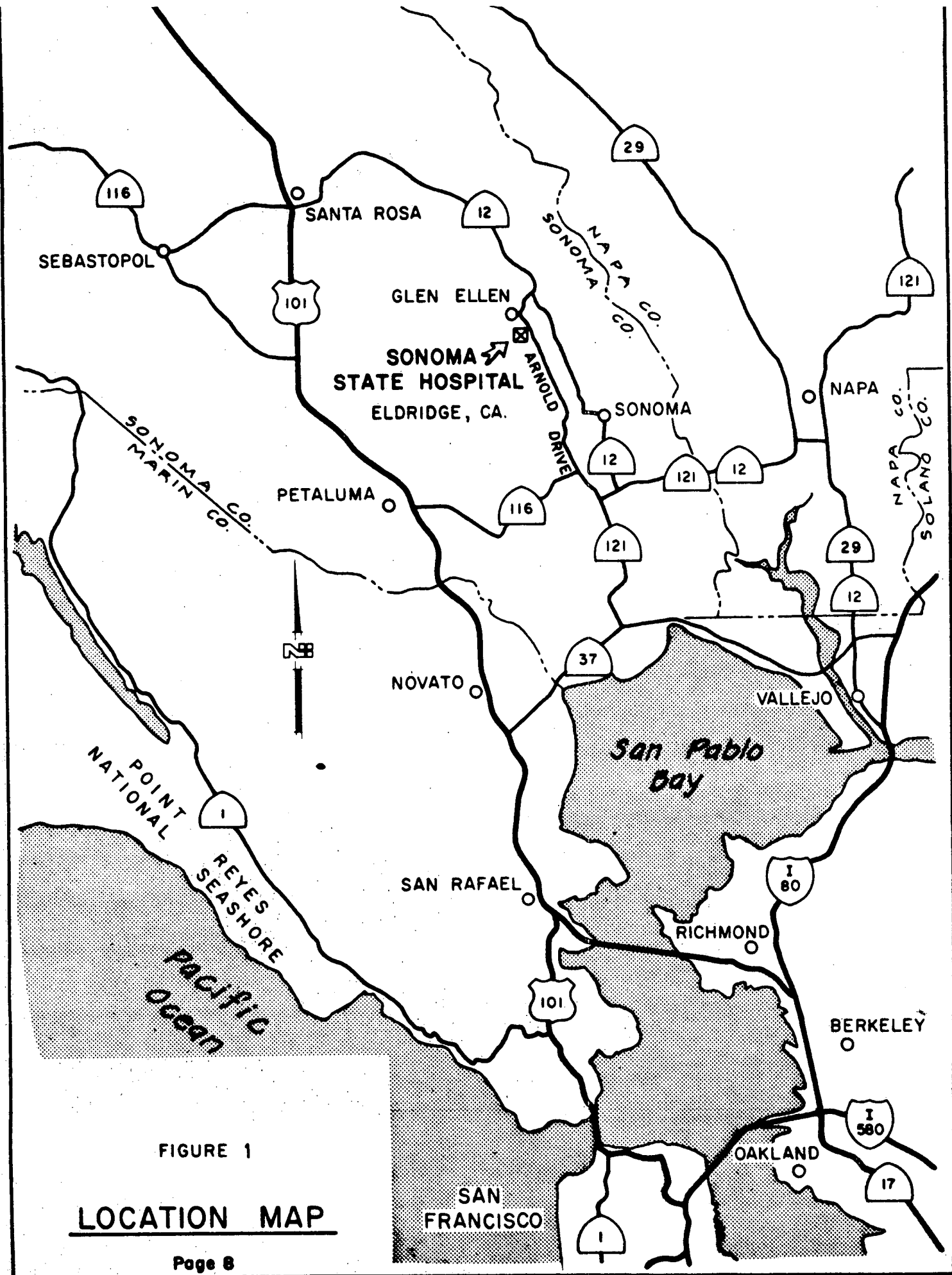


FIGURE 1

LOCATION MAP

TABLE 1

MONTHLY HEATING DEGREE-DAYS: 1977-1981 FOR  
 NAPA, SANTA ROSA, AND SONOMA  
 SOURCE: U. S. WEATHER SERVICE

LOCATION	MONTH												TOTAL	YEAR
	JULY	AUGUST	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE		
Napa State Hospital	8	3	39	103	277	380	408	315	197	269	73	34	2,106	1977
Santa Rosa	0	0	12	96	287	394	429	340	215	282	71	11	2,137	
Sonoma	5	0	19	61	259	378	386	327	199	274	45	20	1,973	
Napa State Hospital	20	15	9	83	375	612	526	409	292	245	109.3	39	2,739	1978
Santa Rosa	9	10	6	59	<u>315.3</u>	577	545	<u>329</u>	<u>315</u>	<u>259</u>	<u>123.7</u>	<u>39.3</u>	2,587.3	
Sonoma	7	1	4	51	<u>379</u>	630	530	<u>389</u>	<u>313</u>	<u>213</u>	<u>86</u>	<u>13</u>	2,616	
Napa State Hospital	5	8	1	85	322	444	472	287	326	214	182	88	2,434	1979
Santa Rosa	19	9	4	96	363	471	485	314	354	263	206	97	2,681	
Sonoma	2	5	1	82	357	479	462	256	313	229	161	<u>11</u>	2,358	
Napa State Hospital	16	30	24	105	281	440	438	300	323	211	73	4	2,245	1980
Santa Rosa	36	45	43	134	296	506	503	333	376	232	94	10	2,608	
Sonoma	15	8	17	122	272	489	465	319	362	235	111	0	2,415	
Napa State Hospital	12.25	14	18.3	94	313.8	469	461	327.8	289.5	234.8	109.3	41.3	2,379	Average
Santa Rosa	16	16	16.3	96.3	315.3	487	490.5	329	315	259	123.7	39.3	2,503	
Sonoma	7.3	3.5	10.3	79	316.8	494	460.8	322.8	296.8	237.8	100.8	11	2,340.5	

Underlined values are months of no record. Values shown are averages of other years of record for the location.



Typical annual degree-day information for Napa will be used to determine average annual heating requirements at Sonoma Hospital for the same reason. Average annual heating degree-days for Napa (at Napa State Hospital Station) were reported to be 2769. (Reference 13.)

**B. Theoretical Building Heating Requirements**

Because of the number of different buildings and construction types at the hospital, the time and budget available did not permit performing a detailed heating load calculation for each building. It was necessary to utilize heat loss calculations based upon overall averages. However, as a check, a detailed load calculation was done for the Bemis Residence Hall utilizing the original construction drawings, remodeling drawings (FLSEI), and data gathered in the field. This analysis indicated that the installed heating capacity continued to have capacity well beyond that needed to meet theoretical building heat losses and ventilation requirements, and substantiated the use of average heat losses.

**C. Steam Production Records**

Records of monthly steam production were obtained from the hospital plant operations staff for the period of March, 1979 through November, 1981. These were compared to the degree-day information discussed above in order to determine the relationship between climatic conditions and steam consumption. This relationship is shown graphically in Figure 2. A linear regression analysis was performed for each heating season (1979-80 and 1980-81). The correlation coefficient computed for the 1979-80 heating season was quite good whereas the correlation coefficient for the 1980-81 season was somewhat lower.

The probable reason for this difference is that Phases I and II of the FLSEI remodeling program were under way during the 1980-81 season. This remodeling required the shuffling of staff and patients from one building to another in order to vacate buildings for renovation. According to the move schedule supplied by the hospital, all of the moving between phases I and II occurred from December through March.

The general relationship shown in Figure 2 will be used as the basis for and/or a check on further assumptions. Steam demand will occur at a rate of 31,000 lbs. per degree-day. At 1,100 BTU of usable heat per pound of steam a total of 34,100,000 BTU per degree-day is needed. The peak heat demand would occur at the design temperature gradient of 40°F at the following hourly rate:

$$\frac{34,100,000 \text{ BTU/DD}}{24 \text{ hr/day}} \times 40^{\circ}\text{F} = 56,833,333 \text{ BTUH}$$

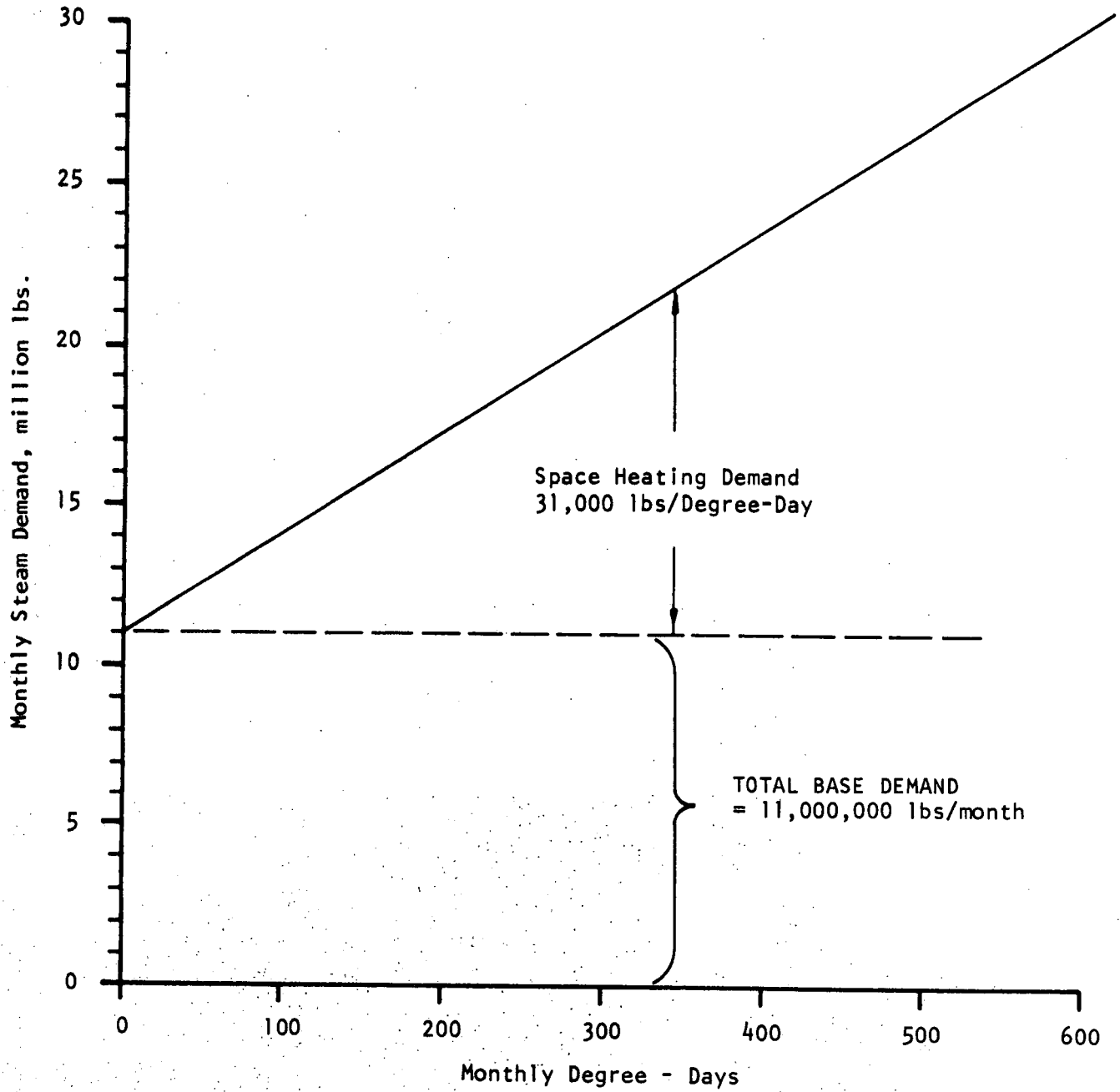


Figure 2

MONTHLY STEAM DEMAND AND DEGREE-DAY RELATIONSHIP



An average unit heating requirement can be computed by dividing this number by the total building floor area of all buildings at the hospital:

$$\frac{56,833,333 \text{ BTUH}}{1,078,100 \text{ SF}} = 52.7 \text{ BTUH/SF}$$

Individual buildings may require more or less than the average.

Expressed as BTU per degree-day-square-foot, the average installed heating system capacity would need to be:

$$\frac{52.7 \text{ BTUH/SF} \times 24 \text{ hr/day}}{40^\circ\text{F}} = 31.6 \text{ BTU/DD-SF}$$

This value can be used to compare Sonoma's heating requirement to other similar institutions, whether or not the climatic conditions are the same.

**D. Existing Installed Capacities**

The final check on the building heating requirements consisted of a determination of the installed equipment capacities from the construction drawings and specifications on file at the Office of the State Architect. This information is summarized in Table 2 on the following page. A considerable range of capacities is shown -- from a low of 35.6 BTUH/SF to a high of 166.8 BTUH/SF. Compared to rule-of-thumb capacity requirements contained in reference 2, all buildings have capacities well in excess of that required to meet the heating load of a continuously heated building.

The apparent oversizing of the existing heating systems in the hospital is a result of a number of factors. First would be the normal engineering practice of utilizing safety factors and/or conservative sizing criteria. Second, currently available design information may not have been available when the building's heating system was designed. This would include climatological data, heat loss characteristics of various building components, and infiltration allowances, among others. Third, the installation of commercially available nearest-size-larger components will contribute to an oversized system. Component size availability was not as great when the systems were installed as it is today. Fourth, common design practice was to assume that temperature settings would be turned down at night and back up again in the morning. This usually resulted in the specification of a capacity that was 20 to 25 percent greater than that required for continuous heating. For this project, geothermal heat energy will be continuously available without extra cost and there would be no advantage to nighttime thermostat setbacks. Finally, remodeling activities and energy conservation measures performed since the installation of the building's heating system would further reduce the required heating capacity. Obvious changes of this type would include the addition of insulation, weather stripping and double-pane glass. Less obvious measures are the provision of carpets, lower ceilings, and smaller rooms.

TABLE 2

## EXISTING HEATING SYSTEM INSTALLED CAPACITIES

<u>Building Name</u>	<u>Floor Area SF</u>	<u>No. of Similar Buildings</u>	<u>Installed Capacities</u>		
			<u>BTUH</u>	<u>BTUH/SF</u>	<u>BTU/DD-SF</u>
H-Buildings	16,839	14	625,500	37.1	22.3
Nelson Treatment Center	91,000	1	3,237,000	35.6	21.4
Ordahl-Johnson	42,100	2	2,180,000	51.8	31.1
Parmelee	22,000	2	1,514,000	68.8	41.3
Butler	43,100	1	1,732,635	40.2	24.1
Thompson-Bane	17,000	1	1,165,900	68.6	41.2
Hill	13,300	2	844,425	63.5	38.1
Tallman Nursery	8,400	1	500,400	59.6	35.8
Porter Administration	29,500	1	1,426,140	48.3	29.0
Kitchen	35,900	1	3,145,440	87.6	52.6
Sheet Metal Shop	2,900	6	528,000	182.1	109.3
King	14,200	1	819,405	57.7	34.6
CD Ward	4,500	1	750,600	166.8	100.1
Warehouse	<u>11,800</u>	1	<u>604,800</u>	<u>51.3</u>	<u>30.8</u>
TOTALS OR AVERAGES	663,346		34,384,170	51.8	31.1

13  
 $\Delta T = 40^{\circ}F$



Another change which has occurred is in the buildings' occupancy level. This has been considerably reduced, thereby lowering ventilation requirements and air leak losses resulting from people entering and leaving the buildings.

## 2. HOT WATER REQUIREMENTS

No data on hot water requirements are kept by the hospital other than as part of the overall hospital steam demand. Data available in the literature were also limited and not readily usable since it was generally oriented toward the determination of peak demand for system sizing rather than overall energy requirements. It was necessary to estimate the amount of steam consumed for hot water heating in order to determine the energy savings that will be realized through the use of geothermal heating.

The laundry was the one exception where a very precise estimation of its hot water requirements was possible. Physical dimensions were measured and/or obtained from nameplate data. Water temperatures, depths, cycle times, and load numbers were provided by the superintendent of laundry operations. Each washer consists of a cylindrical tub with its axis in a horizontal position. The number of units, capacities and basket dimensions are summarized as follows:

Capacity, Lbs.	No. of Units	Basket Dimensions diameter x length (in.)
800	4	54" x 108"
400	7	42" x 96"
225	1	42" x 54"
175	1	36" x 36"

Clearance between the basket and the tub was measured to be 1 1/2 inches on the sides and 5 inches on each end. Each machine does six loads per day. Each load requires one hour to complete and is comprised of six cycles of equal time. Total gallons used for each cycle are as follows (all 13 machines):

Stage	Water Temperature	Depth	Gallons
Pre-Soak	Cold Water	6"	1,045
Wash	160° F	6"	1,045
Rinse 1	160° F	15"	3,191
Rinse 2	150° F	15"	3,191
Rinse 3	90° F	15"	3,191
Rinse 4	90° F	15"	3,191



The depth values refer to the depth to the basket. The hot water consumption was then calculated to be 9819 gallons/hour of 160° F water for 6 hours per operating day. Calculations of the total water consumption (hot and cold) utilizing this same procedure agreed within 3 percent of the value obtained from water softening records. Consequently, it is felt that the hot water estimate is quite accurate. If the make-up water is supplied at 40° F, the heating requirement will be 58,960,000 BTU/day. The laundry operates 5 days per week year-round, so the total annual heating demand is 15,372,000,000 BTU or 13,974,286 lbs. of steam. No reduction in this demand has been assumed from the waste heat recovery exchanger because of its frequent down time due to clogging and because of the lack of storage facilities needed to match waste heat supply with clean hot water demand. Although this unit may be effective in damping the extreme peaks in steam demand, its overall energy savings potential (especially on an annual basis) is estimated to be negligibly small.

The remainder of the hot water consumed by the hospital is for bathing, dishwashing, personal laundry, therapeutic purposes and cleaning operations. These uses are scattered throughout the hospital with the demand varying with the building uses. Consequently, hot water demands on the steam system were estimated on a per capita unit demand basis. These rates were assumed to be 30 gpcd for hospital patients and 10 gpcd for employees. For 1500 patients and 2300 employees, this results in a daily consumption of 68,000 gallons and annual energy requirements of 20,699,880,000 BTU or 18,818,073 lbs. of steam. Geothermal heating retrofit sizing requirements for domestic hot water heating were based on current installed capacities, where known. Otherwise, a unit recovery rate of 0.0009 GPM per square foot was assumed.

### 3. STEAM CONSUMPTION SUMMARY

The preceding information makes it possible to develop a typical annual steam production profile and distribute it among the various demands. Annual steam production for July 1979 through June 1980 was 208,730,100 lbs. and the total number of heating degree days was 2358 °F-days for that year.

1. Space Heating. The total amount of steam required to meet space heating needs in 1979-80 is then  $2358 \times 31,000 = 73,098,000$  lbs. leaving a balance of 135,632,100 lbs. A typical year would have 2769 °F-Days and a space heating requirement of  $2769 \times 31,000 = 85,839,000$  lbs.
2. Laundry. Total daily steam demand by the laundry was determined to be 87,416 lbs. Hot water heating requires:

$$\frac{58,960,000 \text{ BTU/day}}{1100 \text{ BTU/lb.}} = 53,600 \text{ lbs./day}$$



The balance (33,816 lbs./day) is used by the dryers and pressing machines. Total annual requirements for each use at the laundry are then

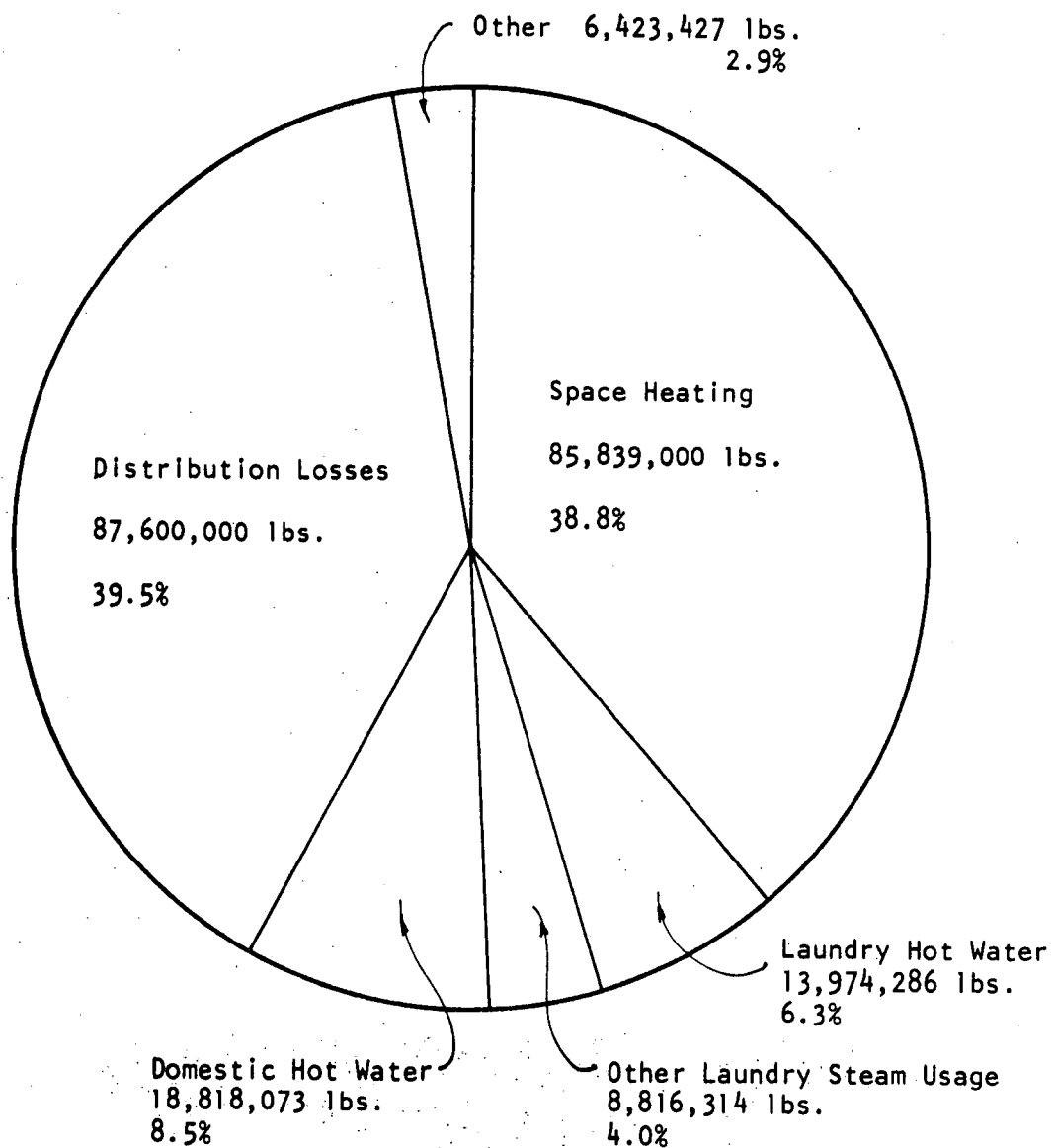
$$\begin{aligned} 53,600 \times 365 \times 5/7 &= 13,974,286 \text{ lbs. and} \\ 33,816 \times 365 \times 5/7 &= 8,816,314 \text{ lbs.} \end{aligned}$$

for hot water heating and other laundry uses respectively.

3. Domestic Hot Water. Total annual steam demand for domestic hot water is 18,818,073 lbs./year, assuming 30 gpcd for patients and 10 gpcd for employees.
4. Distribution System Losses. Analysis of Figures 3.2-3 and 4.1-2 of the Cogeneration Study (Reference 1) for the minimum steam demand experienced at Sonoma indicates that a base demand of 10,000 lb/hour under zero-demand conditions would be appropriate. (These figures have been reproduced in Appendix A.) This amounts to  $10,000 \times 24 \times 365 = 87,600,000$  lbs/year of steam consumption to meet the losses in the system.
5. Other Steam Uses. Subtraction of the above computed values for space heating, laundry, domestic hot water and system losses from the total steam production for 1979-80 leaves 6,423,427 lbs/year for the remaining steam demand at the hospital. This figure is reasonable since the only remaining known demand would be the food steamer pots in the kitchen.

Typical annual steam demand is displayed in the pie-chart in Figure 3. Of particular significance is the magnitude of the losses through the system - nearly 40 percent of the total annual demand. This figure is quite high and probably results from a number of factors, including:


1. Age. Losses that may be expected through a steam distribution system increase with the age of the system. Older systems are typically poorly insulated due to the low cost of energy at the time of construction and the state of insulation technology available at the time. Deterioration of insulation also occurs with age. Much of the hospital's steam distribution system is quite old.
2. Leaks. Leaks from the piping can be significant and will increase with time. Based on water softening records, 38,000 to 50,000 gallons of makeup water are presently needed each week. This represents 16,500,000 to 21,750,000 lbs. of steam per year, or 19 to 25 percent of the estimated losses.
3. Size. The distribution system consists of nearly 20,000 feet of high pressure steam piping ranging from 1 1/4 to 8 inches in diameter, and 19,000 feet of condensate return piping from 1 to 4 inches in diameter. This is quite an extensive network for a system with a moderate actual heating requirement.



TOTAL ANNUAL DEMAND = 221,471,100 lbs.

Figure 3

TYPICAL ANNUAL STEAM CONSUMPTION

- 
4. Temperatures. Temperatures within the steam piping range from 300 to 400° F. This results in a significant temperature gradient between the steam and ambient ground temperatures and causes high heat losses from the system.

The magnitude of the losses from the steam distribution system indicates that much of the energy saved by the conversion to geothermal heating will result from reductions in distribution losses, made possible by closing off portions of the existing steam distribution system. It could also make the conversion of other buildings to geothermal heat cost effective if the heat losses from the remaining distribution system are taken into account. This can be investigated in more detail when final design of a geothermal heating system is performed.

#### 4. GAS CONSUMPTION SUMMARY

Monthly gas consumption records were also obtained and compared to steam consumption records for the same period. Charge rates and billing computation procedures were obtained from the Pacific Gas and Electric Company.

Steam generation efficiencies were found to vary seasonally, with higher efficiencies occurring during the winter months. This is probably due to the fact that the higher steam demand during the winter requires operation of the boilers at more efficient levels. The cost of steam production was determined to range from \$5.15 per thousand pounds to \$6.73 per thousand pounds. The average cost was \$5.68 per thousand pounds over the period of March 1979 to November 1981 (based upon the 1981 gas price of \$0.46080 per therm).

Gas prices paid by the hospital are lower than usual for two reasons. First, it is a large customer which, under the current rate structure, results in a lower unit cost. Second, the hospital is a Group IV customer, meaning that the hospital would be among the first group of users to be cut off in the event of a gas shortage or interruption in the area. During such times, the boilers would operate on No. 2 diesel oil stored onsite in four 16,454 gallon tanks. Costs of this alternative fuel utilization are not included in the above steam cost.



## E. GEOTHERMAL HEATING CONCEPT

A number of different methods could be used to meet the space heating and domestic hot water requirements of the hospital with geothermal hot water. The concept presented here was selected by George S. Nolte and Associates and Geo-Heat Center staff as the alternative that is most likely to prove feasible.

Geothermal fluid for the hospital is to be provided by a private developer at a point near the existing powerhouse as a byproduct of electric power generation. The hospital will distribute the fluid to the points of use, collect it, and return it to the developer for reinjection at a point east of Railroad Avenue. The developer has already acquired the rights to the geothermal resources in the area from the State Lands Commission. Test drilling is expected to commence in the Spring of 1982. The developer hopes to locate geothermal steam at sufficient temperatures and pressures to operate a steam turbine and generate electricity. Geothermal fluid consisting of condensed steam would then be given to the hospital for heating purposes. Feasibility investigations by the developer have indicated that a cost effective power generation project would result in a geothermal fluid flow of at least 2,500 gpm at 180°F. Additional amounts of power could be generated if the geothermal fluid temperatures could be reduced to 170°F.

Although this is the envisioned project concept, it is possible that the geothermal resources in the area will not be adequate for the generation of electricity. If this were to be the case, the geothermal fluid could still be directly used in the hospital's system described below. The developer could either maintain ownership of the well or sell it to the State. Such a case would reduce the overall cost effectiveness of the project since the cost of the wells would be added to the cost of the project.

Use of the geothermal fluid by the hospital for heating purposes is beneficial to both the hospital and the geothermal developer. The obvious benefit to the hospital would be a significant reduction in the costs incurred for natural gas purchases by the hospital to operate its steam heating system. The benefit to the developer is a reduction in the temperature of the geothermal fluid beyond that attainable through the steam turbine. This would reduce the costs of reinjection since a cooling system would otherwise be needed and/or require higher discharge pressures on the reinjection pumping system. (The higher density of lower temperature fluid enables gravity to assist in reinjection.)

Geothermal fluid would be distributed to each building through buried factory-insulated fiberglass-reinforced epoxy pipe. After use, the geothermal fluid would be collected in uninsulated fiberglass-reinforced epoxy pipe. This material was selected as the basis for the preliminary design because of its ability to resist corrosive fluids, produce minimal



expansion due to temperature fluctuations, and tolerate high temperature fluids without deterioration. Other materials are available, and could be evaluated in the design phase of the project.

No information on the chemical quality of the geothermal fluids is currently available since the well has not been drilled. However, since most geothermal fluids are high in total dissolved solids and corrosive chemicals it has been assumed that direct use of the geothermal fluid in the existing hydronic heating system and/or introduction into the domestic hot water piping would be neither desirable nor allowable. A heat exchanger will then be needed at each point of use to extract the heat from the geothermal fluid.

Plate and frame type heat exchangers were selected as the basis of the conceptual design and costing. This type of heat exchanger appears to be particularly well suited to geothermal heating applications for the following reasons:

1. Full countercurrent flow is achieved, thereby giving closer approach temperatures (approach temperature = temperature of entering geothermal fluid minus the temperature of exiting heated fluid) and good extraction of heat from the geothermal fluid. A 5°F approach temperature has been used for this study.
2. Compact designs require less floor space than existing shell and tube steam/water exchangers, thereby assuring that there will be adequate space in each building's mechanical room even though many are quite cramped.
3. Plate and frame type exchangers are more economical if materials other than mild steel are required to resist the corrosive components in the geothermal fluid and/or scale buildup. Stainless steel plates have been assumed for the purposes of this study since this material has worked successfully in other geothermal applications. Other materials are available at additional cost which have even higher corrosion resistance.
4. Maintenance of the units is relatively easy. Additional plates would be provided for each size of exchanger used at the hospital. Maintenance would be scheduled during the summer months when a two to three hour interruption in the hot water supply to the building could be tolerated. This would consist of exchanging the spare plates for the ones in use. The used plates could then be returned to the shop and cleaned of any scale buildup that may be occurring and inspected for corrosion. Once cleaned, these plates would be exchanged as before with plates in another building. In this manner, a standby exchanger in each building would not be required.
5. Plate and frame exchangers can be used to provide cascade heating of two secondary fluids in a single exchanger. Other types would require two separate units that would add to the space requirements of the installation and increase construction and operation costs.



6. Finally, a considerable range of transfer capabilities is possible within each frame size by varying the number of plates installed with the unit. Therefore, if the heating needs of the building change in the future, it can be accommodated by changing the number of plates instead of replacing the entire unit.

A cascade heating concept will be utilized in most cases to provide different temperature fluids for the space heating loop and domestic hot water services. The first stage will be used for the space heating fluid since its required operating temperatures and maximum heat demand are the highest of the two. Additional heat will be removed from the geothermal fluid by the domestic hot water loop. A typical profile of the temperatures expected across the exchanger is shown in Figure 4.

Water temperatures attainable with the geothermal system will be lower than that currently provided by the steam system. Operating temperatures in the steam system range from 300 to 400°F whereas the geothermal fluid begins at only 180°F. Losses in the geothermal fluid distribution system have been conservatively estimated to reduce the temperatures at the point of use to 175°F. Assuming a 5°F approach temperature difference (temperature difference between the entering geothermal fluid and the exiting heated water) at the heat exchanger, the heated water will have a temperature of no more than 170°F under design conditions.

Existing installed heating coil rated capacities are based upon 200°F water in the hydronic loop. If 170°F water was used, the rated heating capacity of the heating coils would be decreased since entering air temperatures would remain the same and a lower temperature gradient would result. Two methods were used to determine the resulting loss in heating capacity. The first utilized the curve shown in Figure 5. This showed that 70 to 73 percent of the original rated heating capacity would be obtained. The second method was to refer to actual manufacturer's rating curves for hydronic heating coils. This method gave ratings of 80 percent. Since the curve utilized in the first method is a very generalized one for a number of different heating devices (cast iron radiators, finned tubes, and fan coils), the second method was considered more accurate and was therefore selected as a basis for conceptual design.

The necessary oversize factor for the existing hydronic heating systems that would be required in order to allow direct use of the geothermal fluid would be:

$$1/0.8 = 1.25$$

or 25 percent oversize. The oversizing discussed in the previous section is probably at least this much. For this reason, no other modifications to the existing heating systems are considered necessary. (This assumption should be verified as part of the design of the geothermal system). If any buildings are unable to tolerate a 20 percent loss in heating capacity, deeper coils may be installed to permit the air flow to extract more heat from the hydronic fluid and, in turn, from the geothermal fluid. Another option would be to install additional coils to preheat incoming ventilation air. The final option would be the installation of a heat exchanger at the

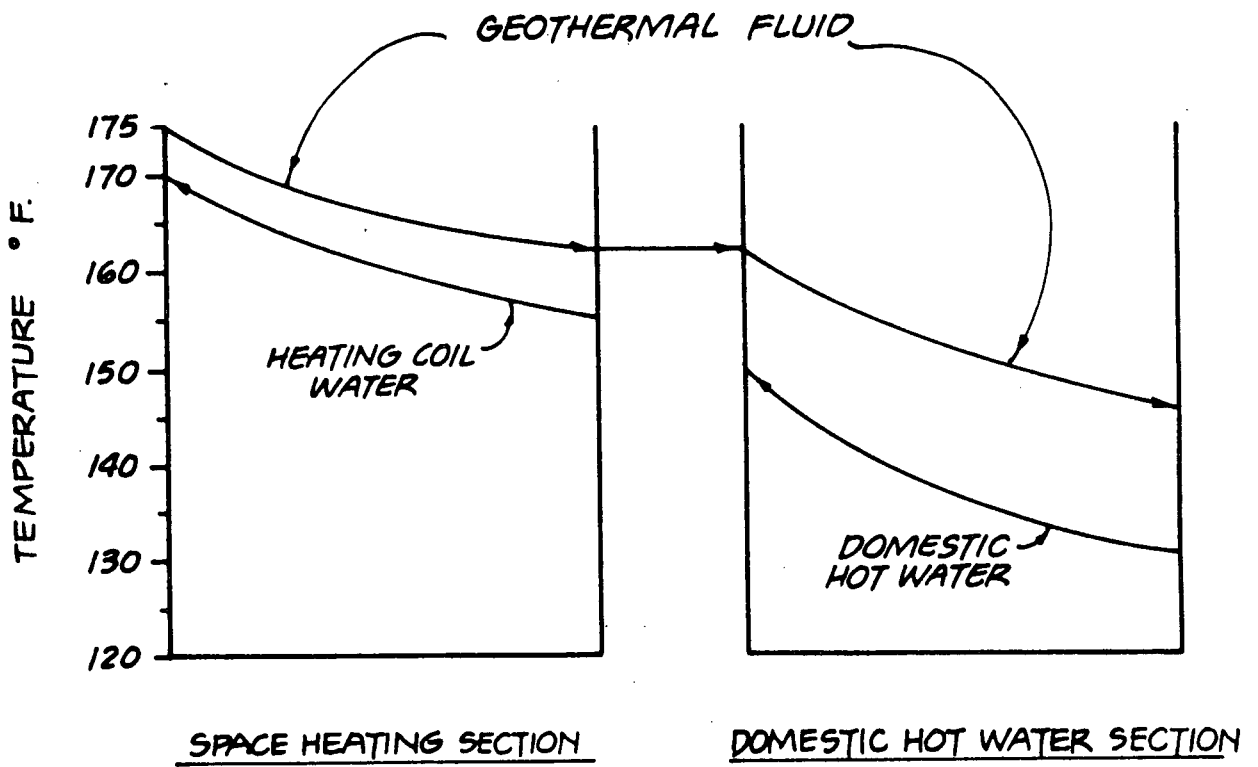


FIGURE 4  
 CASCADE HEATING CONCEPT  
 TYPICAL TEMPERATURE PROFILE

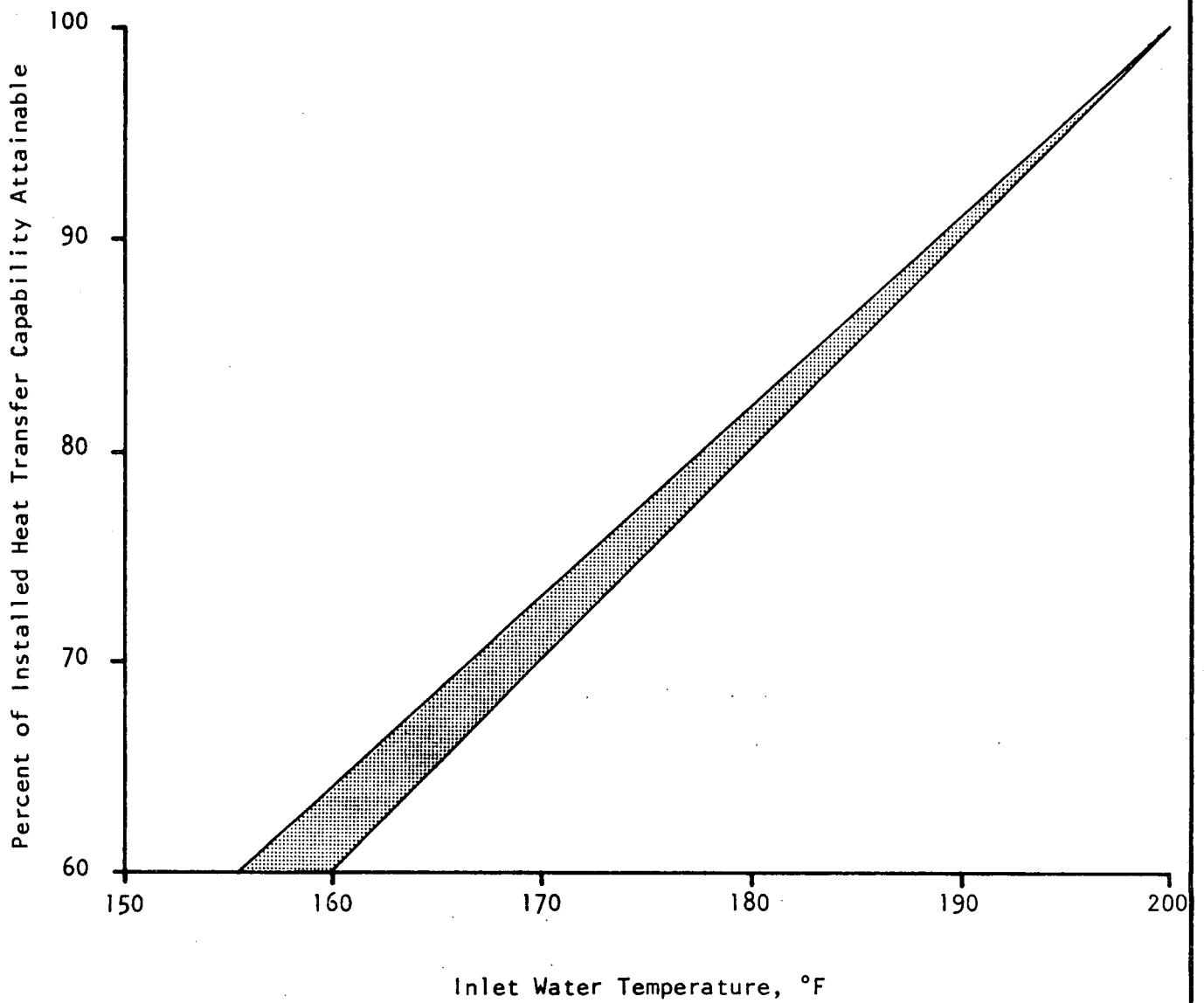


Figure 5

Derating Curve for Existing Hydronic Heating Coils

(Interpreted from Figure 6 of Reference)



powerhouse that would utilize reserve capacity in the boiler system to boost the temperature of the geothermal fluid in the entire system. The best option could be determined by an economic analysis.

A geothermal heating system capable of meeting the hospital's space heating needs during the extreme weather conditions on which its design is based will have excess capacity for much of the year. It would then be possible to operate the system during the low heating season (6 to 9 months per year) with a lower temperature in the geothermal fluid. This would enable greater amounts of electrical power to be generated by the developer.



## F. RELIABILITY EVALUATION

A particular concern of this study is the need to provide a system of high reliability in each major component. Interruptions and/or reductions to the heat and hot water supply cannot be tolerated because of the importance of these services to the health of the patients. Relocation to another facility in the event of a system failure is not practical due to the number of patients at the hospital and the distances involved.

The distribution system and heat exchangers used to provide geothermal heating would have a reliability that would equal or exceed that currently provided by the equivalent components of the existing steam system. The four-boiler steam generation system has a high level of reliability because all but one of the boilers has sufficient capacity to meet the entire steam demand (excluding the laundry) of the hospital. To provide an equivalent level of reliability in the geothermal system, a bypass around the electrical power generation system must be provided. The bypass is necessary to maintain geothermal fluid flow in the event that the power system is inoperative. Only one well will be needed to meet reliability criteria since wells producing dry steam do not contain mechanical equipment.

If the test well produces only hot water instead of steam, then two wells would be required since pumps would need to be installed in the wells. It may also be necessary to boost the temperature in the geothermal fluid stream during a well shutdown in order to compensate for the reduction in flow. This could be done with the reserve capacity in the steam generation system.

## G. GEOTHERMAL HEATING SYSTEM DESIGN



The preliminary design of the geothermal fluid distribution and collection system and of the retrofits necessary in each building to be converted is based upon existing building conditions and usage. No allowances were made for future connections to the system, changes in demand, or extensions into other areas of the hospital. Some flexibility and reserve capacity will exist in the system, however, due to conservative design and the incremental component sizes that are available. If reserve capacity is desired, the means of obtaining it would be determined during the detailed design phase since more information of future hospital heating needs could be determined at that time. Allowances for future additional heating needs could increase the cost of the project, but not significantly. Offsetting these costs would be the future energy savings that would be realized.

### 1. HEATING SYSTEM RETROFITS

Interfacing of the geothermal fluid heat exchangers with the existing space heating and hot water equipment for a typical building is shown in Figure 6. In most cases it was found that the most economical exchanger system would be to place both exchangers in the same frame. Frame sizes were generally determined by the space heating requirements due to the large amount of heat that was needed and small temperature differences involved (e.g. between the geothermal and heating system fluids and between the inlet and outlet temperatures of the heating fluid). After exiting the space heating side of the exchanger, a portion of the geothermal is sent directly to the geothermal fluid return main and no more heat will be extracted from it. The remainder of the fluid is sent through the domestic hot water side of the heat exchanger and then to the geothermal fluid return main. In a few cases where a significant difference existed between the heat needed for space heating and domestic hot water, a separate exchanger with smaller plates was found to be more cost effective.

One exception to the above configuration would be that provided for the Frederickson Receiving Center. Because this building's heating system utilizes 100 percent makeup air, the exit water temperature of geothermal fluid will be too low to meet the building's domestic hot water requirements. A second exchanger and supply of geothermal fluid would be provided for the domestic hot water and unit heater system at this location.

Another major exception was the laundry. The proposed system here would provide a heat exchanger and three storage tanks in order to eliminate extreme demand fluctuations of the type caused by the present instantaneous system. A schematic diagram and temperature profile are shown in Figure 7. The exchanger is sized to meet the average rate of hot water consumption

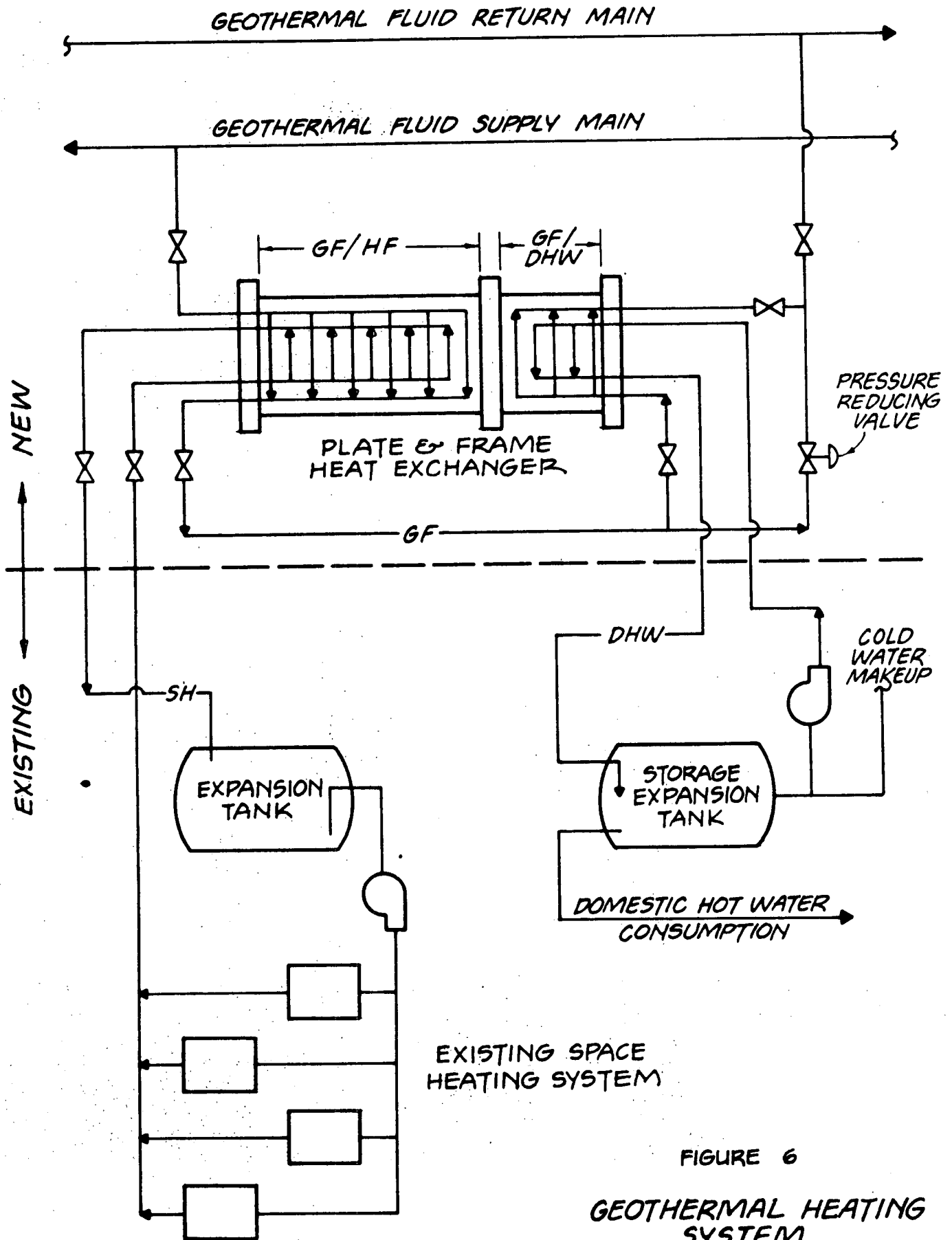
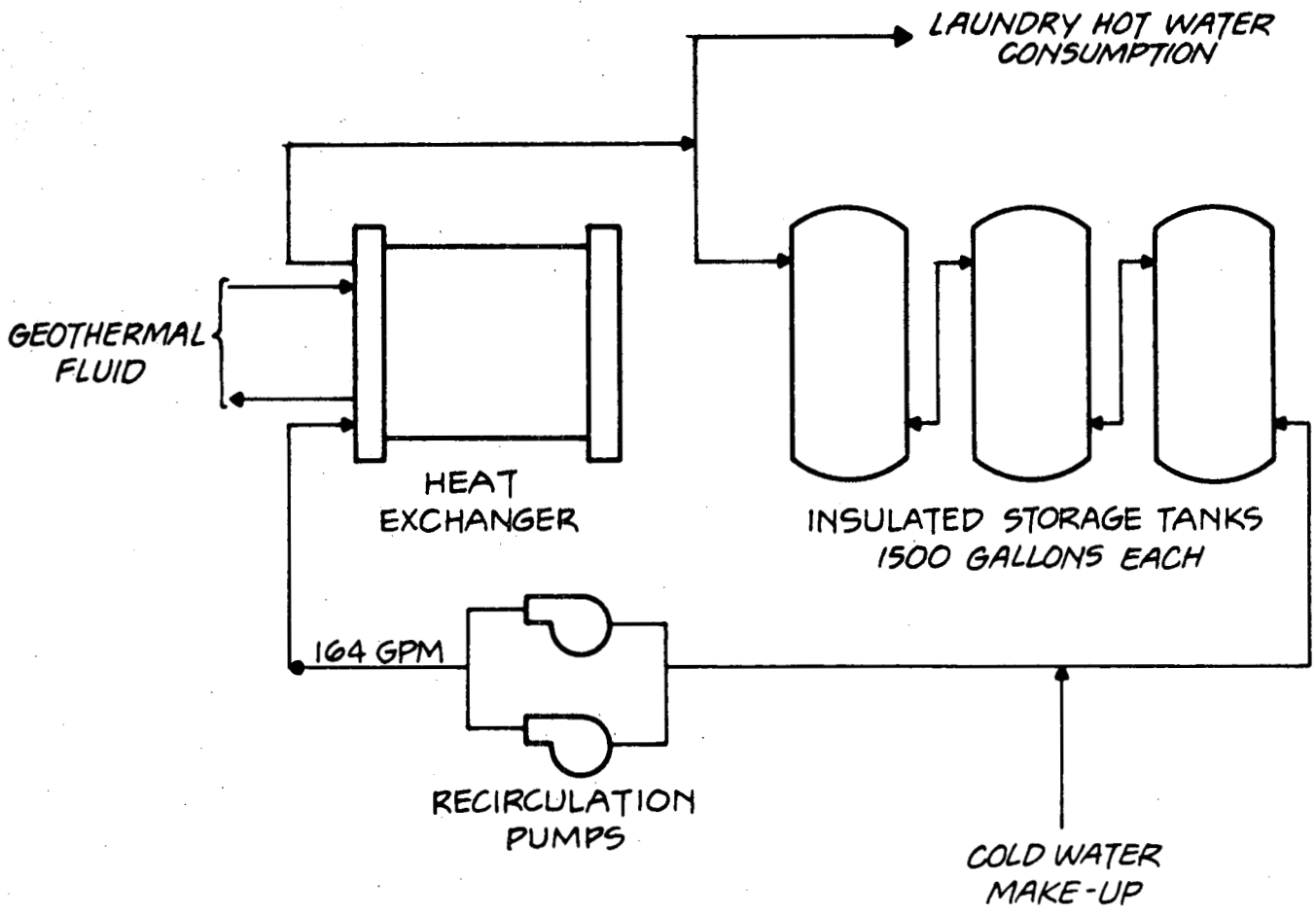
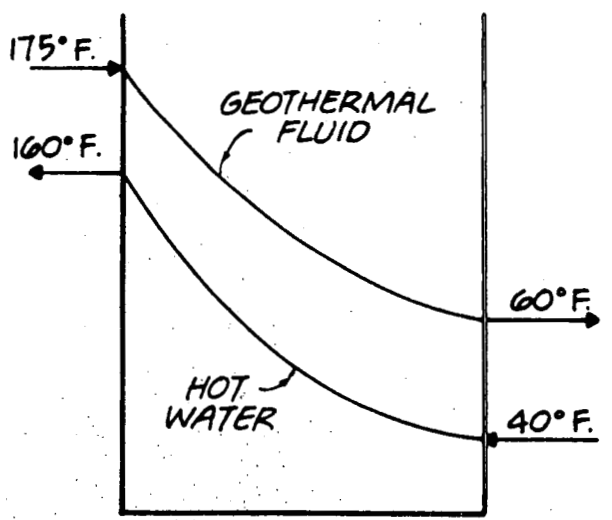


FIGURE 6  
GEOHERMAL HEATING  
SYSTEM  
RETROFIT SCHEMATIC



INSTALLATION SCHEMATIC



TEMPERATURE PROFILE

FIGURE 7  
 GEOTHERMAL RETROFIT  
 LAUNDRY HOT WATER



during one hour of operation. The storage tanks would provide the additional hot water during the peak demand periods. Sufficient heat would be removed from the geothermal fluid to preclude its use for any other heating use. It would therefore be returned directly into the collection piping.

The final configuration would be that required for the Butler swimming pool. This system would differ from all of the others in that it would use the geothermal fluid in the return main instead of the supply main. Temperatures in the return main are expected to be sufficient for shower water and pool heating — especially during the times of the year that the pool would be in use.

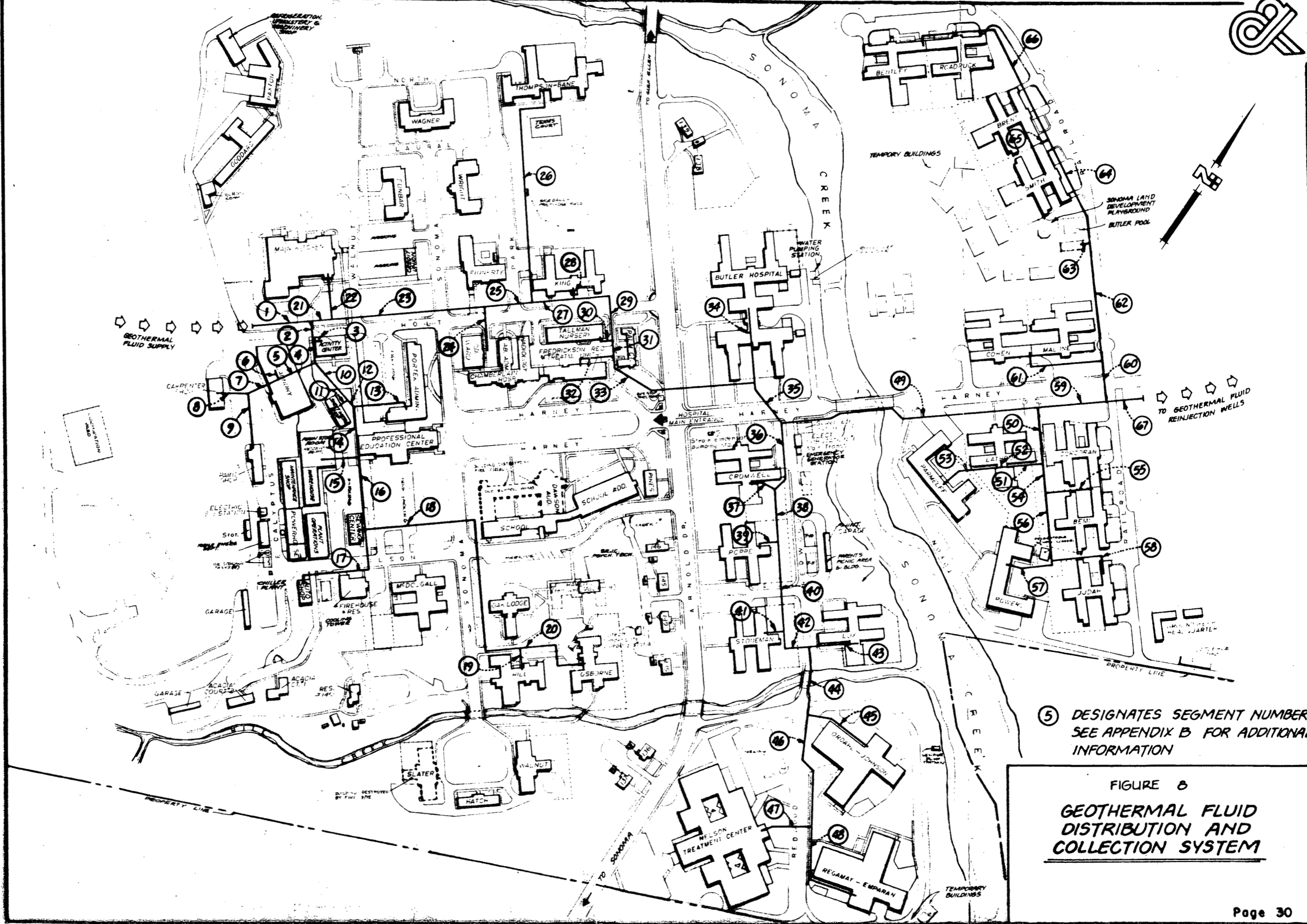
A total of 35 heat exchangers will be required to convert those buildings included in this study. Plate areas ranged from 16 square feet for the Butler pool to 746 square feet for the Nelson Treatment Center. Costs for the heat exchangers are based upon an evaluation of actual quotations made by the manufacturer for similar fluid temperatures and plate materials in 1981. It was not possible to determine the installation requirements for each building due to the number of buildings involved. Consequently, a conservative factor of 120 percent of the purchase price was used as the estimate of the installation costs. The major cost components of the retrofits required in the buildings are estimated as follows:

Heat Exchangers	\$187,663
Installation	225,195
Laundry Hot Water Storage	<u>27,375</u>
	\$440,233

## 2. DISTRIBUTION SYSTEM

A preliminary layout of the geothermal fluid supply and return piping system is shown in Figure 8. Generally, each segment shown represents both a supply and a return pipe. The estimated quantities of pipe required can be summarized as follows:

Internal Diameter Inches	Pipe Lengths, Feet	
	Supply Main	Return Main
1.5	25	25
2	845	845
2.5	2,135	2,135
3	2,835	2,835
4	1,820	1,820
5	1,110	900
6	745	745
8	1,755	1,985
10	1,655	1,480
12	185	325



⑤ DESIGNATES SEGMENT NUMBER. SEE APPENDIX B FOR ADDITIONAL INFORMATION

FIGURE 8  
**GEOHERMAL FLUID DISTRIBUTION AND COLLECTION SYSTEM**



Pipe diameters were determined from the aggregate flows that the pipe must carry, using the criteria that velocities should not exceed 10 feet per second and/or pressure losses should not exceed 0.8 psi per 100 feet of pipe length.

The routing shown in Figure 8 is based upon an attempt to minimize the amount of pipe involved for purely economic reasons. More economical routings will probably be developed during the detailed design phase. Suggestions have been made to utilize the existing steam tunnels running almost the entire length of Harney Street in order to minimize costs of excavation in areas with many buried utilities and in crossing Arnold Drive. However, this option did not appear to be cost-effective due to the number of places where the tunnel would need new access points (there is no existing provision for inserting lengths of pipe) and its distance from some of the major geothermal fluid demand points. Nevertheless, use of the steam tunnel should be evaluated during detailed design. Likewise, use of the crawl spaces below many of the existing buildings has also been suggested. This could potentially reduce the costs of the geothermal fluid piping network, provided that the temperature increase of the crawl space from the heat lost from the return piping will not adversely impact the use of the building during the summer.

The cost breakdown for the piping is as follows:

Pipe and fittings	\$724,223
Excavation, backfill, installation	99,502
Additional for extreme utility conflicts	22,012
Pavement replacement	13,316
Arnold Drive crossing	<u>17,000</u>
TOTAL	\$876,053

A detailed quantity take-off and cost estimate by segment is given in Appendix B.

### 3. COST SUMMARY

Total construction costs of the geothermal heating system developed in this study are determined as follows:

Distribution and Return Piping	\$ 876,053
Building Retrofits	<u>440,233</u>
Subtotal	\$1,316,286
Allowance for engineering, legal, and contingencies (35%)	<u>\$ 460,700</u>
TOTAL PROJECT COSTS	\$1,776,986
USE	\$1,777,000



Operation and maintenance costs attributable to the geothermal heating system would be partially offset by reductions in the operation and maintenance costs of those portions of the existing steam heating system that would be either abandoned or removed. However, no allowance will be made for this reduction in order to obtain a conservative estimate of the net change in operation and maintenance costs at the hospital.

1. Pipelines. Generally, little if any maintenance of the pipelines will be required. However, an allowance of one-half of one percent of the construction cost will be made:

$$0.005 \times \$876,053 = \$4,380/\text{year}$$

2. Heat exchangers.

- A. Inspections: 1.0 hour/month/exchanger
- B. Servicing: 4.0 hours/year/exchanger
- C. Labor costs: \$25/hour including benefits and associated overhead
- D. Total labor costs  
 $35 [(1 \times 12) + 4] \times 25 = \$14,000/\text{year}$
- E. Miscellaneous hardware and chemicals: Allow \$2,000/year.
- F. Replacement: This item will vary with time. Little cost will be incurred in the early years, and above average cost will be incurred after several years of use. This cost is therefore a budget item and is based upon complete replacement of the heat exchangers within 10 years.

$$\frac{\$187,663}{10 \text{ years}} = \$18,766/\text{year}$$

or about \$20,000/year

3. Total annual operation and maintenance costs.

Pipeline	\$ 4,380
Labor	14,000
Replacement	20,000
Miscellaneous	<u>2,000</u>
TOTAL	\$40,380/year

All costs given above are based on 1981 prices.

## H. ESTIMATED ENERGY SAVINGS



The theoretical cost of natural gas needed to operate the steam generation system can be obtained as follows:

$$\begin{aligned} \text{Unit steam cost} &= \$5.68/\text{thousand pounds (based on 1981 gas costs)} \\ \text{Average annual steam production} &= 221,471,100 \text{ lbs.} \\ \text{Total cost} &= \$5.68 \times \frac{221,471,100}{1,000} = \$1,257,956/\text{year} \end{aligned}$$

Not all of this cost can be saved since some current steam uses did not appear to be cost effective to convert and others were technically infeasible. The estimation of the anticipated energy cost savings will be done using the steam consumption breakdown shown in Figure 3.

1. Space heating. Current steam requirement is 85,839,000 lbs/year. Less than half of the buildings on the site will be converted but they represent over two-thirds of the total floor area. They also represent all of the buildings having 24 hour per day occupancy and some of the more energy intensive heating systems. For these reasons, an estimated 90 percent of the current space heating steam demand will be saved by the proposed geothermal heating system, or

$$0.90 \times 85,839,000 = 77,255,100 \text{ lbs/year}$$

2. Laundry hot water. The current annual steam requirement is 13,394,286 lbs/year. All of this would be saved by the proposed geothermal heating system.
3. Other laundry steam usage. The current annual steam requirement in this category is 8,816,314 lbs/year. It is not technically feasible to utilize geothermal fluid to meet this demand because the temperatures needed are too high. No reduction of this portion of the annual steam production has been assumed.
4. Domestic hot water. Current annual steam requirement for this item was estimated to be 18,818,073 lbs/year. Because all residences and the kitchen will have been converted, the hot water demand in the remaining buildings is almost incidental. Therefore, a reduction of 95 percent of the current requirement has been assumed, or

$$0.95 \times 18,818,073 = 17,877,169 \text{ lbs.}$$

5. Distribution losses. Current annual steam produced to meet this demand has been estimated to be 87,600,000 lbs/year. This is made up of thermal losses in the distribution system and actual leakage of steam. A minor amount of loss results from intentional boiler blowdown needed to reduce the mineral buildup in the boilers. This, however, will be directly related to the leakage in the system.



In all cases, it has been assumed that this loss is directly related to the extent of the steam distribution system in place and, to a much lesser extent, the number of end use points. The extent of the steam distribution system can be expressed in terms of the number of inch-diameter-feet of distribution piping. Of the piping shown on the hospitals steam distribution layout drawing, a total of 34,121 in-dia-ft. can be eliminated from the system and 33,162 in-dia-ft. will remain. If a proportional reduction in steam losses is assumed, then

$$\frac{34,121}{34,121 + 33,162} \times 100 = 50.71 \text{ percent}$$

of the current losses would be saved or

$$0.5071 \times 87,600,000 = 44,424,291 \text{ lbs/year.}$$

6. Other uses. The total annual steam requirement for the remaining uses at the hospital has been estimated to be 6,423,427 lbs/year. These uses are also assumed to be technically infeasible to meet with geothermal fluid and no savings will occur.
7. Summary. The total estimated reduction in the annual steam demand resulting from the proposed geothermal heating system is then:

<u>Category</u>	<u>Annual Demand, lbs.</u>
Space Heating	77,255,100
Laundry Hot Water	13,394,286
Other Laundry Uses	0
Domestic Hot Water	17,877,169
Distribution Losses	44,424,291
Other Uses	<u>0</u>
	152,950,846

This represents,

$$\frac{152,950,846}{221,471,100} \times 100 = 69.06 \text{ percent}$$

of the current estimated annual steam demand. The total estimated annual savings is then,

$$0.6906 \times \$1,257,956 = \$868,761/\text{year}$$

Gas costs, however, are increasing at a rate greater than the general inflation rate. Forecasts of energy prices for California utilities are made biannually by the State Energy Commission. Data from the most recent report (Reference 14) are shown graphically in Figure 9 on the following page. Gas prices are expected to double nearly once every six years for an

CURRENT \$ = ACTUAL PRICE  
1980 \$ = CURRENT DOLLARS ADJUSTED  
FOR INFLATION

Source: Reference 14

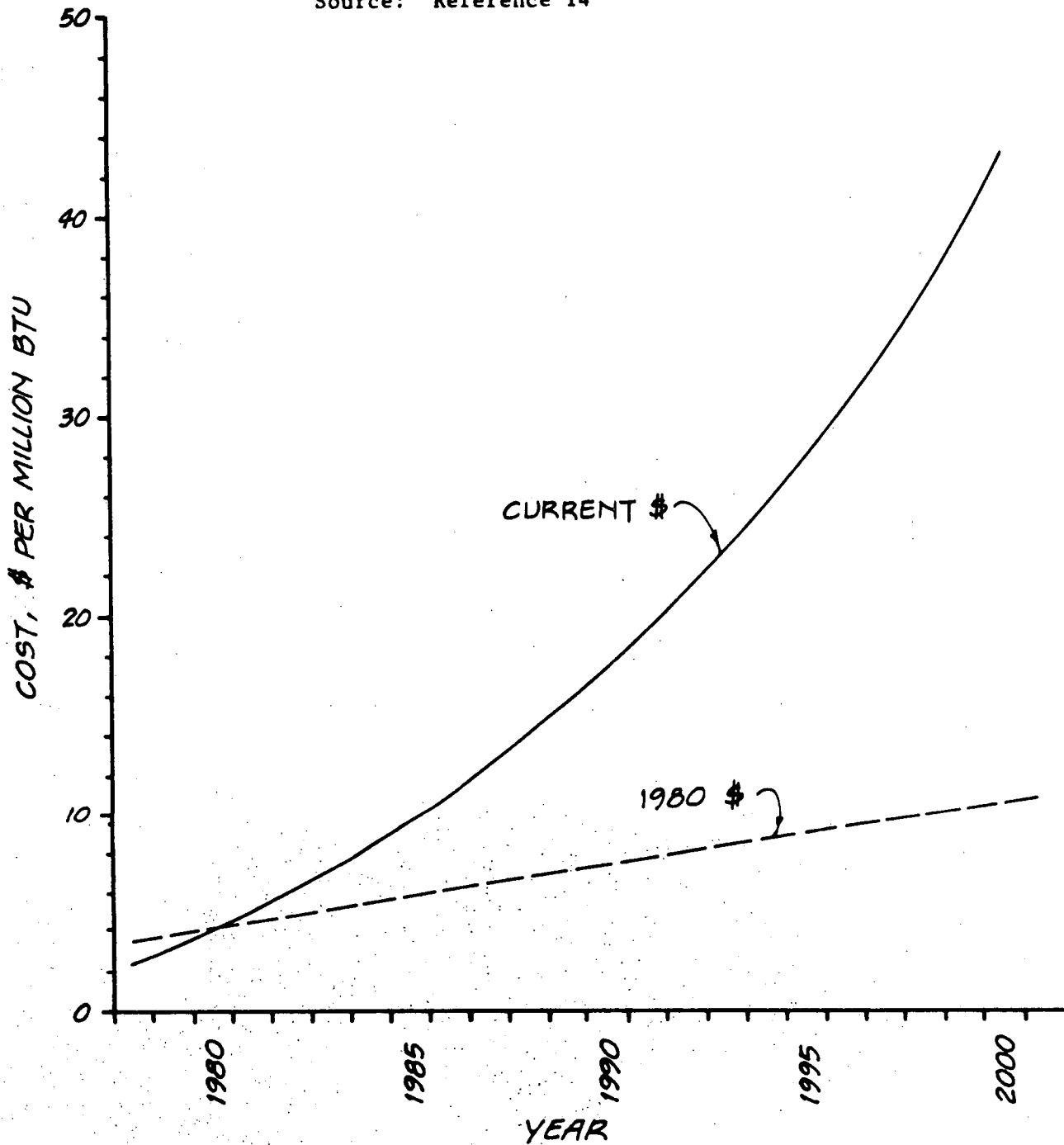


FIGURE 9  
FORECASTED PG&E  
NATURAL GAS PRICES  
from Reference 14



effective annual inflation rate of over 12 percent. After discounting for inflation, the unit cost of natural gas to Sonoma State Hospital is expected to increase at a uniform rate of \$0.02855/therm/year for the remainder of the century. With a current average annual steam production of 221,471,100 lbs., natural gas costs (not including inflation) at Sonoma State Hospital will increase uniformly by \$77,940/year for the next 20 years.

## I. ECONOMIC ANALYSIS AND CONCLUSIONS



The value of the hospital's natural gas consumption that would be displaced by the geothermal heating system developed in this study is approximately \$73,000 per month at 1981 gas prices. Operating costs of the geothermal heating system (including operation, maintenance, replacement, insurance, and geothermal fluid purchase) are estimated to be less than 25 percent of the current value of the displaced natural gas. In order to achieve this savings, a capital investment of \$1,777,000 will be required. A key indicator of the attractiveness of the project is the time required to recover the initial investment through savings in operating costs. Another indicator is the benefit/cost of the project.

### 1. PAYBACK PERIOD

An initial analysis was performed by the Geo-Heat Center using their standard computer program. The assumptions, basis of analysis, and results are shown in Appendix C. That analysis determined that the proposed geothermal heating system is highly cost effective with payback periods of three to four years.

An additional analysis was made by George S. Nolte and Associates based on projected natural gas prices in California, since these differ somewhat from the State of Oregon projections used by the Geo-Heat Center. Also, since it was clear that payback periods would be very short, the payback periods were computed on a monthly basis. Additional assumptions used in the analysis were as follows.

- A. Total construction cost = \$1,777,000 and with an interest rate of 12 percent per year.
- B. Operation and maintenance costs will be \$40,380 for the first year (\$3,384/month) and will increase at the general inflation rate of 7 percent per year.
- C. Insurance costs will be \$8,885 for the first year (\$741/month) and increase at a rate of 2 percent per year - as had been done in the Geo-Heat Center's analysis.
- D. Natural gas costs were assumed to increase in accordance with current State Energy Commission projections as discussed in the previous section.
- E. Geothermal fluid purchase costs were assumed to be based upon \$0.08 per therm of current gas consumption that would be displaced by the geothermal heating system. This amounts to \$150,827 in year one (\$12,703/month). This cost will increase over time at the same rate as for natural gas - approximately \$9,050 per year in real terms plus 7 percent per year for inflation.



Project cost amortization over the time period required for payback is shown in Table 3. The payback period was determined by applying the projected displaced natural gas cost, less total operating costs, toward the amortization of the capital cost until the entire initial investment has been paid off. Payback is achieved in 32 months. After payback, operating costs of the project would be 22 percent of the cost of the displaced natural gas.

The very rapid payback period computed and the cost savings that will occur after the payback period make geothermal heating as a byproduct of geothermal power generation a very attractive alternative. However, if the geothermal resources in the area cannot be used to generate electricity, then the cost of the production and reinjection wells would be added to the initial project costs. An additional analysis was performed to determine the impact of well costs on the payback period. Drilling and equipping of the wells were estimated to add approximately \$2,000,000 to the cost of the project. Initial total operating costs were assumed to be equal to the initial geothermal fluid purchase costs utilized earlier. However, this cost would increase at the general inflation rate and not at the accelerated rate used for natural gas. Insurance costs would be greater also since the entire project would be operated by the hospital.

## 2. BENEFIT/COST RATIOS

Monthly savings will continue to increase beyond the payback period in all cases. To account for this, the present worths of the benefits (displaced natural gas costs) and the costs (capital recovery, operation and maintenance, insurance, and geothermal fluid purchase) were compared over 10 and 20-year planning periods for each option. The results are summarized in Table 5. In all cases, the benefit/cost ratio exceeded 1.0, thereby justifying the project. The present worths of the savings for each case are also shown in Table 5. The magnitude of the savings further illustrates the attractiveness of the project - regardless of whether geothermal electric power can be produced.

## 3. CONCLUSIONS

The conclusions reached by the economic analyses may be summarized as follows:

- A. The proposed project is very attractive economically. Total operating cost savings are capable of paying back the initial investment in 32 months from start-up. Over 10 and 20-year planning periods, the benefit/cost ratios of the project are estimated to be 2.60 and 3.62, respectively. Present worths of net savings are estimated to be \$7,003,458 and \$20,211,713, respectively.



TABLE 3

## PROJECT COST AMORTIZATION OVER PAYBACK PERIOD

	<u>Month 1</u>	<u>Month 31</u>	<u>Month 32</u>	<u>Month 33</u>
Principal Balance	1,738,428	36,390	-0-	-0-
Value of Displaced Natural Gas: Energy Commission Projection	73,170	99,589	100,586	101,591
Monthly Costs				
Operation and Maintenance	3,384	4,008	4,030	4,053
Insurance	741	779	780	781
Geothermal Fluid Purchase	12,703	12,296	17,469	17,643
Interest	<u>17,770</u>	<u>1,128</u>	<u>365</u>	<u>-0-</u>
Subtotal	34,598	23,211	22,644	22,477
Net displaced cost applied to amortization of principal.	38,572	76,378	36,390	-0-
Net savings over existing steam heating system (monthly).	-0-	-0-	41,552	79,114



TABLE 4

PROJECT COST AMORTIZATION OVER PAYBACK PERIOD  
INCLUDING GEOTHERMAL RESOURCE DEVELOPMENT COSTS

	<u>Month 1</u>	<u>Month 65</u>	<u>Month 66</u>	<u>Month 67</u>
Principal Balance	3,759,200	33,109	-0-	-0-
Value of Displaced Natural Gas: Energy Commission Projection	73,170	138,389	139,697	141,015
Monthly Costs				
Operation and Maintenance				
Heating System	3,384	4,855	4,882	4,910
Geothermal Wells	12,640	18,133	18,235	18,338
Insurance	1,576	1,752	1,755	1,758
Interest	37,770	1,453	331	-0-
Subtotal	55,370	26,192	25,203	25,006
Net displaced cost applied to amortization of principal.	17,800	112,187	33,109	-0-
Net savings over existing steam heating system (monthly).	-0-	-0-	81,385	116,009



TABLE 5

## BENEFIT/COST RATIOS AND NET SAVINGS

	PLANNING PERIOD	
	<u>10 YEARS</u>	<u>20 YEARS</u>
<u>Electric Power/Geothermal Heating</u>		
Construction Cost = \$1,777,000		
Present Worth Values		
Natural Gas Displaced	11,388,157	27,916,717
Capital Amortization (32 Mos)	1,928,134	1,928,134
<u>Total Operating Costs</u>	<u>2,456,565</u>	<u>5,776,870</u>
Total Costs	4,384,699	7,705,004
Benefit/Cost Ratio	2.60	3.62
Net Savings (pw)	7,003,458	20,211,713
 <u>Geothermal Heating Only</u>		
Construction Cost = \$3,777,000		
Present Worth Values		
Natural Gas Displaced	11,388,157	27,916,717
Capital Amortization (66 Mos)	4,337,635	4,337,635
<u>Total Operation Costs</u>	<u>2,476,753</u>	<u>5,906,231</u>
Total Costs	6,814,388	10,243,866
Benefit/Cost Ratio	1.66	2.73
Net Savings (pw)	4,573,769	17,672,851



- B. The proposed project remains economically attractive even if the geothermal resources cannot be used to generate electricity and the hospital would be required to make a greater initial investment and pay additional operating costs. The payback period is estimated to extend to 66 months (5.5 years). Over the 10 and 20-year planning periods the benefit/cost ratios would be 1.66 and 2.73, respectively, and the present worth of the net savings would be \$4,573,769 and \$17,672,851, respectively.
- C. Other buildings that had been excluded from the study for a variety of reasons can probably be provided with a geothermal heating system without significantly affecting the computed payback periods. This is especially true if heat energy losses in the steam piping are taken into account. The benefit/cost ratios would also remain much the same. The present worth of the net savings would increase, however, due to the further reductions in natural gas consumption that would occur.
- D. A lower growth rate in natural gas prices than that currently projected by the State Energy Commission would lengthen the payback periods and reduce the benefit/cost ratios and present worth of the net savings that would be attainable. However, even if natural gas price projections are reduced to the same rate as the general inflation rate, the project remains economically viable and desirable (see Appendix D).



## J. REFERENCES

1. Resources Agency of California, Department of Water Resources, Energy Division. Cogeneration Feasibility Studies Report, June 1981, Report No. 80-41-RE, prepared by Kaiser Engineers.
2. Geothermal Resources Council, Geo-Heat Utilization Center, Oregon Institute of Technology. Direct Utilization of Geothermal Energy: A Technical Handbook, 1979, Geothermal Resources Council Special Report No. 7.
3. Khashab, A. M. Heating, Ventilating, and Air Conditioning Systems Estimating Manual, 1977, McGraw-Hill, Inc.
4. State of California Energy Resources Conservation and Development Commission. Energy Conservation Design Manual for New Nonresidential Buildings, October 1977.
5. Culver, Gene. Personal Communication, Associate Director, Geo-Heat Center, Oregon Institute of Technology, 1981, Klamath Falls, Oregon.
6. Lindermyer, Ed, Wally German, and Craig McDonald. Personal Communications, Plant Operations Staff, Department of Development Services, Sonoma State Hospital, 1981, Eldridge, California.
7. Fisher, Leonard A. Personal Communication, Professional Mechanical Engineer, 1981, San Francisco, California.
8. Kut, David. Heating and Hot Water Services in Buildings, 1968, Pergamon Press Ltd.
9. Jennings, Burgess. Environmental Engineering: Analysis and Practice, 1970, International Textbook Co.
10. American Society of Heating Refrigeration and Air Conditioning Engineers, Fundamentals Handbook, 1977.
11. Lee Saylor, Inc. Current Construction Costs, 1980.
12. McMahon, Leonard A. and Percival E. Pereira. 1981 Dodge Guide to Public Works and Heavy Construction Costs, 1980, McGraw-Hill Information Systems Company.
13. Goodridge, James. Personal Communication, Climatologist, 1981, State of California Resources Agency, Department of Water Resources.
14. California Energy Commission. California Energy Prices: 1980-2000, Staff Report, July 1981, Biennial Forecast, Document Number P300-81-015.

APPENDIX A



Energy Profiles for Sonoma State Hospital taken from the Cogeneration Feasibility Study prepared by Kaiser Engineers.

1. Figure 3.2-1 Average Monthly Electric and Gas Consumption, 1975-1980.
2. Figure 3.2-3 Typical Winter and Summer Steam Demand.
3. Figure 3.2-4 Estimated Maximum and Minimum Steam Demand.
4. Figure 4.1-2 Projected Future Annual Steam Consumption.

FIGURE 3.2 - 1  
AVERAGE MONTHLY ELECTRIC AND GAS CONSUMPTION, 1975 - 1980  
SONOMA STATE HOSPITAL

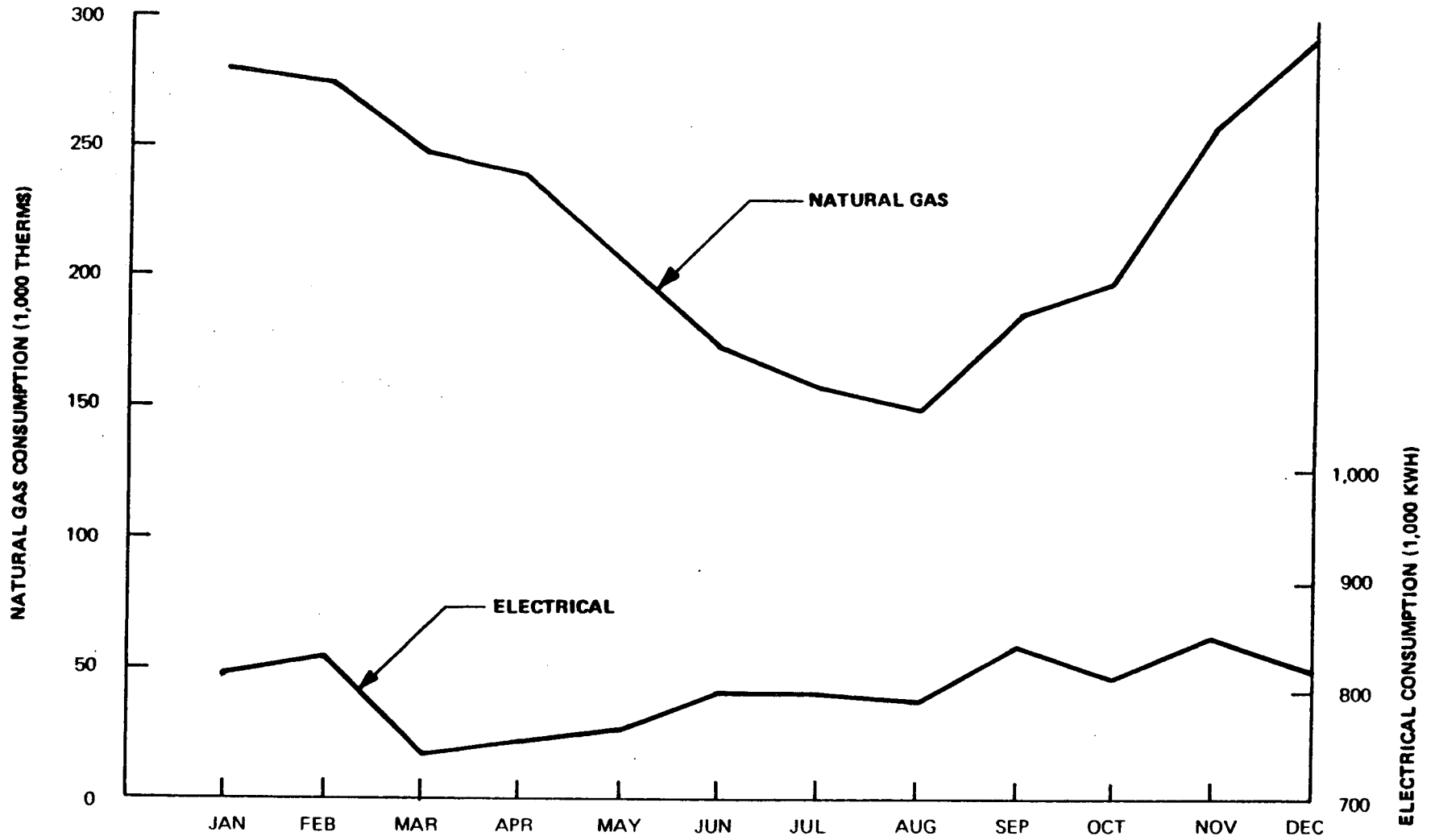


FIGURE 3.2 - 3  
TYPICAL WINTER AND SUMMER STEAM DEMAND  
SONOMA STATE HOSPITAL

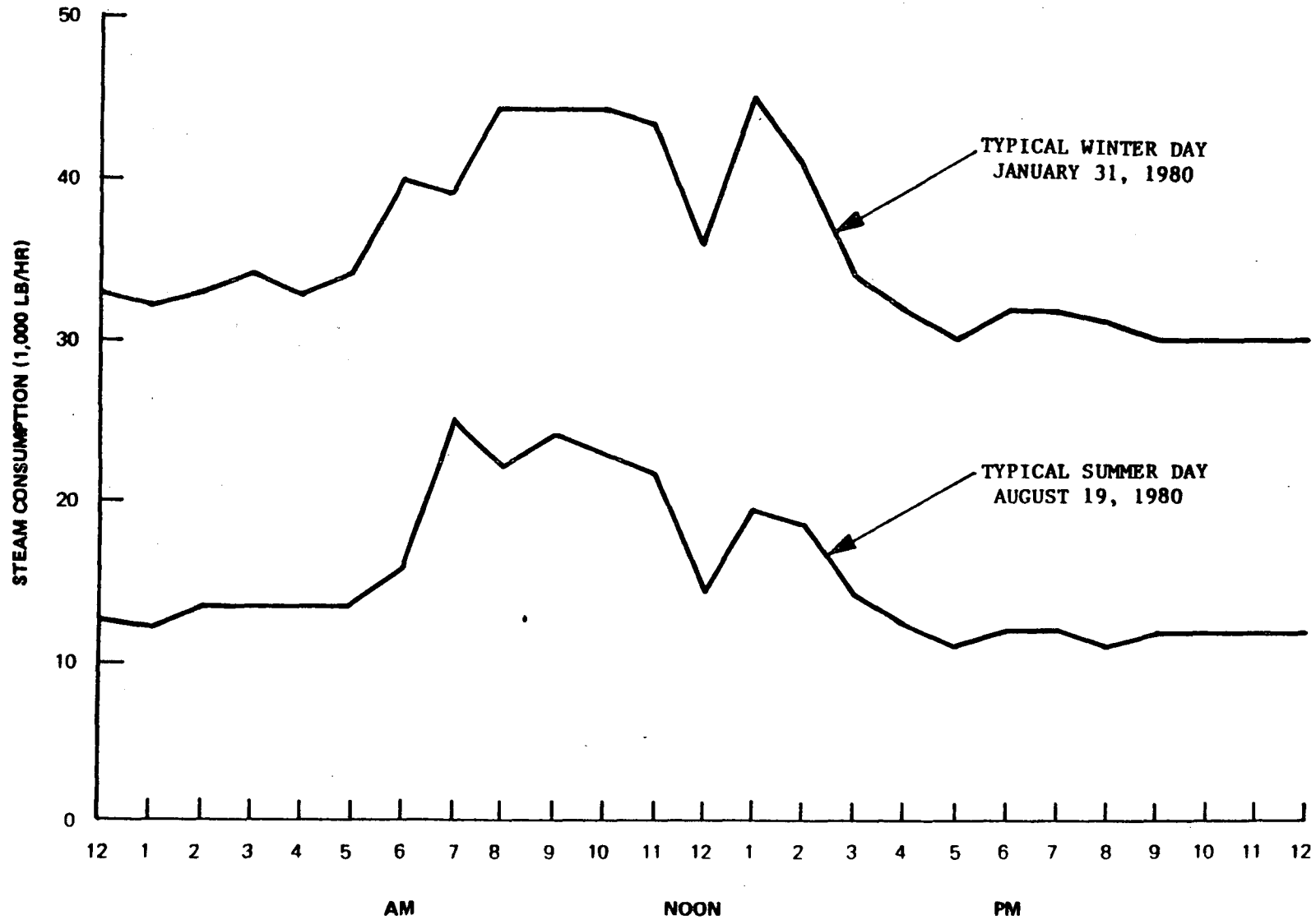


FIGURE 3.2 - 4  
ESTIMATED MAXIMUM AND MINIMUM STEAM DEMAND  
SONOMA STATE HOSPITAL

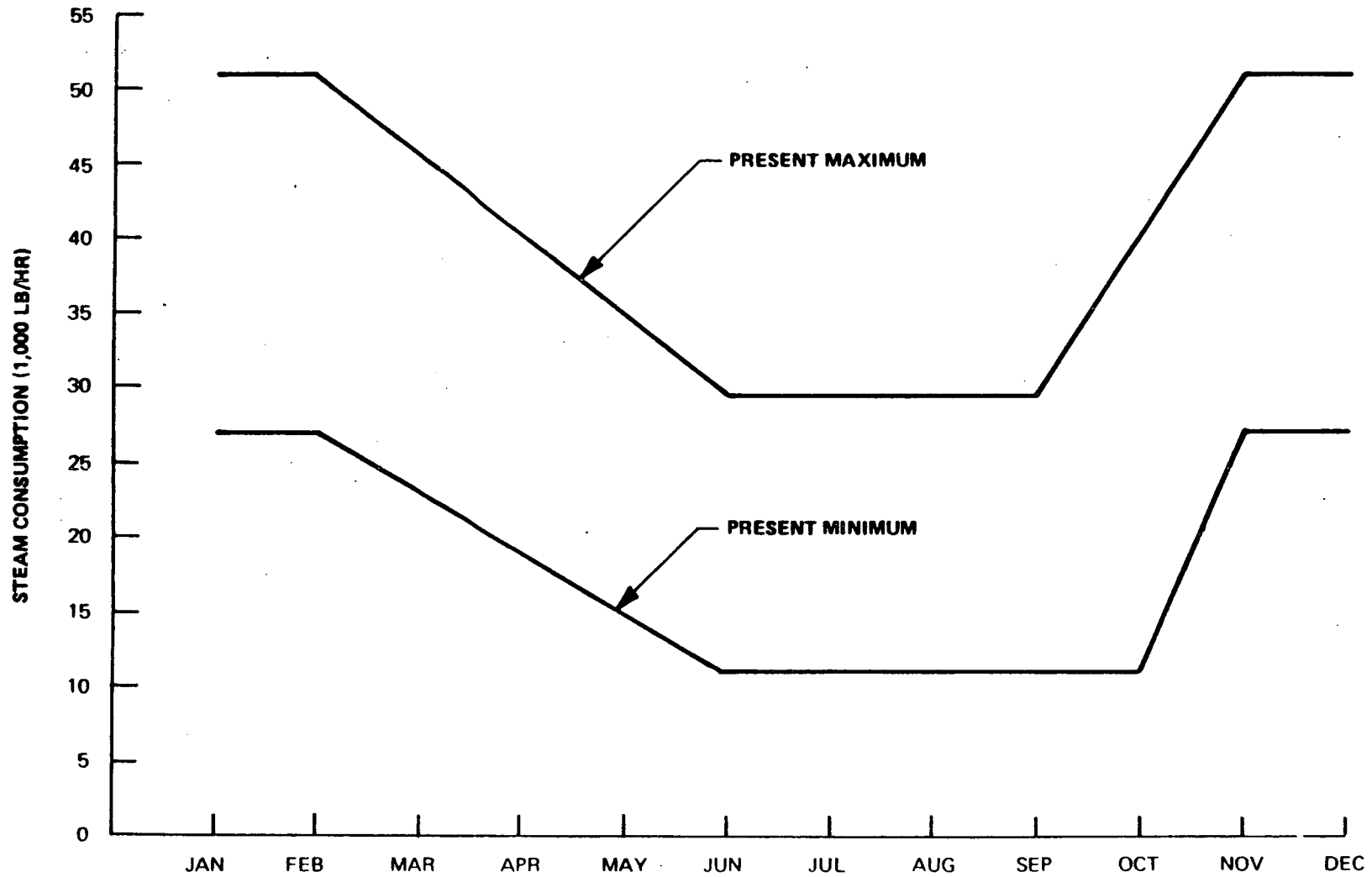
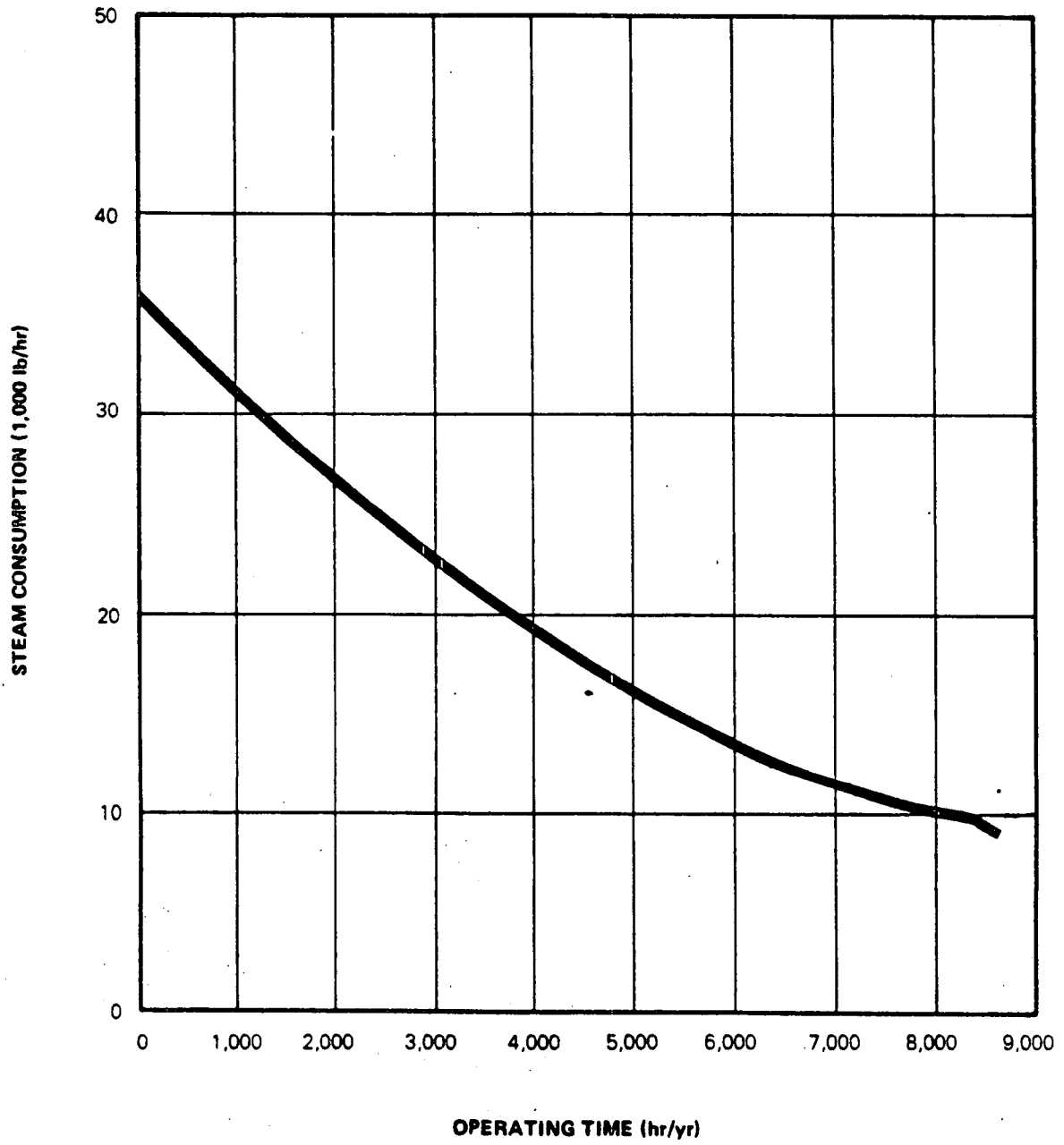


FIGURE 4.1 - 2  
PROJECTED FUTURE ANNUAL STEAM CONSUMPTION  
SONOMA STATE HOSPITAL





APPENDIX B

Geothermal Fluid Distribution and Return System -- Detailed Quantity  
Take-offs and Cost Estimate.

SUBJECT Geo Thermal Fluid Distribution & Return  
Quality Takeoff and Cost Estimate

DATE \_\_\_\_\_  
 DESIGNED BY P. Schulte  
 CHECKED BY JWD

Segment	Supply Pipe φ	Return Pipe φ	Total Length ft.	Unit Cost \$/LF	Pavement		Congested Area		Total Cost \$	Flows, gpm	
					Length	\$/LF	Length	\$/LF		S	R
1	12	—	185	96.35	32	7.09	—	—	18,051.63	3799	—
2	8	8	135	99.40	135	5.93	60	10.10	14,825.55	1036	1036
3	2	2	50	31.55	0	3.85	0	6.55	1577.50	48	48
4	8	8	55	99.40	55	5.93	0	10.10	5793.15	988	988
5	5	5	125	53.09	30	4.84	0	8.24	6781.45	373	373
6	5	5	35	53.09	0	4.84	0	8.24	1858.15	277	277
7	2.5	2.5	105	34.99	38	4.01	85	6.82	4373.95	96	96
8	2	2	95	31.55	30	3.85	0	6.55	3112.75	48	48
9	2	2	180	31.55	70	3.85	0	6.55	5948.50	48	48
10	6	6	155	60.19	60	5.16	0	8.78	9639.05	615	615
11	2	2	40	31.55	0	3.85	0	6.55	1262.00	48	48
12	5	5	25	53.09	0	4.84	0	8.24	1327.25	567	567
13	3	3	185	38.57	0	4.19	0	7.13	7135.45	130	130

SUBJECT Geothermal Fluid Distribution & Return  
Quantity Takeoff and Cost Estimate

DATE \_\_\_\_\_  
 DESIGNED BY D. Schultz  
 CHECKED BY l.w.

D S P	Segment	Supply Pipe Ø	Return Pipe Ø	Total Length ft.	Unit Cost \$/LF	Pavement		Congested Area		Total Cost \$	Flow (gpm)	
						Length	\$/LF	Length	\$/LF		S	R
	14	5	5	160	53.09	0	4.84	0	8.24	8494.40	437	437
	15	4	4	115	45.86	15	4.50	0	7.66	5,341.40 <del>5291.40</del>	233	233
	16	3	3	230	38.57	200	4.19	0	7.13	9709.10	204	204
	17	2	2	350	31.55	155	3.85	65	6.55	12,065.00	48	48
	18	3	3	750	38.57	145	4.19	85	7.13	30,141.10	156	156
	19	2.5	2.5	65	34.99	20	4.01	0	6.82	2354.55	78	78
	20	2.5	2.5	370	34.99	215	4.01	235	6.82	15,411.15	78	78
*	21	10	8	65	115.43	10	6.27	0	10.67	7565.65	2763	1036
	22	4	4	130	45.86	0	4.50	0	7.66	5961.80	203	203
*	23	10	8	485	115.43	80	6.27	100	10.67	57552.15	2560	1239
	24	2	2	130	31.55	0	3.85	60	6.55	4494.50	62	62
*	25	10	8	145	115.43	50	6.27	145	10.67	18598.00	2498	1301
	26	2.5	2.5	740	34.99	75	4.01	0	6.82	26,193.35	105	105

SUBJECT Geothermal Fluid Distribution & Return  
Quantity Takeoff and Cost Estimate

DATE \_\_\_\_\_  
 DESIGNED BY P. Schmitt  
 CHECKED BY JWJ

D S P	Segment	Supply Pipe φ	Returns Pipe φ	Total Length ft.	Unit Cost \$/LF	Pavement		Congested Area		Total Cost \$	Flow SPM	
						Length	\$/LF	Length	\$/LF		S	R
*	27	10	8	125	115.43	125	6.27	0	10.67	15212.50	2393	1406
	28	2.5	2.5	45	34.99	0	4.01	0	6.82	1574.55	76	76
*	29	10	8	135	115.43	35	6.27	60	10.67	16442.70	2317	1482
	30	2.5	2.5	60	34.99	40	4.01	0	6.82	2259.80	51	51
*	31	10	8	50	115.43	50	6.27	0	10.67	6085.00	2268	1533
	32	2.5	2.5	125	34.99	110	4.01	0	6.82	4814.85	58	58
	33	10	10	500	127.44	60	6.60	0	11.23	64116.00	2198	1601
	34	3	3	235	38.57	0	4.19	0	7.13	9063.95	137	137
	35	10	10	150	127.44	0	6.60	100	11.23	20239.00	2061	1738
	36	8	8	220	99.40	75	5.93	180	10.10	24,130.75	1107	1107
	37	2.5	2.5	75	34.99	0	4.01	0	6.82	2624.25	68	68
	38	8	8	165	99.40	0	5.93	0	10.10	16401.00	1039	1039
	39	2.5	2.5	75	34.99	0	4.01	0	6.82	2624.25	68	68

SUBJECT Geothermal Fluid Distribution & Return  
Quality Takeoff and Cost Estimate

DATE \_\_\_\_\_  
 DESIGNED BY P. Schwitz  
 CHECKED BY J. W.

D S P	Segment	Supply Pipe φ	Returns Pipe φ	Total Length ft.	Unit Cost \$/LF	Pavement		Congested Area		Total Cost \$	Flow gpm	
						Length	\$/LF	Length	\$/LF		S	R
	40	8	8	280	99.40	30	5.93	85	10.10	28868.40	971	971
	41	2.5	2.5	75	34.99	0	4.01	0	6.82	2624.25	68	68
	42	8	8	125	99.40	30	5.93	50	10.10	13107.90	903	903
	43	2.5	2.5	160	34.99	0	4.01	0	6.82	5598.40	68	68
	44	6	6	220	60.19	30	5.16	160	8.78	14801.40	835	835
	45	4	4	215	45.86	0	7.66	0	4.50	9859.90	236	236
	46	6	6	370	60.19	30	5.16	95	8.78	23259.20	599	599
	47	5	5	160	53.09	60	4.84	120	8.24	9773.60	363	363
	48	4	4	310	45.86	0	7.66	0	4.50	14216.60	236	236
*	49	8	10	830	111.40	130	6.26	450	10.65	98068.30	954	2845
	50	5	5	175	53.09	175	4.84	0	8.24	10137.75	579	579
	51	4	4	135	45.86	0	7.66	0	4.50	6191.10	227	227
	52	2.5	2.5	35	34.99	0	~	0	~	1224.65	68	68

SUBJECT Geothermal Fluid Distribution System Return  
Quantity Takeoff and Cost Estimate

DATE \_\_\_\_\_  
 DESIGNED BY P. Schultz  
 CHECKED BY JLD

Segment	Supply Pipe φ	Return Pipe φ	Total Length ft.	Unit Cost \$/LF	Pavement		Congested Area		Total Cost \$	Flow gpm	
					Length	\$/LF	Length	\$/LF		S	R
53	3	3	190	38.57	0	4.19	30	7.13	7542.20	159	159
54	5	5	95	53.09	0	4.84	0	8.24	5043.55	352	352
55	3	3	150	38.57	0	4.19	0	7.13	5785.50	125	125
56	4	4	210	45.86	0	4.50	0	7.66	9630.60	227	227
57	3	3	140	38.57	0	4.19	0	7.13	5399.80	159	159
58	2.5	2.5	205	34.99	0	4.01	0	6.82	7172.95	68	68
* 59	5	12	210	88.79	0	~	0	~	18645.90	375	3424
60	5	5	125	53.09	50	4.84	75	8.24	7496.25	375	375
61	3	3	270	38.57	0	4.19	0	7.13	10413.90	125	125
62	4	4	370	45.86	30	4.50	0	7.66	17,103.20 <del>16,738.20</del>	250	250
63	1.5	1.5	25	26.39	0	~	0	~	659.75	40	40
* 64	4	4	335	45.86	80	4.50	0	~	15,723.10 <del>15,403.10</del>	250	250
65	3	3	30	38.57	0	~	0	~	1157.10	125	125

P S D

\*

SUBJECT Geothermal Fluid Distribution S. Return  
Quantity Takeoff and Cost Estimate

DATE \_\_\_\_\_  
 DESIGNED BY P. Schulte  
 CHECKED BY Jew

Segment	Supply Pipe Pipe φ	Return Pipe Pipe φ	Total Length ft.	Unit Cost \$/LF	Pavement		Congested Area		Total Cost \$	Flow gpm	
					Length	\$/LF	Length	\$/LF		S	R
66	3	3	655	38.57	115	4.19	0	~	25745.20	125	125
67	—	12	115	96.35	25	7.09	115	12.07	12645.55	—	3799
			<u>823,724.90</u>		<u>13,346.03</u>		<u>22,012.20</u>		<u>859,053.13</u>		
							Total		<del>858,508.58</del>		

Material Cost = \$724,222.75

\$99,502.15 For Excavation, Backfill Bedding Placement, basic surface restoration

Total TRENCH length = 13,252.5 ft.

\$99,502.15 / 13,252.5 = \$7.51 / FT.

APPENDIX C



Life Cycle Cost Analysis prepared by the Geo-Heat Center, Oregon Institute of Technology.

## LIFE CYCLE COST ANALYSIS FOR SONOMA STATE HOSPITAL GEOTHERMAL HEATING SYSTEM

Life cycle cost analysis for the conceptual geothermal heating system at Sonoma State Hospital, appears in Tables 1 and 2.

It was assumed that the system would come on line in 1982. The twenty-year forecasts assume a 7% economic inflation rate over the project life, and additional inflation rates for conventional fuels as forecast by the Oregon Department of Energy "Fifth Annual Report" as follows:

### Natural Gas

9.0% through 1984  
9.2% 1985 through 1989  
10.0% 1990 through 1994  
10.2% 1995 through 2001

### Electrical Power

7.9% through 1987  
9.1% through 2001

The project is highly feasible economically with a simple payback of just over two years. Two additional runs were made adding a cost for condensate of \$0.08 per therm. This added cost caused the payback periods to increase to only four years.

Table 1 uses 12% bond financing and Table 2 was run using a regular loan payment at 12% per annum interest.

Table 1

LIFE CYCLE COST ANALYSIS  
 FOR  
 SONOMA STATE HOSPITAL  
 GEOTHERMAL HEATING SYSTEM

Date: Jan. 15, 1982

COST OF CAPITAL  
 TOTAL CAPITAL COST 1777000  
 NET PRESENT VALUE 9112427

	1	2	3	4	5	6	7	
	NATURAL GAS CURRENT SYSTEM	COST OF CONDENSATE \$.08/THERM	MAINTENANCE GEOTHERMAL SYSTEM	INSURANCE GEOTHERMAL SYSTEM	FINANCING 12% BOND	NET ENERGY SAVINGS	DISCOUNTED CASH FLOW 12%	
PRESENT COST	871585	151317	40380	8885				
YEAR								YEAR NUMBER
1982	950028	164936	43207	9063	213240	528646	472005	1
1983	1035530	179780	46231	9244	213240	596279	475350	2
1984	1128728	195960	49467	9429	213240	670061	476936	3
1985	1232571	213988	52930	9617	213240	752413	478172	4
1986	1345967	233675	56635	9810	213240	842417	478010	5
1987	1469796	255173	60599	10006	213240	940734	476630	6
1988	1605018	278649	64841	10206	213240	1048287	474192	7
1989	1752679	304285	69380	10410	213240	1165774	470837	8
1990	1927947	334713	74237	10618	213240	1305757	470869	9
1991	2120742	368185	79434	10831	213240	1459884	470043	10
1992	2332816	405003	84994	11047	213240	1629579	468465	11
1993	2566098	445504	90943	11268	213240	1816411	466227	12
1994	2822707	490054	97310	11494	213240	2022104	463414	13
1995	3110624	540039	104121	11724	213240	2253223	461054	14
1996	3427907	595123	111410	11958	213240	2508134	458227	15
1997	3777554	655826	119208	12197	213240	2789279	454992	16
1998	4162864	722720	127553	12441	213240	3099351	451403	17
1999	4587476	796438	136482	12690	213240	3441317	447507	18
2000	5055399	877674	146035	12944	213240	3818449	443348	19
2001	5571050	967197	156258	13203	1990240	2457355	254746	20
TOTAL	51983500	9024923	1771276	220200	6041800	35145501	9112427	

SIMPLE PAYBACK  
 DISCOUNTED PAYBACK

3 YEARS  
 4 YEARS

Table 1

LIFE CYCLE COST ANALYSIS  
FOR  
SONOMA STATE HOSPITAL  
GEOTHERMAL HEATING SYSTEM

Date: Jan. 15, 1982

COST OF CAPITAL 12%  
TOTAL CAPITAL COST 1777000  
NET PRESENT VALUE 11508839

	1	2	3	4	5	6	
	NATURAL GAS CURRENT SYSTEM	MAINTENANCE GEOTHERMAL SYSTEM	INSURANCE GEOTHERMAL SYSTEM	FINANCING 12% BOND	NET ENERGY SAVINGS	DISCOUNTED CASH FLOW 12%	
PRESENT COST	871585	40380	8885				
YEAR							YEAR NUMBER
1982	950028	43207	9063	213240	693581	619269	1
1983	1035530	46231	9244	213240	776059	618670	2
1984	1128728	49467	9429	213240	866021	616416	3
1985	1232571	52930	9617	213240	966401	614165	4
1986	1345967	56635	9810	213240	1076092	610604	5
1987	1469796	60599	10006	213240	1195957	605909	6
1988	1605018	64841	10206	213240	1326936	600239	7
1989	1752679	69380	10410	213240	1470059	593732	8
1990	1927947	74237	10618	213240	1640470	591570	9
1991	2120742	79434	10831	213240	1828068	588589	10
1992	2332816	84994	11047	213240	2034582	584894	11
1993	2566098	90943	11268	213240	2261914	580577	12
1994	2822707	97310	11494	213240	2512158	575722	13
1995	3110624	104121	11724	213240	2793262	571557	14
1996	3427907	111410	11958	213240	3103257	566954	15
1997	3777554	119208	12197	213240	3445105	561971	16
1998	4162864	127553	12441	213240	3822071	556663	17
1999	4587476	136482	12690	213240	4237755	551076	18
2000	5055399	146035	12944	213240	4696123	545252	19
2001	5571950	156258	13203	1990240	3424552	355012	20
TOTAL	51983500	1771276	220200	6041800	44170424	11508839	

SIMPLE PAYBACK  
DISCOUNTED PAYBACK

3 YEARS  
3 YEARS

Table 2

LIFE CYCLE COST ANALYSIS  
FOR  
SONOMA STATE HOSPITAL  
GEOTHERMAL HEATING SYSTEM

Date: Jan. 15, 1982

	1	2	3	4	5	6	7	
	NATURAL GAS CURRENT SYSTEM	COST OF CONDENSATE \$.08/THERM	MAINTENANCE GEOTHERMAL SYSTEM	INSURANCE GEOTHERMAL SYSTEM	DEBT FINANCING	NET ENERGY SAVINGS	DISCOUNTED CASH FLOW 12%	
PRESENT COST	871585	151317	40380	8885				
YEAR								YEAR NUMBER
1982	950028	164935	43207	9063	237903	503983	449985	1
1983	1035530	179780	46231	9244	237903	571617	455690	2
1984	1128728	195960	49467	9429	237903	645398	459382	3
1985	1232571	213988	52930	9617	237903	727750	462498	4
1986	1345967	233675	56635	9810	237903	817755	464016	5
1987	1469796	255173	60599	10006	237903	916121	464136	6
1988	1605018	278649	64841	10206	237903	1023625	463036	7
1989	1752679	304285	69380	10410	237903	1141112	460876	8
1990	1927947	334713	74237	10618	237903	1281095	461976	9
1991	2120742	368184	79434	10831	237903	1435221	462103	10
1992	2332816	405003	84994	11047	237903	1604917	461375	11
1993	2566098	445503	90943	11268	237903	1791748	459897	12
1994	2822707	490053	97310	11494	237903	1997442	457762	13
1995	3110624	540039	104121	11724	237903	2228561	456008	14
1996	3427907	595123	111410	11958	237903	2483472	453721	15
1997	3777554	655825	119208	12197	237903	2764617	450969	16
1998	4162864	722719	127553	12441	237903	3074689	447811	17
1999	4587476	796437	136482	12690	237903	3416655	444300	18
2000	5055399	877673	146035	12944	237903	3793787	440484	19
2001	5571050	967196	156258	13203	237903	4209693	436405	20
TOTAL	51983500	9024913	1771276	220200	4758052	36429259	9112430	

SIMPLE PAYBACK

4 YEARS

DISCOUNTED PAYBACK

4 YEARS

Table 2

LIFE CYCLE COST ANALYSIS  
FOR  
SONOMA STATE HOSPITAL  
GEOTHERMAL HEATING SYSTEM

Date: Jan. 15, 1982

COST OF CAPITAL 12%  
TOTAL CAPITAL COST 1777000  
NET PRESENT VALUE 11508839

	1	3	4	5	6	7	
	NATURAL GAS CURRENT SYSTEM	MAINTENANCE GEOTHERMAL SYSTEM	INSURANCE GEOTHERMAL SYSTEM	DEBT FINANCING	NET ENERGY SAVINGS	DISCOUNTED CASH FLOW 12%	YEAR NUMBER
PRESENT COST	871585	40380	8885				
YEAR							
1982	950028	43207	9063	237903	668918	597249	1
1983	1035530	46231	9244	237903	751396	599009	2
1984	1128728	49467	9429	237903	841358	598862	3
1985	1232571	52930	9617	237903	941738	598492	4
1986	1345967	56635	9810	237903	1051430	596609	5
1987	1469796	60599	10006	237903	1171294	593414	6
1988	1605018	64841	10206	237903	1302274	589082	7
1989	1752679	69380	10410	237903	1445396	583771	8
1990	1927947	74237	10618	237903	1615808	582676	9
1991	2120742	79434	10831	237903	1803406	580648	10
1992	2332816	84994	11047	237903	2009920	577804	11
1993	2566098	90943	11268	237903	2237252	574247	12
1994	2822707	97310	11494	237903	2487495	570070	13
1995	3110624	104121	11724	237903	2768600	566510	14
1996	3427907	111410	11958	237903	3078595	562448	15
1997	3777554	119208	12197	237903	3420443	557948	16
1998	4162864	127553	12441	237903	3797409	553071	17
1999	4587476	136482	12690	237903	4213092	547869	18
2000	5055399	146035	12944	237903	4671461	542388	19
2001	5571050	156258	13203	237903	5176889	536671	20
TOTAL	51983500	1771276	220200	4758052	45454172	11508839	

SIMPLE PAYBACK 3 YEARS  
DISCOUNTED PAYBACK 3 YEARS

APPENDIX D



Revised Project Cost Amortization Schedules and Benefit/Cost Ratios Based on Modified Projections of Natural Gas Prices.

D-1 Project Cost Amortization over Payback Period.

D-2 Project Cost Amortization over Payback Period Including Costs of Geothermal Resource Development.

D-3 Benefit/Cost Ratios and Net Savings.



TABLE D-1

## PROJECT COST AMORTIZATION OVER PAYBACK PERIOD

	<u>Month 1</u>	<u>Month 35</u>	<u>Month 36</u>	<u>Month 37</u>
Principal Balance	\$1,738,792	\$ 6,934	-0-	-0-
Value of Displaced Natural Gas:				
Energy Commission Projection	73,170	103,625	104,654	105,692
<u>Modified Projection</u>	<u>72,806</u>	<u>88,191</u>	<u>88,689</u>	<u>89,191</u>
Difference	364	15,434	15,965	16,501
Monthly Costs				
Operation and Maintenance	3,384	4,099	4,122	4,146
Insurance	741	784	785	787
Geothermal Fluid Purchase	12,703	17,997	18,176	18,356
<u>Interest</u>	<u>17,770</u>	<u>715</u>	<u>69</u>	<u>-0-</u>
Subtotal	34,598	23,595	23,152	23,289
Net displaced cost applied to amortization of principal	38,208	64,595	6,934	-0-
Savings over existing steam heating system	-0-	-0-	58,603	65,902
Total estimated savings (monthly)	364	15,434	74,568	82,403

\* Current natural gas price projected at current inflation rate (7%).



TABLE D-2

PROJECT COST AMORTIZATION OVER PAYBACK PERIOD  
INCLUDING COSTS OF GEOTHERMAL RESOURCE DEVELOPMENT

	<u>Month 1</u>	<u>Month 81</u>	<u>Month 82</u>	<u>Month 83</u>
Principal Balance	\$3,759,564	\$ 39,285	-0-	-0-
Value of Displaced Natural Gas:				
Energy Commission Projection	73,170	160,599	162,082	163,576
<u>Modified Projection</u>	<u>72,806</u>	<u>114,304</u>	<u>114,950</u>	<u>115,600</u>
Difference	364	46,295	47,132	47,976
Monthly Costs				
Operation and Maintenance				
Heating System	3,384	5,313	5,343	5,373
Geothermal Wells	12,650	19,845	19,957	20,070
Insurance	1,576	1,799	1,802	1,805
<u>Interest</u>	<u>37,770</u>	<u>1,254</u>	<u>383</u>	<u>-0-</u>
Subtotal	55,370	28,210	27,499	27,247
Net displaced cost applied to amortization of principal	17,436	86,094	39,285	-0-
Net savings over existing steam heating system (monthly)	-0-	-0-	48,171	88,353

\* Current natural gas price projected at current inflation rate (7%).



TABLE D-3

## BENEFIT/COST RATIOS AND NET SAVINGS

	PLANNING PERIOD	
	<u>10 YEARS</u>	<u>20 YEARS</u>
<u>Electric Power/Geothermal Heating</u>		
Construction Cost = \$1,777,000		
Present Worth Values		
Natural Gas Displaced *	\$8,760,037	\$17,447,677
Capital Amortization (36 months)	1,941,606	1,941,606
<u>Total Operating Costs</u>	<u>1,999,185</u>	<u>3,954,909</u>
Total Costs	3,940,791	5,896,515
Benefit/Cost Ratio	2.22	2.96
Net Savings (pw)	4,819,246	11,551,162
<u>Geothermal Heating Only</u>		
Construction Cost = \$3,777,000		
Present Worth Values		
Natural Gas Displaced *	8,760,037	17,447,677
Capital Amortization (82 months)	4,446,756	4,446,756
<u>Total Operating Costs</u>	<u>2,079,373</u>	<u>4,084,271</u>
Total Costs	6,526,129	8,531,027
Benefit/Cost Ratio	1.34	2.05
Net Savings (pw)	2,233,908	8,916,650

\* Current natural gas price projected at current inflation rate (7%).