BOISE GEOTHERMAL DISTRICT HEATING, 1892-1982

Part I, Institutional Planning

PART II, Technical Planning

"Boise Geothermal District Heating, 1892-1982"

Part I, Institutional Planning

by

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ABSTRACT

Use of geothermal hot water for district space heating, recreation, and domestic purposes began in Boise, Idaho in 1890. The wells and pipeline system established ninety years ago for these purposes is still in use. The system serves approximately 250 residences. The system has gone through a number of historical changes the most recent receiving its impetus from the energy shortage that began in 1973. This most recent change is development of a joint partnership between Boise Warm Springs Water District (the old system), and Boise City to improve and expand the old system and develope a new space heating system to serve Boise central business district. The system is planned for completion in 1983, will serve about 500 households, 2 million feet of office and retail space in 8 buildings, and cost an estimated $8 million. This project, financed with local and DoE funds, is described in terms of institutional and technical considerations.

INTRODUCTION

My name is Phil Hanson and I am director of Boise Geothermal. Boise Geothermal is an organization with responsibility for planning, designing, and developing a district heating system based on geothermal water. This system is located in the City of Boise, Idaho. The Boise Geothermal organization, and the work it is doing, is the result of a series of fortuitous but related historical events. The workability, the technical characteristics, the financial considerations, the legal and organizational setting, and the problems of a space heating system, as represented by Boise Geothermal, all grow out of those historical events. It is the purpose of this paper to summarize these events in two parts -- institutional considerations, and technical considerations.

I. HISTORICAL BACKGROUND

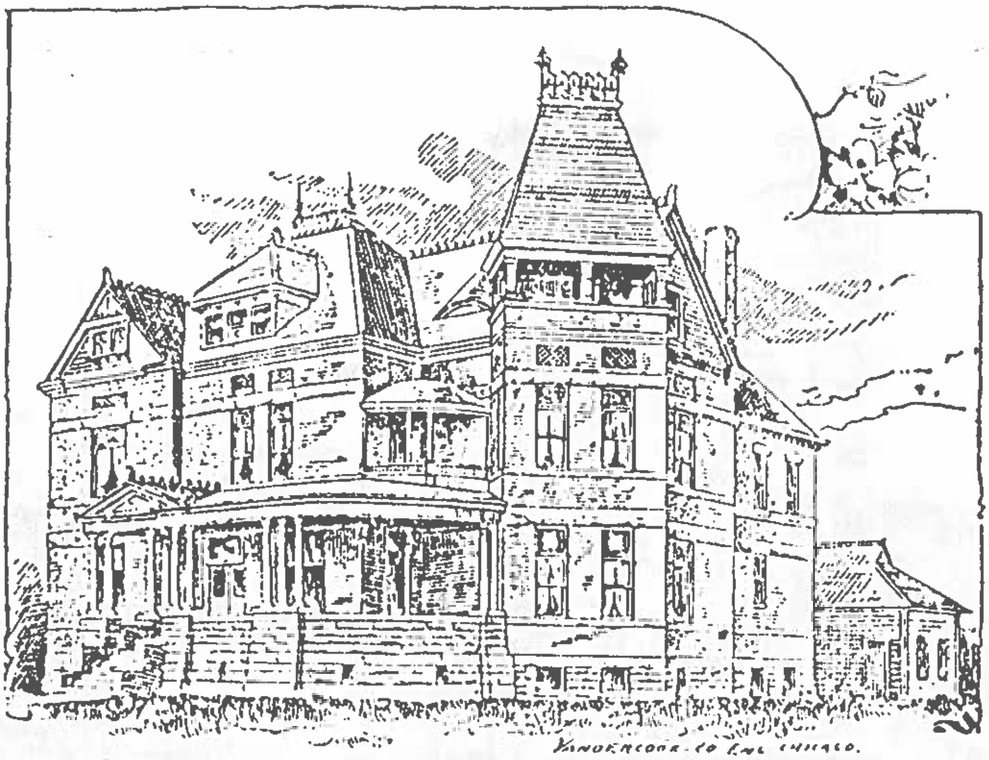
A. Boise Warm Springs Water District (BWSWD)

In the 1890's Boise population was approximately 2,500. Most of this population was settled along a street east of downtown called Warm Springs Avenue. This street, apparently, received its name from a warm spring that flowed at its eastern end. Two residents in the area decided to drill wells near Warm Springs Ave. to provide domestic water to residents in the area. The wells, drilled to approximately 400 feet, encountered hot instead of cold water, water with a temperature of 170°F (77°C). It was thus understandable that the owners of this new venture should chose to call their company the Artesian Hot and Cold Water Co.

Satisfied that the water was hot and chemically pure enough for a number of uses, the owners set out to sell the water for these uses. It was piped to some Warm Springs Ave. homes to provide space heat. It was also used by many of those same homes for domestic purposes. The first such home was that of C. W. Moore who became an early advocate of hot water for many uses. This large, 9,000 square foot home, shown in Figure 1, is still used as a residence and is heated with the same geothermal hot water.

The well owners also decided to build a natatorium, heated with geothermal water, as a resort area near the well sites. This resort was designed to compete with Kelley Hot Springs a few miles further from downtown Boise than the Natatorium. The "Nat" is shown in Figure 2. The Nat was opened for business in 1892 and was used continuously until 1935 when dry rot in the all wood structure, and heavy winds, led to its demolition. Otherwise hot water from the Warm Springs wells has been used continuously for domestic and heating purposes to the present time. A newspaper article in 1893 supplied prophetic insight to this energy source for the city's future.

> It is probable that Boise people do not fully realize the value of the hot water that flows in such abundance from the artesian wells. It is understood in a general way to be a nice idea to have houses heated by such an agency, but very few whose attention has not been called to the subject appreciate what the influence of this method of heating will be upon the future of the city.
>
> There are several things that can make a great city, but of not the least importance is that it should be a desirable place of residence. Business advantages build up a community, but it is often found that people, while making their money in one city, will live in another, because of superior attractions of the place that they select for their residence. When business advantages are equal, the city that offers the greatest inducements as a city of homes, forges ahead of its rivals; where business and residence advantages are combined, as in the case of Boise, the city must make great progress.
>
> The hot water supply gives the city a leverage that no other place in the country enjoys; when we stop to consider what the possibilities of the system of heating are, that fact immediately appears. So far as we know, coal will always be expensive; so also will wood. At best, both wood and coal are expensive, and create dirt and smoke. Those who have always had them about the house may have become accustomed to their litter, but there is no one who would not appreciate a heating system that would be free from all the objectionable features of the stove and fireplace.
>
> In time, this hot water will come into general use. All houses will be heated by it, and the heating will be done without care or annoyance on the part of the occupants, while the savings in expense will be enormous.



— Photograph courtesy Idaho State Historical Society

FIGURE 1. First Geothermally Heated Home in Boise Built in 1892.

FIGURE 2. The Boise Natatorium Built in 1892 and Using Geothermal Water for Resort Purposes.

The total investment in the system at that time was estimated to be $20,000 with fuel savings for the community figured at $50,000 a year.

While use of this resource has been essentially continuous for the past 90 years, there have been a number of institutional changes. The original organization changed hands a number of times. By the 1970's the hot water system was owned and operated by the major domestic water supplier -- Boise Water Co. In 1974 the now archaic system was turned over to a special district created by the Idaho state legislature. The resulting Boise Warm Springs Water District is present owner/operator of the system.

Another aspect of the system which has changed over the years is the number of patrons connected to the system. At the height of system usage, and prior to the advent of widespread natural gas use, there were about 400 residential units on the system. As low priced natural gas usage expanded, hot water use for space heating and domestic water use diminished. By the early 1970's the number of patrons had shrunk to around 150. Since initiation of the present energy crisis in around 1973 the number of customers has increased. At present there are approximately 250 household custormers, and a waiting list of more than 350 homes that have applied for connection.

The present BWSWD is managed by a five member board of directors who are responsible for setting rates, managing system operation, and defining policy for expansion. Present rates are based on a flat annual charge for different orifice sizes. These rates are shown in Table 1. More than 60% of the custormers have orifice sizes between 5/32" and 9/32". These rates are set from estimated operating budgets that include only a minimum for system expansion or refurbishment.

TABLE 1. Number of Boise Warm Springs Water District Customers by Orifice Size and Usage of Water for Heating & Domestic Uses.

Revenue Projections

No.	Type of Use	Rate	Total
1	Domestic Only	$ 75.00	$ 75.00
136	Domestic/Heat	75.00	10,200.00
14	2 Domestic/Heat	150.00	2,100.00
7	3 Domestic/Heat	225.00	1,575.00
4	4 Domestic/Heat	300.00	1,200.00
1	5 Domestic/Heat	375.00	375.00
	TOTAL DOMESTIC REVENUE		$15,525.00
13	1/8 Heating	$210.00	$ 2,730.00
19	5/32 Heating	290.00	5,510.00
133	3/16 Heating	375.00	49,875.00
15	9/32 Heating	470.00	7,050.00
32	1/4 Heating	555.00	17,760.00
3	9/32 Heating	630.00	1,890.00
	TOTAL HEATING REVENUE		$84,815.00
	TOTAL FLAT RATE REVENUE		$100,340.00
	10 Metered Accounts and New Hookup Fees-Estimated Revenue		20,760.00
	TOTAL PROJECTED REVENUE		$121,100.00

B. The State of Idaho

The BWSWD hot water system, as far as is known, is the largest such system with the longest operating history for any community in the U.S. Beginning in 1973 there were some activities initiated which were to result in the increasing involvement of the state government in geothermal. This involvement included geology studies by Boise State University and other state agencies as well as some exploratory well drilling. The drilling was funded by the federal Department of Energy and the State. In earlier history the state had drilled wells to serve the Old Penitentiary on ground near the Warm Springs well site. Most recently, however, a major 34,000 foot state building in this same area was connected to the BWSWD system. The addition of this larger building to the BWSWD system thus changed its patron compostion from primarily residential to a combination of residential and commercial. Other state buildings near the Warm Springs wells may be connected to the system in the near future.

In this way the State has initiated its involvement in geothermal. That involvement has gradually increased since 1975. The legislature appropriated almost $200,000 in 1977 to connect eight major State office buildings to geothermal when it is available to them. They have also formed a Geothermal Energy Task Force made up of three high level state employees to accelerate involvement in this alternative energy source. Another exploratory well, to a target depth of 2,200', is contemplated this year.

C. Boise City

The activities of Boise City accelerated toward geothermal beginning in 1975. Initially these activities were focussed through the City Energy Office which was disbanded in 1978 with its responsibilities transferred to Boise Geothermal in 1979. All new City buildings near service lines, present or planned, are designed to accomodate geothermal water for space heating. This includes a new

City Hall (1978), a new fire station (1980), and a senior citizens center (1978) that together aggregate about 140,000 square feet of area.

D. Private Landowners

In the hostoric period since 1890 hot water has been a real factor in local affairs. Over that period all three levels of government have become, individually, more involved with geothermal. In other words government involvement in geothermal is a definite, and now large scale activity. But the private sector, in that same time period, has been very active also. Data has been assembled about more than 140 hot wells, i.e. more than 20°C (68°F), drilled by private land owners. The water from these wells is or has been used for many purposes. Not a few well owners use the water for space heat. At least two owners use the water for large scale greenhouse operations. Others do not use the water at all or for relatively minor purposes. In many cases owners were upset having discovered hot water when the goal was cold or cool water for crops and cattle. The drilling of these wells has, among other things, tended to confirm the areal extent of a hot water resource if not the reservoir size.

Individual and agency involvement in geothermal has been much more extensive than this brief summary indicates. The point is, nonetheless, that the involvement while waxing and waning over time has been continuous and is presently increasing. Another way of viewing this summary is to map significant factors about the Boise geothermal resource. This has been done in Figure 3. That map shows location of the historic Warm Springs system and service area, the downtown area, the State Capitol mall complex, and general locations of some of the hot water wells. This history is also summarized in Table 2.

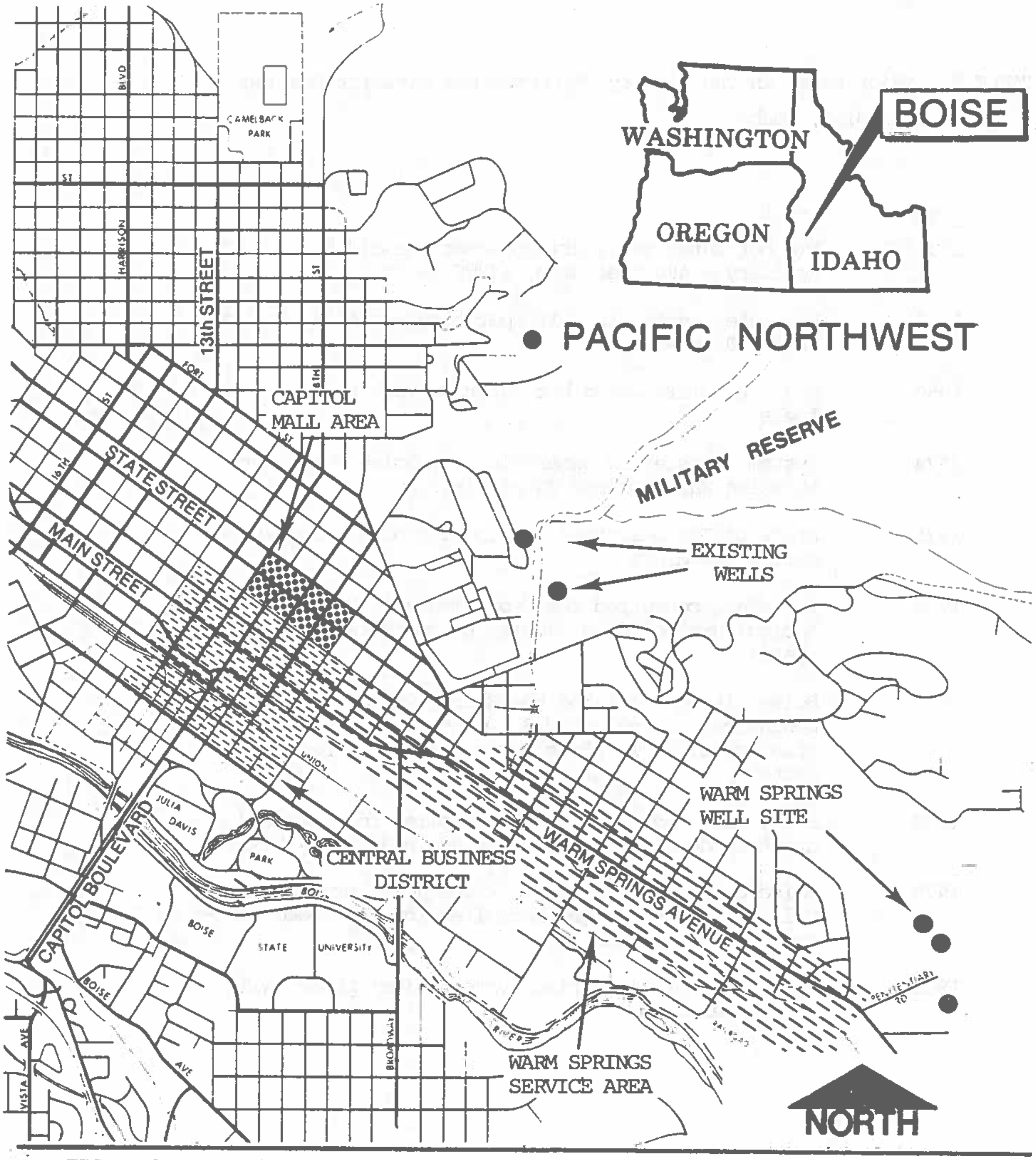


FIGURE 3. Location of Major Elements of the Boise Geothermal District Heating Project.

TABLE 2. Major Dates in the History of Geothermal District Heating in Boise, Idaho.

Date	Event
1892	Two hot water wells drilled near the old State Penitentiary - 400 feet deep, 170°F water
1930	Hot water system in full operation served approximately 400 homes
1950	Many customers using hot water convert to fossil fuels
1974	System transferred ownership from Boise Water Corp. to Boise Warm Springs Water District
1975	State of Idaho studied feasibility of heating state office buildings
1976	The state converted the Departments of Health and Agriculture building complex to geothermal heating system
1976	Boise City established the Energy Office to develop geothermal energy. A U.S. Department of Energy (DoE) grant resulted in plans for a geothermal heating system
1978	Boise City and BWSWD jointly applied for a second grant to develop geothermal space heating systems
1979	Boise Geothermal is formed - the joint program which will enable use of geothermal energy for space heating in the Boise area
1983	Boise geothermal heating system, first phase, will begin operation

II. BOISE GEOTHERMAL

A. Present Organization

This long history of geothermal in Boise and the concomitant heightened awareness of its potential were all magnified by a growing energy problem. All of these came fortuitously together in a Department of Energy Program Opportunity Notice (PON) issued in mid-1978. This PON solicited proposals for direct heat application projects. Enough contact had been established historically at all levels so that a project involving the State, the City, the County, BWSWD, and private landowners was possible. The County and the State chose to take no active role in the proposed project. The result was a joint proposal submitted by the City, BWSWD, and a major land owner just beginning a large residential subdivision.

The proposal was prepared and submitted to DoE. The project that it outlined was designed to accomplish three things. First, the project would refurbish the existing BWSWD wells and pipeline system, and lay new pipeline to extend the service area. The result of this work would be improved service to present Warm Spring customers, and extension of service to contiguous residential areas. Secondly, the project would develop a totally new well field to provide service to the Boise central business district. This part of the project would emphasize space heating large commercial buildings. The third facet of the project is related to the first. It would direct service to a new geographical area, and a new residential subdivision.

The proposal for this three faceted project estimated costs to be just in excess of $15,000,000. Costs were proposed to be paid by DoE funds, local cash, and local cash match. The ratio of federal to local share worked out to approximately 8 to 2. If this proposal had been funded the resulting project would have included 6-7 wells supplying heat to about 1,000 residential units and 10-12 major buildings circumscribing about 2 million square feet of commercial office space. The very large heat load of these buildings would, with geothermal heat, see potential displacement of 500,000 barrels of oil per year.

But the proposal was not funded to this $15 million level. DoE responded with funding of $4.9 million or about half of the share requested of them. As a result the project scope was reduced. The items deleted included the new residential subdivision, and half of the new production wells. The resulting project now possesses the potential to deliver heat to about 500 residences and 8 major office buildings, a project that will have an estimated capital value of approximately $8 million.

B. Project Plans, 1979-1983.

When the grant was awarded the partners in the project decided to establish an organization to serve as neutral ground in coordinating work for two governments. The resulting organization is called Boise Geothermal. Its responsibilities are to manage some project tasks, administer project contracts and finances, and attempt to raise additional money for future system expansion or improvement. The structure of the organization has been kept intentionally simple. The organization includes one full time City employee, and one full time consultant serving as director. All other organizational responsibilities are subcontracted to appropriately qualified individuals or companies. The organization is shown in Figure 4.

The serious work of this organization began in March 1979 after the usual delays attending contract development and negotiation. DoE made funds available for the first year to complete a number of important tasks that would define a project course through September 1983. These initial tasks included preparation of an environmental report which has been completed describing no significant adverse impacts deriving from the project. The tasks also required sufficient geolo-

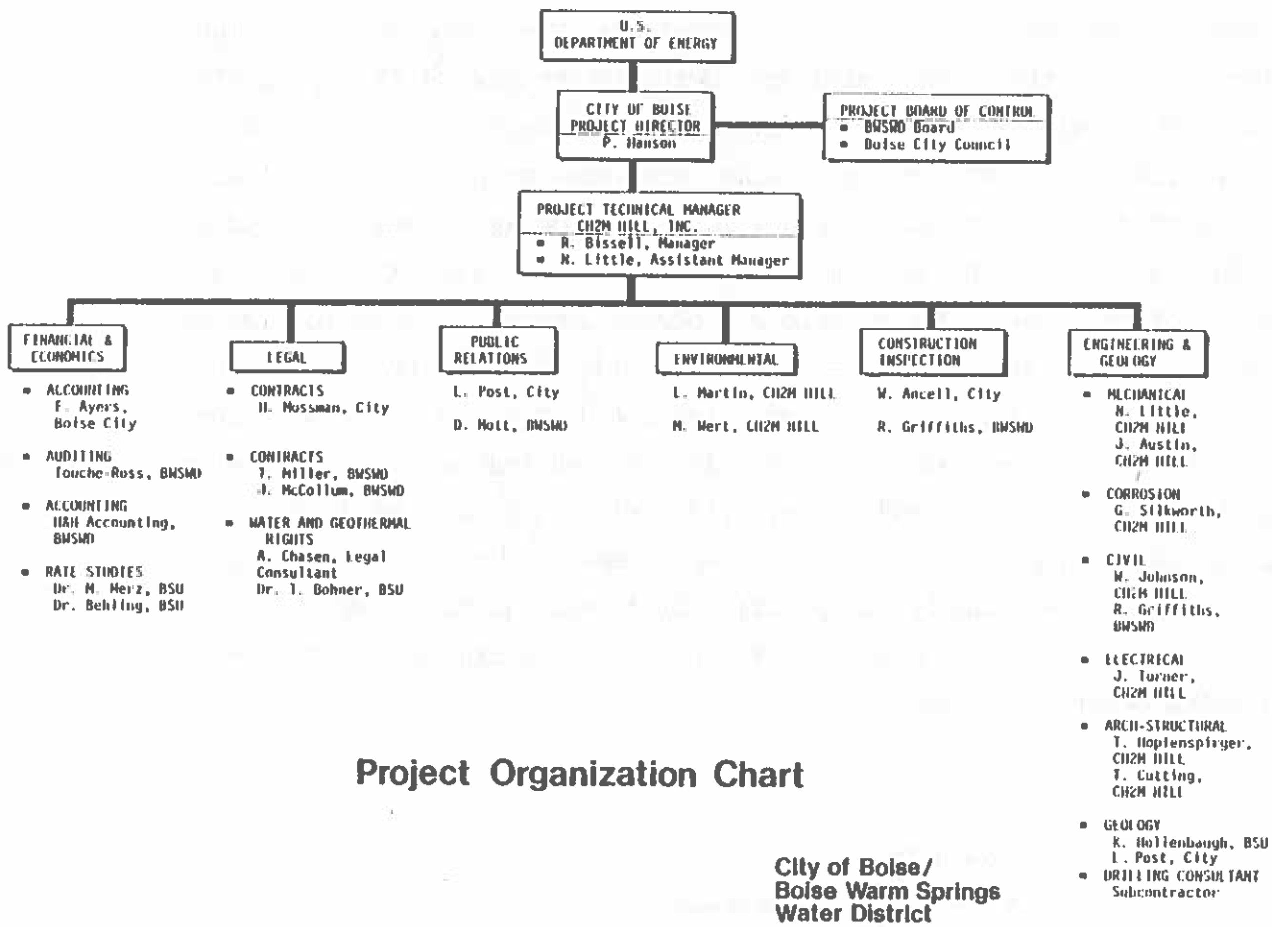


FIGURE 4. Organization Chart for Boise Geothermal District Heating Project.

gical study to determine the need for further ground surveys and to select drilling sites. This task is near completion. A market and rate study was also called for, and has been completed.

Perhaps the most important tasks were to prepare a report of system design for the funds made available through the PON, and to prepare a project plan. Both of these tasks have also been completed. Taken together they are a much more detailed version of this presentation. The design report is fairly straightforward in presenting detail of distribution system design, market and rate strategies, and alternative methods for disposal of spent water. This report will be discussed as the second part of this presentation. The plan report contains a number of sections. One describes probable funding sources to finance some aspects of the present system but mostly focusses on the period after 1983. It also discusses organizational and legal issues facing the project, issues such as the distinction between water for domestic and agricultural uses, and water, often out of the same well, used for its energy content. In summary project tasks include the following divided into those applying specifically to each partner (BWSWD or Boise City), and those shared by the partners in common (identified as Boise Geothermal tasks).

BWSWD Tasks

- Refurbish existing hot water wells
- Drill an additional geothermal well on district property
- Acquire new facilities and equipment for the wells
- Replace deteriorated existing distribution mains
- Construct pipelines to new customer services area

Boise City Tasks

- Drill geothermal production wells on or around Military Reserve Park
- Install distribution lines to serve the downtown business district
- Install equipment to provide space heat using
- Install equipment to provide space heat using geothermal water in City Hall

Boise Geothermal Tasks

- Conduct additional geological study
- Complete environmental studies to determine the impact of a geothermal system
- Plan for future growth of geothermal energy in Boise
- Evaluate the market for geothermal energy and service charges to customers

C. Conclusion

Completion of these tasks by October 1983 will result in the nations largest geothermal water based district heating system. In this sense it will continue the history of geothermal space heating begun in Boise in the 1890's.

ACKNOWLEDGEMENT

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BOISE GEOTHERMAL HEATING, 1892-1982

PART II - TECHNICAL PLANNING

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ABSTRACT

Two 10-MW geothermal district heating systems are being developed by Boise City and the Boise Warm Springs Water District (BWSWD) for Boise, Idaho. These systems will provide 170°F (348°K) geothermal water for space heating in downtown Boise and eastern Boise, respectively. This paper summarizes the major technical aspects of the preliminary design for the Boise City geothermal district heating system. In general, the discussion also applies to the BWSWD system.

NOMENCLATURE

C	Hazen-Williams coefficient
C_h	Lost revenue due to heat loss, \$/hr
C_p	Pumping cost, \$/hr
D	Inside diameter of pipe, ft
k_i	Pipe insulation thermal conductivity, Btu/hr ft°F
k_s	Soil thermal conductivity, Btu/hr ft°F
N	Pipe burial depth, ft
Pg	Geothermal water cost, \$/Btu/hr
r_o	Outside radius of insulated pipe, ft
r_i	Inside radius of insulated pipe, ft
t_f	Geothermal water temperature, °F
t_s	Soil temperature, °F

BACKGROUND

Residential homes in eastern Boise have been heated by a geothermal district heating system, presently known as the Boise Warm Springs Water District (BWSWD), since the early 1900's. Under a cost-sharing agreement with the Department of Energy (DOE), the possibility of refurbishing and expanding the BWSWD system, and building a new geothermal district heating system for downtown Boise, is being investigated. The background of this project is discussed in more detail in "Boise Geothermal District Heating System-Institutional Planning."[1]

MARKET

Until recently, geothermal space heating in Boise has been restricted primarily to residences. In 1974 the State of Idaho began exploring the possibility of retrofitting State buildings for geothermal heat.[2] Subsequently, several studies[3,4] have considered the possibility of retrofitting specific buildings in downtown Boise for geothermal space heating. More recently, a 42-block downtown area has been surveyed to provide design bases for this project, and to characterize the potential commercial market.

Each downtown building has been characterized by two parameters: a load parameter and a retrofit parameter. The load parameter was estimated by determining the heated volume of each building and multiplying by 4.34 $Btu/hr/ft^3$ (44.93 W/m^3),[5] and dividing by a constant.

$$\text{Load Factor} = \frac{\text{Building Heated Volume X 4.34}}{\text{Constant}}$$

The retrofit factor was determined by the product of three indices proportional to the building's life expectancy, the relative cost difference of the heat available from geothermal water to the heat available from the building's existing heating fuel, and the ease of retrofitting the building for geothermal heat.

Retrofit Factor = building life index
x relative fuel cost index
x system retrofit index

Considering only those buildings having relatively high retrofit factors, several generalizations can be made:

o Twenty buildings in downtown Boise account for almost 90 percent of the potential system load.

- Five State of Idaho buildings account for almost 20 percent of the potential system load.

- The total potential system demand during initial system operation is approximately 3,000 gpm (0.189 m^3/s). This assumes that all potential buildings use the geothermal water for space heating and a 50°F (281°K) temperature drop in the geothermal water across each building heating system.

The ultimate market for the heating system will depend upon:

- Penetration of the market described above. This is presently being pursued.

- The development of a proposed downtown mall. This mall could potentially have 800,000 square feet (74,320 m^2).

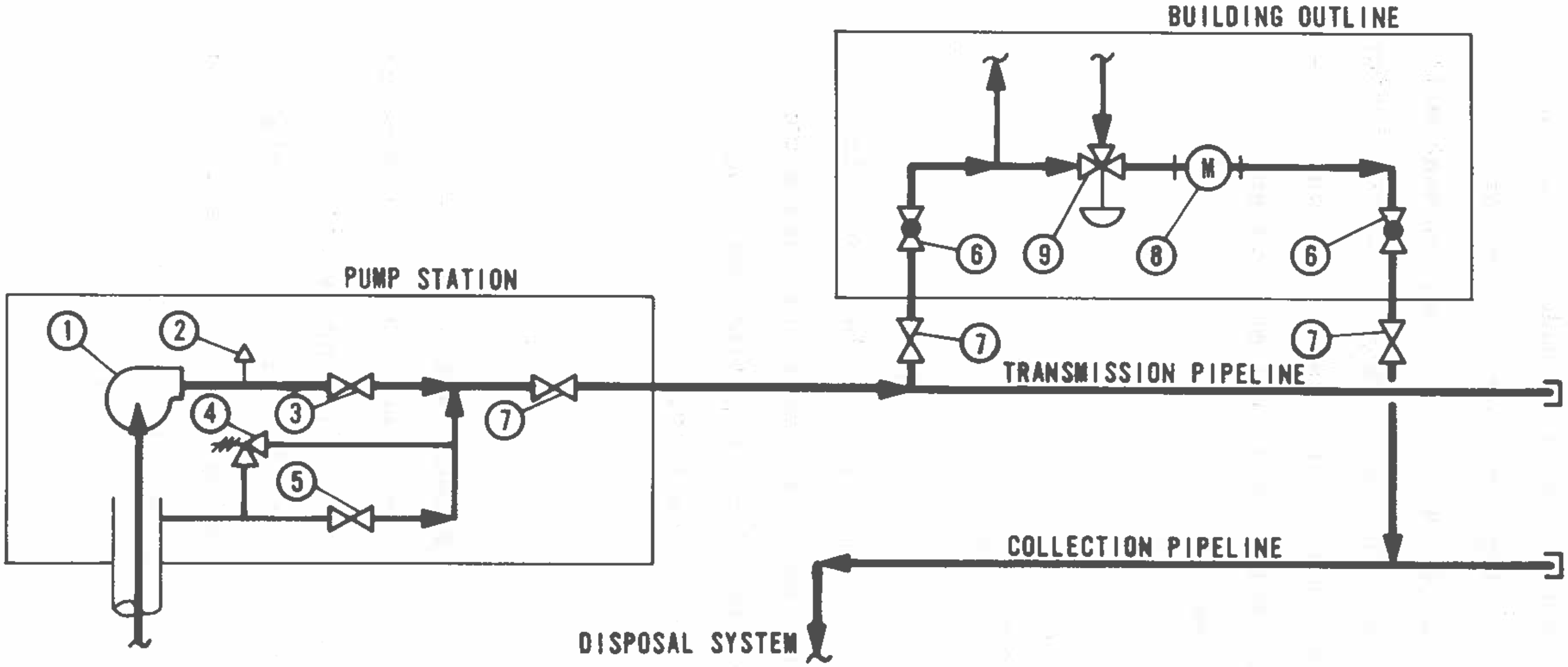
- The average temperature drop of the geothermal water through building heating systems. A temperature drop of 50°F (281°K) has been assumed. If the difference is 30°F (270°K), this would correspond to a 67 percent increase in demand for geothermal water.

SYSTEM DESIGN

System Description

The proposed Boise City district heating system will utilize the local geothermal resource, which is 140 to 175°F (331 to 351°K) and is located at approximately 500 to 1,500 feet (152 to 457 m) of depth. The water is of excellent quality, and will be used directly in the system. Production wells will be located approximately 1-1/2 miles from the primary load, in downtown Boise. The pipeline will be sized for 4,000 gpm (0.252 m^3/s), although the initial production capacity is expected to be approximately 2,000 gpm (0.126 m^3/s).

Production well pumps will deliver water to the transmission pipeline through a pressure control valve. The transmission pipeline pressure, and thus the system load, will be sensed and automatically maintained by adjusting the pressure control valve (Figure 1). System flows, temperatures, and pressures would be monitored and recorded.



1 VERTICAL TURBINE PUMP
2 AIR RELEASE VALVE
3 PRESSURE CONTROL VALVE
4 PRESSURE RELIEF VALVE
5 ARTESIAN FLOW BYPASS
6 BALANCING VALVE
7 ISOLATION VALVE
8 FLOW METER
9 TEMPERATURE REGULATOR

BOISE GEOTHERMAL SYSTEM SCHEMATIC
(BOISE CITY)
FIGURE 1

Customer service connections will be made between the transmission and collection pipelines, using a primary-secondary crossover hydronic circuit. This arrangement will tend to hydraulically isolate customer system characteristics from the geothermal system characteristics. Individual flow meters and temperature control valves will measure and regulate flow to the customers.

Pipeline

Introduction

The retrofit and load parameters have been used to determine tentative routing and capacity requirements for the system pipelines. Design of the pipelines was then based upon the following considerations.

Pipeline Materials

The pipeline materials considered are summarized in Table 1. The temperature of the geothermal water is expected to be about 140 to 175°F (331 to 351°K), thus eliminating most plastic pipes from consideration. Pipeline materials costs have been developed, including makeup and installation costs, to allow a comparison of relative capital costs for various pipeline materials.

Table 1
PIPELINE MATERIALS COMPARISON TABLE

Material	Sizes, in.	Joints	Expansion Loops	Corrosion Protection
Ductile Iron	3 - 20+	Push-on	No	Interior - none Exterior - tape wrap and cathodic protection in moist soils
Steel	3/4 - 20+	Welded	Yes	Interior - none Exterior - tape wrap and cathodic protection
Asbestos-Cement	6 - 20+	Push-on	No	Interior - epoxy Exterior - none
FRP	3/4 - 12	Fusion Bonded	No	Interior - none Exterior - none

Corrosion Protection

Corrosion noted on the existing BWSWD pipeline has been primarily on the exterior surfaces of the buried cast iron pipeline. Test sections show that the interior of the cast iron pipe is in very good condition even though it has been in use for 40 years. The exterior of the cast iron pipe, however, is very corroded in areas of moist soil. Little exterior corrosion has been noted on sections removed from areas free of ground water. This is consistent with corrosion associated with district heating systems which appear to operate under similar conditions in Moscow and Kiev, U.S.S.R.[6]

Based upon experience with the BWSWD system, the interior surfaces of steel and ductile iron pipe would undergo very little corrosion. The rate of corrosion would not be expected to be more than 0.001 to 0.002 inch per year (2.54×10^{-5} -5.08×10^{-5} m/yr), as long as oxygen is kept out of the system. The exterior surfaces of steel piping would require corrosion protection in most areas. Tightly wrapped tapes of polyethylene, polypropylene, butyl rubber, and polyvinyl chloride generally provide excellent protection for steel pipes. Electrostatically-applied epoxy coatings would also provide excellent protection, but would have limited availability in the Boise area and be more costly. Cathodic protection would have to be applied to all areas of steel pipeline to stop corrosion at breaks in the coating. Dielectric (insulating) fittings would be required at all taps and connections to the pipe, and all valves and fittings would be coated similar to the pipe. These measures would reduce excess power consumption by the cathodic protection system. Ductile iron pipe could generally be laid bare in noncorrosive or mildly corrosive soils. In corrosive soils, a film of polypropylene would have to be wrapped loosely around all pipe and fittings. In wet soils, cathodic protection may be advisable.

Asbestos-cement and fiberglass-reinforced plastic (FRP) pipe would not require any exterior corrosion protection. Previous tests have indicated that there may be a chemical reaction between the geothermal water and asbestos-cement pipe. This leads to speculation on whether asbestos fibers could be released into the water if the reaction continues throughout the life of the system. Since this is undesirable in light of current thinking on asbestos, the prudent approach calls for additional testing and a lining on all asbestos-cement surfaces exposed to the geothermal water. At this time, epoxy would be the only lining material recommended.

Insulation

Several insulation systems for the transmission pipeline have been considered. Pipe can be purchased as a preinsulated system, or can be insulated after it is installed. The insulation systems have been compared by summing the material costs, installation cost, and heat loss cost. The preinsulated pipe appears to be slightly less expensive than the other alternatives. Spray-on urethane insulation was not considered, due to the difficulty in controlling the quality of installation and the potential for moisture penetrating the insulation. The optimum insulation thickness has been determined by calculating the heat loss per unit length of pipe for various insulation thicknesses, and calculating the marginal benefit of increasing the insulation thickness. The optimum thickness is approximately 2 inches of insulation having a thermal conductivity of 0.015 Btu/ft hr°F (0.027 W/m °C).

Relative annual preinsulated pipeline costs are shown in Figure 2, including the cost of pipeline materials, required corrosion protection systems, and insulation costs.

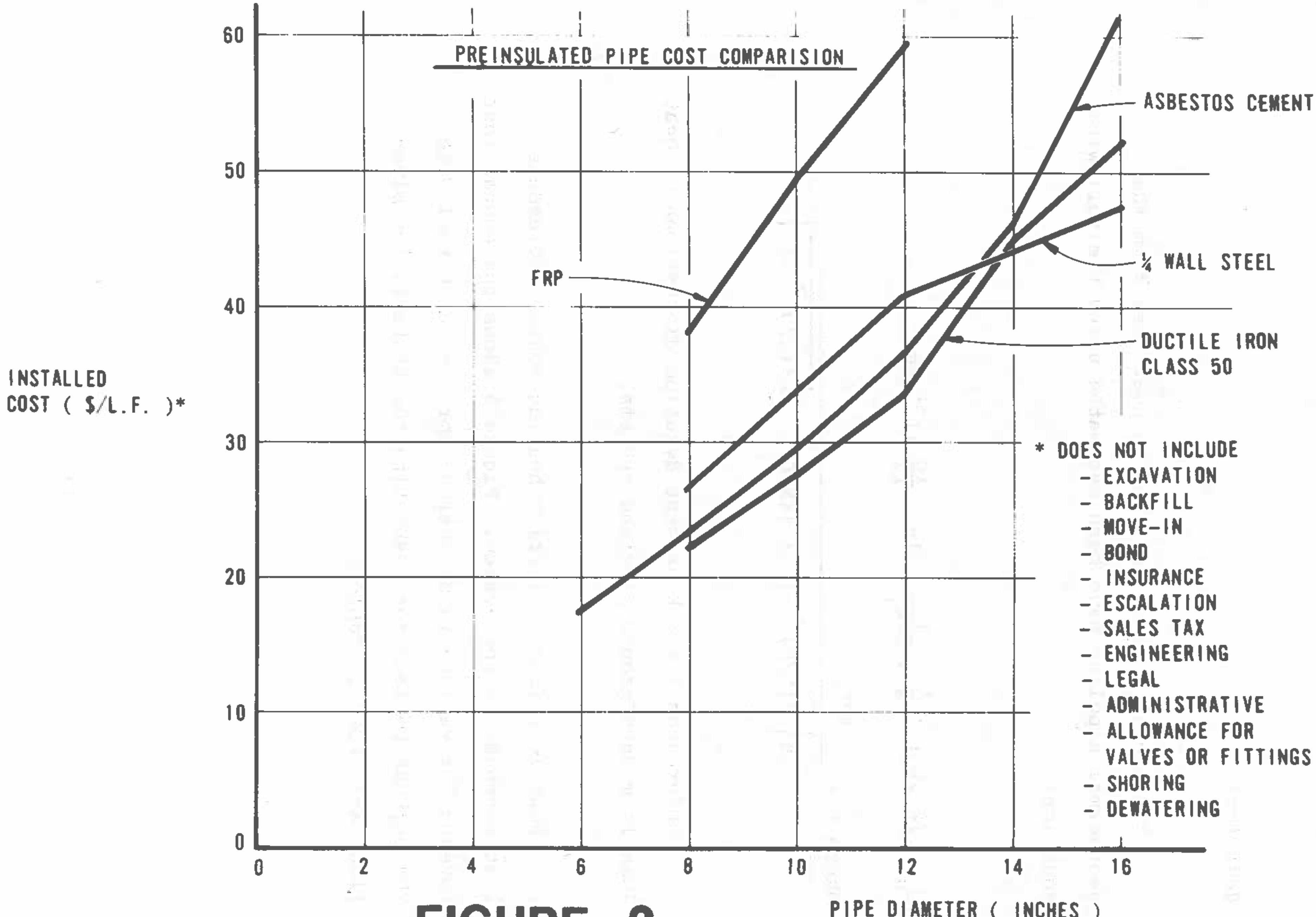

PREINSULATED PIPE COST COMPARISION
INSTALLED COST ($/L.F.)*
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
PIPE DIAMETER (INCHES)
FRP
ASBESTOS CEMENT
¼ WALL STEEL
DUCTILE IRON CLASS 50
* DOES NOT INCLUDE
- EXCAVATION
- BACKFILL
- MOVE-IN
- BOND
- INSURANCE
- ESCALATION
- SALES TAX
- ENGINEERING
- LEGAL
- ADMINISTRATIVE
- ALLOWANCE FOR VALVES OR FITTINGS
- SHORING
- DEWATERING

FIGURE 2

Heat Loss

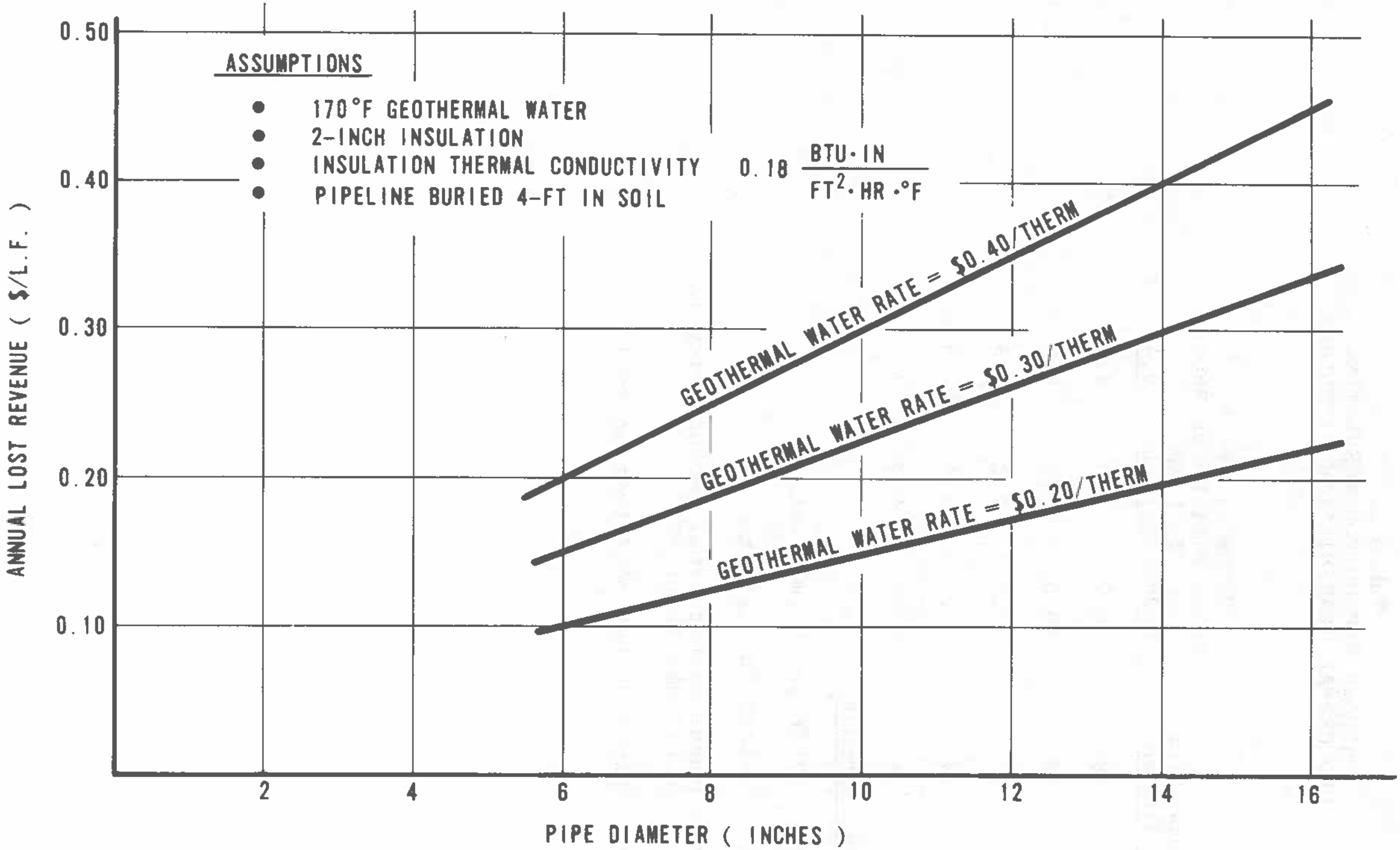
The annual revenue lost due to heat loss from the geothermal pipeline have been estimated using the following equation:

$$C_h = (t_f - t_s) \left(\frac{1}{S} + \frac{1}{2\pi k_i} \ln \left(\frac{ro}{ri} \right) \right)^{-1} Pg$$

where $S = \dfrac{4\pi k_s}{\ln \left\{ \left[8(N/D)^2 - 1 \right] + 4(N/D) \sqrt{4(N/D)^2 - 1} \right\}}$

References 7 and 8 present detailed discussions of heat loss from underground pipeline systems.

Heat loss from a district heating system represents lost revenues to the system. Figure 3 shows the annual lost revenue for various rates charged for the geothermal water. The payback periods for insulating the transmission pipelines are shown in Table 2.



ANNUAL LOST REVENUE DUE TO PIPELINE HEAT LOSS

FIGURE 3

Table 2
PAYBACK PERIOD FOR INSULATING
GEOTHERMAL TRANSMISSION PIPELINES

Pipe Size Inches	Payback, Years Geothermal Water Rate, $/therm 0.20	0.30	0.40
8	8.7	5.8	4.4
10	10.0	6.7	5.0
12	10.9	7.3	5.5
14	14.1	9.4	7.0
16	13.9	9.3	7.0

Assumptions

- 170°F geothermal water
- 2-inch insulation
- insulation thermal conductivity is 0.015 Btu/ft hr °F
- pipeline buried 4 feet in soil

Pumping

The annual cost of pumping, per unit length of pipe, has been calculated using the following equation. A pumping efficiency of 60 percent, electrical cost of $0.04/kWh, and 2,190 hours of operation were assumed.

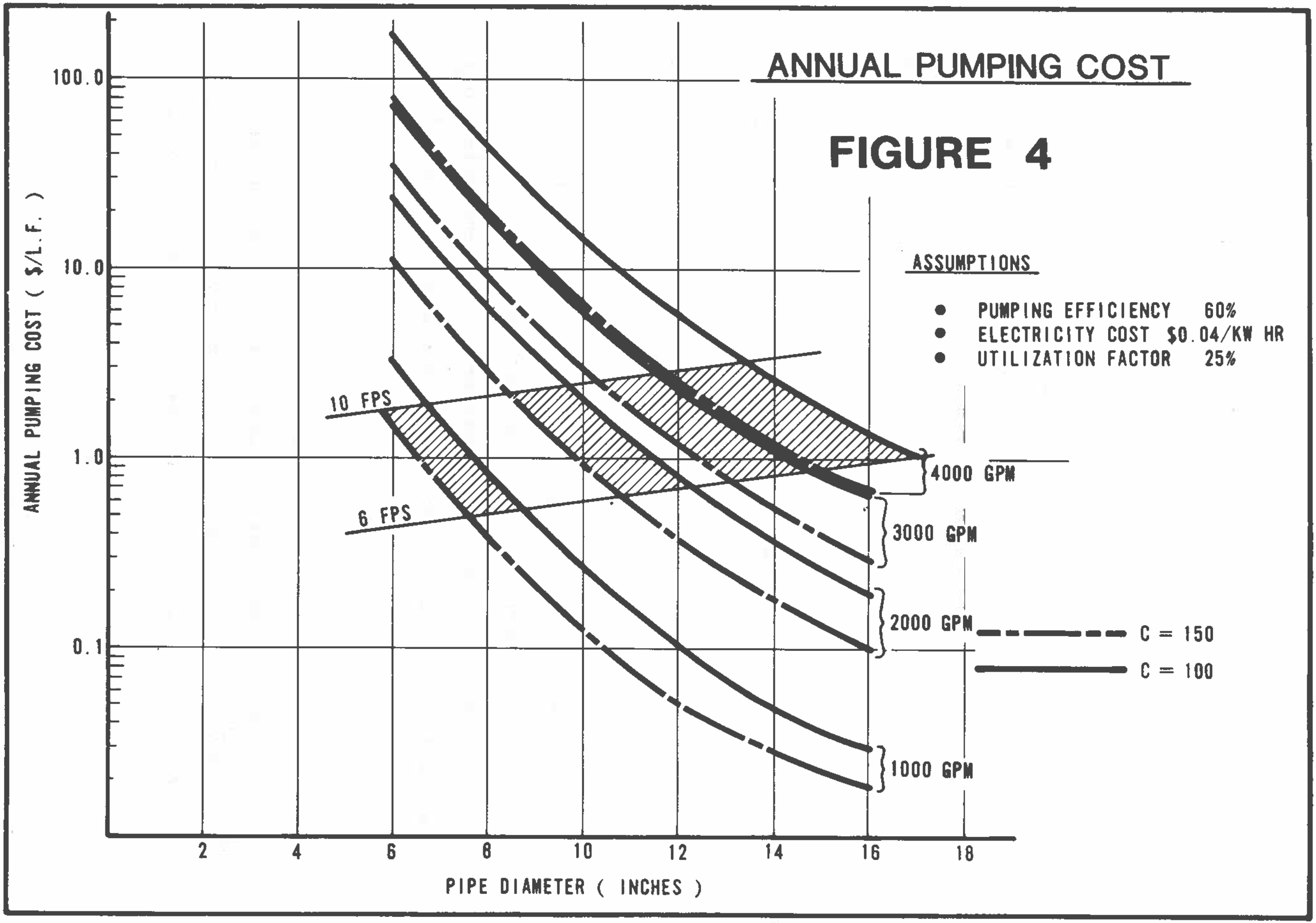
$$C_p = (0.288)\ (gpm)^{2.85}\ (D)^{-4.87}\ (C)^{-1.85}$$

The results for various flow rates, pipe diameters, and friction coefficients are shown in Figure 4.

Total Pipeline Costs

The total discounted present worth costs for cast iron, steel, asbestos-cement and FRP pipelines have been calculated including the cost of pipeline materials, corrosion protection, insulation and heat loss, and pumping costs, as discussed above.

The analysis assumed a system life of 30 years, an inflation rate for the cost of electricity of 4 percentage points greater than the general inflation rate, and a discount rate of 2 percentage points less than the general inflation


ANNUAL PUMPING COST
FIGURE 4
ASSUMPTIONS
● PUMPING EFFICIENCY 60%
● ELECTRICITY COST $0.04/KW HR
● UTILIZATION FACTOR 25%
10 FPS
6 FPS
4000 GPM
3000 GPM
2000 GPM
1000 GPM
C = 150
C = 100
100.0
10.0
1.0
0.1
ANNUAL PUMPING COST ($/L.F.)
2
4
6
8
10
12
14
16
18
PIPE DIAMETER (INCHES)

rate. It was assumed that the inflation rate for the geothermal water rates would be approximately equal to the market discount rate. This determines a conservatively high rate, since the fixed costs (e.g., depreciation, debt service, etc.) of the system are equal to approximately half the total revenue requirements for the system.

The results indicate that, for pipeline diameters between 8 and 16 inches (.20 and .41 m), preinsulated asbestos-cement or ductile iron pipelines would be most economical over the lifetime of the proposed system.

Production Pump Stations

The stations used for pumping the geothermal water will be similar to those designed for municipal water systems. A deep well vertical turbine pump will draw water from the geothermal well and discharge directly into the transmission pipeline. Due to the relatively low flows and utilization factors involved, the flow will be controlled by throttling the discharge flow of the pumps.

Water Disposal

The options for disposal of the geothermal water in Boise are generally as follows:

- o Disposal to the Boise River
- o Discharge to irrigation canals
- o Disposal by injection back into the geothermal water aquifer
- o Disposal into deep wells

A comprehensive review of these options is currently being carried out. Final system design will depend upon the outcome of this review.

ECONOMICS

A preliminary system economic analysis has been performed, and is summarized in Table 3. The results are based upon conceptual design cost estimates. As discussed in Reference 1, the proposed Boise geothermal district heating system will most likely be owned and operated by Boise City,

Table 3
BOISE CITY RATE COMPARISON

		System Capacity (gpm)	Cost of Service	
			$ per 100 ft^3	$ per Useful Therm[a]
1.	Public Ownership DOE cost-share	2,000	0.75	0.24
2.	Public Ownership No DOE cost-share	2,000	1.50	0.49
3.	Private Ownership DOE cost-share	2,000	0.96	0.31
4.	Private Ownership No DOE cost-share	2,000	2.80	0.91

[a]Assumes a 50°F useful temperature drop in geothermal water.

and will be partially funded by DOE under a cost-sharing agreement. The economic analysis was carried out for four options, to provide a basis for comparison:

1. Public ownership of the system built with DOE cost-share funding.

2. Public ownership of the system built without DOE cost-share funding.

3. Private ownership of the system built with DOE cost-share funding.

4. Private ownership of the system built without DOE cost-share funding.

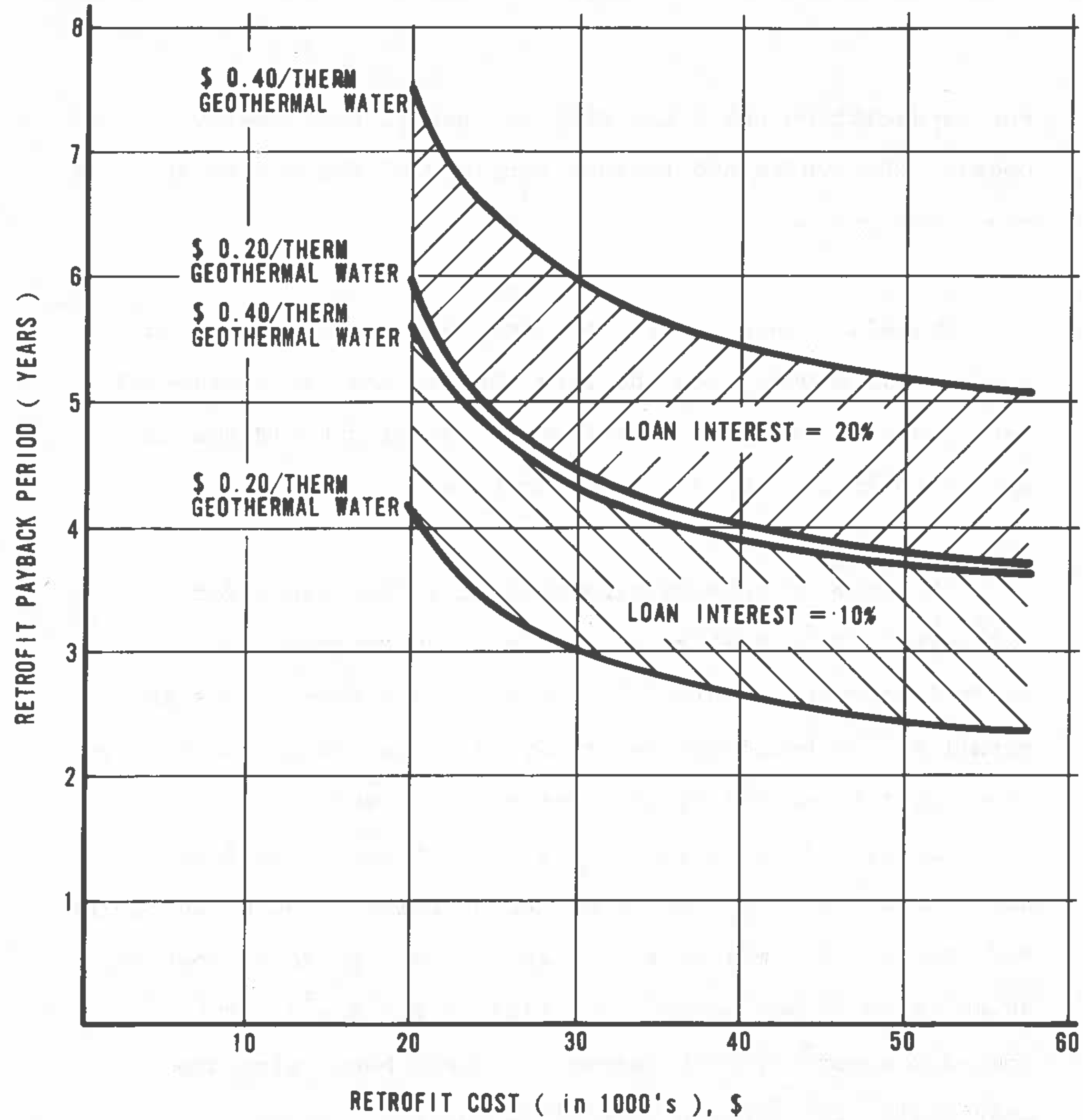
A total revenue requirement was calculated for each option, including operating and maintenance expenses, depreciation, debt service, taxes, and a return on the rate base. The DOE cost-share portion of the project was not considered part of the rate base. However, it was used as part of the total investment within the cost base used to calculate depreciation. This policy is considered prudent financial management, because system revenues then include a provision for depreciation which the City can use to continually upgrade the system and replace portions of the system as they wear out.

Overall economics of the geothermal district heating system will depend upon the rate charged for the geothermal water, and the cost of retrofitting existing buildings to use geothermal water for space heating.

The cost of retrofitting commercial buildings for geothermal space heating is difficult to characterize. Several previous studies[3,4] have developed these costs in detail for 15 buildings currently using hot water for heating that might be served by the system. The retrofit cost, in 1980 dollars, is approximately \$0.015/Btu/hr (\$0.004/W). Assuming a heat loss rate from the building of 30 to 50 Btu/hr ft^2 (95 to 158 W/m^2) this corresponds to a retrofit cost of \$0.45 to \$0.75 per square foot (4.8 to 8.1 $\$/m^2$). This compares favorably with values that have been calculated previously[9] for apparently similar typical systems.

Figure 5 shows estimated payback periods for various retrofit costs, given the following assumptions:

- Cost of heating fuel currently used is \$.60/useful therm, inflating at a rate of 17 percent per year.



RETROFIT PAYBACK PERIOD FOR TYPICAL COMMERCIAL BUILDINGS

FIGURE 5

- Cost of geothermal water will inflate at a rate of 8 percent per year.

- Retrofit costs payed for by a 20-year loan.

CONCLUSION

The preliminary design for a Boise geothermal district heating system indicates that the system is technically and economically feasible.

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