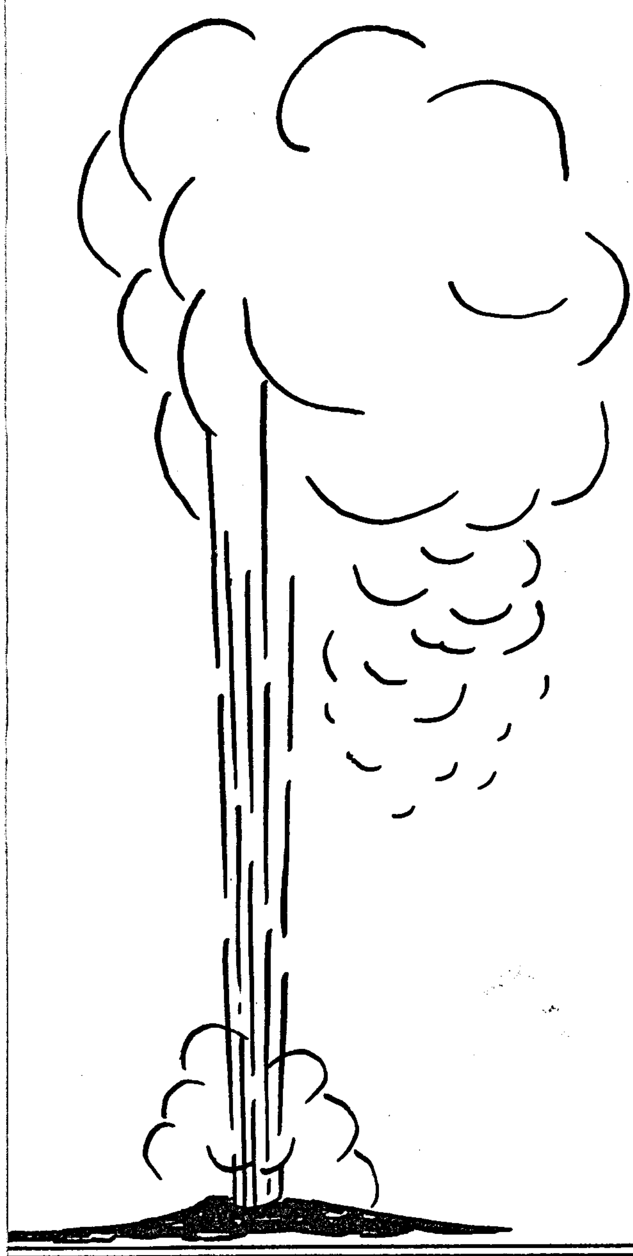
DOE/ET/27059-1
(DE83013375)



DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR SPACE AND WATER HEATING AT MARLIN, TEXAS

Final Report

By
Marshall F. Conover
Thomas F. Green
Ronald C. Keeney
Peter F. Ellis II
Robert J. Davis
Robert C. Wallace
Fred B. Blood

May 1983

Work Performed Under Contract No. AC08-78ET27059

Radian Corporation
Austin, Texas

U. S. DEPARTMENT OF ENERGY
Geothermal Energy

DISCLAIMER

DCN 83-212-300-19

DOE/ET/27059-1
(DE83013375)
Distribution Category UC-66d

FINAL REPORT

DIRECT UTILIZATION OF GEOTHERMAL ENERGY FOR SPACE AND WATER HEATING AT MARLIN, TEXAS

Marshall F. Conover
Thomas F. Green
Ronald C. Keeney
Peter F. Ellis II
Robert J. Davis
Robert C. Wallace
Fred B. Blood

May 1983

RADIAN CORPORATION
Austin, Texas

Under Subcontract to the

TORBETT-HUTCHINGS-SMITH MEMORIAL HOSPITAL
Marlin, Texas

For the

UNITED STATES DEPARTMENT OF ENERGY
Nevada Operations Office

Under Contract
No. DE-AC08-78ET27059

ABSTRACT

This final report documents the Torbett-Hutchings-Smith Memorial Hospital geothermal heating project, which is one of nineteen direct-use geothermal projects funded principally by DOE. The five-year project encompassed a broad range of technical, institutional, and economic activities including: resource and environmental assessments; well drilling and completion; system design, construction, and monitoring; economic analyses; public awareness programs; materials testing; and environmental monitoring. Some of the project conclusions are that: 1) the 155°F Central Texas geothermal resource can support additional geothermal development; 2) private sector economic incentives currently exist, especially for profit-making organizations, to develop and use this geothermal resource; 3) potential uses for this geothermal resource include water and space heating, poultry dressing, natural cheese making, fruit and vegetable dehydrating, soft drink bottling, synthetic rubber manufacturing, and furniture manufacturing; 4) high maintenance costs arising from the geofluid's scaling and corrosion tendencies can be avoided through proper analysis and design; 5) a production system which uses a variable frequency drive system to control production rate is an attractive means of conserving parasitic pumping power, controlling production rate to match heating demand, conserving the geothermal resource, and minimizing environmental impacts.

ACKNOWLEDGEMENTS

The authors are grateful for the encouragement, support and leadership provided throughout this project by J.D. Norris, Jr., Administrator of the Torbett-Hutchings-Smith (T-H-S) Memorial Hospital, Marlin, Texas.

Additionally, the authors are indebted to many people who have enthusiastically supported this geothermal direct-use demonstration project. While it is not possible to name here all those who assisted, special gratitude must be expressed to the following persons without whose professional assistance this project would not have been possible.

- T.E. Alexander - Maintenance Director, T-H-S Memorial Hospital, Marlin, TX
- R. Butler - Student, Baylor University Law School, Waco, TX
- J.W. Dillard - Vice President, Layne Texas Co. Dallas, TX
- P.H. Dobbins - Engineer, Ham - Mer Consulting Engineers, Austin, TX
- R.L. Hahn - Maintenance Staff, T-H-S Memorial Hospital, Marlin, TX
- A.C. Johnson - City Manager, City of Marlin, TX
- W.M. Parrish, Jr. - CPA, Parrish, Greenstein, Moody and Harelik, Marlin, TX
- R.D. Spencer, AIA - Architect, Spencer Associates, Austin, TX
- J. Welch - Attorney, Welch and Stem, Marlin, TX
- B. Wills - Superintendent, Lochridge-Priest, Waco, TX
- C.M. Woodruff, Jr. - Geologist, Texas Bureau of Economic Geology, Austin, TX

May 1983
Austin, Texas

Marshall F. Conover, P.E.
Geothermal Program Manager

DOE DIRECT-USE GEOTHERMAL PON PROJECT

1. Project Title: Direct Utilization of Geothermal Energy for Space and Water Heating at Marlin, Texas

DOE CONTRACT INFORMATION

2. Number: DE-AC08-78ET27059
3. Former No. ET-78-C-08-1154
4. Period: 5/15/78 to 5/31/83
5. Value: $1,144,174
6. Shares:

- US DOE	$ 868,440	75.9%
- State of Texas	81,492	7.1%
- T-H-S Hospital	88,722	7.8%
- City of Marlin	5,520	0.5%
- Central Texas S&L	100,000	8.7%

7. Project Application: Decrease the Torbett-Hutchings-Smith Memorial Hospital's reliance on fossil fuel for space and domestic water heating by directly utilizing the Marlin geothermal resources in an environmentally acceptable manner.

8. Project Location: Marlin, Texas; 130 miles south of Dallas, Texas

9. Well Name/Location: Well No. 1/T.J. Chambers A-12 Survey 5310 FEL & 12,020 FWL

10. Peak Heat Load: 4.8×10^{6} Btu/hr

11. Annual Heat Load: 11.5×10^{9} Btu's

12. Break-Even Period: 12.5 years*

13. Project Status: The geothermal heating system officially began operation in January 1982. Peak well temperature has reached 155°F. Operation of the complete system has been very satisfactory and has reduced the annual average natural gas consumption by 61 percent.

14. Principal Investigator: J. D. Norris, Jr., Administrator

15. Firm: T-H-S Memorial Hospital
16. Address: P.O. Box 60, Marlin, TX 76661

17. Telephone: (817) 883-3561

*For profit-making organizations.

OTHER PARTICIPANTS

18. Firm/Activity: Radian Corporation/Geothermal Consultants
System Design & Test
Environmental Compliance
Public Awareness
Materials Testing

Address: 8501 Mo-Pac Blvd.
P.O. Box 9948
Austin, TX 78766

Phone/Contact: (512) 454-4797/Marshall F. Conover, P.E.
Program Manager

19. Firm/Activity: Layne Texas Company/Well Drilling & Completion

Address: Box 280098
Dallas, TX 25228

Phone/Contact: (214) 288-1087

20. Firm/Activity: Ham-Mer Consulting Engineers, Inc/Design Review & Construction Coordination

Address: 1601 South I-35
Austin, TX 78741

Phone/Contact: (512) 444-6531/J.G. Meredeith, President

21. Firm/Activity: Spencer Associates/Building Design & Architectural Coordination

Address: 117 East Seventh Street
Austin, TX 78701

Phone/Contact: (512) 476-3568/Ralph D. Spencer, AIA

22. Firm/Activity: Lochridge-Priest, Inc./System Construction

Address: 225 Lake Air Dirve
Waco, TX 76710

Phone/Contact: (817) 772-0670/James M. Kruse

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

Section | Page

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

1. INTRODUCTION

1.1 Report Format

This final report follows a general outline which was developed for all US DOE Program Opportunity Notice (PON) geothermal projects. The intent of the outline is to provide general uniformity in reporting format and content. Since the scopes of the projects vary, some sections of the general outline may not be applicable to all projects. Sections not applicable to this report are so identified in those sections.

1.2 Objectives

1.2.1 US DOE Program Opportunity Notice Solicitations

The private sector's use of geothermal energy for direct heating within the United States has been quite limited to date. Yet, there is a large potential market for thermal energy in such areas as industrial processing, agribusiness, and space/water heating of commercial and residential buildings. Technical and economic information is needed to assist in identifying prospective direct heat users and to match their energy needs to specific geothermal reservoirs. Technological uncertainties and associated economic risks have influenced potential user perception of profitability to the point of limiting private investment in geothermal direct heat applications.

In September 1977 and April 1978, the Department of Energy, Division of Geothermal Energy (now the Division of Geothermal and Hydropower Technologies), issued two Program Opportunity Notices. These solicitations were part of DOE's national geothermal energy program plan, which had as its objective the near-term research and development of hydrothermal resources by the private sector. Encouragement was given to municipalities and the private sector by DOE offering to share a portion of the front-end financial risk in a limited number of field experiment projects. After competitive evaluations, 23 PON projects were selected from the two Program Opportunity Notice solicitations. Subsequent events caused four of these projects to withdraw from the program.

To assist future final report searches, a list of all 19 DOE Direct-Use Geothermal PON Projects that will be using this final report format is presented in Table 1-1. The DOE report number will be of the form DOE/ET/2XXXX-N where 2XXXX are the last five digits of the DOE contract number (given below) and N is the sequential order of reports issued by the subject project, printed by the federal government for general distribution, and available through the National Technical Information Service (NTIS).

This final report documents the DOE Direct-Use Geothermal PON Project in Marlin, Texas.

1.2.2 Demonstration Project

The objective of this project was to demonstrate technical feasibility and to analyze economics of the direct-use of geothermal energy. To meet this objective, space and domestic

TABLE 1-1. DOE DIRECT-USE GEOTHERMAL PON PROJECTS.

Contract Number	Project Name	Location	DOE Office
DE-FC07-78ET27054	Monroe	Monroe, Utah	ID
DE-FC07-78ET27080	Haakon School	Phillip, South Dakota	ID
DE-FC07-78ET28419	Diamond Ring Ranch	Haakon County, South Dakota	ID
DE-AC07-78ET28424	Ore-Ida Foods	Ontario, Oregon	ID
DE-FC07-78ET28441	St.Mary's Hospital	Pierre, South Dakota	ID
DE-FC07-79ET27027	Utah State Prison	Draper, Utah	ID
DE-FC07-79ET27028	Madison County	Rexburg, Idaho	ID
DE-FC07-79ET27030	Pagosa Springs	Pagosa Springs, Colorado	ID
DE-AC07-79ET27033	Elko Heat Company	Elko, Nevada	ID
DE-FC07-79ET27053	Boise	Boise, Idaho	ID
DE-AC07-79ET27055	Warm Springs State Hospital	W.S.S.H., Montana	ID
DE-AC07-79ET27056	Utah Roses, Inc.	Sandy, Utah	ID
DE-AC03-78ET27154	Klamath Falls	Klamath Falls, Oregon	SAN
DE-AC03-79ET27029	Moana, Reno	Reno, Nevada	SAN
DE-AC03-79ET27040	Susanville	Susanville, California	SAN
DE-AC03-79ET27045	El Centro	El Centro, California	SAN
DE-AC03-79ET27047	Aquafarms	Dos Palmas Area, California	SAN
DE-AC08-78ET27059	T-H-S Hospital	Marlin, Texas	NV
DE-FC08-79ET27058	Navarro College	Corsicana, Texas	NV

requirements of the Torbett-Hutchings-Smith (T-H-S) Memorial Hospital in Marlin, Texas were augmented using local geothermal energy.

1.3 Project Location

Marlin is the county seat of Falls County, Texas and had a 1980 population of about 7,100. As depicted in Figure 1-1, Marlin is situated 130 miles south of Dallas and 38 miles northeast of Temple.

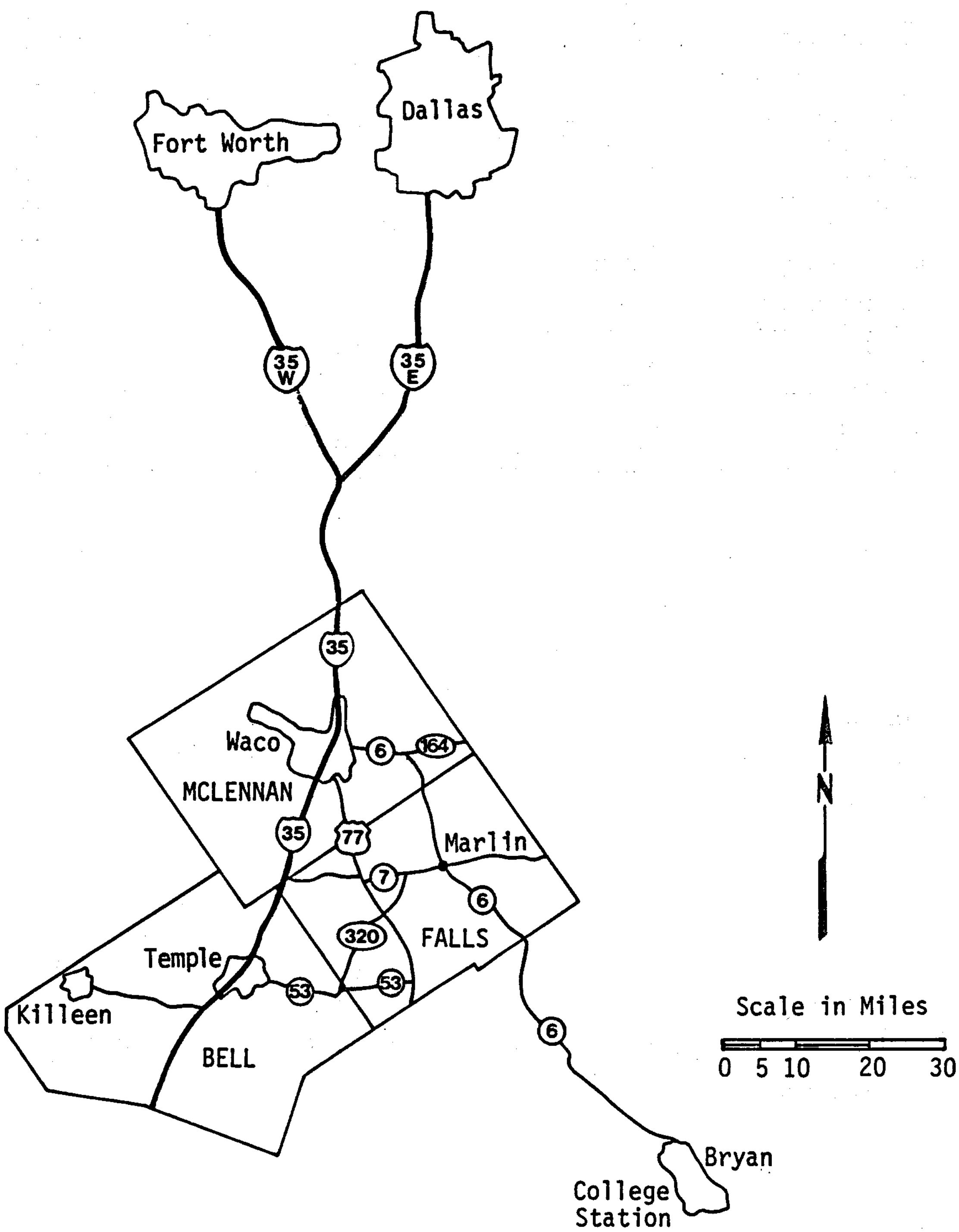


Figure 1-1 Location of Marlin, Texas

A map of the downtown area of Marlin, showing the location of the T-H-S Memorial Hospital and Clinic complex, is presented in Figure 1-2. The hospital is located at 322 Coleman Street. Figure 1-3 shows a plan of the hospital site and outlines the relationship of the geothermal well, heat exchanger building, and disposal line to the existing hospital.

1.4 Pre-Project Background

In an attempt to locate fresh water in 1891, the City of Marlin dug a well to a depth of more than 3,000 feet. No fresh water was found but two strata of hot mineral water were tapped. At first the artesian-pressured mineral water was just discharged, but soon the City began using it for fire fighting and street sprinkling, and selling it to public bath houses and a few private residences. Local citizens who drank and bathed in the water reported its healing effect for a variety of ailments from rheumatism to skin disorders.

Stories of the mineral water cures spread throughout the state and even the nation. By the late 1890's a flourishing health spa business attracted trainloads of tourists and patients, the latter often arriving on stretchers and crutches. At its peak in the 1920's, Marlin was the permanent training site of the New York Giants and was a fashionable resort. It supported a prosperous industry of hotels (including Hilton's eighth), clinics, bath houses, and boarding rooms. This industry had all but disappeared shortly after the Second World War as America's fascination with mineral waters was replaced by the discovery of "wonder drugs."

By 1970, the architectural reminders of Marlin's heyday were still in evidence but the mineral waters were no longer a

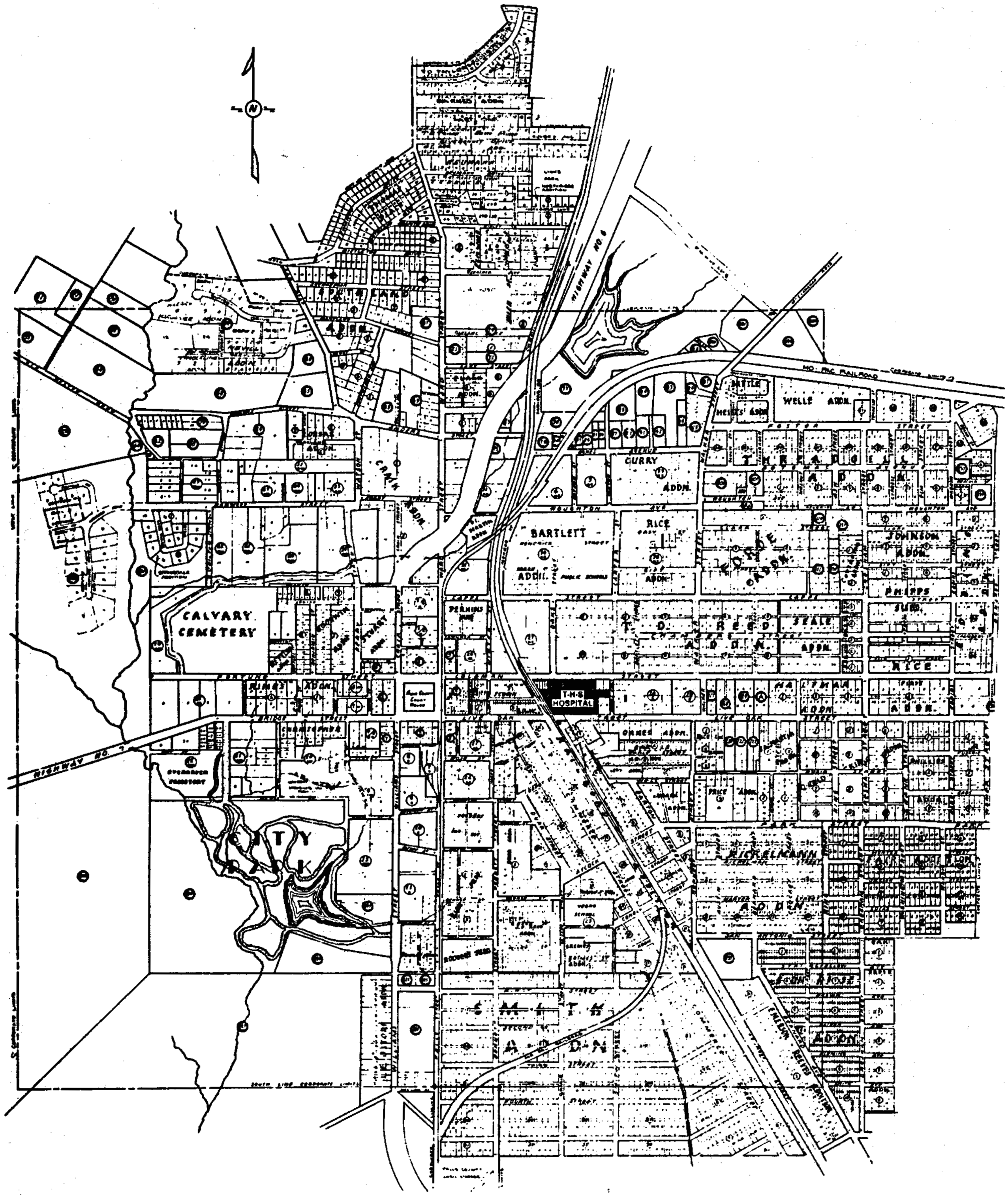


Figure 1-2   Location of T-H-S Memorial Hospital in Marlin, Texas

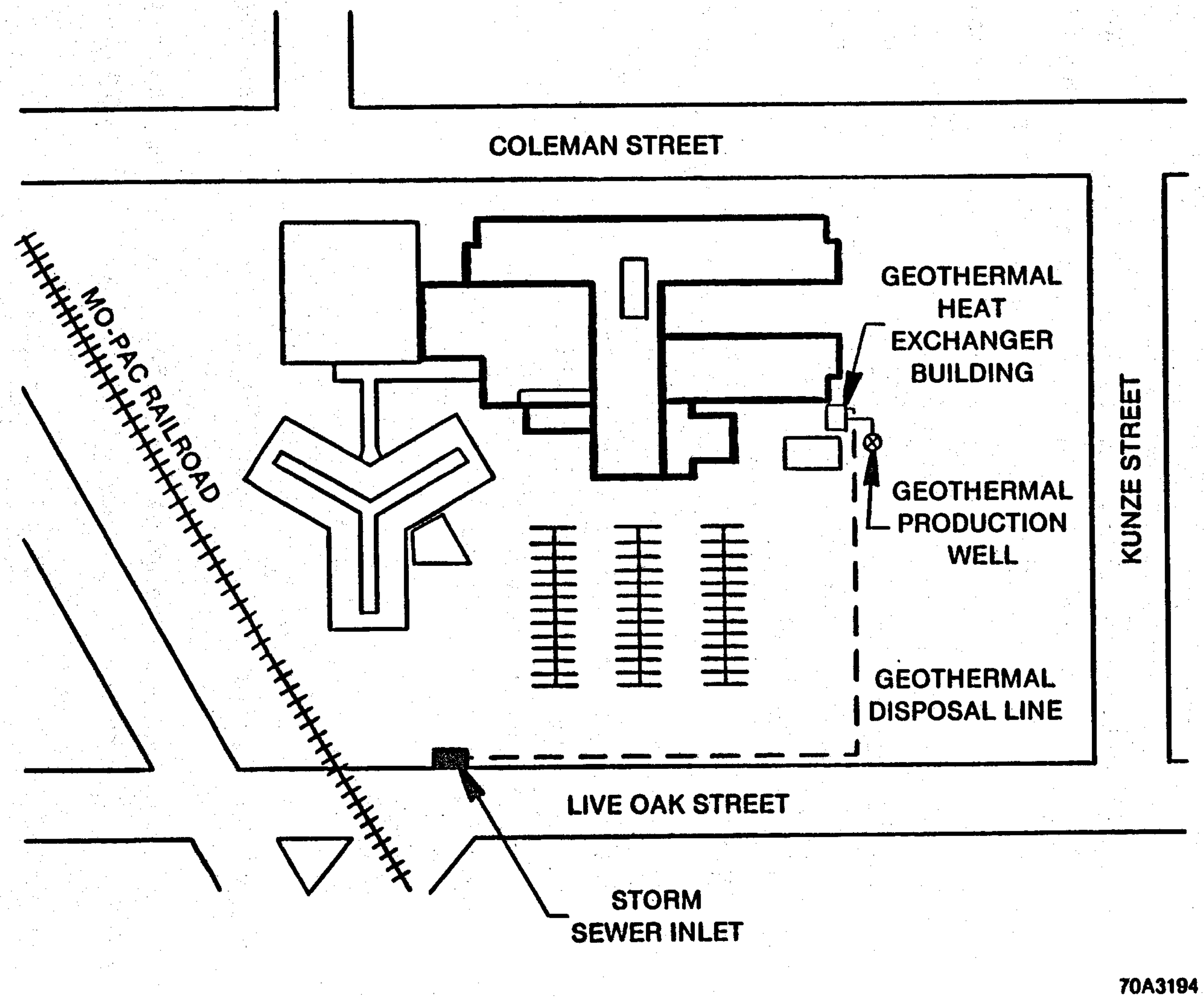


Figure 1-3 Site Plan of T-H-S Memorial Hospital

commercial attraction. However, energy shortages and rapidly increasing oil and natural gas prices renewed community interest in their hot mineral waters, now known as geothermal energy.

With the advent of soaring natural gas prices in the 1970's, concerned Marlin leaders began searching for ways to use their geothermal resource. As an active Chamber of Commerce member, Mr. J. D. Norris Jr., provided the leadership that led to his hospital's response to the DOE 1977 PON by forming a special Marlin Chamber of Commerce Committee on Energy Resources. As shown in Table 1-2, this committee was constituted from a broad cross-section of Marlin citizens and interests. It was chartered to promote alternative energy resources in Marlin, including geothermal, solar and lignite.

In November 1977, the T-H-S Memorial Hospital submitted its proposal [T-H-S 1977] to the US DOE and the State of Texas for a cost-share geothermal project based on the evidence of known geothermal resources beneath Marlin. In May 1978, the US DOE and State of Texas signed contracts with the T-H-S Memorial Hospital and the project began.

1.5 Project Scope

The overall scope of this project did not change over its course of execution and consists of the following elements:

- Drill and complete a modern, low temperature geothermal water well of high production capacity.

TABLE 1-2. MARLIN ENERGY RESOURCES COMMITTEE MEMBERSHIP

Administrator, T-H-S Memorial Hospital
President, Marlin Chamber of Commerce
Director, Marlin Chamber of Commerce
Attorney
Mayor, City of Marlin
City Manager of Marlin
Director, Marlin V.A. Hospital
Manager, Wallace Business Forms
Owner, Marlin Mills
Farmers Home Administration
Superintendent, Marlin Ind. School
Publisher, Marlin Daily Democrat
Manager, Swift Dairy & Poultry Co.
Physician
Retired Citizen
Housewife
Minority Representative
President, First State Bank
Investments Firm
Manager, Central Texas Savings & Loan
President, Marlin National Bank
Sprinkles Motor Co.
W. M. Parrish & Co.

- Design and construct a geothermal heating system that would provide long service in augmenting the hospital's space and water heating loads.

- Dispose of the spent geothermal water in an environmentally acceptable and legal manner.

- Develop and conduct a public awareness program to make others aware of the project's feasibility and success.

1.6 Growth Potential

Growth has already been seen in several areas.

First, the Marlin Chamber of Commerce is now using the City's original 1891 well to heat their offices and further demonstrate to potential new businesses the future benefits to be derived from a geothermal heating system.

Second, as a result of the public awareness program, scores of organizations have learned of this project through presentations, news releases, media coverage and brochures. Consequently, many industries have inquired about relocation to Marlin and about its geothermal resource.

More immediate growth is possible in that the maximum output for the T-H-S well can easily achieve 600 gallons per minute (gpm), whereas the hospital's peak demand is only about 160 gpm. Therefore, the potential exists to supply three more users of this size, or dozens of smaller ones.

2. SUMMARY

The objectives of the Torbett-Hutchings-Smith (T-H-S) Memorial Hospital geothermal heating project have been: 1) to demonstrate the technical feasibility of direct-use geothermal energy, and 2) to use actual project data to analyze economic incentives for geothermal initiative in the private sector. Several activities were undertaken and completed during the five-year effort which successfully accomplished these objectives. Table 2-1 briefly describes these activities. It serves as a concise summary to the project and to this report.

Activities of primary interest in Table 2-1 include the system monitoring and economic analyses. It was from these efforts that the hospital's natural gas savings and the private sector's economic incentives were derived. Figure 2-1 illustrates the impact that the geothermal retrofit has had upon the T-H-S Hospital's natural gas consumption. From the figure it can be determined that:

- the monthly peak consumption has been reduced by 75 percent (from 1740 MCF to 450 MCF)

- geothermal heat provides 93 percent of the peak heating loads which could be addressed by this geothermal resource (i.e., excluding base loads such as cooking, 180°F domestic water heating, etc.)

TABLE 2-1. SUMMARY OF T-H-S MEMORIAL HOSPITAL GEOTHERMAL HEATING PROJECT

Activity	Summary
• Resource Assessment	Based on historical evidence of geothermal resource in Marlin and available geologic data, anticipated a highly productive 150°F resource having less than 5000 ppm TDS at a depth of 3400 ft.
• Well Drilling, Completion, and Testing	Instituted measures to prevent drilling noise from becoming an environmental problem. Drilled 3885 ft. well which produces 153°F water at 300 gpm. TDS content is ~4000 ppm. Maximum production rate ~600 gpm.
• Environmental and Institutional Issues	Anticipated disposal by injection using old nearby well, but injection tests proved this option unfeasible. Investigated other options and selected surface discharge. After environmental surveys and appropriate agency reviews, secured appropriate permits for surface discharge.
• System Design and Material Selection	Evaluated materials for their compatibility with the T-H-S geofluid. Prepared preliminary and final designs which use a cascaded arrangement of plate heat exchangers and which adhere to materials and process constraints.
• Bidding and Construction	Issued plans and specifications to candidate contractors through open bidding process. Selected contractor based on price and qualifications. Construction proceeded on schedule and system became fully operational in January 1982. Conducted Acceptance Test and prepared monitoring logs and Operating Manual for T-H-S Hospital personnel.
• System Monitoring and Dedication Ceremonies	Conducted a 1-yr. monitoring phase to monitor system performance, orient T-H-S personnel, and assist in troubleshooting as needed. No interruption of geothermal service has been experienced since system startup in January 1982. In April 1982, T-H-S Hospital sponsored a dedication ceremony which was well attended by the press, Marlin citizens, political figures and project participants.
• Economic Analyses	Performed economic analyses to evaluate private sector incentives for continued development of Central Texas geothermal resource. Concluded that larger heating loads than those at T-H-S are likely needed before economics become attractive for non-profit organizations, but that economics for profit-making organizations can begin to be attractive even at T-H-S heating loads.
• Public Awareness	Throughout the project, implemented strategies to inform general public about geothermal energy and the T-H-S project, and to attract potential geothermal users. Elements included press releases, fact sheets, site signs, system displays, color brochures, and audio/visual slide show.
• Materials Testing	During actual system operation, conducted 7-month corrosion test of common materials of construction in order to promote widespread use of the Central Texas geothermal resource. Identified suitable materials and confirmed the selections made for the T-H-S system.
• Environmental Monitoring	Conducted field sampling and inspection of the geofluids surface discharge route and analyzed environmental conditions. Concluded that T-H-S discharge does not significantly impact the regulated surface waters (Brazos River) in the discharge route. Noted that the storm sewer catchment pond which first receives the T-H-S geofluid is in a stressed condition, but could not determine impact by T-H-S discharge in the absence of baseline data.

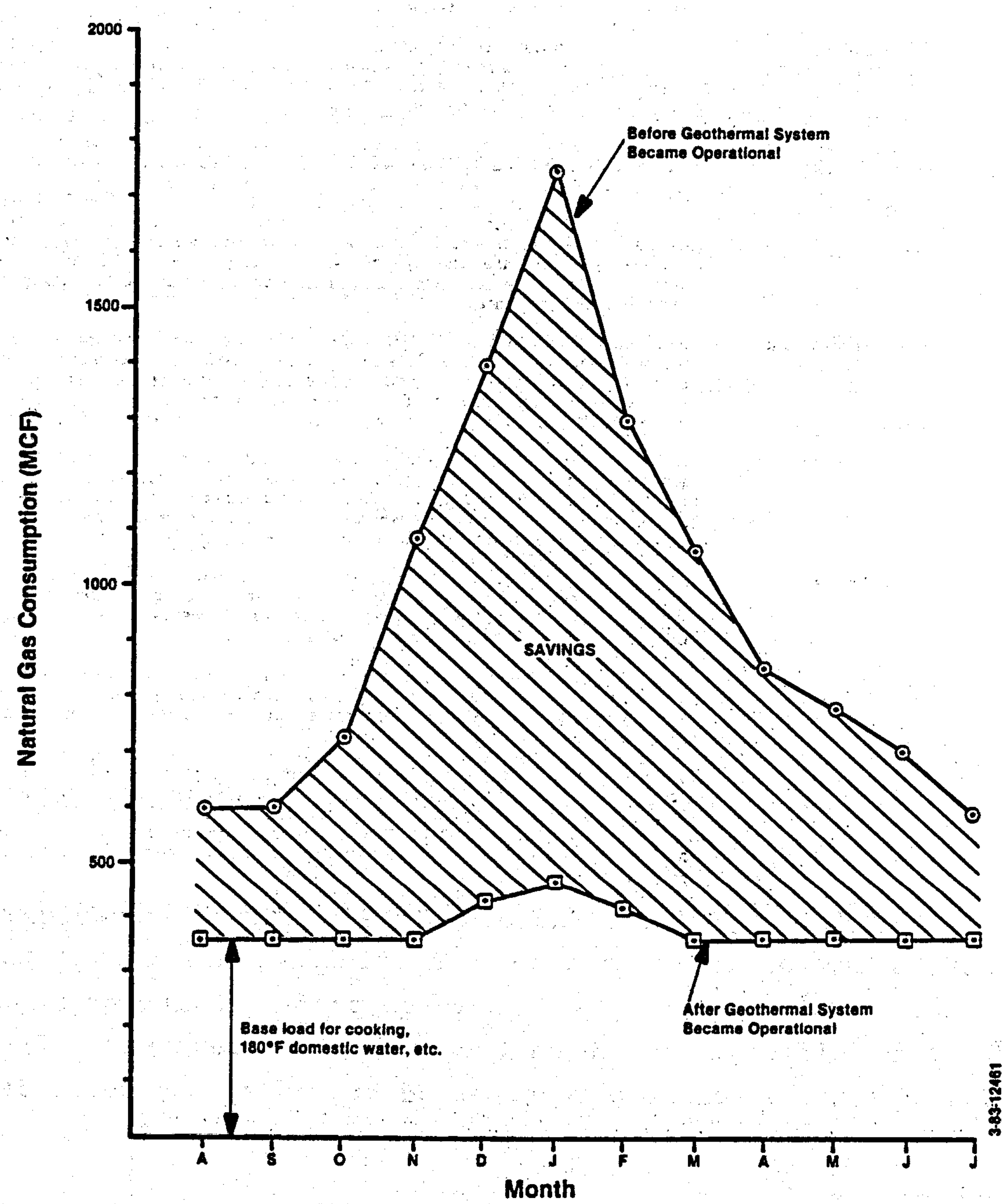


Figure 2-1 Impact of the T-H-S Geothermal Retrofit on Natural Gas Consumption

- the annual natural gas consumption has been reduced by 61 percent (from 11,500 MCF to 4500 MCF)

To evaluate the economics of future Central Texas geothermal projects of similar size, two analyses were performed. These analyses used actual T-H-S costs and savings data to analyze a system equivalent to that at T-H-S, except that first time development and other similar costs were excluded. One analysis considered a non-profit organization such as the T-H-S Memorial Hospital, and the other considered a profit-making organization. In each, discounted cash flow analyses were used to determine the breakeven period (payback which accounts for time value of money) and the real return on investment over the first fifteen years of operation.* The results are:

- Non-Profit Organization

-- Breakeven Period	17 years
-- Return on Investment over first 15 years	0.2 % above inflation

- Profit-Making Organization

-- Breakeven Period	12.5 years
-- Return on Investment over first 15 years	10% above inflation

Two important factors affect these economics: tax benefits and well utilization. The results illustrate that the tax incentives currently available to profit-making organizations have a significant impact on the economic incentives. Additionally, the economics of both types of organizations could improve

*30 year system life expected

immensely if heating loads larger than those in the T-H-S system were displaced with the geothermal heat. This improvement would occur because the T-H-S heating loads are large enough to use only about ten percent of the yearly energy which could be extracted from the geothermal well. If the well, which is an expensive capital item, were utilized more fully, greater savings would be achieved at minimal additional costs, and economics would improve.

3. CONCLUSIONS AND RECOMMENDATIONS

The T-H-S Memorial Hospital geothermal project has encompassed a broad range of technical, institutional, and economic activities, many of which have been pioneering efforts. Accordingly, a great deal has been learned in the project, and future geothermal development can benefit greatly from the project's conclusions. A total of fifteen conclusions and recommendations are presented below. They are organized as technical, institutional/environmental, or economic.

3.1 Technical Conclusions and Recommendations

- The Central Texas geothermal resource near Marlin can produce large quantities of relatively clean geothermal waters having temperatures in excess of 150°F. It is capable of supporting additional geothermal development.

- A production system which uses a variable frequency drive (VFD) to control pump speed and flow rate is a reliable, economic means of conserving parasitic pumping power, conserving the geothermal resource, and minimizing environmental impacts. Such control systems should be strongly considered for systems with fluctuating heating loads.

- This project has demonstrated that substantial energy savings can be achieved for geothermal systems addressing water and space heating loads, even in relatively mild Texas climates. Other heating loads, especially process heating, which can use this 155°F resource should be considered as geothermal candidates. Typical candidate industries include poultry dressing, natural cheese, dehydrated fruits and vegetables, soft drinks, synthetic rubber, and furniture manufacture.

- Careful consideration of the geofluids corrosion and scaling tendencies must be given in the design stage if these maintenance hardships are to be prevented. Materials testing results from this project should form the basis for materials selections in future geothermal projects having geofluids of similar quality.

- The T-H-S geothermal system has not experienced any interruption in service since final start-up in January 1982, thereby demonstrating that geothermal direct-use systems can be reliable and dependable. Much of this reliability can be attributed to the corrosion and scaling analyses used during the design stage.

- Piping, valves, heat exchangers, and other components contacting the geothermal fluid must be closely specified in order to provide a long-lived system. Plate heat exchangers with suitable plate and gasket materials should be considered.

- Geofluid disposal by injection requires careful planning of the production/injection wells couplet and careful design of the injection well. These efforts are essential if communication between the wells and injectability problems are to be avoided.

3.2 Institutional/Environmental Conclusions and Recommendations

- Well drilling at the T-H-S Hospital was accomplished at low noise levels and without complaints from nearby residents or from hospital patients. Drilling noise should not be considered a hurdle for future projects.

- Obtaining appropriate permits for this first geothermal system in Texas required interfacing and coordinating with several agencies, including the Texas Railroad Commission, the Texas Department of Water Resources, the Texas Department of Health, the Texas Air Control Board, and the U.S. Environmental Protection Agency. However, most of these permits were readily obtained and the effort required to secure them should not be considered a deterrent to potential geothermal users. Potential users should, however, allow time to secure the permits, especially those related to environmental issues.

- The environmental monitoring conducted after system start-up confirmed the environmental analyses performed prior to geofluid discharge, and concluded that the T-H-S discharge has no significant impact on the regulated surface waterway (Brazos River). In the absence of baseline data, no conclusion could be made regarding the stressed condition of the storm sewer catchment pond which first receives the geofluid. It is therefore recommended that baseline biological sampling be included in future environmental assessments for geothermal systems proposing surface discharge.

- The monitoring logs and Operation Manual prepared for the T-H-S system operators familiarized the operators with the system, provided troubleshooting guidelines, and enhanced operator acceptance of the system. Similar efforts are recommended in future geothermal projects.

3.3 Economic Conclusions and Recommendations

- Economic incentives currently exist for a profit-making organization to pursue geothermal systems using the Central Texas geothermal resource, provided that a heating load at least as large as that at T-H-S is available. Larger heating loads can strengthen the incentives. It is recommended that facilities which can use substantial amounts of energy at or below 150°F investigate geothermal opportunities.

- Pursuit of Central Texas geothermal systems by non-profit organizations does not appear economically attractive unless a heat load significantly larger than that at the T-H-S Hospital is available, or unless subsidies are available to decrease the cost to the organization.

- The economic attractiveness of Central Texas geothermal development is due largely to the well defined resource, and the associated low risk involved in drilling a successful well. To expand this attractiveness to the Trans-Pecos (West Texas) geothermal resource, as well as other out-of-state resources, it is recommended that efforts be undertaken to fully characterize the less-defined resources.

4. PROJECT DESCRIPTION

4.1 Task Breakdown

The principal tasks and subtasks are delineated in Figure 4-1, which depicts the "as-experienced" schedule for the T-H-S Hospital geothermal project at Marlin, Texas. Much trail blazing was done in the permits area for this was the first low temperature geothermal well permit to be acquired in Texas and the first geothermal surface disposal permit. Additionally, PON requirements contributed to the lengthy schedule by: a) requiring distinct and separate preliminary and final designs and reviews; and b) requiring a one-year demonstration phase of the operating system.

4.2 Organization and Participants

An organization chart showing all the participating organizations and principals, and the roles they performed, is presented in Figure 4-2. Mr. J. D. Norris, Jr., T-H-S Memorial Hospital Administrator, acted as Project Director and coordinated the functions of all the participants as well as interfacing with the two sponsoring agencies.

In addition to the mentioned coordination, the Project Director presented the project to scores of invited engagements, participated at DOE review conferences, and kept the appropriate governmental representatives apprised on the project's status. A large amount of coordination between many elements of diverse interest was done.

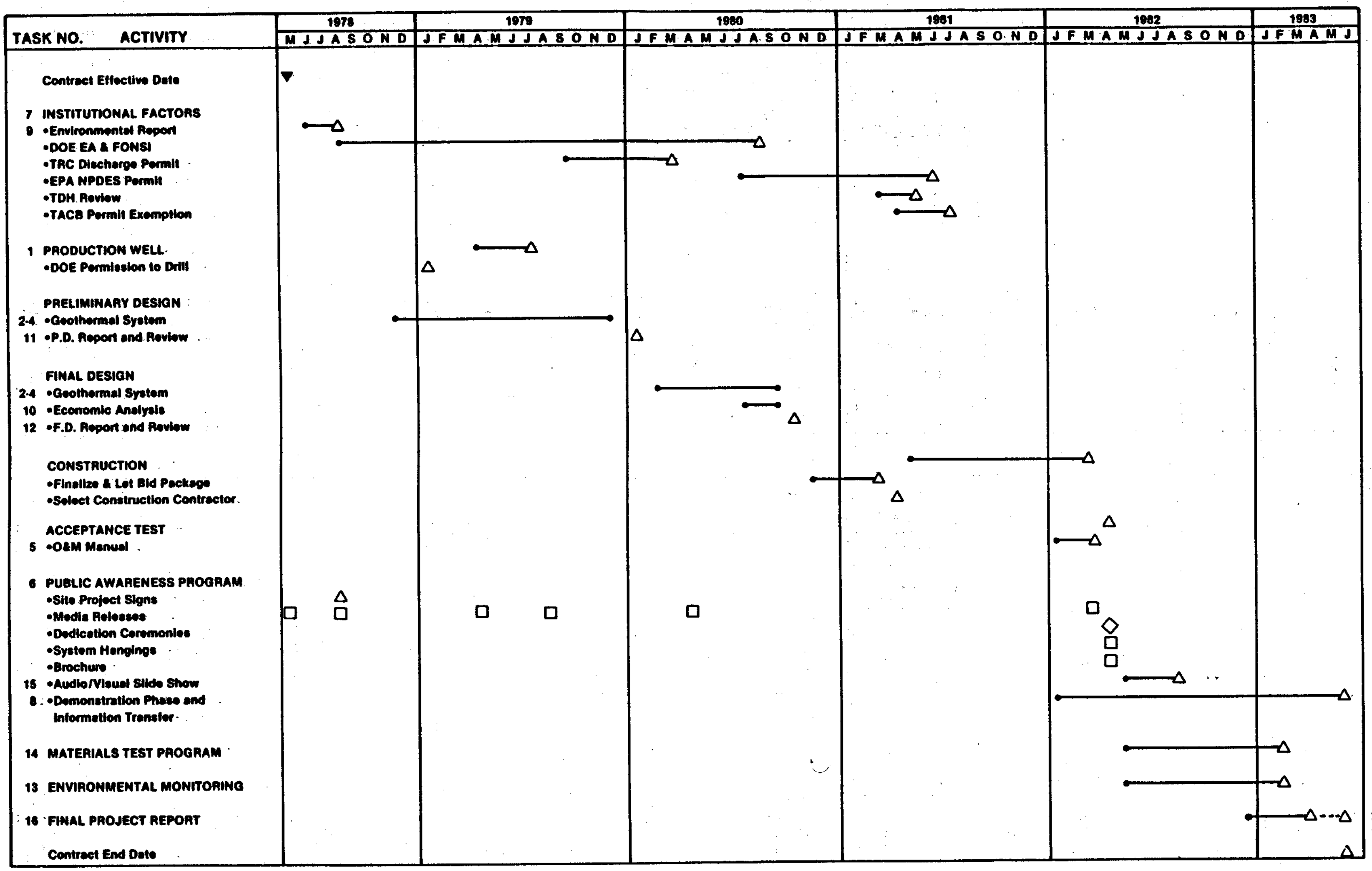


Figure 4-1 Project Schedule

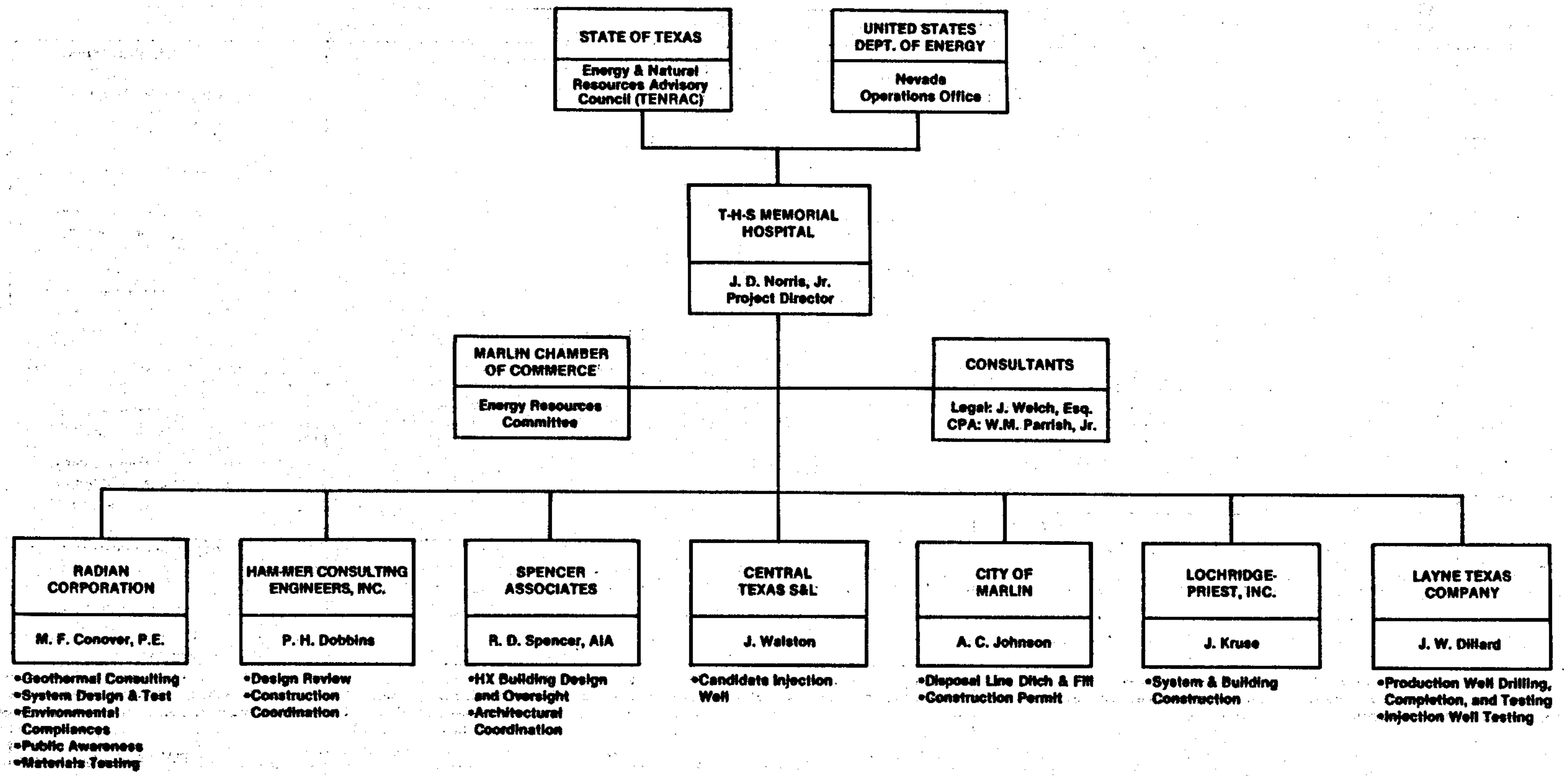


Figure 4-2 Project Organization

4.3 Funding Breakdown

The cost of the project was shared by five sources. Figure 4-3 graphically shows the portions of the project costs that were contributed by each. Not all funding sources contributed funds directly, however. Listed below is the type of contributions made by each.

• US Department of Energy	Funds
• State of Texas	Funds
• T-H-S Hospital	Services-in-Kind
• City of Marlin	Funds
• Central Texas S&L	Donated Well Use

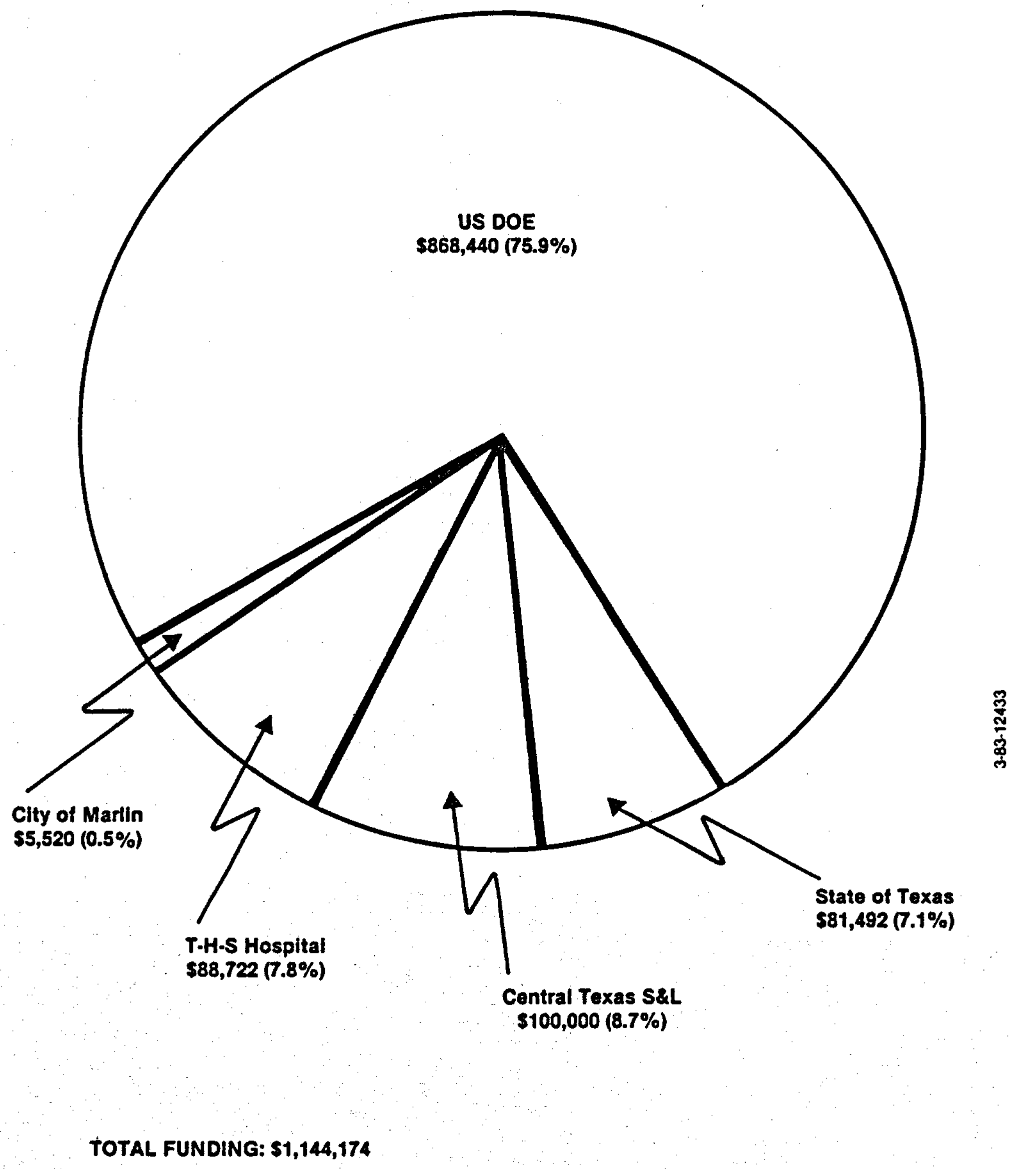


Figure 4-3 Contributions by Project Sponsors

5. RESOURCE ASSESSMENT

The resource assessment done prior to drilling the project's modern production well relied primarily on evaluations of the known regional hydrogeology, and on historical data from previously drilled wells near the project site. From this evaluation, estimates were made of temperature at depth and quality of produced fluids. Although not specifically quantified for this project, data indicate that sufficient fluid volumes are available for long-term production at the required rate.

5.1 Pre-Drilling Assessment

During the proposal stage and prior to drilling, evaluations to characterize the subsurface geology and water resources were made using the available hydrogeological data on the region around Marlin [T-H-S 1977 and Radian 1978]. These evaluations were based on investigations performed by the Texas Department of Water Resources, by the Texas Bureau of Economic Geology, and by oil and gas exploration [Cronin, *et al.* 1973; Hall 1976; Klemt, Perkins, and Alvarex 1975 and 1976; Thompson 1972]. Most recently, the Texas Bureau of Economic Geology has conducted an assessment of the geothermal potential in the Central Texas region, within which Marlin is located [Woodruff and McBride 1979].

This region is generally underlain by intensely deformed (folded, faulted, and altered) metamorphic and metasedimentary rocks of Paleozoic age. These rocks are referred to as the "Ouachita fold belt," and are believed to be the source of heat in the area. Above these rocks lie sedimentary rock of Cretaceous age, primarily sandstone, shale, and limestone. The most promising geothermal potential in the Marlin area occurs in the lower part of these Cretaceous units, the Trinity Group. It is thought that the Mexia-Talco fault system east of Marlin provides a hydraulic interconnection for hot waters from the deeper rocks of the Ouachita fold belt to the shallower aquifers of the Trinity Group. A generalized geologic section is shown in Table 5-1.

Three of the formations in the Trinity Group are important waterbearing units. These are the Glen Rose, the Hensel, and the Hosston.

The shallowest formation, the Glen Rose, can produce small to moderate supplies of water, but it is highly mineralized. Analyses of Glen Rose fluid indicate a progressive increase in the total dissolved solids (TDS) content from the outcrop areas west of the Balcones Fault zone to the Marlin area, down-dip to the southeast. Figure 5-1 shows the dip of the geologic formations in the region, and the severe faulting which has occurred.

A well penetrating the Glen Rose at Rosebud, Texas, located about 18 miles south and slightly west of Marlin, yields water with a TDS content of about 5,500 mg/l. Within the city of Marlin, very near the project site, three old mineral bath wells penetrate the Glen Rose. However, due to the depth of these wells it appears that waters produced are mixtures of highly mineralized Glen Rose and "sweeter" Hosston fluids. Fluid analyses and temperatures for two of these old wells are shown in Table 5-2.

TABLE 5-1. GEOLOGIC UNITS IN THE MARLIN AREA

Era	System	Series and Group		Formation	Approximate Thickness (feet)	Lithology
Cenozoic	Quaternary	Recent and Pleistocene Series undifferentiated		Alluvium	0-60±	Gravel, sand, silt, and clay
Mesozoic	Cretaceous	Gulf Series	Navarro		0	Shale, marl, and sand
			Taylor		1150	Marl and limy shale
			Austin		200	Chalky limestone
			Eagle Ford		100	Shale
			Woodbine			Ferruginous sand, sandstone, shale, sandy shale, clay
		Comanche Series	Washita	Buda	125	Limestone
				Del Rio	77	Shale
				Georgetown	338	Limestone
			Fredricksburg	Edwards		Hard, fossiliferous limestone (often honeycombed), shale, chert, and dolomite
				Comanche Peak	200	Limestone and limy shale
				Walnut		Shale and calcareous clay
			Trinity	Glen Rose	1000	Limestone
				Hensel	10	Conglomerate, sandstone, siltstone, shale, clay, limy clay, and limestone
				Cow Creek	100	Limestone
				Hammett		Shale
				Sligo		Limestone
				Hosston	700	Shale, limestone, dolomite, sandstone, and metamorphic rock
Pre-Cretaceous rocks						Shale, limestone, dolomite, sandstone, and metamorphic rock

Source: Radian, 1978.

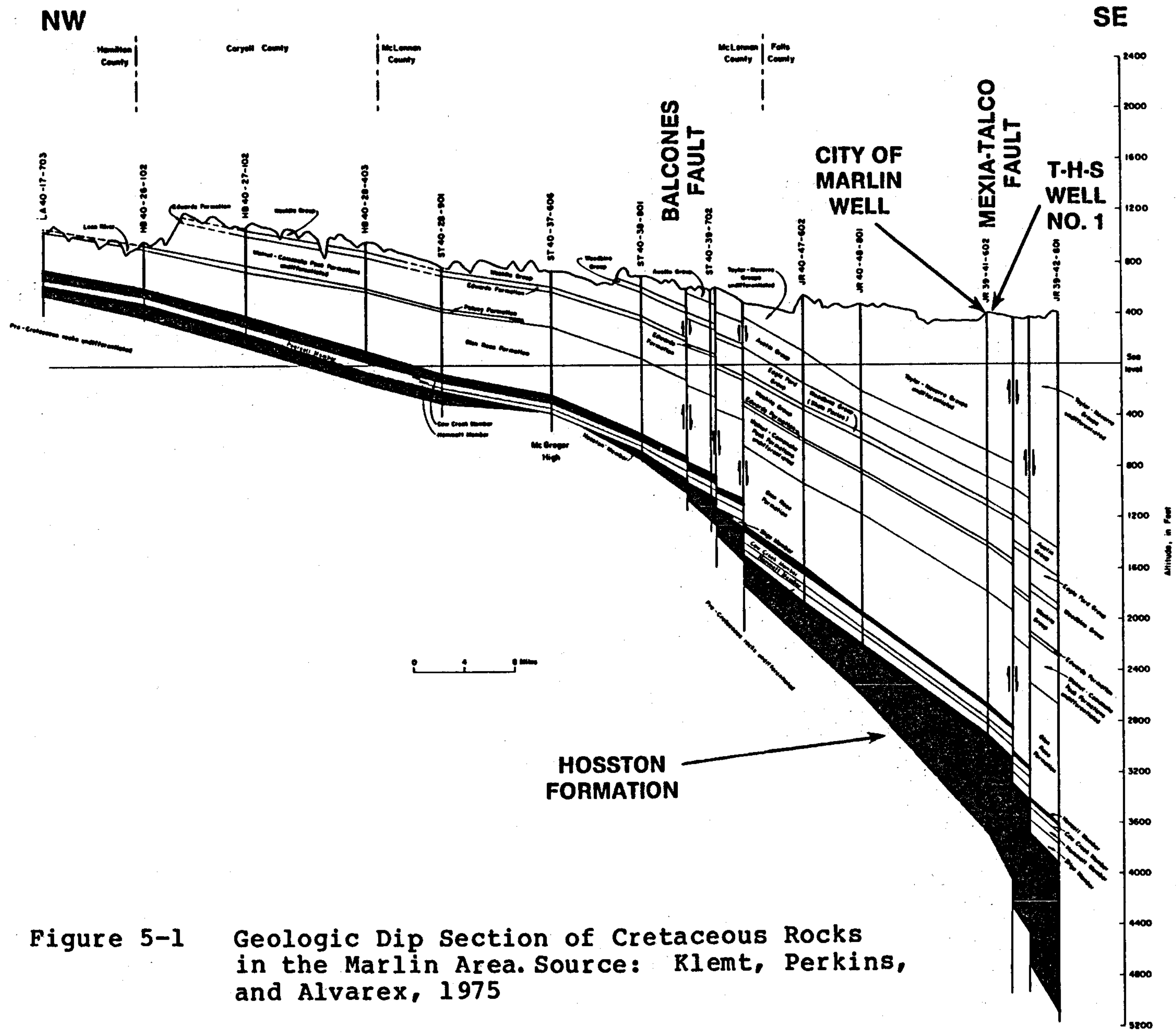


Figure 5-1 Geologic Dip Section of Cretaceous Rocks in the Marlin Area. Source: Klemt, Perkins, and Alvarex, 1975

TABLE 5-2. CHEMICAL ANALYSES OF WATER FROM TWO OLD GEOTHERMAL WELLS IN MARLIN

Parameter	Concentration (mg/l)			
	Well 602 (1967)*	Well 604 (1938)*	Well 604 (1944)*	Well 604 (1960)*
CA^{++}	248	182	193	217
Mg^{++}	64	69	69	66
Na^{+} and K^{+}	3,127	2,993	2,940	2,548
HCO_3^-	481	504	503	488
$SO_4^=$	4,906	4,375	4,330	3,437
Cl^-	1,546	1,615	1,580	1,598
SiO_2	24	--	--	41
Fe	0.32	--	--	--
TDS	10,512	9,482	9,360	9,625
Hardness (as $CaCO_3$)	885	738	765	1,067
pH (units)	7.16	--	--	--
Temperature (°F)	125	--	147	--

*Year in which analysis was performed.

Source: Klemt, Perkins, and Alvarex 1976.

The Hensel formation is a productive aquifer west of Marlin, yielding small to moderate supplies of fresh to slightly saline water. In Marlin, however, the formation is more shaley with a net sand thickness of only 10 feet, effectively limiting this aquifer's production capability.

The Hosston formation was the aquifer targeted for drilling and development for this project. It is the deepest of the productive formations in the Trinity Group, at about 3300 feet, and was expected to yield the hottest fluid. At Marlin, the Hosston is about 700 feet thick. The Hosston is capable of producing moderate to large quantities of water. Up-dip, to the west-northwest, the formation has been an important source of fresh drinking water to communities along Interstate Highway 35. The Hosston water quality ranges from 1060 mg/l to about 5450 mg/l TDS in the area around Marlin, as shown in Table 5-3. There is a slight trend toward increasing TDS levels from north to south in the western part of Falls County. South of Marlin about 20 miles, the TDS content of Hosston water averages about 4950 mg/l, at a temperature of 154°F.

TABLE 5-3. CHEMICAL ANALYSES OF WATER FROM THE HOSSTON FORMATION FOR THREE AREAS SURROUNDING MARLIN

Parameter	Average Concentration (mg/l) in Area		
	10-20 Miles West[a]	8 Miles North[b]	20 Miles South[c]
CA^{++}	39	21	265
Mg^{++}	10	4	47
Na^+ and K^+	427	278	1,384
HCO_3^-	426	455	205
$SO_4^=$	541	212	3,262
Cl^-	79	61	210
SiO_2	32	27[d]	105
Fe	0.88	0.57	0.48
TDS	1,449	1,062	5,445
Hardness (as $CaCO_3$)	137	71	885
pH (units)	8.1	7.6	7.3

[a]11 analyses from 7 wells
[b]2 analyses from 2 wells
[c]5 analyses from 1 well
[d]Single analysis

Source: Klemt, Perkins, and Alvarex 1976.

5.2 Geothermal Energy Estimates

From the data available for the old mineral wells in Marlin, it was anticipated that fluid temperatures of at least 147°F and probably up to 150°F could be expected from a modern production well at 4000 feet. This same data suggested that the lower TDS of the Hosston fluids was diluting the more mineralized Glen Rose fluid produced from these old wells. Other well data indicated that a modern well drilled into the Hosston at the project site would yield fluid with a TDS content of 2500 to 3500 mg/l. Such temperatures and fluid quality would be sufficient for a successful, trouble free geothermal heating system.

Although no specific long-term production rate limit for the project was estimated, the Texas Department of Water Resources has identified that Marlin is an area where the Hosston is capable of further development. Estimates in 1966 were that an additional 6000 gpm could be produced from a 10 to 20 mile-wide band of the aquifer passing beneath Marlin. The transmissivity of the Hosston (the ability of an aquifer to transmit water) at Marlin was measured to be about 16,000 gallons per day per foot (gpd/ft). This value is among the higher ones reported for the Hosston in the Central Texas region [Klemt, Perkins, and Alvarex 1975].

5.3 Drill Site Selection

The proposed site for the new production well was on the T-H-S Memorial Hospital property, midway between two old mineral wells in the Marlin downtown area. The actual site corresponds to the proposed site and is near one of the hospital's mechanical equipment rooms. This location, shown earlier in Figure 1-3, prevented disruption of hospital traffic during drilling. And although the site was in the downtown area, special drilling provisions prevented excessive rig noise from being heard by hospital staff and patients, or by nearby residents.

6. ENVIRONMENTAL ISSUES

6.1 Pre-Drill

As a project requirement, Radian prepared an Environmental Report and submitted it to DOE in August 1978 [Radian 1978]. At this time, DOE began its review of the environmental issues via an independent project environmental assessment. Although the DOE Environmental Assessment Document was delayed until August 1980 [US DOE 1980] because of the uncertainty of the exact fluid disposal method, DOE permission to drill was granted in early 1979.

During the environmental investigations conducted by Radian Corporation, the single most important environmental issue that arose was with regard to the drilling rig noise during drilling. This factor was of concern because the rig would be drilling within 30 feet of the hospital and the rig would also be in a downtown area. Obviously, if drilling were to be done on a 20-24 hour per day basis, it would be necessary to provide a quiet atmosphere for both the hospital patients and the neighboring residents. Such drilling provisions would be needed even though the hospital property borders a Missouri-Pacific Railroad track with 8 to 12 daily trains, 2 to 5 of which pass during the night. The train horns produce a very loud 95 dbA at the hospital center.

Drilling noise levels are a function of the type of diesel engines used, the number of engines, the type of muffler employed, and the type of turntable drive. For the T-H-S hospital production well activity, the Layne Texas Company employed a single Caterpillar diesel and a special large muffler. The rig's turntable was not a source of significant noise.

The precautions taken by the driller to reduce noise paid off handsomely as no noticeable noise could be heard from the rig while one stood in the hospital's parking lot. During the three-month drilling and completing effort, while operating 20 hours per day and six days per week, not one complaint was received from a patient or a nearby resident.

6.2 Post-Drill

The most significant post-drilling environmental factor revolved around the disposal method for the spent geothermal water. This issue was not a factor in the pre-drill assessment because the conceptual approach had been to dispose by injection using an existing well donated by the nearby Central Texas Savings and Loan. However, actual injection testing showed a great amount of injection pressure would be required, thereby placing a significant operation and economic burden on the geothermal users.

In addition, the observed permeability of the producing formation was such that the donated well was far too close to the hospital's well for them to be used for a production/injection couplet. Had such been done, the injected cool water would have returned to the producing well before being reheated in the formation, thereby cooling the produced hot water. It was concluded that a properly located injection well should be at least one mile away. Since this approach would have required obtaining and purchasing surface/subsurface rights, drilling an injection well, constructing a pipeline, and providing much additional pumping power, another disposal technique was sought.

Other alternatives such as direct input to the Marlin surface water supply and chemical treatment of the geothermal water prior to release were investigated and were found to be unsatisfactory.

The disposal option eventually adopted was to surface discharge into the Brazos River via the City's storm drainage system and approximately five miles of creeks. Radian Corporation conducted an environmental survey of this discharge route and the effects, if any, that it might have on the environment [Radian 1979]. The Texas Railroad Commission--which regulates all oil, gas and geothermal production and saline water disposal in Texas-- conducted an independent environmental survey and also concluded that the small production rates of the T-H-S Hospital would not harm the Brazos River or cause its water quality standards to be violated. Similarly, the T-H-S production would not harm the surface waterways to the Brazos. The US EPA concurred by issuing its permit to discharge directly to the Brazos River via the existing surface water courses. Appendix B contains additional documentation on this disposal route, and Section 36 details environmental monitoring which occurred during geothermal system operation.

7. INSTITUTIONAL ISSUES AND PERMITS

Like most projects, all activities related to construction (including well drilling) of the T-H-S Memorial Hospital geothermal heating system were required to comply with applicable federal, state, and local regulations.

7.1 Issues

The most significant institutional issue to be addressed was that of the environment and what effect, if any, the proposed project might have on it. The environmental review responding to this issue was a project requirement and was separate from any later permitting requirements. Since federal funds were used for the project, an Environmental Report [Radian 1978] was required by DOE as a precursor to its environmental assessment [US DOE 1980]. This assessment was required under the National Environmental Policy Act (NEPA) of 1969 for all federal actions. Although the final Environmental Assessment Document was delayed due to questions about the disposal permitting process, DOE eventually found that the project did not significantly affect the environment and issued a "Finding of No Significant Impact" (FNSI) [Clusen 1980]. Such a finding eliminated the need for a more detailed environmental impact statement.

Sections 6 and 36 discuss the environmental issues in more detail.

7.2 Permits

The Texas Railroad Commission (TRC) has regulatory jurisdiction over all Texas geothermal operations, and receives input, as required, from the Texas Department of Water Resources (TDWR) to protect ground and surface water supplies. The typical TRC permits required for drilling, completing, developing, and testing a geothermal resource are summarized in Table 7-1.

Since the hospital owned the subsurface and surface water rights to the property, a permit to drill was readily obtained from the TRC. A licensed water well drilling firm was used to insure compliance with approved drilling practices of both the TRC and the TDWR. Contact was maintained with TRC field personnel and City of Marlin officials during drilling, and permission was received to temporarily discharge produced geothermal fluid directly into the city storm sewer during the 24-hour production test. Since the City of Marlin was an active member of the project team, it supported the hospital in all permitting efforts.

TABLE 7-1. SUMMARY OF PERMITS AND REPORTS GOVERNING NEW GEOTHERMAL PRODUCTION WELLS REQUIRED BY TEXAS RAILROAD COMMISSION.

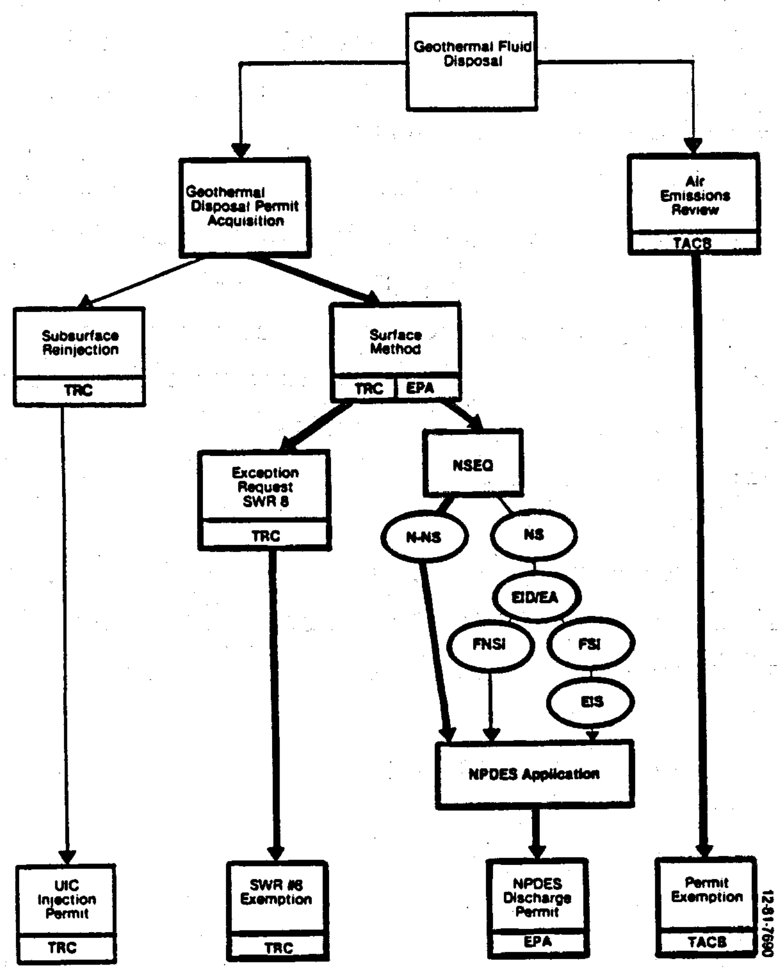
Permit Number	Description
W-1	Application to drill, deepen, or plug back a geothermal well
W-12	Inclination Report
W-13	Cementing Report
GT-1	Geothermal Production Test Completion Report and Log
GT-2	Producers Monthly Report of Geothermal Wells

Source: Green 1982.

By far the most important permitting issue was that of long term geofluid disposal. Responding to this issue received the most attention of all the permitting activities related to the project [Radian 1979]. In the case of the hospital, a permit to surface discharge was eventually received from the US EPA (Appendix B). Figure 7-1 summarizes the environmental reviews/ assessments required for disposal by surface discharge and by injection. The bold tracks in Figure 7-1 indicate the steps actually taken during this project's environmental permitting process. Due to minimal emissions of atmospheric pollutants, the project was exempted from the air emissions review by the Texas Air Control Board (Appendix B).

Note in Figure 7-1 that if EPA had determined the hospital's discharge to be a "new source", then further EPA review and assessment might have been required. However, with DOE as the lead agency in the project, the environmental assessment performed by DOE would likely have led to a concurrence by EPA on the DOE-issued FNSI.

An additional review of the system design and approval of the project plans were required from the Texas Department of Health under the Hospital Licensing Standards and Life Safety Code Standards. This approval (Appendix B) was obtained prior to letting the project out for bid.



ABBREVIATIONS

EA	Environmental Assessment
EID	Environmental Information Document
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency (US)
FNSI	Finding of No Significant Impact
FSI	Finding of Significant Impact
N-NS	Not a New Source
NPDES	National Pollutant Discharge Elimination System (Permit)
NS	New Source
NSEQ	New Source Environmental Questionaire
SWR	Statewide Rule (TRC)
TACB	Texas Air Control Board
TRC	Texas Railroad Commission
UIC	Underground Injection Control (US Program)

Figure 7-1 State and Federal Geothermal Environmental Permitting. Source: Green, 1982

8. PRODUCTION DRILLING AND LOGGING

As originally proposed, the T-H-S Memorial Hospital Well No. 1 was to be drilled to approximately 3400 feet with pressure, temperature, and fluid samples being obtained as drilling progressed via drill stem tests. Electric logs were also to be run. If from these tests it appeared that the Hosston formation was the hottest and produced relatively low TDS fluids, the well would be completed in this formation only. Otherwise, the other shallower productive formations in the Trinity Group would also be completed. A 24 to 48 hour pump test was planned.

An established water well drilling company, Layne Texas Company of Houston, was contracted for drilling. Layne Texas Company is familiar with the Central Texas area, having drilled several municipal wells in the region and having reworked in 1967 the old Central Texas Savings and Loan well (No. 602) located about 800 feet east of the hospital. As contracted [Dillard 1978] the well was to be drilled and completed to a total depth of 3400 feet with drill stem tests and well cuttings obtained along the way to characterize productive zones. A set of logs by a wireline service company, including induction, micro and gamma ray density, and temperature, were included in the contract. A pump test was also specified.

Spud-in ceremonies took place on 13 April 1979 with actual well drilling beginning on 16 April 1979. The well was completed and tested by the end of July 1979. During this period eight to twelve persons were on site. Drill cuttings were hauled to an approved disposal site. Other solid waste was disposed of in the City of Marlin landfill. Surface runoff and produced fluids were discharged into the city storm sewer with the approval of state and local regulatory agencies.

During the drilling operation, careful evaluation of the cuttings and formations indicated that a deeper well would be more productive. Contract changes were made and approved, resulting in a deeper well of slightly different construction than originally planned. These differences are indicated in Table 8-1. A full description of the drilling activities including a drillers log, all tests performed, and the logs run are included in the completion report [Layne Texas Company 1979]. Appendix A contains some of this data. The final as-completed well is illustrated in Figure 8-1.

The present producing interval is located, as planned, in the Hosston formation, slightly deeper than originally estimated.

TABLE 8-1. T-H-S MEMORIAL HOSPITAL WELL NO. 1 COMPLETION SPECIFICATIONS

Item	Original Well Contract Specifications (length-ft)	Dimensions	Final Well Configuration (length-ft)	Dimensions
Casing	300	10-3/4 in. O.D. (31 lb/ft,J-55)	330	10-3/4 in. O.D. (45.58 lb/ft,J-55)
	2,800	7 in. O.D. (23 lb/ft,J-55)	3,090	8-5/8 in. O.D. (28 lb/ft,J-55)
Blank Liner	110	5-1/2 in. O.D.	240	5-1/2 in. O.D. (14 lb/ft,K-55)
Slotted Liner	200	5-1/2 in. O.D.	270	5-1/2 in. O.D.
Total Well Depth	3,400	--	3,885	--

Sources: Dillard 1978; Layne Texas Company 1979; Wolterink 1979.

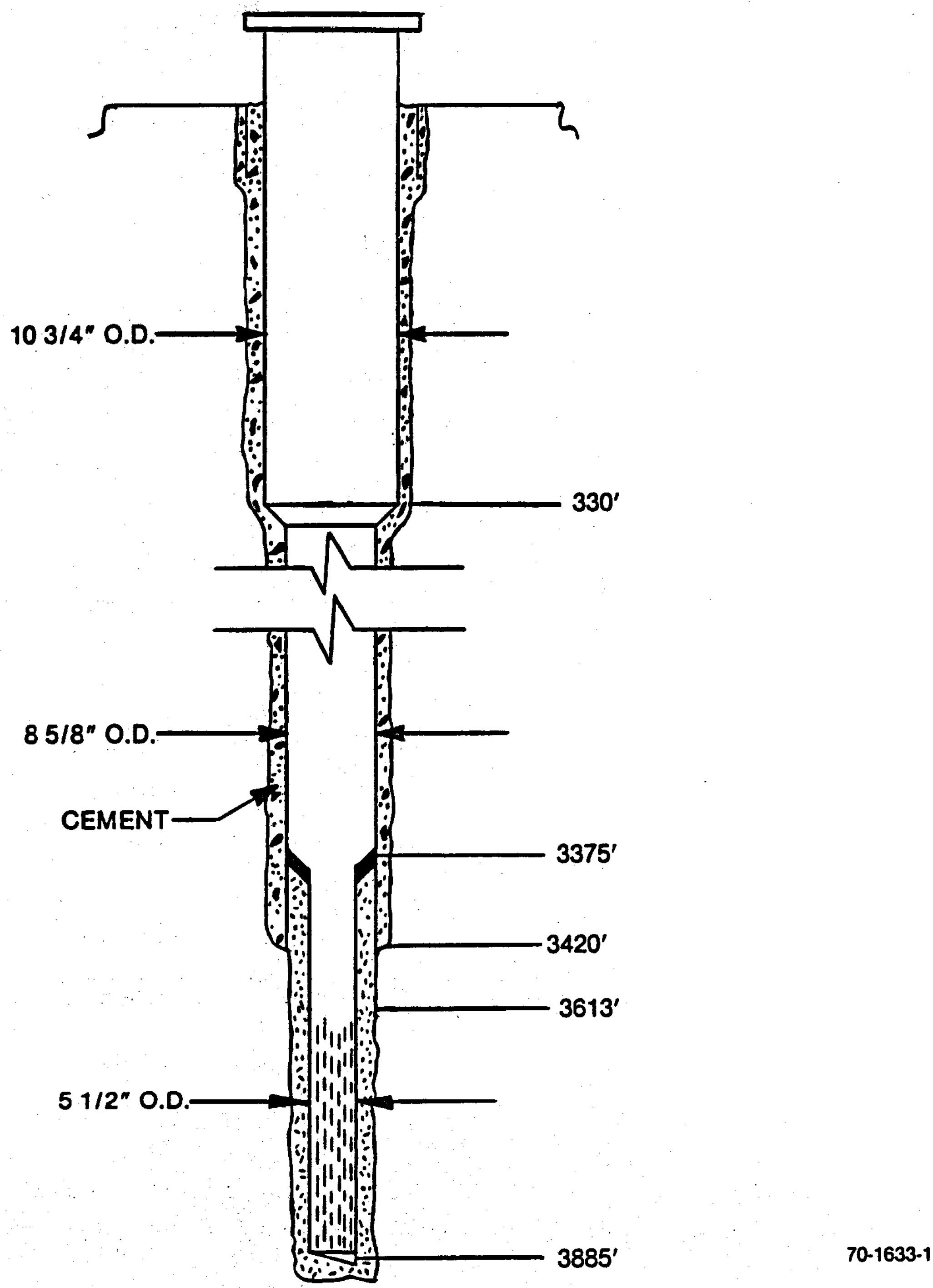


Figure 8-1 T-H-S Memorial Hospital Well No. 1 Completion Schematic

9. RESOURCE TESTING

9.1 Geothermal Fluid Analysis

During each opportunity to produce fluid from the resource, fluid samples were obtained from the well for analysis of its chemical composition. Samples were taken several times during available production testing periods: during drill stem testing prior to well completion; during pump testing and well development after well completion; during the materials selection period; and during the pump testing later conducted under a separate effort by the Texas Bureau of Economic Geology. Samples were analyzed by standard analytical techniques used by commercial water and waste-water laboratories.

The typical composition of the fluid from the T-H-S Memorial Hospital Well No. 1 is shown in Table 9-1. Note that composition ranges are the results of slightly different analytical methods and operations employed by the different laboratories performing the analyses.

9.2 Flow and Temperature Testing

Following final well completion in July 1979, the well contractor used a line shaft pump for a 24-hour production test in which production rate, fluid level drawdown, and producing well temperature were measured. This pumping was also performed to develop the well and to clean out debris from the producing

TABLE 9-1. GEOTHERMAL FLUID ANALYSIS FROM T-H-S MEMORIAL HOSPITAL WELL NO. 1

Parameter	Mean Concentration (mg/l)	Number of Samples Analyzed
Carbon dioxide	15.5-176	2
Hydrogen sulfide	0.05-<1.0	3
Conductivity	3930-4580[1]	5
pH	6.2-7.3[2]	5
Total dissolved solids	3605-4235	5
Total suspended solids	16	1
Aluminum	<0.1	3
Ammonia	1.19-1.2	3
Arsenic	<0.01	3
Barium	0.08-1.4	3
Beryllium	<0.02-0.03	3
Bicarbonate	128-222	5
Boron	1.4-1.72	2
Cadmium	<0.01	3
Calcium	268-344	5
Carbonate	0	5
Chloride	83-114	5
Chromium	<0.05	3
Cobalt	<0.05	3
Copper	<0.05	3
Fluoride (total)	0.8-3.7	5
Iron (total)	1.8-5.5	5
Lead	<0.10-0.10	3
Lithium	0.45-0.60	3
Magnesium	35-46	5
Manganese (total)	<0.05-0.55	5
Mercury	<0.001	2
Molybdenum	<1.0	3
Nickel	<0.05	3
Nitrate	<0.5	4
Selenium	<0.01	3
Silica	31-40	5
Silver	<0.02	3
Sodium & Potassium	765-1049	5
Sulfate	2054-2585	5
Zinc	0.04-0.06	3
Gross Alpha (Radioactivity)	1.4-1.95[3]	4

[1]μmhos/cm
[2]Standard units
[3]pCi/l
Sources: US DOE 1980; Radian 1979

formation around the well bore. Data on well recovery were also taken after shutting the pump down. About one year later, the Texas Bureau of Economic Geology performed (under a separate effort) a similar pump test for 18 hours to determine communication between the T-H-S Memorial Hospital Well No. 1 and the older, shallower mineral wells in the downtown Marlin area.

Table 9-2 indicates the results of these production tests. Originally, it was thought that the specific capacity measured in the Bureau of Economic Geology pump test may have benefited from that test's additional development of the well. However, as shown in Section 26, the difference in specific capacities is more likely due to seasonal changes in reservoir performance.

TABLE 9-2. T-H-S MEMORIAL HOSPITAL WELL NO. 1 FLOW TESTING

Method	Date	Flow Rate (gpm)	Temperature (°F)	Static Fluid Level (ft)	Specific Capacity (gpm/ft)
Artesian	7/28/79	75	140	14.85 above ground level	--
Pumped	7/27-28/79	307	153	198 below ground level	1.44
Pumped	9/23-24/80	310	153	140 below ground level	2.00

Sources: Layne Texas Company 1979; Woodruff 1980

The temperature of produced geothermal fluid was measured at every available opportunity, during times of high volume pumped production and during times when the well was allowed to flow under artesian conditions. Figure 9-1 illustrates the production temperatures that can be expected from the well as a function of production rate. At maximum production rates expected for the T-H-S system, a production temperature of 150°F was expected. Maximum production temperatures of approximately 155°F are achievable at higher production rates.

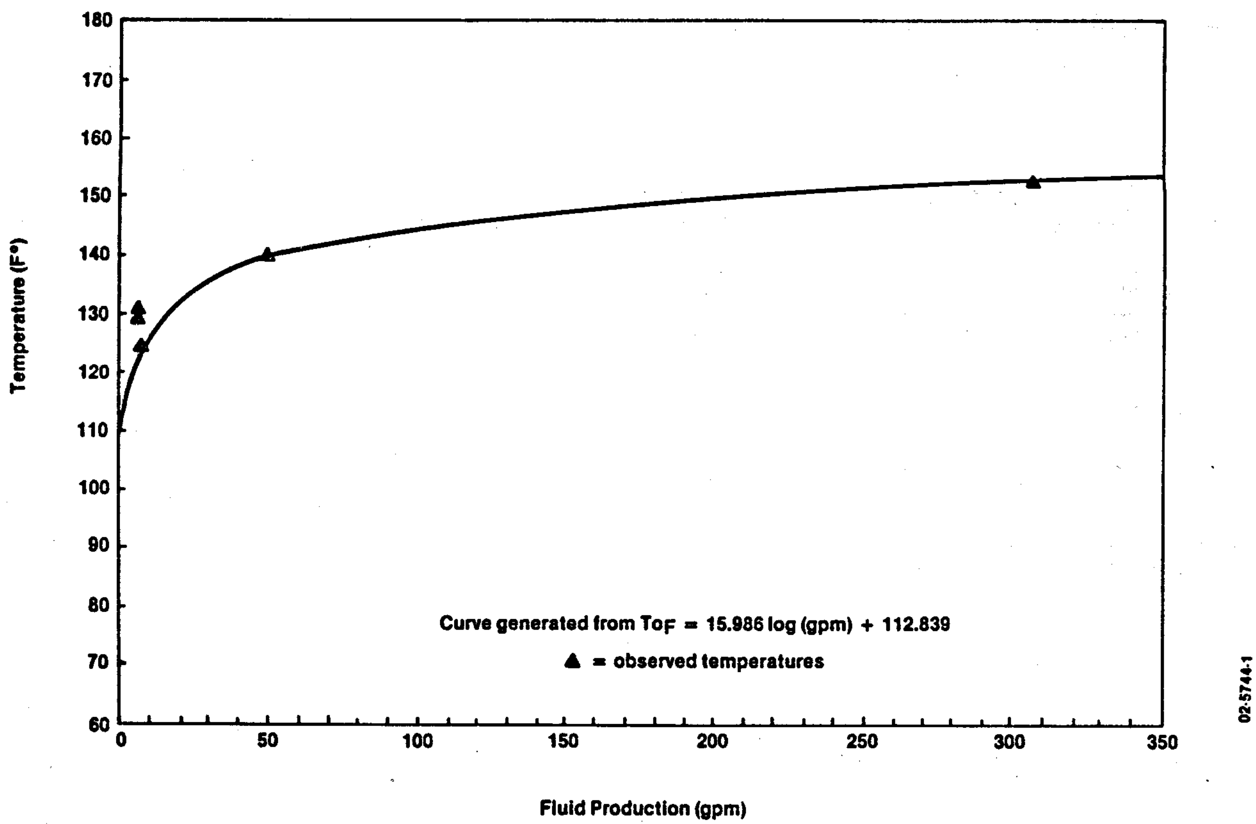


Figure 9-1 Flow Rate vs. Temperature of T-H-S Memorial Hospital Well No. 1

10. DISPOSAL DRILLING AND LOGGING

Since no disposal well was drilled for this project, this section is not applicable.

11. DISPOSAL TESTING

It was originally proposed that the old Central Texas Savings and Loan well 800 feet east of the hospital be used as an injection well to dispose of the produced geothermal fluid. As shown in Table 11-1, however, injection testing performed by the well drilling contractor indicated that excessively high pressures would be required to dispose the fluid by injection. Additionally, the wells were found to be too close for a production/injection couplet.

It was at this point that the investigation of alternative methods of disposal was begun. Refer to Section 6 for a brief discussion of these alternatives.

TABLE 11-1. WELL INJECTION TESTING

Well	Date	Initial Flow Rate/Pressure (gpm/psig)	Final Flow Rate/Pressure (gpm/psig)
Central Texas Savings and Loan	7/31/79	21/175	10/175
T-H-S Memorial Hospital Well No. 1	7/30/79	232/200	126/340

Sources: Layne Texas Company 1979; Radian 1979

12. APPLICATION ANALYSIS

Once the well's temperature and flow characteristics were established through resource testing (see Section 9), a check was made to verify that the proposed heating loads could be addressed with this geothermal resource. In this check, the temperature and flow requirements of the hospital's heating systems were re-examined. It was concluded that not only could the 150°F production temperature address the proposed loads, but that fresh air preheating and linen drying could be added to the addressed loads without additional production from the well.

To orient the reader to the hospital's heating system, an overview of its utilities is presented in Figure 12-1. This diagram shows that natural gas is used for most of the water and space heating, but that electricity also provides some space heating. By extracting the temperatures needed for each heating load from Figure 12-1, one can see that the loads encased in bold lines can be addressed by this geothermal resource. In some cases, the 150°F is capable of completely displacing the loads. In other cases, such as the 180°F domestic hot water loads, geothermal energy can only supplement the heating. Table 12-1 summarizes this applicability of geothermal heating for the T-H-S Memorial Hospital.

Table 12-1 evidences that the T-H-S heating system was a prime candidate for a geothermal retrofit which uses a çascaded heat exchanger arrangement. In such a system, the geofluid passes through a series of heat exchangers, each of which is

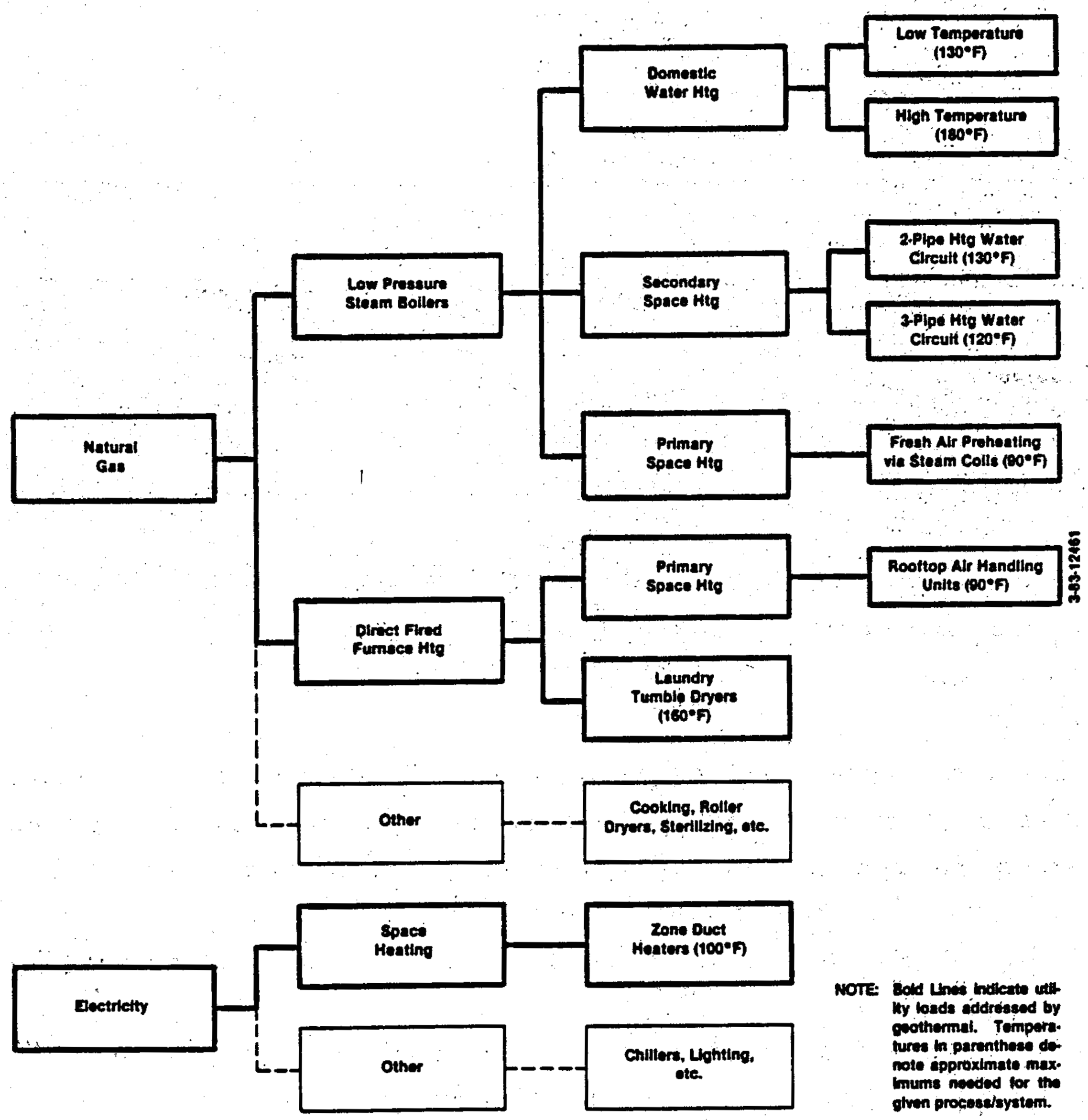


Figure 12-1 Utility Overview For T-H-S Memorial Hospital

TABLE 12-1. SUMMARY OF HEATING LOADS ADDRESSED BY GEOTHERMAL ENERGY AT T-H-S MEMORIAL HOSPITAL

T-H-S Heating Load	Utility Displaced	Temperature Requirement	Geothermal Contribution
High Temperature Domestic Water	Natural Gas	180°F	Supplements
Laundry Tumble Dryers	Natural Gas	160°F	Supplements
Low Temperature Domestic Water	Natural Gas	130°F	Displaces
Secondary Space Heating (2-Pipe Circuit)	Natural Gas	130°F	Displaces
Secondary Space Heating (3-Pipe Circuit)	Natural Gas	120°F	Displaces
Primary Space Heating (Return Air Rooftop Air Handlers)	Natural Gas, Electricity	100°F	Displaces
Primary Space Heating (Fresh Air Preheating)	Natural Gas	90°F	Displaces

dedicated to a particular heating load. The major benefit from a cascaded arrangement is that the heating system can deliver maximum heat with minimum geofluid production. The geofluid's temperature progressively drops as it proceeds through the heat exchanger cascade. The first heat exchanger supplies heat for the load requiring the highest temperature. The last heat exchanger is for the load requiring the lowest temperature.

Of the seven heating loads presented in Table 12-1, three were added to the system design as a result of the application analysis. The laundry drying and the two primary space heating loads were included because they were readily accessible systems which could be easily retrofitted. And because these loads fit into the cascaded heat exchanger design, their inclusion would not require additional geothermal production.

13. OBTAINING USER COMMITMENT

This section is not applicable to the T-H-S project.

14. SYSTEM LOADS AND DESIGN OVERVIEW

14.1 Natural Gas Loads

The T-H-S Memorial Hospital's natural gas profile prior to the geothermal retrofit is shown in Figure 14-1. This profile was determined by using heating degree day data to correct actual 1980 gas consumption to an average year. The profile shows that the consumption ranged from a summer low of 590 MCF (thousand cubic feet) to a January high of 1740 MCF. The yearly consumption totaled 11,500 MCF. Of this total, approximately 4500 MCF was for space heating, approximately 2800 was for 130°F domestic water heating, and the remaining 4200 MCF was for 180°F domestic water heating, laundary linen drying, cooking, and miscellaneous gas loads.

14.2 Overview of Heating System Prior to Geothermal Retrofit

The hospital's heating system prior to the geothermal retrofit is shown schematically in Figure 14-2. This schematic includes the domestic water heating system, the primary and secondary space heating systems, and the linen tumble dryers. The miscellaneous systems not retrofitted with geothermal are not shown.

Figure 14-2 shows the pre-existing heating system to rely primarily on natural gas-fired equipment. Low pressure boilers produce steam which is passed through steam-to-water or steam-to-air heat exchangers to meet the particular water or

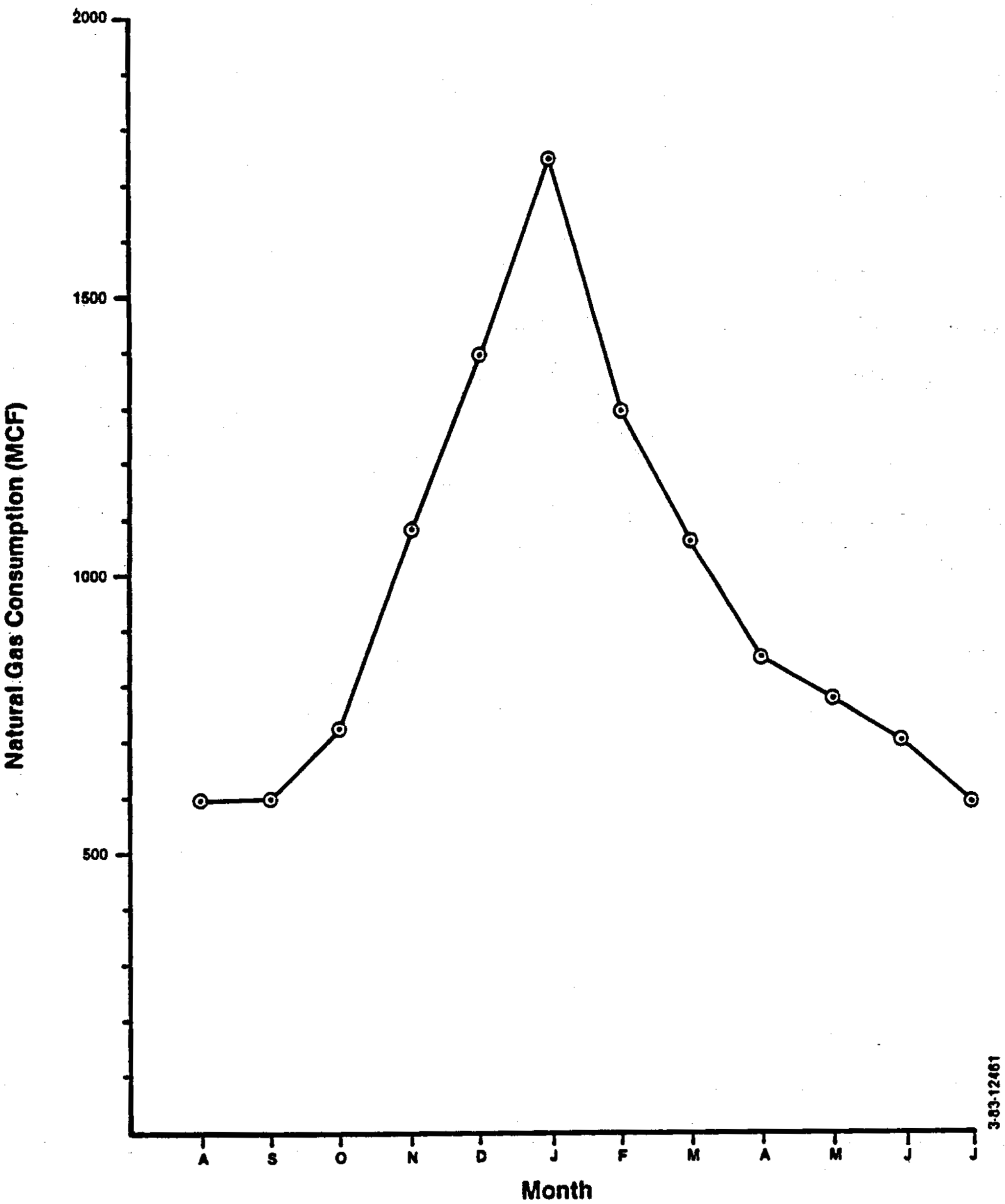


Figure 14-1 Average Monthly Natural Gas Consumption Prior to Geothermal Retrofit

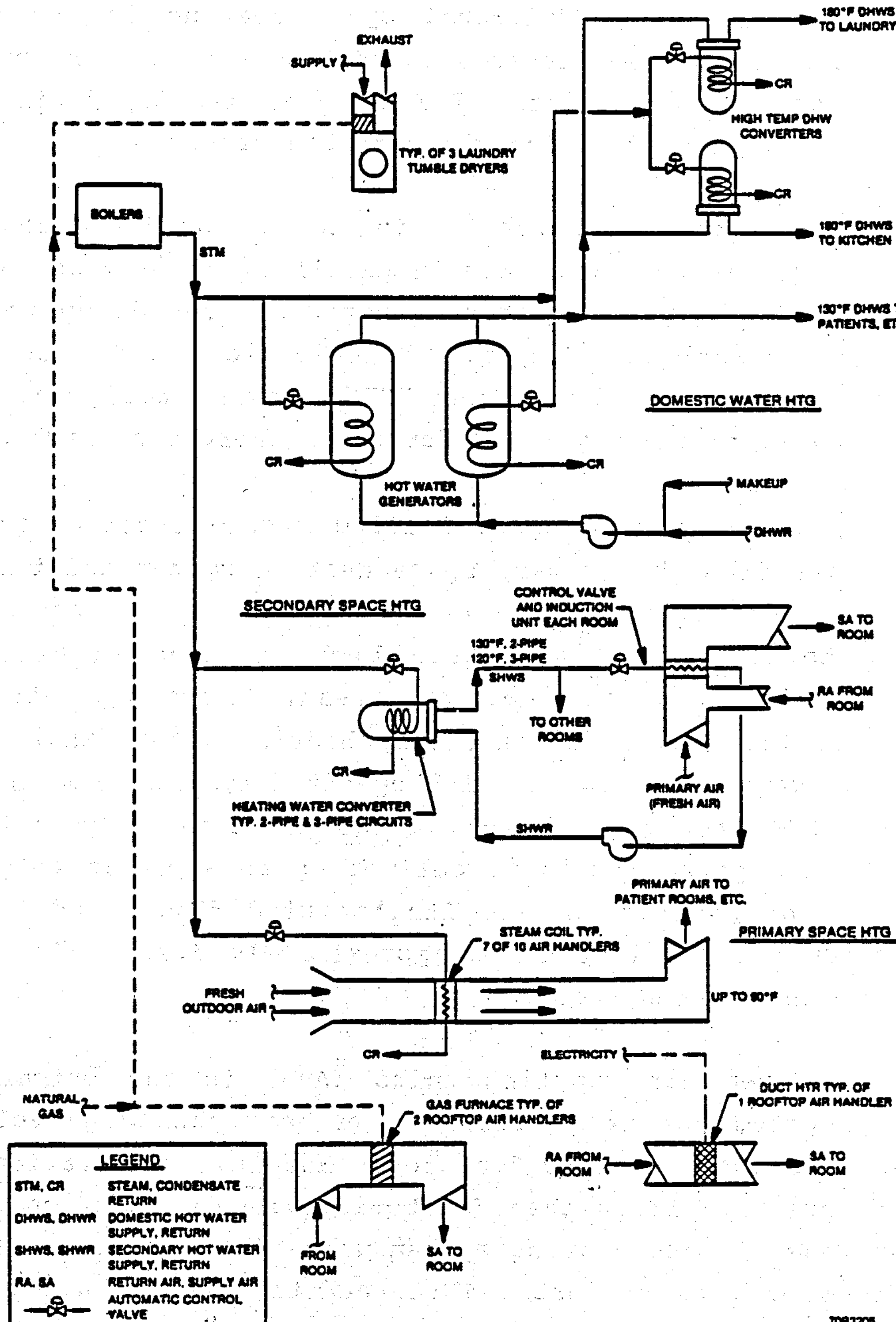


Figure 14-2 T-H-S Memorial Hospital Heating System Overview

space heating load. Additional space heating is accomplished with natural gas-fired furnaces in rooftop air handling units and with electric duct heaters. The hospital laundry facility also uses natural gas to fire its three tumble dryers.

The domestic water heating system used two 650 gallon hot water generators, operated in parallel, to provide 130°F hot water for the hospital. These generators provide up to 1.01×10^6 BTUH (Btu/hr) for heating the domestic water. On demand, part of the domestic hot water (DHW) leaving the generators is boosted to approximately 180°F for the laundry and kitchen.

The secondary space heating system receives preheated outdoor air from the primary space heating system and tempers it to maintain individual room or zone comfort. Induction units similar to that shown in Figure 14-3 are used in all patient rooms and also in many non-patient areas. A two-pipe circuit and three-pipe circuit supply secondary heating water (SHW) to individual induction units. A valve operated by the room thermostat controls SHW flow through the induction units. Operating data show the two pipe circuit to deliver up to approximately 0.46×10^6 BTUH for heating the hospital's third floor, and the three pipe circuit to deliver up to approximately 1.25×10^6 BTUH for the first and second floors.

Seven air handling units (AHU) in the primary space heating system use steam coils to preheat the large volumes of outdoor air (OA) required for proper hospital ventilation. Much of this primary air is then fed to individual induction units in the secondary space heating system where it is tempered to maintain room or zone comfort. Three additional AHUs use gas-fired furnaces or electric duct heaters to provide comfort for their respective zones. Operating data show these ten primary air handlers, summarized in Table 14-1, to provide up to approximately 2.06×10^6 BTUH of space heating.

TABLE 14-1. SUMMARY OF PRIMARY SPACE HEATING AIR HANDLERS

AHU	Location	Percent Outside Air	Heating Mechanism	Area Served	Secondary Heating Method
1	Boiler Room Roof	100	Steam Coil	First Floor (Surgery)	Room Steam Coils
2	Penthouse ME[1] Room	100	Steam Coil	First and Second Floors	3-Pipe SHW Circuit (Induction Units)
3	Penthouse ME Room	100	Steam Coil	First and Second Floors	3-Pipe SHW Circuit (Induction Units)
4	Central Supply Room	100	Steam Coil	First Floor (Kitchen)	None
5	Penthouse ME Room	100	Steam Coil	Third Floor (Patient Rooms)	2-Pipe SHW Circuit (Induction Units)
6	Penthouse ME Room	10	Steam Coil	Third Floor (Nurses Station, Hallways)	None
7	First Floor Roof	0	Electric Duct Heaters	First Floor (Administrative Offices, Laboratories)	None
8	First Floor ME Room	0	Steam Coil	First Floor (Kitchen)	None
9	First Floor Roof	0	Natural Gas Furnace	First Floor (Radiology, Corridors)	None
10	Third Floor Roof	0	Natural Gas Furnace	Third Floor (Corridor)	None

[1]ME = Mechanical Equipment

Source: Radian 1980

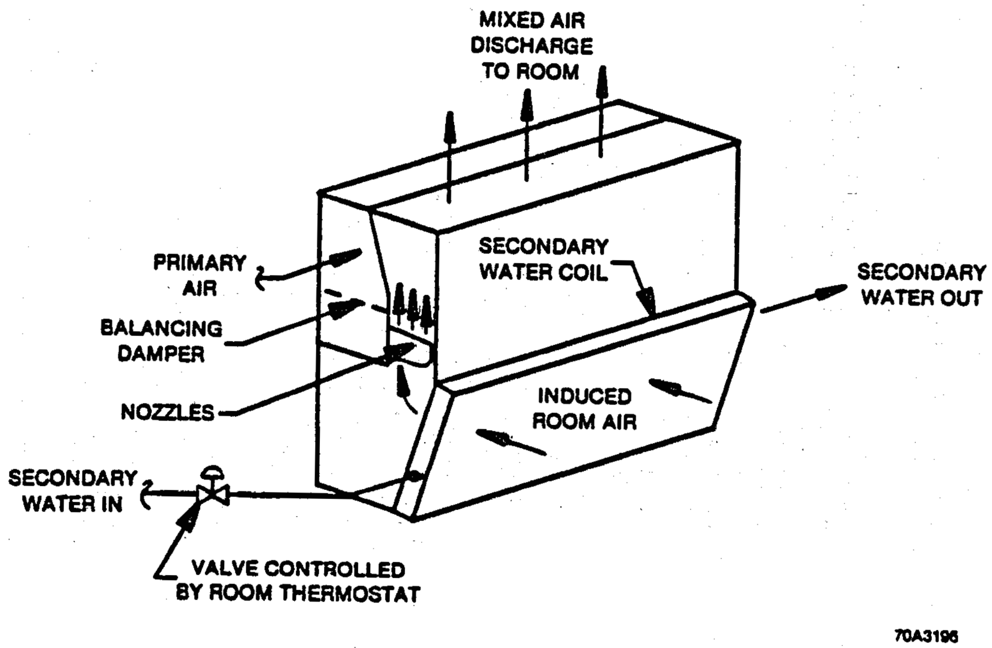


Figure 14-3 Typical Induction Unit in Secondary Heating System

14.3 Overview of Geothermal Retrofit

The design strategy for the geothermal retrofit was to intercept the hospital's heating system upstream of the steam, gas, or electric heating components. These components would be left operational with their controls modified so they would operate as a backup system. Therefore, the pre-existing system would supply heat only if the geothermal system could not meet heating demand.

As shown in Figure 14-4, the geothermal heating design consists of a production system, a domestic water heating system, two secondary heating water (SHW) systems, and a primary heating water (PHW) system. An overview schematic of this design's interface with the pre-existing system appears in Figure 14-5. Comparing Figures 14-2 and 14-5 shows that the geothermal system operation resembles that of the natural gas system, except that the geothermal well replaces the natural gas boilers.

More detail descriptions of the geothermal design are presented in Sections 15 through 19. A site plan showing the well location is presented in Figure 1-3.

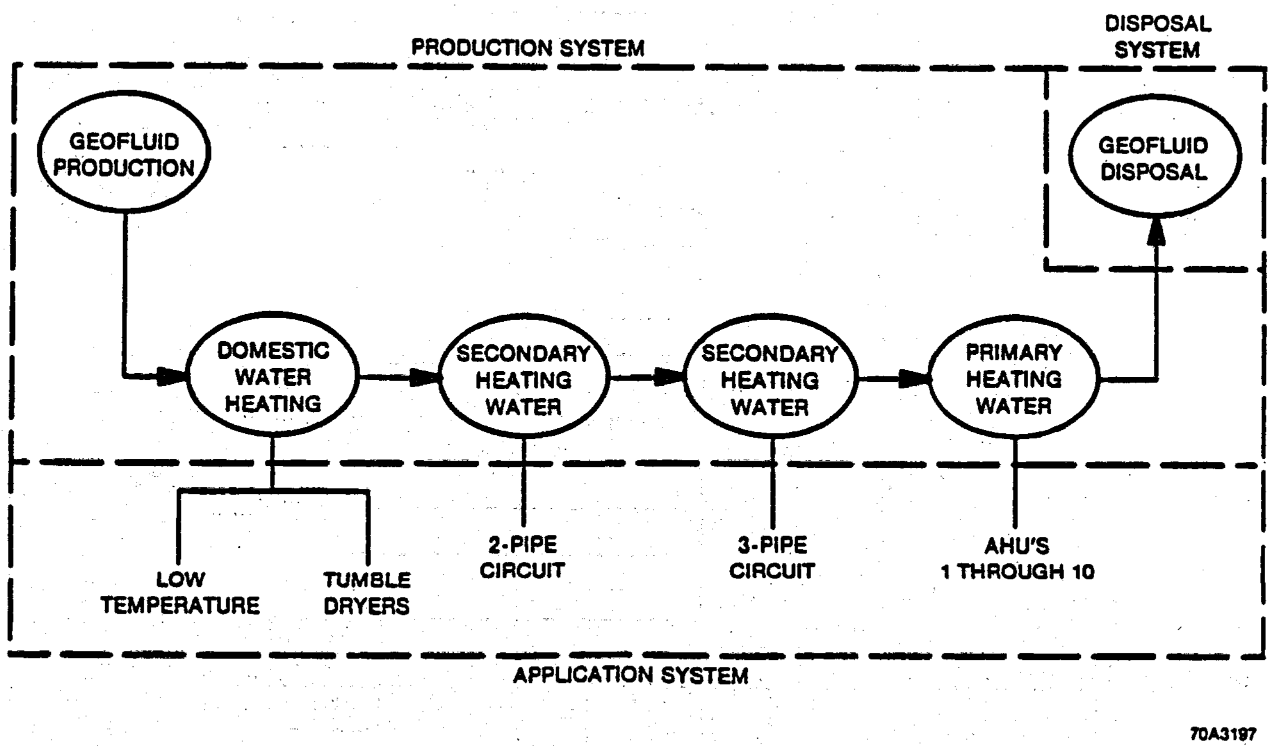


Figure 14-4. Geothermal Heating System Overview

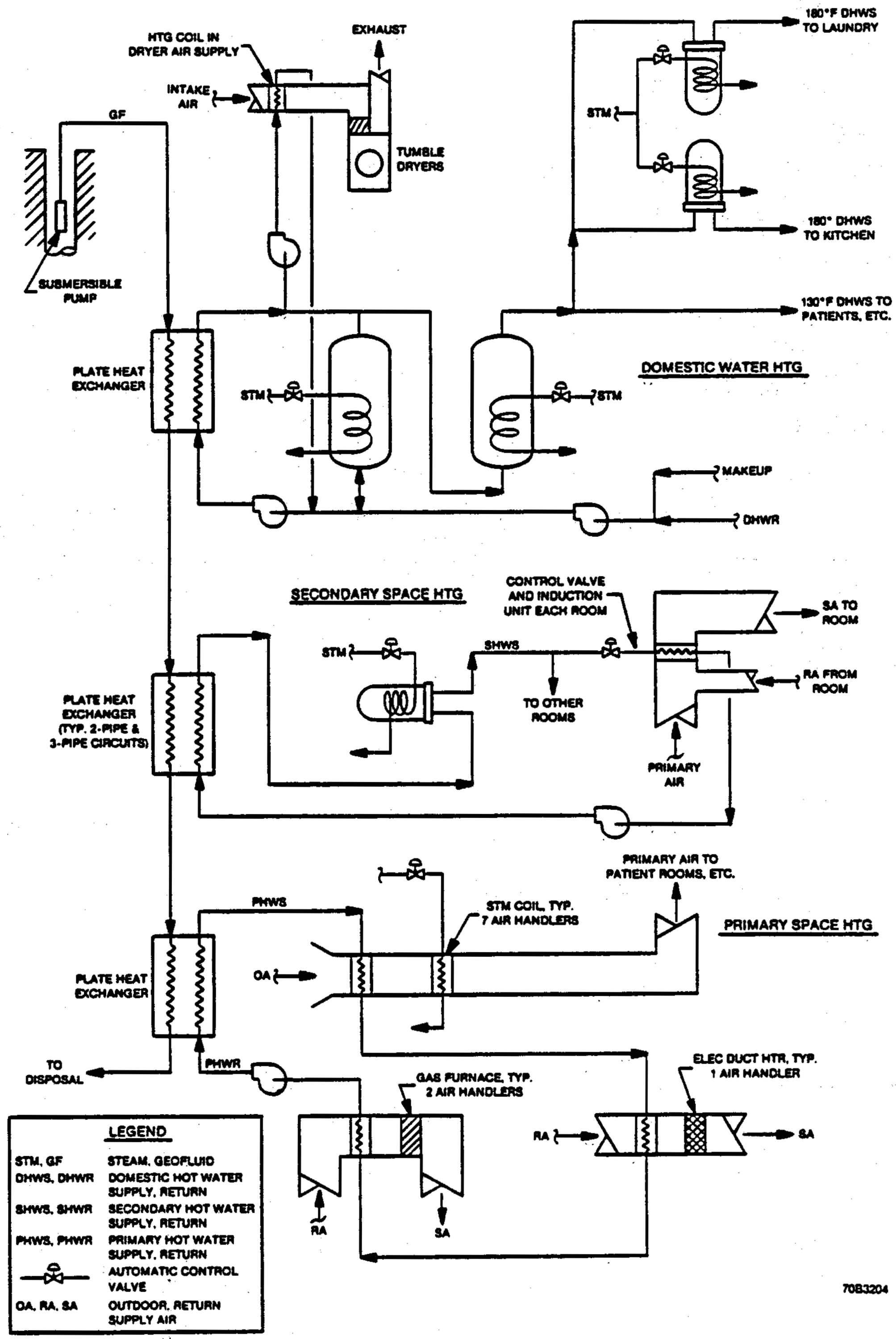


Figure 14-5 Overview Schematic of Geothermal Retrofit

15. PRODUCTION SYSTEM DESIGN

The production system in the T-H-S Memorial Hospital's geothermal heating system is defined to include the production well, the submersible pump and its control system, the plate heat exchangers, and the associated geofluid valving and piping. This section includes a discussion of all these elements except the production well, which is discussed in Section 8. Because preventing corrosion and scaling is critical in geothermal systems, this section also discusses the steps taken to recognize and remedy these problems.

15.1 Materials Selection and Scaling Prevention

Corrosion and scaling in geothermal systems have shown themselves to be critical problems. If addressed properly during design, these problems can usually be overcome economically. If not addressed properly, they can create many operation and maintenance (O&M) difficulties and result in very high O&M costs.

To determine the corrosion, scaling, and other pertinent characteristics of the T-H-S geofluid, five fluid analyses were performed. A summary of these analyses is presented in Table 15-1. The summary shows the fluid to have a total dissolved solids (TDS) concentration of about 4000 mg/l, with the major contributor being sulfates. The total suspended solids (TSS) concentration is relatively low at approximately 16 mg/l. Hydrogen sulfide, which is vaguely detectable by smell, is present at concentrations of approximately 0.2 mg/l.

TABLE 15-1. SUMMARY OF T-H-S GEOFLUID ANALYSES

	Drill Stem[1]	Pumped[2]	EWL[3]	PNL[4]	SWL[5]	Mean	Standard Deviation	95% Confidence Limits Lower	95% Confidence Limits Upper
pH	7.25	7.33	7.15	6.16[6]	7.2	7.02	0.484	6.75	7.28
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Cl^-	114	87	84	95.7	82.7	92.7	12.95	85.5	99.9
HCO_3^-	222	168	171	164.3	128	170.7	33.55	152.0	189.3
CO_3^{-2}	0	0	0	0	0	0	0	0	0
SO_4^{-2}	2054	2256	2410	2585	2395	2340	197.99	2230	2450
H_2S			0.2	<1	0.05	Range 0.2 - 0.05			
NH_3			1.2	1.2	1.19	1.20	.006	1.19	1.20
SiO_2	31	40	40	35.2	39.7	37.2	4.01	34.95	39.41
Na+K (as Na)	765	815	874	1049	1000	901	121	834	968
Mg	37	35	39	46.3	41.4	39.7	4.37	37.3	42.2
Ca	268	278	284	334	332.7	299.3	31.6	281.8	316.9
TDS	3605	3925	4037	4235	3862	3933	232	3804	4061
TSS	-	-	-	16	-	16	-	-	-

[1]Drill steam test - 18 June 1979
[2]Pump test - Sampled after 23 hrs production at 307 gpm. Temp = 152.6°F, 28 July 1979.
[3]Sampled at natural flow conditions - 29 August 1979. Temp = 140°F.
[4]Sampled at natural flow conditions - 19 October 1979.
[5]Sampled at natural flow conditions - 19 August 1979.
[6]Wellhead Measurement
1,2,3 Analyzed by Edna Wood Laboratories, Inc.
4 Analyzed by Pacific Northwest Laboratories.
5 Analyzed by Southwestern Laboratories.

Using these analyses and Radian's geothermal corrosion and failure analysis experience [Ellis and Conover 1980; 1981], candidate materials of construction were categorized as not acceptable, not recommended, provisionally acceptable, acceptable, or recommended. Table 15-2 presents the pertinent results for various standard materials of construction. Using these results, the materials in Table 15-3 were selected for the geofluid stream. Materials testing done during system operation (Section 35) confirmed these selections. Note that these materials restrictions apply only to components wetted by the geofluid. Standard heating system materials were used otherwise.

In addition to corrosion, scaling caused by the geofluid is a critical problem which can inflict high maintenance costs on a geothermal system. In its least severe forms, scaling fouls heat exchanger surfaces and reduces the heat delivered to the system. In more severe cases, scaling can plug pumps, piping, and heat exchangers, and can render a system inoperative.

TABLE 15-3. PRODUCTION SYSTEM MATERIALS SELECTED FOR T-H-S DESIGN

Component(s)	Material Selected
• Production Piping (in the well)	Schedule 80 carbon steel[1]
• Surface Piping	Schedule 80 CPVC
• Valves	CPVC body with 300 series stainless shaft and Buna-N or Viton elastomerics
• Heat Exchanger Plates	Type 316 stainless steel
• Pump Bowls and Impellers	Ni-Resist[2]
• Pump Shaft	Monel K500[2]
• Pump Bearings	Leaded Red Bronze[2]

[1]Carbon steel suitable in this application since pump is expected to be replaced at approximately 7 year intervals, at which time tubing may be inspected and replaced as needed.
[2]Standard materials in selected submersible production pump.

TABLE 15-2. SUMMARY OF MATERIALS EVALUATIONS FOR T-H-S DESIGN[1,2]

Part	Material of Construction	Corrosion Comments	Design Comments
Pipe/Tubing	Carbon steel (mill scale free)	Oxygen-free corrosion rates acceptably low. Oxygen contamination greatly accelerates corrosion (by up to ten-fold).	Provisionally acceptable Must exclude oxygen. Avoid threaded joints because of maintenance problems. Protect exterior.
	Carbon steel (with mill scale)	Mill scale cathodic to clean metal. Will cause rapid pitting of pipe at defects in scale.	Not Acceptable
	Galvanized	Zinc not protective at operating temperature. May promote rapid pitting.	Not Acceptable
	Stainless Steel	See Heat Exchanger Plates below	Acceptable
	Plastic Pipe	Corrosion resistance good. Temperature resistance of CPVC, PVDF, and polypropylene suitable. Some fiberglass reinforced piping carries risk of fraying after extended service if not specified closely. PVC temperature resistance not suitable.	Recommended CPVC likely most cost effective.
	Copper	H_2S attacks copper, and copper-zinc alloys risk H_2S dezincification.	Not Acceptable
Valves	Carbon steel body and trim.	Trim life not accepable. Not Recommended.	Probable failure trim related. Valves should be easy to remove and maintain. Wafer valves recommended.
	Carbon steel body - AISI 300 series trim.	Trim life satisfactory. Acceptable.	
	Carbon steel body - AISI 400 series trim.	Pitting of trim probable. Not Acceptable.	Gate/Globe valves not recommended because of plug/stem corrosion problems and reciprocating stem motion which causes seal failure.
	Brass[2] body with brass trim and stainless steel stem.	Corrosion rates probably satisfactory. Cathodic to steel piping. Potential galvanic effect probably not severe.	Ball or Butterfly valves recommended. Minimal seal problems. AISI 300 series or elastomeric seat (Buna N, Viton, TFE), satisfactory.
	Plastic body with plastic trim	Corrosion resistance good. Temperature resistance of CPVC, PVDF, and polypropylene suitable. Recommended.	Gate valves. Potential stem/seal problems.

(Continued)

TABLE 15-2. SUMMARY OF MATERIALS EVALUATIONS FOR T-H-S DESIGN (Continued)

Part	Material of Construction	Corrosion Comments	Design Comments
Heat Exchanger Plates	T304 Stainless	Low uniform corrosion rates. Slight possibility of stress corrosion cracking. Can be acid cleaned.	Plates should be stress relieved after forming. Acceptable.
	T316 Stainless	Low uniform corrosion rates. Risk of stress corrosion cracking less than for T304. Can be acid cleaned.	Plates should be stress relieved after forming. Recommended.
	Incoloy 825	Should be equivalent to T316 except immune to stress corrosion cracking. Can be acid cleaned.	Stress relieving not required. More expensive than T316. Acceptable.
	Titanium	Should resist pitting and crevice corrosion. Not susceptable to stress corrosion cracking. Very low corrosion rates compared to T304. Can NOT be acid cleaned.	Scratching with steel tools or brushes may cause pitting. Expensive. Not recommended.
Pump Bowls	Cast Iron	Uniform corrosion rate probably low. Provisionally Acceptable.	Must exclude oxygen.
	Ni-Resist Cast Iron	Superior to cast iron. Recommended.	May be cathodic to Monel K500 (see shafts below).
	Coated cast iron or steel	Numerous proprietary materials available. General geothermal experience is that many coatings give good service for three to five years. Acceptable.	Damage to coating may cause accelerated pitting. Extreme care in handling and installation required.
Pump Impellers	Aluminum bronze	Probably low corrosion rate. Immune to stress corrosion cracking. Recommended.	Potential for galvanic corrosion of impellers if coupled to 17-4PH.
	Aluminum nickel bronze	May corrode more rapidly than nickel free alloys. Acceptable.	Little galvanic effect if coupled to Monel K500.
	Copper-zinc alloys	Great risk of dezincification of even "resistant alloys." Not Acceptable.	
	Alloy 20 CN-7M	Slight risk of stress corrosion cracking. Do not allow oxygen contamination. Acceptable.	Little galvanic effect if coupled to 17- 4PH. If coupled to Monel K500 may cause pitting of Monel K500.
	Ni-Resist Cast Iron	See pump bowls above. Recommended.	

(Continued)

TABLE 15-2. SUMMARY OF MATERIALS EVALUATIONS FOR T-H-S DESIGN (Concluded)

Part	Material of Construction	Corrosion Comments	Design Comments
Pump Shafts	Monel K-500	Design restriction must be met. Widely used in oil patch. Recommended.	Shaft must be electrically coupled to appreciable area of more active metal such as cast iron or carbon steel bowls.
	17-4PH	Resists localized attack in T-H-S fluid. Recommended.	
Pump Bearings	SAE 660 or other high lead bronze bearings	Experience in other low temperature (<212°F) service indicates this material satisfactory at T-H-S levels of H_2S. Acceptable.	
	Other bearing materials such as TFE, Nylon 6/6.	Other geothermal lineshaft pumping experience indicates TFE resists corrosion and has temperature resistance to above 300°F for lineshaft bearings. Acceptable.	
Shaft Coupling		Component usually stainless steel. Satisfactory unless AISI 400 series used.	
Shaft/ Impeller Coupling			Taperlock - crevice corrosion could cause rapid failure due to slippage of impeller and gauling of shaft. Split ring and key - preferred because less susceptable to crevice corrosion. Key should be cathodic to impeller and shaft.

1. Evaluations performed during design phases. Materials testing during system operation documented in Section 35.

2. Retrospective note: Under valves, "brass" should be restricted to leaded red bronzes, aluminum bronzes and aluminum-nickel bronzes only. Under pump impellers, leaded red bronze is probably acceptable. Please refer to section 35 for detailed corrosion test results.

Source: Updated from Radian 1979.

To quantify the scaling potential of the T-H-S geofluid, three scaling analyses were performed. In examining gypsum and silica scaling potential, the actual ion concentration products in the T-H-S geofluid were compared to the solubility products over the range of temperature expected in normal operation. If the actual ion concentration products of the T-H-S fluid are less than the solubility products, then scaling is thermodynamically forbidden. Figures 15-1 and 15-2 graphically present results of the gypsum and silica analyses. These figures showed that a slight chance for gypsum scaling exists, but that silica scaling is not expected.

The tendency for calcium carbonate ($CaCO_3$) scaling was determined by comparing the pH of geofluid samples with the Lowenthal-Marais-Langelier calcium carbonate saturation pH [Lowenthal and Marais 1976] of the T-H-S geofluid. It was found that the pressurized wellhead geofluid samples were undersaturated with calcium carbonate indicating no potential calcium carbonate scaling problem. But as the dissolved carbon dioxide off-gased from the samples, the pH increased until a potential calcium carbonate scaling problem was indicated.

To quantify this problem, wellhead pH and ionic species concentrations were used as inputs to a comprehensive computerized aqueous equilibrium program. The partial pressure of carbon dioxide in the reservoir and the system operating pressure required to prevent off-gasing were calculated. From this analysis it was concluded that maintaining the geofluid above 5-10 psig would keep the carbon dioxide in solution, thus keeping the fluid pH low enough to prevent calcium carbonate scaling.

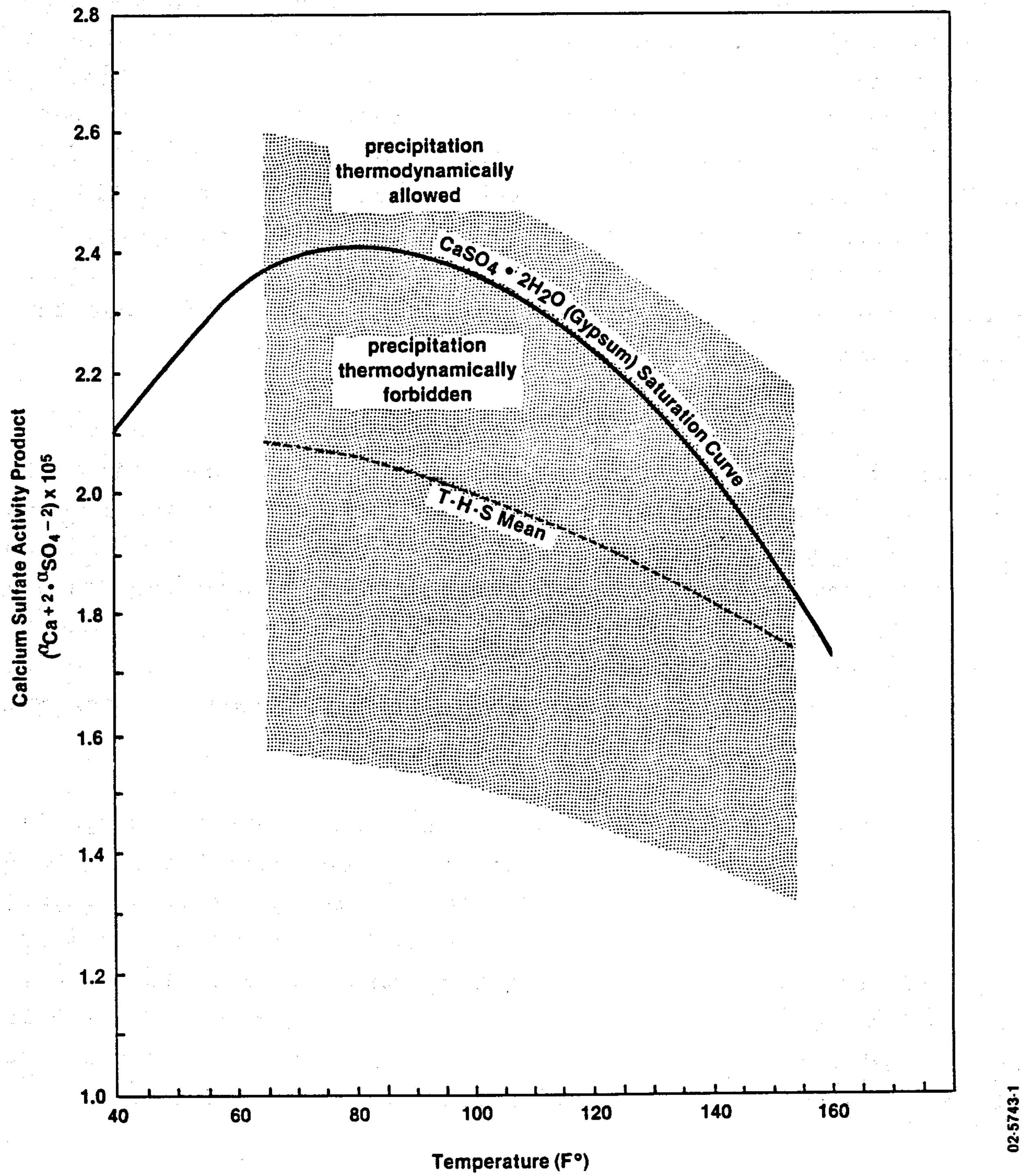


Figure 15-1 Gypsum Scaling Tendency in T-H-S Fluid (Shaded area denotes ± 2 sigma ranges)

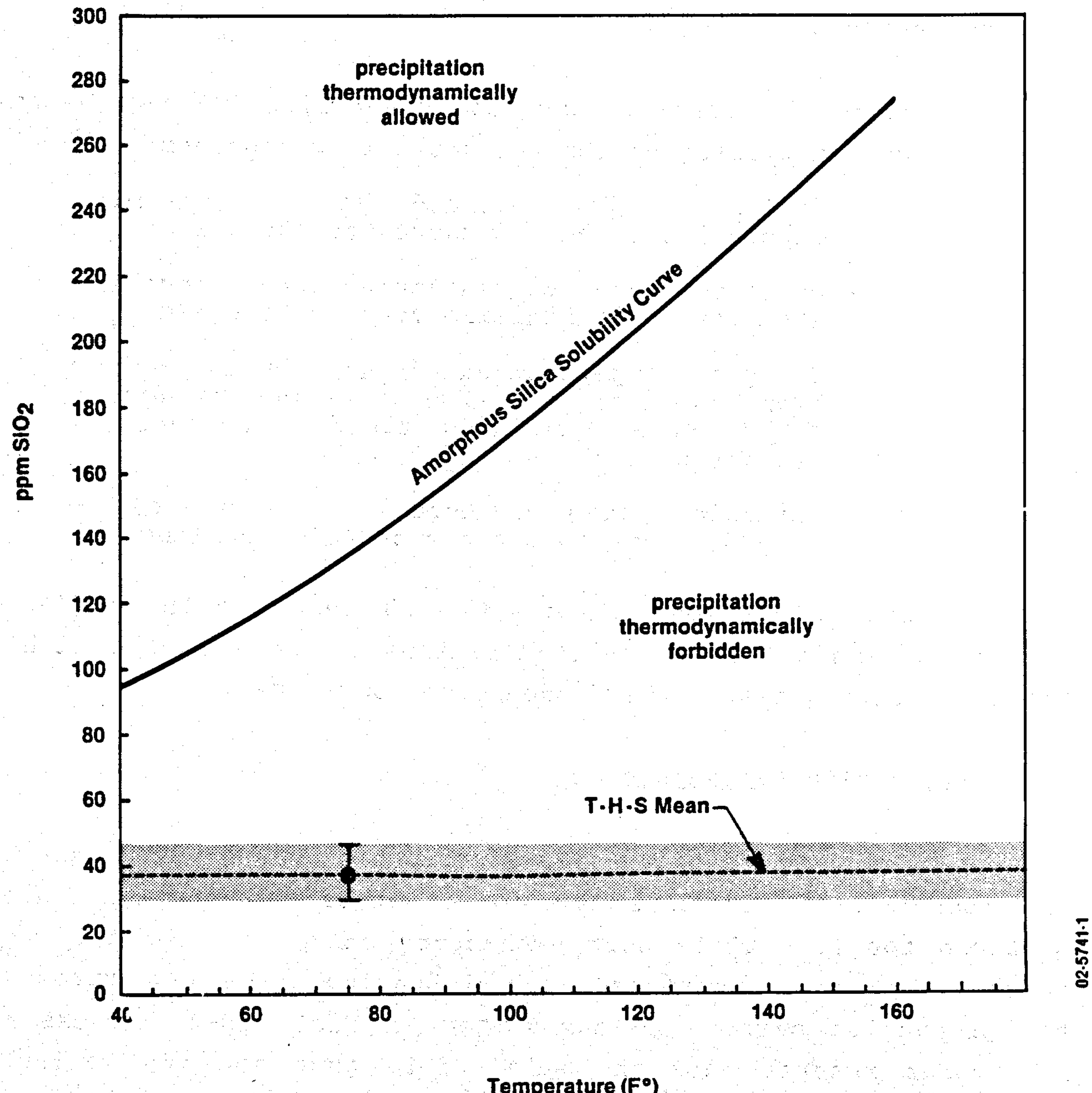


Figure 15-2 Silica Scaling Tendency at T-H-S (Shaded area denotes ± 2 sigma ranges)

As discussed in Section 26 and Appendix D, inspection of the completed T-H-S system after seven months of normal operation disclosed no evidences of scaling by gypsum, silica, or calcium carbonate.

From the corrosion and scaling analyses also grew some important design strategies for the geofluid components:

- Design a closed geofluid system to minimize oxygen intrusion and therefore corrosion;
- Minimize use of valves having a reciprocating stem action to minimize stem scale buildup;
- Use plate type heat exchangers, which provide high levels of corrosion resistance at acceptable costs, and high fluid turbulence to discourage scaling; and
- Maintain system pressure at approximately 8 psig or above to discourage $CaCO_3$ scaling.

As discussed in Sections 26 and 35, adherence to these design strategies and materials recommendations has provided a highly reliable heating system which should be long-lived.

15.2 Production System Design

A schematic of the T-H-S production system is presented in Figure 15-3. In this system, a submersible pump produces geofluid for four plate heat exchangers which transfer the geothermal heat to the various hospital heating loads. Features of the production system are summarized in Table 15-4. Those of particular interest are the submersible pump and its variable frequency drive (VFD) control system, the airtight wellhead with a vacuum breaker, and the Btu meter.

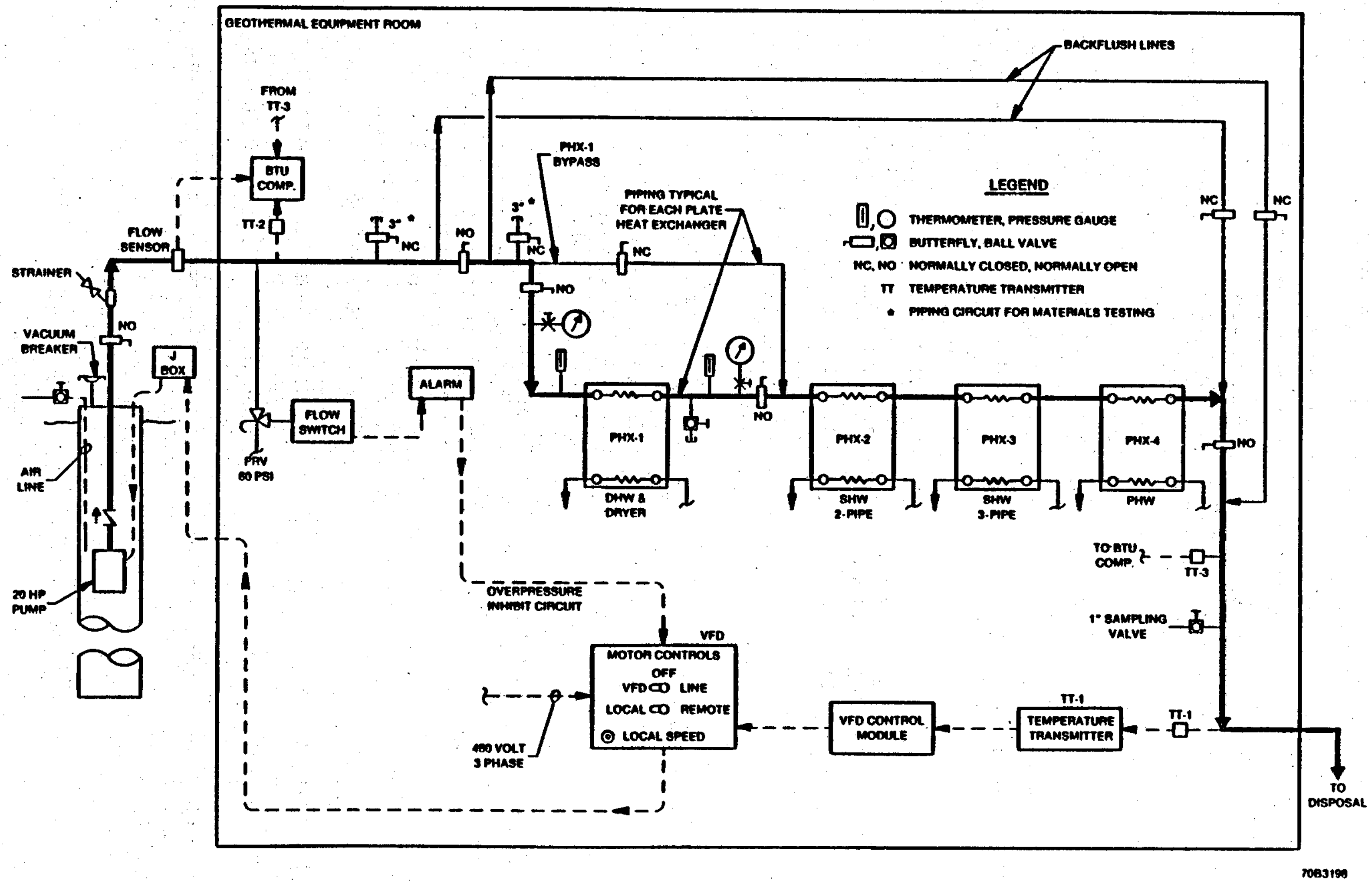


Figure 15-3 Production System Schematic

TABLE 15-4. PRODUCTION SYSTEM DESIGN FEATURES

Design Feature	Comments
Submersible pump	Suitable materials of construction, easily installed and pulled.
Air line	Enables drawdown and well productivity to be tracked
Air tight Wellhead with Vacuum Breaker	Limits the air changes in the well bore as pumping rates vary, thereby reducing oxygen in well bore and its corrosive effects
Variable Frequency Drive Control System	Varies production rate to match heating demand, thereby conserving pumping energy, conserving the geothermal resouce, and minimizing environmental impact
Btu Computer	Measures instantaneous flow rate (gpm), temperature drop, and heating rate (Btu/hr), and totalizes flow (gal) and heat delivered (Btu)
Plate Heat Exchangers	Economically provide high corrosion resistance, high heat transfer coefficients, close approach temperatures, scaling resistance, easy cleaning, and minimal floor space requirements
Backflush lines	Enables heat exchangers to be routinely backflushed to discourage scale buildup

The submersible pump is a five-stage Centrilift S-175 with a twenty horsepower motor. Its production tubing is 4 inch schedule 80 carbon steel pipe, with schedule 80 being chosen to provide additional corrosion allowance. The pump's speed is controlled by the VFD control system to produce from 35 to 160 gpm. This control system operates by sensing the geofluid system discharge temperature and adjusting the pump speed according to that temperature. Since the discharge temperature is a direct measure of the heating demand, the flow rate is automatically adjusted according to demand.

Aside from providing an important control function, this VFD system also has other benefits [Ferguson and Green 1981]. Since the pumping power varies as the cube of the speed, the VFD saves significantly on parasitic power. An economic analysis showed that the VFD should pay for itself in electricity savings within its expected fifteen year life. Also, since only that fluid required to meet heating demands is produced, the geothermal resource is conserved. Similarly, environmental impacts are lessened since less geofluid must be disposed. In addition, although VFD's have shown themselves to be reliable, a VFD bypass which enables the pump to run "across the line" is provided.

Another notable production system feature is casing and production tubing corrosion protection provided by the airtight wellhead assembly. By sealing the cable and its penetration through the wellhead, and by installing a vacuum breaker, the wellbore serves as a compression tank. Only during those few instances of peak heating demand, when the pump is running at full speed and the water level is lowest, will the vacuum breaker open to allow air into the wellbore. And this intrusion is minimal because the pressure inside and outside the wellbore is nearly equal. At all other times, the vacuum breaker is closed and the wellbore becomes a closed system.

The third especially notable feature of the production system is the Hersey Model 7003 Btu meter. This microprocessor system uses a turbine flow meter and two temperature sensors to continuously monitor flow rate and temperature drop, and to compute total production (gal) and heat delivered (Btu). Each of these measurements--gpm, temperature drop, Btu/hr, gallons, and Btu's--can be digitally displayed on the face of the meter.

16. DISPOSAL SYSTEM DESIGN

Because discharge into the City's storm drainage system is an appropriate disposal method for the T-H-S system (Refer to Sections 6 and 36), the disposal system is simple. It consists only of approximately 420 feet of buried, uninsulated CPVC pipe and a backpressure valve. The backpressure valve's purpose is to maintain at least an 8 psig pressure within the geofluid production piping at all times. As shown in the scaling discussions in Section 15, maintaining this pressure prevents calcium carbonate ($CaCO_3$) scaling.

17. TRANSMISSION SYSTEM DESIGN

Because the production well is on the hospital premises and within 20 feet of the heat exchangers, this section of the report is not applicable to the T-H-S system.

18. DISTRIBUTION SYSTEM DESIGN

Because the production well is on the T-H-S Hospital premises and because the hospital is the sole user of the geofluid, this section is not applicable.

19. APPLICATION SYSTEM DESIGN

The application system for the T-H-S Memorial Hospital uses geothermal energy for domestic water heating, linen drying, and space heating. Four cascaded plate heat exchangers extract the geothermal heat for these uses. The first is dedicated to domestic water heating and linen drying. The second and third are dedicated to secondary space heating, and the fourth is dedicated to primary space heating. Each of these subsystems within the application system is described below.

19.1 Domestic Water Heating and Laundry Drying

In this system, shown schematically in Figure 19-1, the hot water generators (HWG) piping was modified for series rather than parallel operation. HWG-1 is maintained at its desired temperature by a thermostatically controlled pump which circulates DHW through heat exchanger 1 (HX-1). Thus, HWG-1 becomes the geothermally-heated storage tank and HWG-2 becomes, if needed, a boosting tank. However, since the previously existing DHW pump continually circulates DHW from HWG-1 to HWG-2, the boosting is seldom needed.

In the unlikely event of a heat exchanger leak, two methods of preventing geofluid (GF) from entering the DHW system are provided. The first is pressure differential. As shown in Figure 19-1, the entering geofluid pressure at full flow is

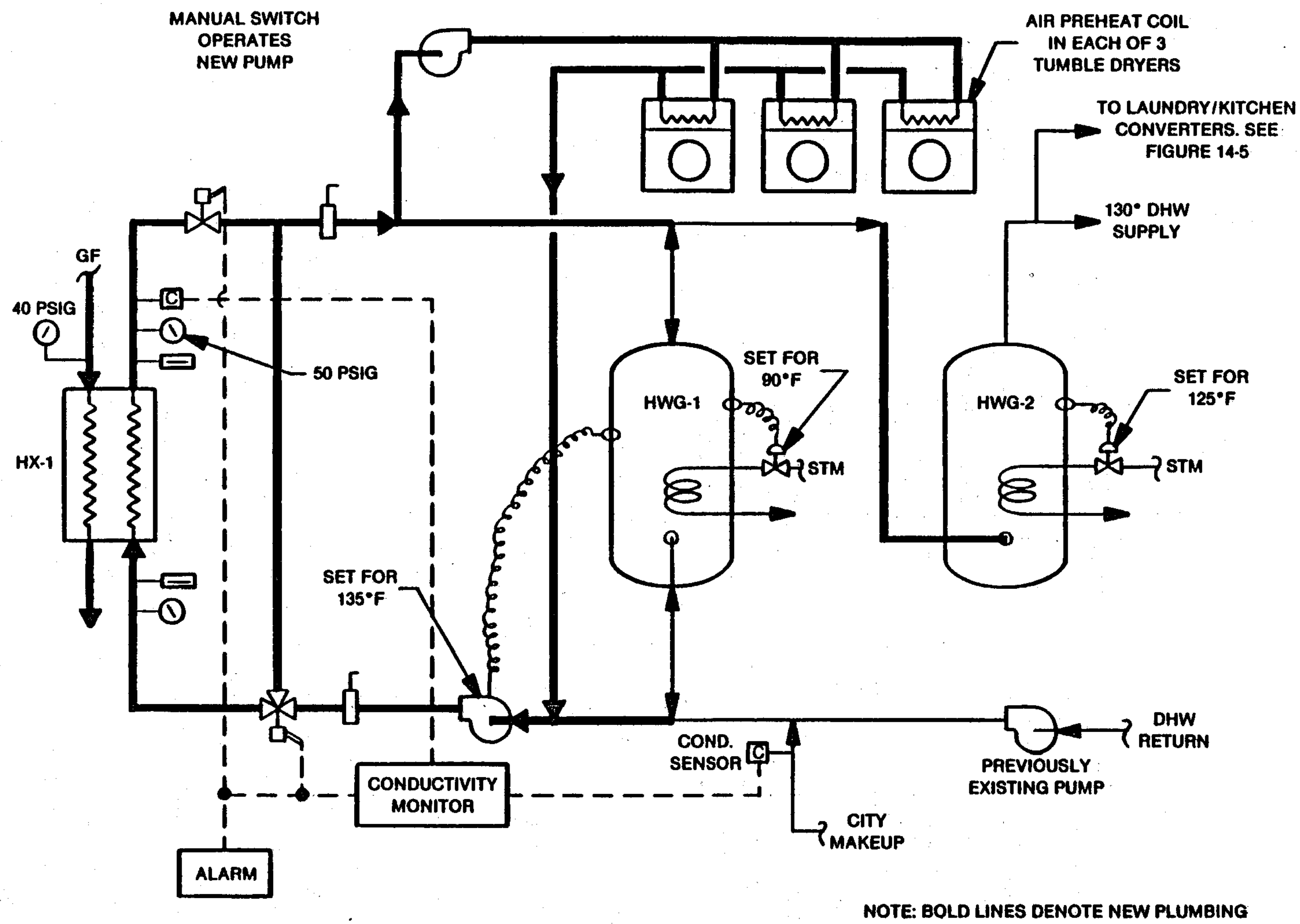


Figure 19-1 Schematic of Retrofit to Domestic Water Heating and Laundry Drying

approximately 40 psig and the exiting DHW pressure is approximately 50 psig. Therefore, a leak condition would result in DHW entering the geofluid stream rather than vice versa.

The second method uses a conductance probe in the heat exchanger exit stream to continuously monitor DHW conductance. If an intrusion occurs, two automatic valves bypass flow around the heat exchanger and an alarm alerts the operator to the condition. By checking the conductivity of makeup water with the same monitor, the operator can determine if the alarm is false. In either case, corrective action is defined in the system O&M manual [Ferguson and Green 1982].

It should be noted that, because the geofluid is relatively "clean," this monitoring is mainly used to prevent a detection of the <u>secondary</u> drinking water standards (those related to taste and other aesthetic qualities). Such a violation would occur at approximately 7.2 percent leakage*, while the monitor permits detection of a 5 percent leakage. Violation of the primary drinking water standards (those related to health and safety) would not occur until a 98 percent leakage occurred. The monitoring also therefore guards against violation of primary standards.

The tumble dryer air preheat uses a hot water coil installed in each of the three dryer air intakes to preheat air entering the dryers. A manually controlled pump is operated by laundry personnel to activate the air preheat when the dryers are being used.

---

*Mixture of geofluid and DHW containing 7.2 percent geofluid.

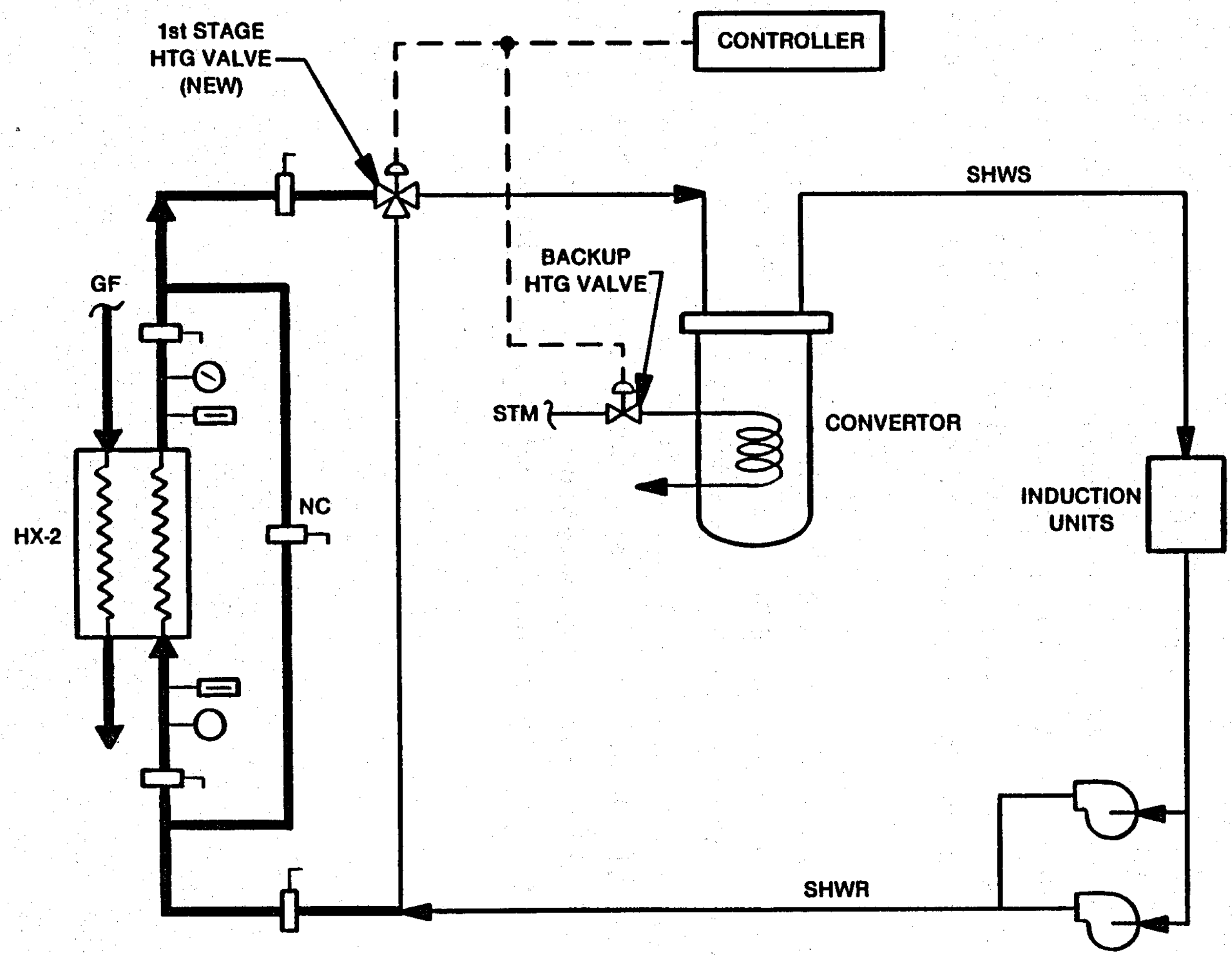
19.2 Secondary Space Heating

Most of the secondary space heating at the hospital is accomplished by circulating secondary heating water (SHW) through room induction units (refer to Figure 14-3). Two SHW circuits, a 2-pipe and a 3-pipe, exist. The 3-pipe circuit services the first and second floors, and the 2-pipe circuit services the third floor. A plate heat exchanger is dedicated to each because the circuits operate at different temperatures. The 2-pipe circuit requires up to 130°F SHW, while the 3-pipe circuit requires only 120°F.

Figure 19-2 is a schematic of the retrofit for the 2-pipe circuit. The 3-pipe circuit is similar. As shown, the SHW return is diverted as needed to the plate heat exchanger prior to reaching the convertor. The three way modulating valve controls the amount of water bypassing the heat exchanger according to heating demand. It is staged with the convertor's steam valve such that all the SHW flow passes through the heat exchanger (i.e., maximum heating) before the steam valve opens to provide supplemental heating. Only during about five percent of the heating season should the steam valve ever be needed for either the 2-pipe or the 3-pipe circuits.

19.3 Primary Space Heating

Retrofitting the primary space heating system with geothermal required installation of a primary heating water (PHW) circuit. The PHW in the circuit is a 70 percent water/30 percent propylene glycol solution. This anti-freeze solution provides protection in the event circulation is lost during freezing weather.



NOTE: BOLD LINES DENOTE NEW PIPING.
3-PIPE CIRCUIT SIMILAR TO THIS
SCHEMATIC FOR 2-PIPE CIRCUIT.

Figure 19-2 Schematic of Retrofit to Secondary Space Heating

The schematic in Figure 19-3 shows that the PHW circuit supplies heat to four air handlers in the penthouse mechanical room, to three other remote air handlers, and to three rooftop air handlers. The PHW retrofit uses two pumps in parallel to circulate PHW from a plate heat exchanger through the four penthouse air handlers. A third pump will extract some of the PHW leaving the penthouse to provide heat for the remote air handlers within the building. Similarly, a fourth pump will circulate PHW through the rooftop units. Each pump is thermostatically controlled to operate according to heating load. The overall pumping scheme is a primary/secondary system in which the (parallel) primary pumps also supply a zone (penthouse air handlers).

For each of the ten air handling units in the primary space heating system, a PHW coil was installed ahead of the existing heating component. The PHW flow through each coil is controlled with automatic valves. These valves are modulating in seven of the air handlers and are two position in the remaining three. In each case, the heating is staged so that backup heating is allowed only if the PHW cannot meet demand.

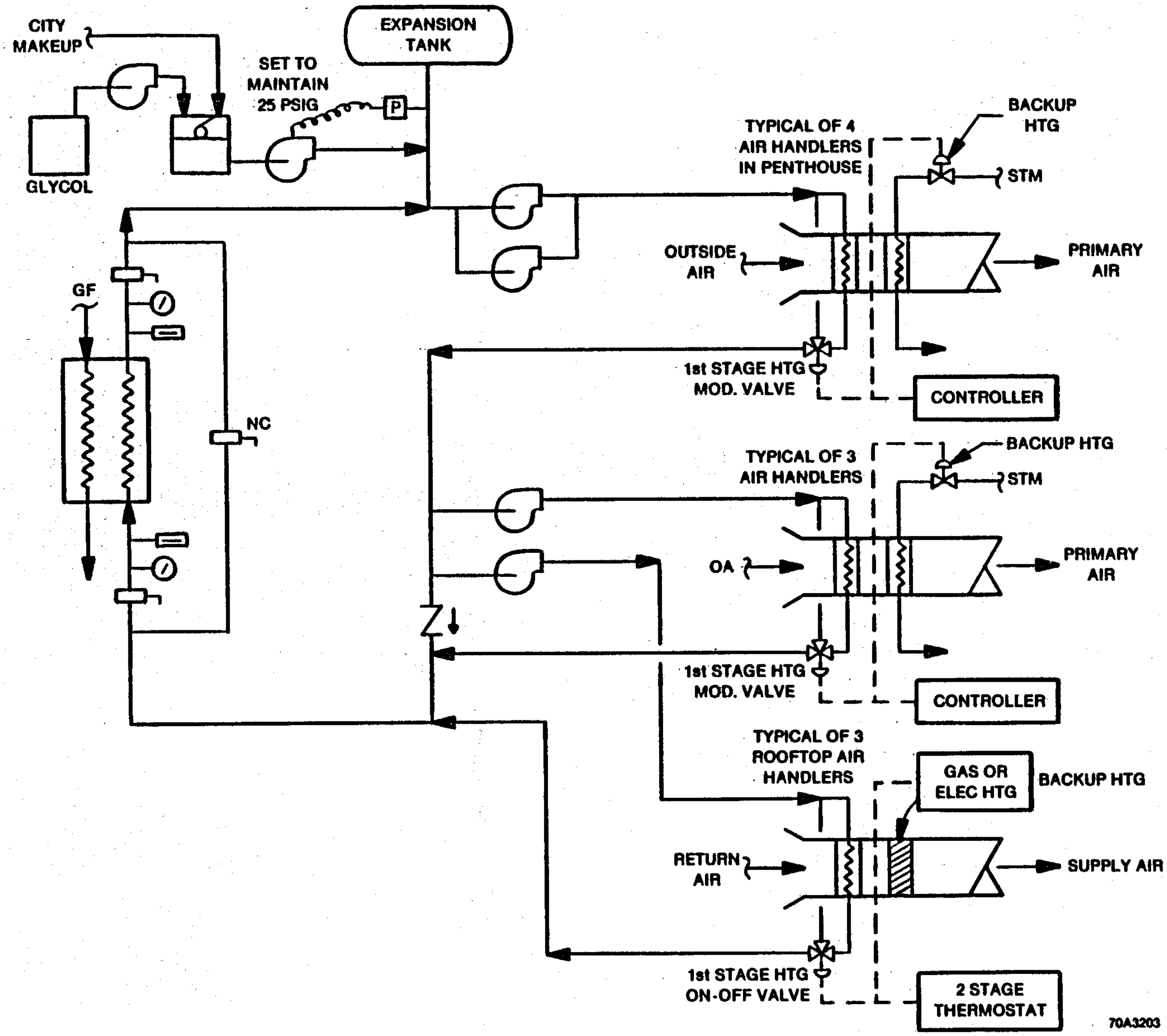


Figure 19-3 Schematic of Retrofit to Primary Space Heating

20. PRODUCTION SYSTEM CONSTRUCTION

Production system construction at the T-H-S Memorial Hospital was completed under two separate efforts. The first was the 1979 well drilling, completion, and testing. This effort is described in Sections 8 and 9. The second effort, which included installation of the production pump and its controls, occurred concurrently with the construction of the application system (1981/1982). Supplemental information, such as the construction system bidding and contractor selection, is therefore included with the application system construction in Section 24.

The production system as installed has only one deviation from that designed and specified in the original bid package. The Hersey Btu Meter was added to the production system during construction and installed under an Engineering Change Order (ECO). This addition enables the Texas Railroad Commission's production reporting requirements to be met. It also provides energy monitoring data and system troubleshooting aid.

Other parts of the production system are installed as designed and specified. The Centrilift submersible pump is set at 200 feet below the surface and uses a variable frequency drive (VFD) manufactured by Industrial Drive Maintenance. Also as designed, the VFD and its controls include a bypass feature to allow the pump to be run "across the line" in the event of a VFD failure.

21. DISPOSAL SYSTEM CONSTRUCTION

The T-H-S disposal system was constructed concurrently with the application system. Supplemental information such as the bidding and contractor selection is therefore included with the application system construction in Section 24.

Two deviations did occur from the disposal system which was designed and specified in the bid package. At the request of the City of Marlin, the disposal piping route was altered so that the geofluid would be discharged into the storm sewer system at a different curbside drainage box than originally planned. The City felt the new route would be less likely to impact street flooding occasionally experienced near the originally-targeted drainage box. Because the new route was suitable technically and required minor additional expense, the 420 feet of disposal piping was buried along the new route (refer to Figure 1-3).

The second construction modification was in a changeout of the backpressure valve (this valve maintains system pressure above 8 psig to discourage calcium carbonate scaling). A spring-loaded check valve of CPVC construction was originally specified for this component. However, this valve "chattered" excessively and was unacceptable. Technically, the valve was an underdamped mechanical system. The spring and ball check continually reciprocated in a piston-like fashion, damaging the ball seat after only a few days of operation. The ball check valve was replaced with a "Claval" Series 50-01 backpressure valve which has operated reliably and without incident.

22. TRANSMISSION SYSTEM CONSTRUCTION

Because the production well is on the hospital premises, a transmission system was not needed. This section is therefore not applicable to the T-H-S project.

23. DISTRIBUTION SYSTEM CONSTRUCTION

Because the production well is on the hospital premises and because the T-H-S Hospital is the sole user of the geofluid, no distribution system was needed. This section is therefore not applicable to the T-H-S project.

24. APPLICATION SYSTEM CONSTRUCTION

The construction plans and specifications for the T-H-S Memorial Hospital Geothermal Heating System included not only the application system, but also the disposal system and part of the production system (excluding well). Therefore, the bidding and contractor selection process discussed below applies to the production and disposal systems as well as the application system. However, the construction modifications described below focus only on the application system. Construction phase modifications for the production and disposal systems are discussed in Sections 20 and 21, respectively.

24.1 Bidding and Contractor Selection

Construction of the T-H-S system was predominantly of a mechanical nature. Consequently, a mechanical contractor was sought to operate as a prime contractor and to employ the necessary general, well pump, electrical, and controls subcontractors.

An open bidding process, summarized in Figure 24-1, was used to solicit candidate bidders. The "Notice to Bidders" was published in four area newspapers for two weeks prior to the start of the bid period. At the start of the bid period, plans and specifications were distributed to central plan rooms of the F. W. Dodge Information Systems and the Association of General Contractors of America, Inc.

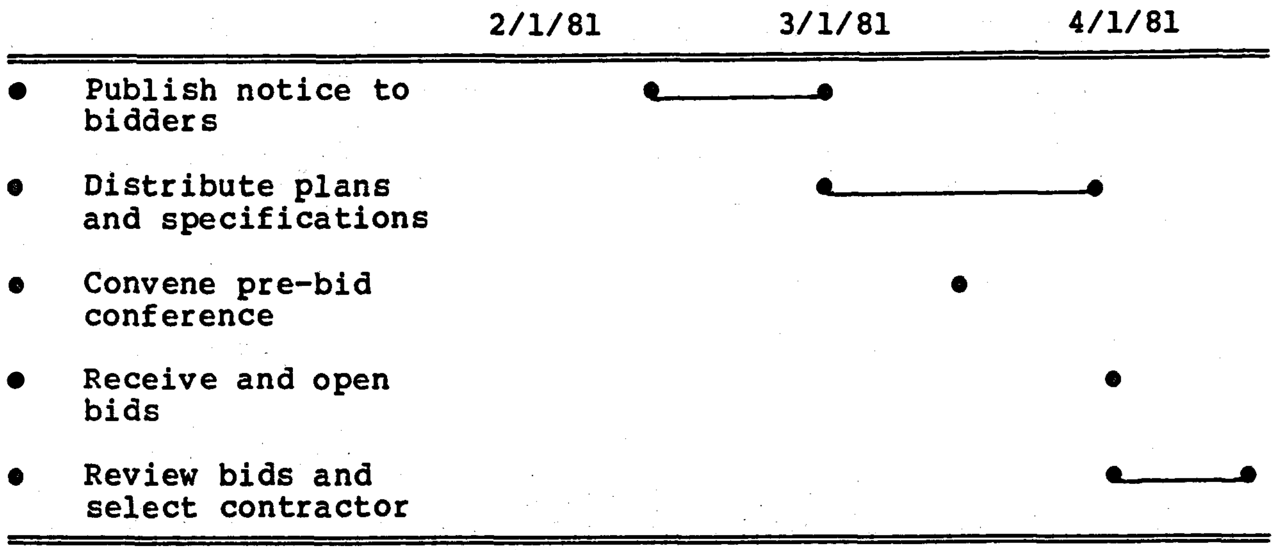


Figure 24-1 Summary of Bidding Process

During the one-month bid period beginning March 2, 1981, approximately twenty-five sets of plans and specifications were distributed to interested contractors. In the middle of the bid period, a pre-bid conference was held at the hospital to answer questions posed by prospective bidders and to consider the need for addenda to the bid package. Contractors were also given a tour of the parts of the hospital affected by the work.

Sealed bids for the T-H-S Memorial Hospital Geothermal Heating System were received and opened on April 2, 1981. These bids are summarized in Table 24-1. Although the bid range was very large, it is not particularly unusual for retrofit projects. Typically, contractors that study the work very closely are likely to provide the low bid because they become comfortable with lowering the contingencies associated with retrofits.

Based on qualifications and price, Lochridge-Priest, Inc., was selected as the prime contractor. (Subcontractors are footnoted in Table 24-1.) The Notice to Proceed was issued on May 1, 1981.

TABLE 24-1. BIDS RECEIVED FOR THE T-H-S MEMORIAL HOSPITAL GEOTHERMAL HEATING SYSTEM

Bidder	Location	Bid Amount
Capital Mechanical	Austin, TX	$490,000
Grunau	Fort Worth, TX	430,936
Jacobs-Cathey	Waco, TX	689,000
Lochridge-Priest, Inc.[1]	Waco, TX	369,780

[1] Selected contractor based on qualifications and price. Subcontractors were as follows: well pump - Smith Pump Co., Waco, TX; electrical - Commercial Electric, Waco, TX; controls - Johnson Controls, Dallas, TX.

24.2 Construction Activities

System installation occured generally as scheduled. The submersible pump was installed in mid-December 1981, and the hospital began using the geothermal energy for secondary space heating at that time. Domestic water heating and primary space heating with geothermal, however, did not begin until January 1982. Substantial completion was achieved on schedule in January 1982.

Although no significant modifications to the application system were required during construction, several minor ones were needed. These included installation of a concrete ramp and walkway, installation of manual air bleeds on control valves, and modification of ductwork.

To assist hospital personnel who would operate the system, a set of monitoring logs and an operating manual were prepared. The logs identified data which the operators should take periodically to familiarize themselves with the system. These logs also provided a good foundation for troubleshooting.

The operating manual [Ferguson and Green 1982] also assisted the T-H-S personnel in understanding and troubleshooting the system. The manual provides for a sound and complete understanding of the basic concepts of the geothermal system and how it interfaces with the pre-existing system. It is written for the T-H-S maintenance personnel, who have a good understanding of heating, ventilating, and air conditioning equipment. The manual covers the production and disposal systems as well as the application system.

After substantial completion and completion of most of the Engineering Change Orders, Radian engineers performed extensive acceptance testing to ensure the system was operating properly. Generally, all systems were found to be operative. Several important controls did need adjustment, however, in order to derive maximum benefit from the geothermal energy. These adjustments were completed by the contractor. A copy of the acceptance test report is included in Appendix C.

In April, 1982, a system dedication ceremony ws held at the hospital. The project history and results to date were accounted, system tours were given, and system brochures (see Section 34 and Appendix F) were distributed. The ceremony was sponsored by the T-H-S Hospital and Marlin civic groups, and was well attended by state and local political figures, local citizens, press, and project participants.

25. SYSTEM MANAGEMENT AND ORGANIZATION

The T-H-S Memorial Hospital is the owner and sole user of the T-H-S geothermal system. The hospital also manages and operates the system, and is responsible for all maintenance.

26. PRODUCTION SYSTEM PERFORMANCE

26.1 Performance Summary

Since production system start-up in December 1981, geofluid production at T-H-S has been maintained without interruption. The system has required no corrective maintenance, and the operators have expressed high levels of satisfaction. No post-construction modifications have been needed. And, except as noted in the next paragraph, the pump and variable frequency drive (VFD) have automatically produced only that geofluid needed to supply the heating demand.

In January, 1982, while still in the construction phase and after about one month of production system operation, the VFD did experience a failure. This failure required the VFD to be off line for about four days while warranty repairs were made. During this period, the bypass feature on the pump controls enabled the pump to be run at full speed "across the line." Consequently, production was not lost even though the VFD was out of service.

Since Janaury, 1982, no other component failures have occurred, although the operators did report a barely audible "rattle" at the wellhead in November 1982. The noise was investigated independently by Smith Pump Company (submersible pump installers) and by Radian. The noise was tentatively diagnosed as stemming from the downhole check value. Assuming this diagnosis is correct, no near-term problems should arise. Even in the event the rattle was due to another component, such as the pump itself, identifying the cause and predicting failure would be extremely speculative. Furthermore, the expense of pulling the pump for inspection would be difficult to justify since inspection may not reveal the cause and since replacing the pump without damaging it in the process is not assured. Consequently, unless more conclusive evidence appears which would warrant pulling the pump, it will remain in operation.

26.2 Well and Pumping System Performance

The data logs prepared for system monitoring included provisions for tracking well drawdown, and for correlating production rate with outdoor air temperature. By tracking drawdown, changes in reservoir performance can be identified. This information can assist in troubleshooting when it otherwise appears that pump performance is degrading. For example, if the pump must run at higher speeds in July than in December to produce equivalent flows, is there likely a pump problem? Figure 26-1 shows that the cause of such a condition is probably the seasonal reservoir performance. As shown, the summer drawdowns are higher than winter and are likely due to less summer precipitation (reservoir recharge) and more summer withdrawal in areas where the reservoir is shallower and used for municipal water supplies. The broken line in Figure 26-1 indicates a period when no data were taken. Note that specific capacity (S.C.) results are consistent with previous well tests.

Fiqure 26-2 illustrates how the VFD control system varies production rate to match heating demand. Using outdoor air temperature as an indicator of heating demand, the figure shows that production rate increases as outdoor temperature

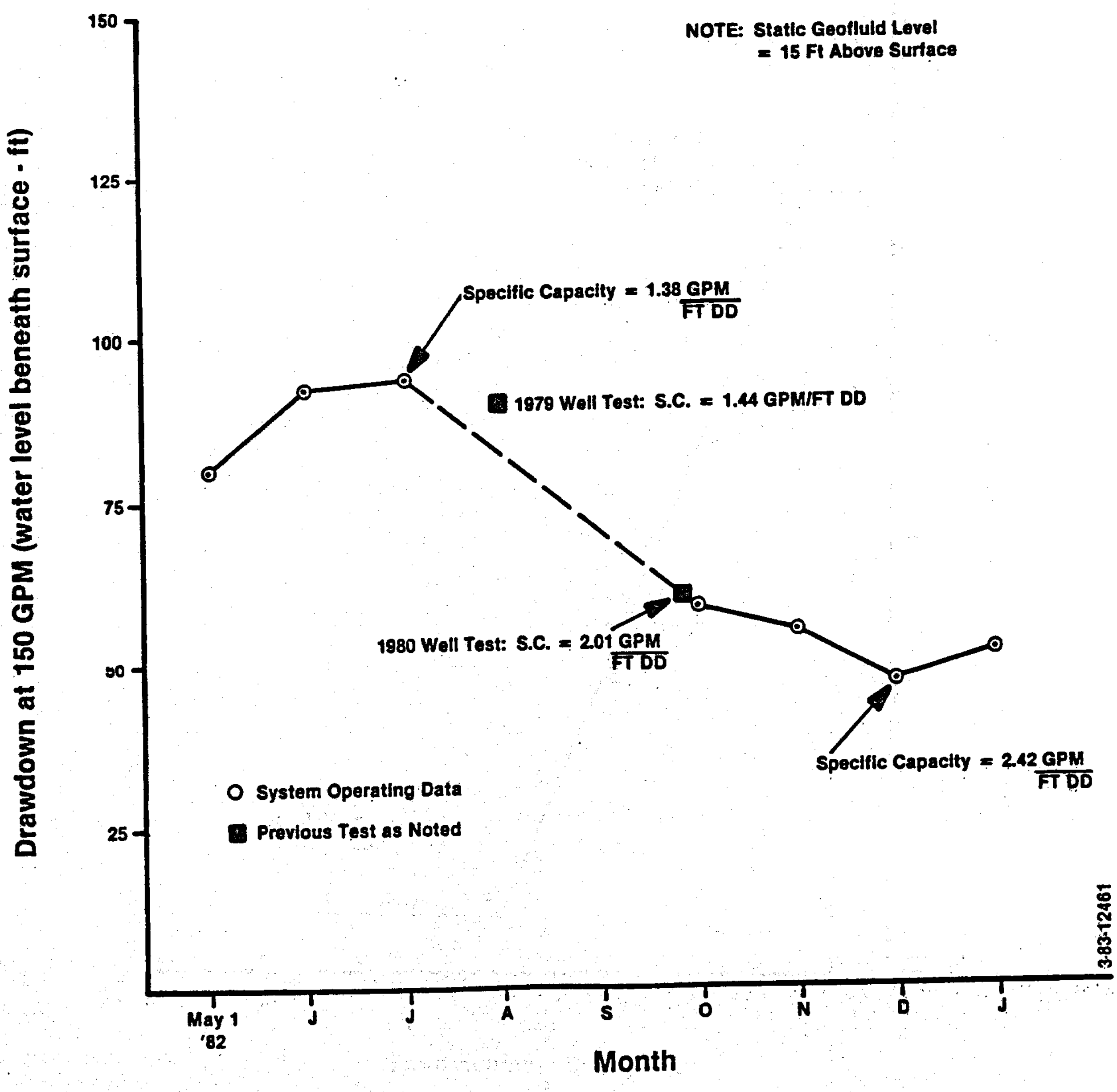


Figure 26-1 Production Well Performance

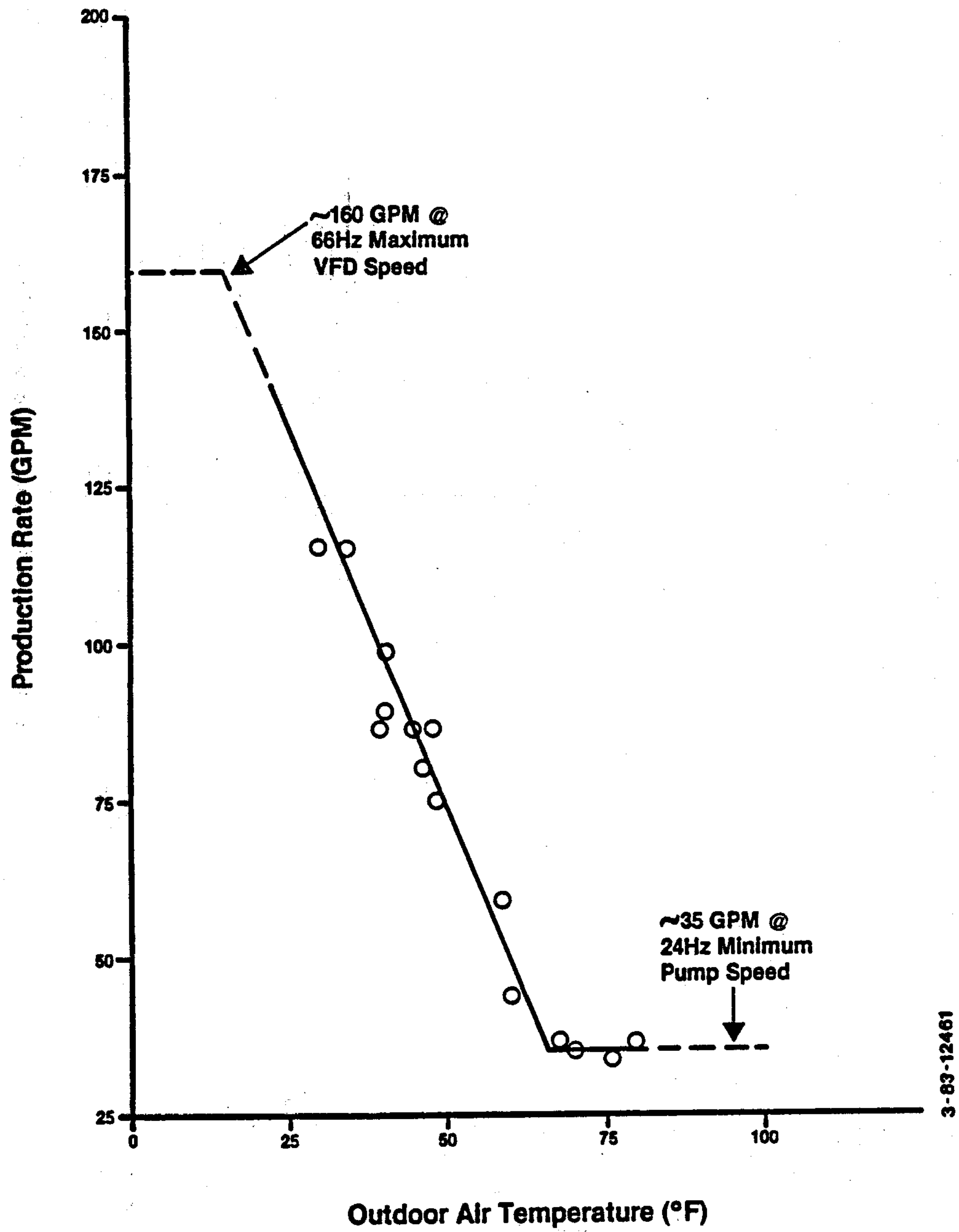


Figure 26-2 Pump Production Rate as a Function of Outdoor Temperature

decreases. Note that the data plotted in Figure 26-2 are confined to approximately the same time of day to prevent domestic water heating loads (which are functions more of time than outdoor temperature) from scattering the data. Also note that the horizontal segments at approximately 35-40 gpm and approximately 160 gpm denote the control system is out of its 24 Hz to 66 Hz (pump frequency/speed) control range.

26.3 Heat Exchanger Inspection

In mid-July 1982, after seven months of production system operation, the domestic hot water heat exchanger (HX-1) was disassembled for inspection. Disassembly of the plate heat exchanger was easily accomplished by the operators. Plates were visually inspected for pitting, corrosion, and scaling. The geothermal side of the plates was found to be essentially free of deposits and shiny metallic in appearance. An extremely thin layer of gray material was observed at the inlet ports of some plates, but this material was not a mineral scale. Laboratory analysis of the material revealed it was composed mostly of iron sulfide corrosion products, probably derived from the well casing. No evidence of pitting or corrosion was visible with the naked eye.

After recording observations, one of the Type 316 stainless steel plates was removed for a microscopic examination. No corrosion or pitting was evident under a 400X magnification. (This magnification is sufficient to reveal corrosion and pitting if either were occurring.) More detail concerning the inspection is available in the inspection reports provided in Appendix D.

The conclusion is that the system design is precluding corrosion and scaling, thereby reducing or possibly eliminating the high maintenance costs associated with these problems.

27. DISPOSAL SYSTEM PERFORMANCE

Disposal of the spent geofluid in the T-H-S system is accomplished with surface discharge into the Brazos River via Marlin's storm sewer system and surface waterways. This surface discharge strategy is discussed in Section 6, and environmental monitoring is discussed in Section 36. The brief performance discussion within this section is limited to the disposal system itself, which consists of the disposal piping and the backpressure valve.

The backpressure valve is the only active component in the system. This self-contained valve modulates as flow changes to maintain a constant inlet pressure (backpressure) of 8 psig. Since its original setting in March 1982, it has maintained this pressure under all flow conditions and has not required any maintenance or attention. In March 1983, the valve control parts were disassembled by the operator for cleaning and inspection. The internals were found to be in good condition with only very thin deposits on some of the control tubing. With these results, the operator believes that future maintenance will be needed only once every two to three years.

28. TRANSMISSION SYSTEM PERFORMANCE

Because a transmission system does not exist in the T-H-S system, this section is not applicable.

29. DISTRIBUTION SYSTEM PERFORMANCE

Because a distribution system does not exist in the T-H-S system, this section is not applicable.

30. APPLICATION SYSTEM PERFORMANCE

Since the application system came fully on line in January 1982, it has operated without interruption of service and without a single failure. The system has required neither corrective maintenance nor post-construction modifications. The operators have expressed a high level of satisfaction with the system's reliability and automation. The hospital's turning off of the steam valves to the domestic hot water generators is testimony to their satisfaction.

Operating data for the application system has been recorded by T-H-S personnel on monitoring logs. As in the production system, completing these logs familiarized the operators with the system. The log entries were periodically checked to ensure the system was operating properly.

Performance of the application system can best be measured by the change in the hospital's natural gas consumption. Figure 30-1 illustrates this change. It presents the average monthly natural gas profiles, as determined by correcting actual data for average heating degree days. As is evident, the peak consumption was reduced from 1740 MCF (thousand cubic feet) to 450 MCF, for a 75 percent peak savings. Moreover, this figure shows that the T-H-S geothermal system provides 93 percent of the peak heating loads which could be addressed by this geothermal resource (i.e., excluding base loads such as cooking, 180°F domestic hot water, etc.). It also demonstrates a reduction in average annual consumption from 11,500 MCF to 4500 MCF, or a 61 percent savings. At the hospital's 1982 natural gas prices, this savings equates to $34,400. As natural gas prices continue to rise, the dollar savings will become greater.

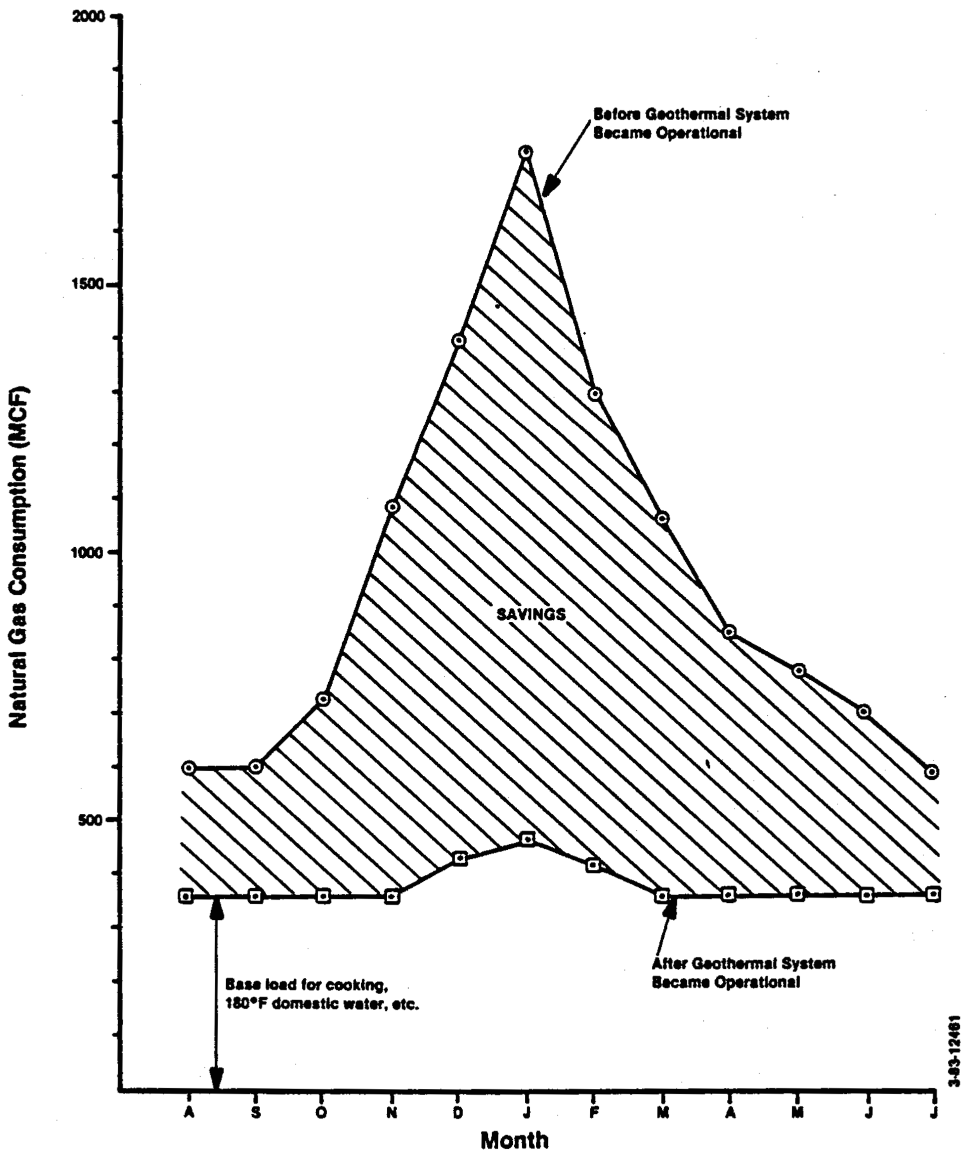


Figure 30-1 Comparison of Natural Gas Consumption Before and After Geothermal

31. CONSTRUCTION COSTS

The total construction cost for the T-H-S Hospital geothermal heating system reflects two "construction" efforts. The first was the 1979 well drilling, and the second was the 1981/1982 system construction. As presented in Section 24, the base bid for the system construction was approximately $369,800. To this bid, $15,900 in Engineering Change Orders were added, yielding a 1981/1982 construction contract total of $385,700.

A breakout of this total is presented in Table 31-1. Also included is the cost of well drilling and completion, escalated to 1982 dollars. Table 31-1 shows that the well plus system construction costs for the T-H-S geothermal heating system, in 1982 dollars, is $672,200.

TABLE 31-1. BREAKOUT OF T-H-S GEOTHERMAL SYSTEM CONSTRUCTION COSTS[1]

PRODUCTION SYSTEM		
• Well drilling, completion, testing[2]	$286,500	
• Geothermal equipment room[3]	18,200	
• Production pump	21,900	
• VFD and controls	25,100	
• Plate heat exchangers	28,900	
• Btu meter	5,100	
• Piping, valves, insulation, etc.	32,300	
Subtotal		$418,000
DISPOSAL SYSTEM		
• Piping	11,600	
• Backpressure valve	1,800	
Subtotal		$ 13,400
APPLICATION SYSTEM		
• Geothermal equipment room[3]	18,200	
• Pumps	12,500	
• Heating coils (air handlers and dryers)	13,100	
• Piping, insulation, etc.	128,700	
• Controls, motors, wiring, startup, etc.	68,300	
Subtotal		240,800
TOTAL CONSTRUCTION COSTS[4]		$672,200

[1]1982 dollars
[2]1979 costs of 224,300 escalated at 8.5 percent annually to 1982 dollars. This item not part of construction contract costs.
[3]Geothermal equipment room cost of 36,400 prorated evenly between the production system and application system.
[4]Includes well drilling and completion.

32. OPERATING AND MAINTENANCE COSTS

Operating and maintenance (O&M) costs include those related to parasitic electric power, labor, and repair or replacement materials. The parasitic electric power arises primarily from the system's pumps, and produces an annual operating expense of approximately $2,100. However, approximately $400 is recaptured in savings from not using three electric duct heaters for secondary space heating. Therefore, the net annual parasitic power costs for the system is $1,700.

The T-H-S system was designed for minimal operator attention and is operating in that fashion. The T-H-S maintenance staff has not been enlarged and is not expected to be. Consequently, O&M costs need not include a specific salary and benefits provision.

Instead, average maintenance costs have been allocated based on those parts of the system requiring maintenance. Since the system is expected to have a 30 year life, 3 percent of the qualifying costs are included as a maintenance allowance. Note that the well, the geothermal equipment room, piping, and heating coils should not require maintenance for the entire life of the system, and therefore are not part of qualifying costs.

Major components expected to need replacement during the system life are also not part of qualifying costs. These components include the production pump and the variable frequency drive (VFD), which are expected to have seven year and fifteen year lives, respectively.

The O&M costs are summarized in Table 32-1. These costs are included in the economic analyses of Section 33.

TABLE 32-1. SUMMARY OF T-H-S O&M COSTS ESTIMATES

Item	Annual Cost
• Net Parasitic Electric Power	$1,700
• Submersible Well Pump[1]	3,100
• Variable Frequency Drive[2]	1,700
• Other Maintenance[3]	4,900
TOTAL ANNUAL O&M	$11,400

[1] A sinking fund allowance for pump replacement. $21,900 installed cost divided by 7 years.

[2] A sinking fund allowance for VFD/controls replacement. $25,100 installed cost divided by 15 years.

[3] $163,600 relevant (qualifying) installed cost x 0.03.

33. SYSTEM ECONOMICS

Two economic analyses were performed for a geothermal system equivalent to that at the T-H-S Hospital. One analysis reflects the economics of a non-profit organization, and therefore does not account for tax benefits. The other reflects after tax economics of a profit-making organization.

An analysis reflecting the economics for a local government or other non-profit bonding authority was not undertaken, although other analyses [Hederman and Cohen 1982] indicate these cases may enjoy the best economics. As will be seen, the current tax benefits available to geothermal systems have a significant impact on the economic attractiveness of geothermal systems similar to T-H-S.

It should be noted that the economics presented in this section do not reflect the actual T-H-S project economics. The project intent has never been to demonstrate economic feasibility, but rather to demonstrate technical feasibility and analyze economic incentives for private sector initiative. It has always been recognized that development costs would be incurred in this project which need not be duplicated in future projects.

To account for these development costs and to provide a true picture of private sector incentives, capital costs for an "equivalent" system are used in the economic analyses. The distinction between the equivalent system and the T-H-S system is subtle but important. The capital costs of the equivalent system are based on the actual costs experienced at T-H-S, except that costs which would not be required in similar future projects using this resource are excluded. Appendix E details the derivation of these capital costs.

The assumptions used in the economic analyses are similar to those made by ICF, Inc. in their analyses of DOE direct utilization projects in the U.S. [Hederman and Cohen 1981; Cohen 1982; 1983]. An important difference, however, is that natural gas price escalations used in this analysis are regional estimates rather than national averages. Since Texas is continuing to experience yearly natural gas price increases of 25 to 30 percent and since national averages are much lower, using regional estimates provides a more accurate economic picture for this geothermal resource. A summary of assumptions is provided in Table 33-1.

33.1 Non-Profit Organization Economics

The economic analysis for a non-profit organization constructing a system equivalent to that at T-H-S is summarized in Table 33-2. Although the break-even period (payback which accounts for time value of money) is well below the 30 year operational life of the system, it exceeds the values generally accepted as attractive in the private sector. The real return on investment (i.e., percent above inflation) over 15 years is correspondingly low.

These generally unfavorable non-profit economics are a consequence of several items, one of which is low well utilization. The production well and resource at T-H-S are capable of producing 500-600 gpm steadily throughout the year. However, the T-H-S system averages only about 55 gpm over a year, thereby extracting only about 10 percent of that energy which could be

TABLE 33-1. ASSUMPTIONS USED IN ECONOMIC ANALYSES

ITEM	ASSUMPTION
• System Operational Life	30 years
• Investment Life[1]	15 years
• Capital Costs	"Equivalent system" costs, excluding those not required in similar future projects[2]
• Inflation Rate	6% annually
• Natural Gas Escalation[3]	Year / Real Escalation[4]: 1 – 18%; 2 – 15%; 3 – 12%; 4 – 9%; 5 and beyond – 6%
• O&M Costs Escalation	6% annually, equal to inflation rate (0% real escalation)
• Discount Rate (minimum allowable return required by organization)	Non-profit: 2% real Profit: 8% real
• Depreciation	Straight line depreciation over 5 years.
• Corporate Tax Rate	46%

[1]Period used to analyze after tax return or investment.
[2]Refer to discussion in text and Appendix E.
[3]Estimates of regional natural gas escalations, not national average escalations. Economic results sensitive to these estimates.
[4]Real denotes % above inflation.

TABLE 33-2. SUMMARY OF NON-PROFIT ORGANIZATION ECONOMICS[1]

• System Capital[2]	$910,500
• 1st Year Natural Gas Savings (7000 mcf/yr)	$ 34,400
• Annual O&M Costs[3]	$ 11,400
• Break-Even Period[4]	17 years
• Return on Investment over 1st 15 Years of Operation (Real)[4,5]	0.2%

[1]All dollars express as 1982 dollars.
[2]For equivalent system: refer to text and Appendix E.
[3]Presented in Section 32.
[4]Using discounted cash flow analysis and a 10% average well utilization. Results sensitive to well utilization and fuel escalations. Refer to Table 33-1 for assumptions.
[5]Real denotes above inflation.

extracted. Since wells to the depth needed at T-H-S are expensive capital items, system economics improve if the application systems are large enough to more fully utilize the wells.

Another impact on the non-profit economics is that energy tax credits (ETC), investment tax credits (ITC), depreciation, and expensing are not available to T-H-S and similar non-profit organizations. The lack of these benefits further emphasizes that non-profit organizations must fully utilize "deep" wells in order to economically justify geothermal systems.

33.2 Profit-Making Organization Economics

Several tax benefits are available to the profit-making organization to improve geothermal system economics. These are

TABLE 33-3. TAX TREATMENT FOR PROFIT-MAKING ORGANIZATIONS USING GEOTHERMAL ENERGY[1]

Cost Category	Tax Treatment
• Tangible well equipment[2]	Capitalized and depreciated; eligible for ITC and ETC[3]
• Intangible drilling costs[4]	Expensed (or capitalized, at taxpayers' option)
• Design, planning, bidding	Capitalized and depreciated; apportioned among the following categories, as appropriate and treated accordingly
• Pump houses and other equipment structures	Capitalized and depreciated; eligible for ETC only
• Disposal equipment	Capitalized and depreciated; eligible for ITC, assumed eligible for ETC
• All other construction costs	Capitalized and depreciated; eligible for ITC and ETC

[1]Extracted from Hederman 1981, and presented for T-H-S analysis.
[2]Physical well property such as casing, valves, etc.
[3]ITC = Investment Tax Credit (10%), ETC = Energy Tax Credit (15%)
[4]Includes labor, fuel, repairs, hauling, supplies, etc.

summarized in Table 33-3. As shown in Table 33-4, these benefits produce much more favorable results for profit-making organizations than were seen for non-profit organizations.

The 12.5 year break-even period and the 10 percent (real) return on investment are evidence that geothermal systems can begin to be attractive to profit-making organizations, even when heating loads are no larger than those at T-H-S. This outcome is especially significant when one considers the savings are based on an average of only 10 percent well utilization. If the utilization were increased via larger heating loads, economics could improve greatly. These results indicate that development of this geothermal resource by profit organizations can indeed be economically attractive.

TABLE 33-4. SUMMARY OF PROFIT-MAKING ORGANIZATION ECONOMICS[1]

• System Capital[2]		$ 910,500
• Less Tax Credit		
- Tangible well equipment[3]	14,300	
- Equipment bldg	5,500	
- Other	146,900	
	$ 166,700	(166,700)
• Less Expensed Intangible Drilling Costs[4]		(105,400)
• Effective Capital		$638,400
• Less Depreciation Over 5 Years[5]		$(237,800)
• Depreciated Base		$400,600
• 1st Year Natural Gas Savings (7000 MCF/yr)		$ 34,400
• Annual O&M Costs		$ 11,400
• Break-Even Period[6]		12.5 years
• Return on Investment over 1st 15 years of operation (Real)[6,7]		10%

[1]All dollars expressed as 1982 dollars.
[2]For equivalent system. Refer to text and Appendix E.
[3]Based on 20% of well costs. $286,500 x .20 x .25 ETC.
[4]Based on 80% of well costs. $286,500 x .80 x .46 tax rate
[5]Net Present Value (discounted) of depreciation tax savings.
[6]Based on discounted cash flow analysis and a 10% average well utilization. Results sensitive to well utilization and fuel escalation rates. Refer to Table 33-1 for assumptions.
[7]Real denotes above inflation.
NOTE: Analysis assumes organization has sufficient (outside) income to use tax benefits in the year eligible.

34. PUBLIC AWARENESS PROGRAM*

34.1 Objectives

The success of a demonstration project that applies a new technology is dependent on two functions: 1) the technical quality of design, construction and operation of the project; and 2) communication of the technical success and the feasibility of its application on a broader scale and a commercial basis. The Public Awareness Program was the principal means of performing this second function in accordance with DOE's original PON.

This program had two primary objectives:

- To attract potential users of low temperature geothermal energy, and
- To inform the general public of the Marlin project, in particular, and the use of low temperature geothermal energy in general.

34.2 Program Elements

The formal Public Awareness Program was active over the project term and ended with completion of the audio/visual slide

*This section describes an effort which is unique to the T-H-S Hospital project and which is, therefore, in addition to the "standard" DOE PON outline followed for this report.

show in the summer of 1982. However, the public awareness function is an ongoing activity that will continue in the future. The success of the Public Awareness Program was, and is, largely due to the willingness and ability of the hospital administration to respond to news media and public inquiries.

As Radian conducted the program over the project period, the original basic plan was followed and the following elements were created to implement the program objectives.

• Press Releases	Immediately before or after important project milestones.
• Fact Sheets	Summarized important features of the project.
• Site Signs	Site identification and public data on project purposes, scope, participants and sponsors.
• Lobby Displays	Wall hangings of the system overview and the system diagram, for orienting visitors to the hospital's geothermal system.
• Brochure	A handout and mailout overviewing Central Texas geothermal resource, Marlin's geothermal history, poject sponsors, and system design.
• Audio/Visual Slide Show	An automated presentation for visitor education and speeches to groups.

34.2.1 Press Releases

News releases were printed and distributed at five important milestones during the course of the project. These milestones included:

Date	Milestone
2/17/78	Announcement of the project and DOE and State intent to award funding.
8/31/78	Contract-signing ceremonies and DOE Finding of No Significant Environmental Impacts.
4/06/79	Notice of well drilling (or spud-in) ceremony.
8/15/79	Successful completion of the geothermal well.
3/12/82	Notice of project completion ceremonies marking the beginning of the operational phase.

Copies of these releases are provided in Appendix F. Each was written in news style such that it could be used directly by the media. Each release updated the status of the project. The releases were drafted by Radian and approved by the hospital administrator and DOE before being distributed to approximately 200 media outlets and a handful of government offices and public officials. By category, the distribution was as follows:

- 30 copies distributed directly to the National and State wire services and Capitol Press Corp in Austin.
- 18 copies to television stations in Texas.
- 43 copies to weekly newspapers within a 150-mile radius of Marlin.
- 30 copies to Texas daily newspapers.
- 20 copies to radio stations in a 50-mile radius of Marlin.
- 15 copies to national energy publications such as Oil & Gas Journal and the Geothermal Resources Council Bulletin.
- 12 copies to trade press such as ASHRAE Journal or hospital administration publications.

- 20 copies to national general interest and business publications such as Newsweek.

The response to these releases was generally good and several inquires have been received from foreign countries. Articles were printed in major newspapers and other publications, as evidenced by the collage of stories and headlines in Figure 34-1. As intended, the releases were successful in attracting news media coverage, including one statewide television feature on The Eyes of Texas. Direct contact with the media was performed by the hospital administrator.

34.2.2 Fact Sheets

During the course of the project, two series of fact sheets were prepared. The purpose of the fact sheets were to provide a succinct project description and compilation of facts and figures for the public. These were distributed upon request and at meetings, presentations and project ceremonies. Copies can be found in Appendix F. The first fact sheet was prepared for distribution at the spud-in ceremony in April 1979. A second one was prepared one year later, providing an update following completion of the new production well.

34.2.3 Site Signs

Two identical four-by-eight foot signs were designed by Radian to be used during the construction and early operational phases of the project. The signs were constructed by a Marlin advertising firm and were erected at the hospital site on August 13, 1978. A picture of a sign appears as Figure 34-2.

Marlin's THS Hospital gets grant to study hot well water for heat, energy

U.S. Congressman W.R. (Bob) Poage (D-Waco) announced last week that the U.S. Department of Energy has selected the Torbett-Hutchings-Smith Memorial Hospital (T-H-S) of Marlin, Texas, to enter into contract negotiations for field experiments to demonstrate direct utilization of geothermal energy resources.

The program -- the first of its kind in Texas -- calls for using Marlin's hot mineral water as a source of energy for space and water heating in the hospital.

Marlin is one of several Central Texas cities (Rosebud has one of these hot wel' near the city lake) overlie pockets of ' eralized water ' percolated int' in turn ar' earth's ' the sur' pressure. been used spas since the

The estimate' project is $58' proposed federa' totals $379,464. Lo' kind" service contri' will amount to $134,370 another $75,000 has be' requested from the Texa' Energy Development Fund.

establishing the $1.5 million Texas Energy Development Fund, strongly supports Marlin community leaders in their efforts to secure state and federal funding. The Texas Energy Advisory Council Administers the fund and will meet in early March to make initial project awards.

According to Pr' Director and T-H-S Administrator, J' Jr., Radian C' Austin ba' environ' devel'

an existing well located on the property of Central Texas Savings and Loan a' 800 feet east of ' Complex.

...The ' serv'

Marlin Hospital Officials Eyeing Geothermal Heat

By TRAVIS BROWN

MARLIN — When the gas bill or Torbett-Hutchings-Smith hospital topped $35,000 in 1976, hospital officials desperately ...ed to the hot mineral wells ... Marlin for help. ...ty of Marlin, along ... of Central Texas, ...eep pockets of ...eated to high ...he earth's

"But this is all conjecture," he said. "That's what this project is for, to determine what kind of savings can be obtained with geothermal energy."

If the experiment at the Marlin hospital proves successful, then the door may opened for other hospitals, schools, industries and even entire communities in Central Texas to harness geothermal energy. Two major faults in the earth's surface, the Balcones and the Luling-Mexia-Talco cross Central Texas. These faults breaks in the earths surface allow the heat from the ...t from the interior to heat

...al energy is a re... ...gy source that ... entire com... ... Hungary, ... Soviet

Geothermal Project For THS Accepted

U.S. Congressman W.R. (Bob) Poage (D-Waco) announced this week that the U.S. Department of Energy has selected the Torbett-Hutchings-Smith Memorial Hospital (T-H-S) of Marlin to enter into contract for a field experiment to demonstrate the direct utilization of Geothermal Energy Resources.

The program - the first of its kind of Texas - calls for using Marlin's hot mineral water as a source of energy for space and water heating in the hospital.

Marlin is one of several Central Texas cities that overlie pockets of hot mineralized water which have percolated into faults and heated by the earth's hot interior. ...

...reinjected into the producing formation through an existing well located on the property of Central Texas Savings and Loan about 800 feet east of the T-H-S Complex.

The $134,370 ... services share ... will be contributed by the community. ... Central Texas Savings & Loan Association reinjection well will count as $100,000. The hospital will contribute $23,850 and the City of Marlin's share will be $5,520.

Geothermal energy - a term that literally means "heat from the earth" - is a renewable energy source currently supplying heat for whole communities and industries in Iceland, Hungary, New Zealand, and the Soviet Union. At higher pressures and temperatures, geothermal energy is used to generate electric power. One-third of San Francisco's electric power needs are met by geothermal energy.

"If the Marlin project is successful, the question will be asked, 'Can other institutions, perhaps even a community, benefit from the complex, benefit from the wide system and industrial ...'"

...geothermal resources? The answer depends largely on the economic analysis of the project and a separate study assessing geothermal potential in the Central Texas Region. The Texas Bureau of Economic Geology (BEG) in Austin and Baylor University in Waco will conduct this regional assessment.

The BEG is also involved in a multimillion dollar assessment of the Gulf Coast geopressured-geothermal resource in Texas and Louisiana and another geothermal study in far West Texas.

Marlin

By TOM BELDEN
In Dallas News

MARLIN — Each time a passenger train rumbled into this Central Texas town 50 years ago, it carried dozens of people suffering the crippling effects of arthritis and other diseases.

The hot, mineral-laden water that gushed from the earth beneath Marlin turned the little farming community into a health spa when the first well was drilled in 1893. Doctors hailed the healing power of the hot wells in both bathing and drinking, and hotels a... ing houses were plen... take care of the thous... annual visitors.

But the Great Depression the 1930s and the advent of ne... drugs dealt the town, which is about 100 miles north of Austin, a devastating blow. The spas never recovered from those setbacks, and in January, the last operating health spa closed its doors.

Today, across the street from the first well that made Marlin a boomtown, the mod-

N... yea... way... work... But th... and not... until the ... to escalate.

Marlin Gets Geoth...

MARLIN — The Texas Energy Advisory Council has awarded $50,000 for the Marlin geothermal energy testing at Torbet Hutchings Smith Memorial Hospital.

Another $25,000 will be sought from the council for next year.

The state funding, along with $538,000 in federal and local matching funds, will finance the project to see if the hot water from Marlin's wells can be used successfully to provide space h... hospital.

Results of the ... agencies or indust... thermal energy. A pa... of the extent of geoth... waters throughout Centr... ...ation ...derground

Contracts to begin fi... expected to be awarded wit... ...of the project are ...few weeks.

Figure 34-1 T-H-S Hospital Articles

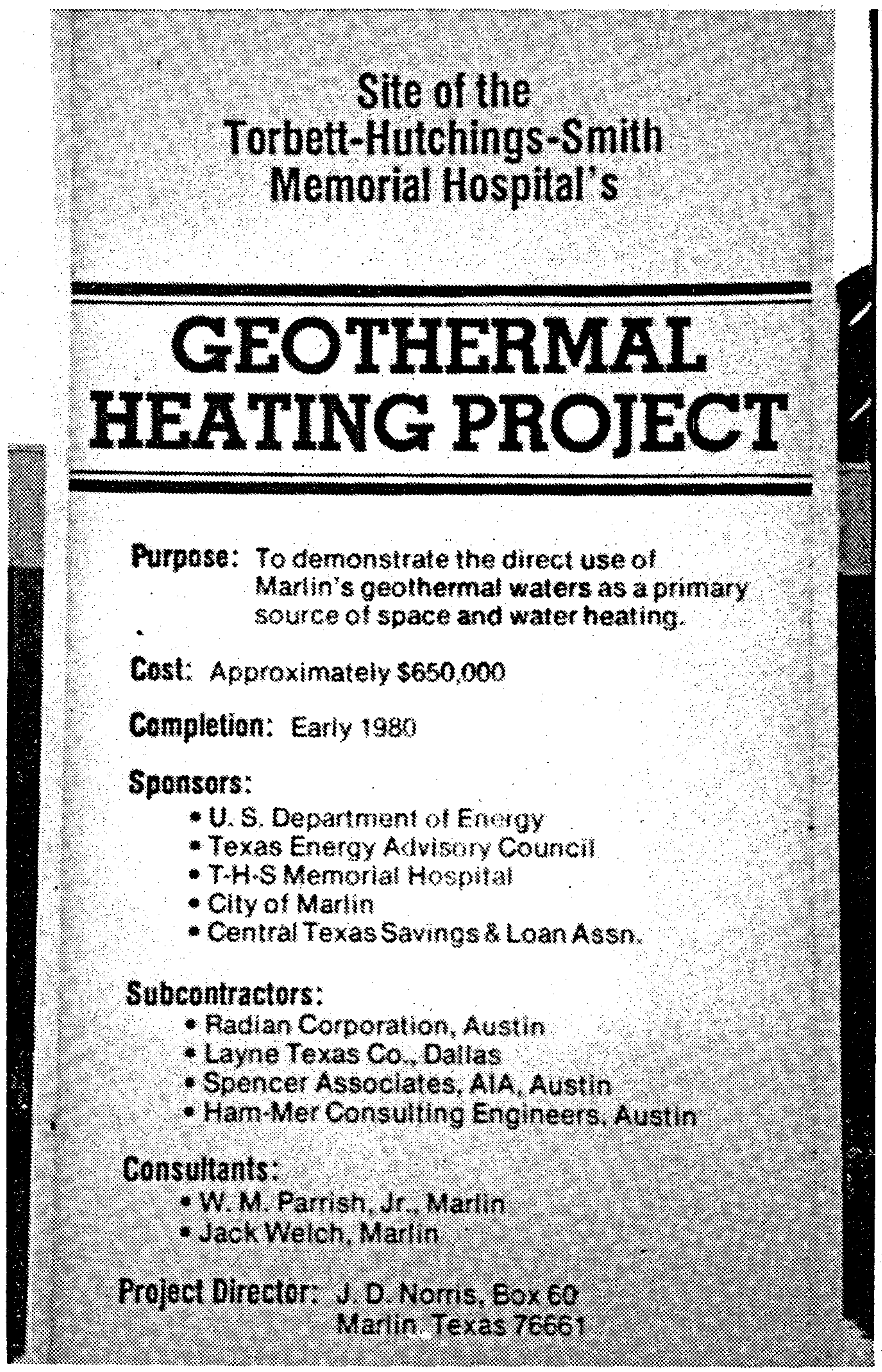


Figure 34-2 T-H-S Project Sign

34.2.4 Lobby Displays

A tour of the T-H-S Hospital's geothermal heating system begins in the lobby. To assist orientation of the visitors, color architectural renderings of the project landscape and of the system design were framed and hung in the lobby. Reduced versions of these renderings make up the front and back covers of the brochure.

34.2.5 Color Brochure

In 1982, 5,000 copies of an 8-1/2 by 11 inch, four-page color brochure were prepared by Radian to replace and provide a final update of material presented in the fact sheets. A black and white copy of the brochure is provided in Appendix F. The first page provides a color aerial view of the hospital and vicinity together with a schematic cut-away view of the geological formation that provides the geothermal resource. The two inside pages provide an illustrated account of the history of the project beginning with the 19th Century discovery of Marlin's hot mineral waters and concluding with a forecast of the heating cost savings for the hospital. The fourth page provides an easy-to-follow color diagram of the geothermal heating and disposal system.

34.2.6 Automated Slide Show

An automated audio/visual slide show was identified as a particularly effective way to inform the public about the Marlin project, and about the feasibility of using geothermal energy in Central Texas. The slide show fulfilled two needs:

1. To serve as an automated audio/visual presentation for the hospital visitors; and

2. To accompany lectures and presentations by hospital personnel, Radian, DOE staff, and others.

Over 110 slides were selected from almost 1,000 slides taken during the course of the project and a script was prepared for the 14-minute presentation. Radian's script benefited from many new ideas as the result of input from several interested and capable Marlin citizens.

A professional announcer was hired to provide a synchronized voice/music track for the show. Also, a self-contained slide projector/cassette player was acquired for the slide presentation.

The final version of the slide show is more than a chronology of events and a description of the system. It includes a discussion of all forms of geothermal energy and the benefits of developing geothermal energy as an alternate energy source. The slide show and the automated audio/visual unit is at the hospital and is available for visitors.

35. MATERIALS TESTS FOR FUTURE CENTRAL TEXAS GEOTHERMAL DEVELOPMENTS*

Materials selections (discussed in Section 15) for the T-H-S system were based predominantly on corrosion experience with chemically similar geothermal resources in South Dakota and on short-term electrochemical tests at T-H-S. The materials selected for T-H-S construction were intended to be conservative.

In order to promote widespread use of this Central Texas geothermal resource, a disciplined 192.8-day corrosion test of 19 engineering alloys, three elastomeric materials and two polymer cements was undertaken to provide the knowledge required for future economical resource utilization. The materials tested cover a spectrum of the alloys most likely to be considered by designers of future systems. Careful use of the results can prevent each new user from reinventing the wheel.

35.1 Test Design and Procedures

35.1.1 General Description

During design and construction of the T-H-S system, valving and tees were provided in the geofluid supply line,

*This section describes an effort which is unique to the T-H-S Hospital project and which is therefore in addition to the "standard" DOE PON outlined followed for this report.

upstream of the first heat exchanger, to allow installation of a full-flow materials test loop (refer to Figure 15-3). This loop, illustrated in Figure 35-1, was fabricated from three inch (nominal) schedule 80 CPVC pipe having an actual ID of 2.90 inches. The loop consisted of two parallel vertical legs, each about six feet long, and a top horizontal segment about two and one-half feet long. The ascending vertical leg and horizontal leg contained corrosion specimens. The decending leg was dedicated to flow monitoring. Flow entered the ascending leg at right angles through a tee, whose flanged-off blind leg allowed insertion of one coupon (corrosion test specimen) rack. Likewise, the horizontal cross leg at the top of the loop was joined with tees oriented so that the blind-flanged legs allowed rack insertion into the horizontal portion of the loop. Flow exited the test loop through an elbow.

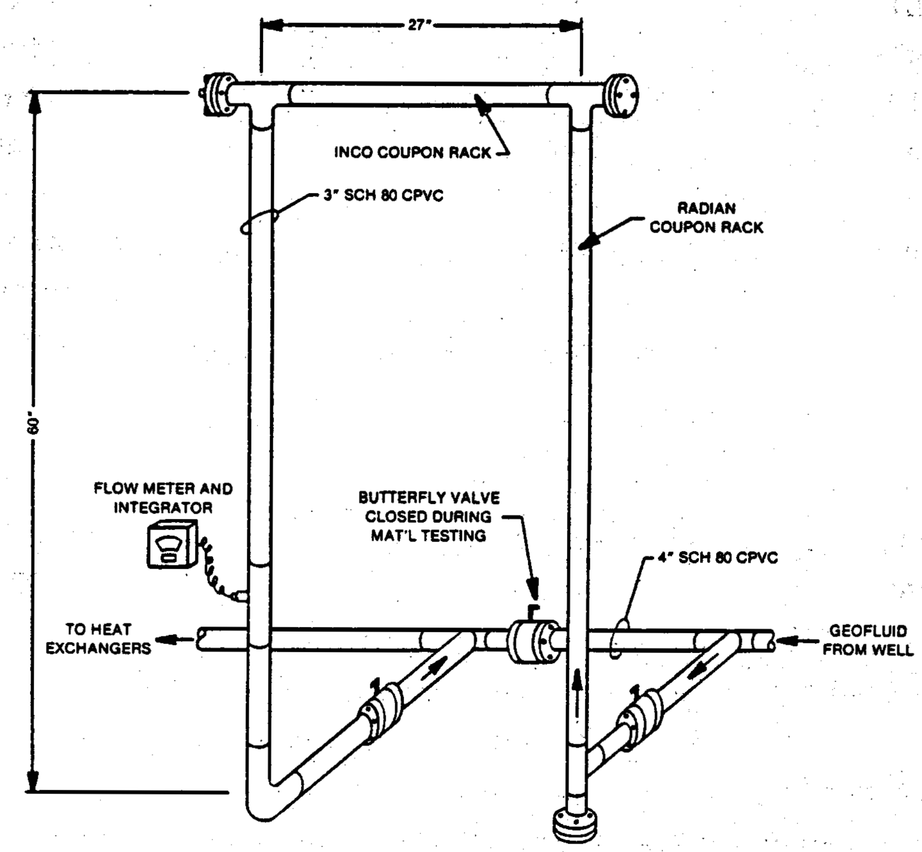


Figure 35-1 Materials Test Loop Apparatus

35.1.2 Materials Tested and Examination Methods

The materials tested consisted of:

- Flat metallic corrosion coupons evaluated for weight-loss corrosion, pitting, and crevice corrosion,
- U-bend specimens evaluated for stress corrosion cracking,
- Elastomeric O-rings tested for compression set, and
- Polymer concrete samples evaluated for critical property changes such as strength and water absorption.

One set of flat metallic coupons, and all of the U-bends were evaluated by Radian's Material Science Laboratory (MSL). These specimens were in the form of 1.0 x 2.0 inch rectangles each with a central mounting hole. The carbon steel (1018) and AISI 4130 coupons were 0.125 inch thick; the Type 304, Type 316, and Monel 400 were 0.0625 inch thick; and the galvanized steel was 0.028 inch thick. The galvanized coupons were intended only as a go/no-go test of the possible protection of steel by galvanizing. All these coupons were commercially acquired and had a "satin" finish produced by glass bead blast.

In addition, disk coupons (2.0 inch diameter by 0.125 inch thickness) of six copper alloys--leaded red bronze (CA 836), wrought aluminum bronzes (CA 613 and 614), and aluminum nickel-bronzes (CA 954, 955, and 958) were provided by Ampco Metals. These coupons appeared to have been parted on a lathe and had slightly grooved surfaces. The unstamped face of each of these coupons was given a 120 grit finish prior to exposure. Only this surface was evaluated for localized corrosion.

All of these flat coupons were mounted on a 5.5 ft. test rack of 0.125 x 1.0 inch Type 316 bar provided with centralizers to keep it centered in the ascending leg of the test loop. The coupons were mounted in pairs, one on each side of the bar. They were electrically isolated with nylon insulators which provided 0.25 inch clearance between the coupons and the rack. The coupons were mounted with their flat faces parallel to the fluid flow, and the rectangular coupons were also oriented with their short edge normal to the flow. The first pair was mounted about one foot downstream of the geofluid inlet tee.

The U-bends were fabricated from 0.75 x 4.0 inch strip 0.049 to 0.062 inches thick. Mounting holes were drilled in each leg. The strips were bent around a one-inch mandrel so that their legs were slightly flaired. These coupons were mounted on the same test rack as the above flat coupons. Each was electrically isolated with nylon insulators. They were mounted with their flat faces parallel to flow so that they presented the minimum cross-section to fluid flow. The mounting nuts were tightened until the legs were parallel.

The polymer cement specimens were 1.5 x 6.0 x 0.25 inch bars with mounting holes at each end. They were provided by Brookhaven National Laboratory (BNL). Two specimens, each of two different formulations (styrene-TMPTMA and styrene-AN-TMPTMA) were mounted in pairs parallel to the test rack bar. Spacers provided 0.125 inch clearance between the specimen and the bar. One specimen of each cement was exposed to direct impingment by inflowing geofluid at the inlet tee. The other pair was mounted downstream of the U-bends.

Another test rack of metallic coupons was provided by the International Nickel Company (INCO) and evaluated by their LaQue Center for Corrosion Technology. This rack was also 0.125

x 1.0 inch bar with centralizers. The 2.25 inch diameter disk coupons were mounted two on each side of the rack with PTFE insulators providing about 0.3 inch clearance between the coupons and the rack. Again the coupons were oriented with their flat faces parallel to the direction of fluid flow. This rack was placed in the horizontal leg of the test loop.

The INCO rack was received "ready to go." Prior to installation on the test rack, the Radian coupons and U-bends were degreased in acetone in an ultrasonic bath and weighed in triplicate to the nearest 0.1 mg. Their physical dimensions were measured in triplicate to the nearest mil (0.001 in).

The O-rings were exposed in a compression set test described by ASTM Practice D-1414. The 0.625 inch diameter O-rings of Buna-N, Neoprene, and Viton, were compressed to 75 percent of their relaxed height between pairs of 1.0 x 1.0 x 0.125 inch plates. Each plate was machined with a size 10 hole at its center. Proper compression was assured with a 0.4375 inch diameter gauge ring machined to 75 percent of the height of its companion O-ring (measured to the nearest mil). To prevent any pressure build-up in the annulus between the gauge ring and the O-ring, a 0.0675 inch diameter hole was drilled through each compression plate to intercept the annulus. The O-ring sandwiches were bolted to a length of 0.125 x 1.0 inch bar which was attached to the INCO rack in the horizontal leg of the test loop. Five specimen of each elastomer were tested.

After exposure the test racks were removed and dried with warm air until all visible moisture was gone. All of the specimens, as well as the test rack itself, were covered with an extremely thin flat black film which readily separated from most surfaces when wet, but which became tenacious when dried. A sample of this film was obtained for analysis.

The INCO rack was shipped to the LaQue Center while the other test racks were returned to the Radian MSL for analysis. The polymer cements were evaluated by BNL.

The metallic coupons were evaluated by the MSL in accordance with ASTM practices for corrosion tests. They were cleaned by a combination of mechanical and chemical means selected to remove all corrosion products or deposits without attacking sound metal. Triplicate post-exposure weights were determined for each specimen, and they were stereomicroscopically examined at 20X and 40X for signs of pitting, crevice corrosion, and stress corrosion cracking. In the case of the copper alloys, evidence of dealloying was also sought. Pit depths were measured with an optical micrometer.

Similar methods were used by the LaQue Center. One important difference, however, is that less magnification (5-10X) was used at LaQue in examining for localized corrosion.

The compression set experiment was evaluated according to ASTM Practice D-1414. The retaining nuts were loosened so that gaps were visible between the O-rings and the compression plates and the O-rings were allowed to recover for 30-minutes. Quadruplicate measurements of the ring height were then made to the nearest mil and compared to similar data taken prior to exposure to determine percent compression set.

35.2 Test Environment

The key corrosive species as well as some other fluid chemistry data are presented in Table 35-1. As shown, this geofluid contains traces of hydrogen sulfide, and is therefore free of dissolved oxygen in the reservoir. This fluid chemistry

TABLE 35-1. COMPARISON OF T-H-S GEOFLUID PROPERTIES AND GEOTHERMAL CORROSION CLASS Va PARAMETERS

Parameter	Marlin No. 1 Geofluid[a]	Corrosivity Class Va[b]
Key Corrosive Species:		
pH	6.16	6.7 - 7.6
Chloride (ppm)	93	21 - 225
Sulfate (ppm)	2340	315 - 2340
Biocarbonate (ppm)	171	126 - 810
Hydrogen Sulfide (ppm)	0.05 - 0.2	0.02 - >5
Ammonia (ppm)	1.2	not specified
Other Species		"
Sodium + Potassium (ppm)	901	"
Silica (ppm)	37	"
Calcium (ppm)	299	"
Magnesium (ppm)	39	"
Total Dissolved Solids (ppm)	3933	"

[a]Values are averages of several analyses, except pH which was measured *in situ* at the wellhead during normal production.
[b]Ellis 1981; 1982.

places the Central Texas resource in Geothermal Corrosivity Class Va. The key chemical characteristics of this class are also presented in Table 35-1. The fluid is produced by a submersible electric pump set well below the minimum water level in the well. The produced fluid is maintained in a closed system at a minimum pressure of 8 psig throughout the T-H-S system. Therefore, it is extremely unlikely that the geofluid contains any dissolved oxygen.

On 23 July 1982 the test racks were inserted into the test loop and the full production flow from the T-H-S geothermal well was diverted through the test loop at 1455 hours on that date. Full flow diversion continued until about 1030 hours on 1 February 1983 for a total of 4627 ±0.5 hours.

The T-H-S production pump is automatically controlled by a variable frequency drive system which varies the geofluid delivery according to heating demand. Based on daily logs of the test loop flow, the geofluid production rate ranged from 28 gpm to 93 gpm. The maximum production rate at peak demand is about 160 gpm, but the system operated at these conditions for only brief periods during the test.

The production temperature at various flow rates was determined during the initial assessment of the T-H-S well performance (See Figure 9-1). The equation describing this temperature is:

$$T\ (^\circ F) = 15.986 \log (gpm) + 112.839 \qquad \text{(eq. 1)}$$

Table 35-2 summarizes the range of flow and temperature observed during the test, but flow rate and temperature data should not be considered as paired. In other words, the minimum flow logged was 28 gpm and the minimum temperature was 124°F but it is not necessarily the case that these two values measured simultaneously. The average flow was calculated from the total production during the test period (14,480,940 gallons). The average temperature was calculated from the average flow by use of eq. 1.

Table 35-2 also contains estimates of the bulk velocity of the geothermal fluid in three areas of the test loop: the Radian coupon section, the U-bend section, and the INCO coupon section. These bulk velocities were calculated from flow and pipe cross section area, with an adjustment to the cross section area equal to the percent occlusion produced by the specimens in that section. As such, the calculated bulk velocity does not indicate any localized high velocities which might be produced by venturi effects, or the increased turbulence produced by the irregular shapes present in the stream.

TABLE 35-2. TEMPERATURE, FLOW, AND VELOCITY DURING T-H-S CORROSION TEST

	Automatic Control			
	Obs'd. min.	Avg.	Obs'd. Max.	Peak[a]
Flow Rate (gpm)	28	52.2	93	160
Temp (°F)	124[b]	140[c]	148	~150
Velocity (ft/sec)				
- Open Pipe	1.4	2.5	4.5	7.8
- Radian Coupon Section	1.6	3.0	5.3	9.2
- U-Bend Section	1.7	3.1	5.5	9.4
- INCO Coupon Section	1.9	3.6	6.4	11.0

[a]Peak flow occurred for only a few hours during the test period.
[b]Measured temperatures at min flow likely inaccurate (low) because thermometer installation encourages low readings at low flows.
[c]Calculated from established flow-temperature relationship (see text).

35.3 Results

The sample of black film recovered from the stainless steel surface of the long test rack was found by X-ray diffraction to be composed of an iron polysulfide ($Fe_{11}S_8$), likely corrosion products derived from the well casing. Energy dispersive X-ray analysis also showed trace amounts of silicon and calcium. This analytical method provides only elemental identification, and does not detect elements of atomic number less than 9 (fluorine).

The results of the metals tests are presented in Tables 35-3 and 35-4. The results obtained by the Radian MSL and those by the LaQue Center are presented separately. Table 35-5 gives the results of the compression set test, while Table 35-6 gives the results of the polymer cement trials. Each material group is discussed in the following paragraphs.

Carbon Steel

The carbon steel specimens evaluated by the MSL (1018 flat coupons and 1010 U-bends) all showed weight-loss corrosion rates of 23-28 mils per year (mpy). There were no discrete pits, but some areas were visibly thinner than others with an unevenness factor of about 1.5 (depth of penetration in some areas was about 1.5 times the average thickness loss). The two INCO coupons exposed in the horizontal section showed corrosion rates of 1.8 and 1.9 mpy and no gross visible evidence of corrosion. These INCO coupons had a different initial surface finish than did the others, and may have had a different microstructure. They may have experienced a difference in turbulance. The order of magnitude difference between these two coupon sets is surmised to be due to such variables.

TABLE 35-3. RESULTS OF ALLOY SPECIMENS EVALUATED BY RADIAN

Alloy	Weight-Loss Corrosion[a] (mpy)	Maximum Pit Depth (mils)	Maximum Crevice Corrosion (mils)	Stress Corrosion Cracking[b]	Comments
Carbon Steel (1018)	25.8	N	N	nt	Surfaces highly irregular
	23.4	N	N	nt	Occluded areas protected
Carbon Steel (1010)	nt	N	N	N(22.6)[c]	
	nt	N	N	N(28.3)	
Galvanized Steel	Parts of each specimen "eaten away." Entire sample too fragile to clean. Zinc coating apparently destroyed except under insulators.				
Low Alloy Steel (4130)	7.0	8.0	8.4		Pitting of coupons is conspicuous to eye, with about 1/2 of surface affected. U-bends do not show pitting, but have more rapid weight loss. Hardness HRC 37-38.
	4.9	7.8	3.3	N(19.0)	
	6.7	7.5	3.7	X(19.1)	
Type 304	0.7	4.1	N	N(0.5)	Few scattered pits (~4 mils dia.) barely visible at 40X. General increase in surface roughness.
				N(0.5)	
Type 316	<0.05	N	N	N(0.1)	No evident change in surface finish.
				N(0.2)	
Monel 400	0.1	N	N	nt	
CA 613	0.2	incip	1.4	nt	Incipient pitting as patches of dense pits or heavy etch <0.5 mil deep.
	0.2	incip	1.4	nt	
	0.3	incip	1.3	nt	
CA 614	nt	N	N	N(0.8)	Only U-bends tested. Pitting and crevice corrosion examination made on U-bends.
	nt	N	N	N(0.8)	
CA 836	0.2	N	0.6	nt	
	0.2	N	1.2	nt	
	0.1	N	0.7	nt	
CA 954	0.1	N	1.3	nt	
	0.2	N	1.5	nt	
	0.1	N	1.1	nt	
CA 955	0.1	N	0.9	nt	5 pinpoint pits--depth not measurable due to deposits in pits. Depth >1 mil.
	<0.05	X	1.0	nt	
	0.1	N	0.9	nt	
CA 958	0.1	1.6	1.4	nt	Few scattered pits on each coupon.
	0.1	1.1	incip	nt	
	0.1	0.9	incip	nt	

General Notes:

1. N = not detected. incip = incipient (<1 mil)
   X = detected. mpy = mils per year
   nt = not tested.
2. Examination for pitting and crevice corrosion was at 40X magnification.

[a]Determined from flat (unstressed coupons).
[b]U-bend specimens.
[c]Number in parenthesis is weight-loss corrosion rate for the stressed U-bend specimen.

TABLE 35-4. RESULTS OF ALLOY SPECIMENS EVALUATED BY INCO

Alloy	Weight Loss Corrosion (mpy)	Maximum Pit Depth (mils)	Maximum Crevice Corrosion (mils)	Comments
Carbon Steel (1010)	1.8	N	N	
	1.9	N	N	
Ni-Resist Type I (Cast Iron)	4.5	N	N	Uneven uniform corrosion and graphitzation
	9.2	N	N	
Monel 400	1.2	N	N	
	1.2	N	N	
Monel K-500	0.1	N	N	
	0.1	N	N	
Type 304	<0.05	N	N	
	<0.05	N	N	
Type 316	<0.05	N	N	
	<0.05	N	N	
Type 317LM	<0.05	N	N	
	<0.05	N	N	
Type 410	<0.05	N	N	Incip indicates <1 mil depth.
	<0.05	N	incip	
Alloy 904L	<0.05	N	N	
	<0.05	N	N	
Nitronic 50	<0.05	N	N	
	<0.05	N	N	
Incoloy 825	<0.05	N	N	
	<0.05	N	N	

General Notes:

1. N = not detected. incip = incipient (<1 mil)
   X = detected. mpy = mils per year
2. Examination for pitting and crevice corrosion was at low magnification (5-10X) only.
3. Results reported rounded to nearest 0.1 mil, thus results reported as 0.0 mpy indicate a corrosion rate of less than 0.05 mpy, as shown in the table.
4. Monel and Incoloy are trademarks of INCO, while Nitronic is a trademark of Armco, Inc.

   Data provided by the International Nickel Company (INCO), Suffern, NY.

TABLE 35-5. COMPRESSION SET OF THREE O-RING MATERIALS AFTER 4627 HOURS EXPOSURE

Specimen	Percent Compression Set		
	Buna-N	Neoprene	Viton
1	42.5	77.6	36.3
2	41.1	67.1	26.4
3	50.2	75.0	34.7
4	45.2	invalid test*	30.3
5	45.1	76.0	31.1
Mean compression set (95 percent confidence level)	44.8 ± 4.4	73.9 ± 7.3	31.8 ± 4.7

*Invalidated because guage ring was not installed, resulting in unknown compression.

Note: The variation in individual compression sets for a given material are of the same magnitude as the uncertainty inherent in the thickness measurement.

This outcome suggests that the coupons in the horizontal leg were protected by a passivation film which did not protect the other specimens. Such an outcome is not unusual for materials which have only marginally suitable corrosion resistance, and is an indicator that such materials should be used sparingly.

Iron sulfides, such as the ferrous polysulfide precipitated from the geothermal fluid, are extremely insoluble so that it is unlikely that iron is in the produced fluid derived from the geothermal formation. Therefore, it is surmised that any iron sulfide in the geothermal water results from the reactions

TABLE 35-6. RESULTS OF POLYMER CONCRETE TEST

Polymer Cement	Weight Change (Percent)	Flexural Strength Increase psi	Flexural Strength Increase (%)	Water Absorption[c] (percent) Initial	Water Absorption[c] (percent) Final	Dimensional Change
R 585 (Styrene-IMPTMA)[a]	-0.1	229	5.3	1.04	2.54	None
R 586	None	303	7.1	1.04	2.44	None
R 587 (Styrene-AN-TMPTMA)[b]	1.1	377	8.7	1.61	2.00	None
R 588	1.3	599	13.9	--	1.76	None

-- Data not available

Note: The average initial flexural strength of these formulations is 4285 psi.

[a]Monomer Formulation: 55.5 wt% styrene - 4.5 wt% polystyrene - 40 wt% TMPTMA with additives 1 wt% S440, 1 wt% A174, 1 wt% DMA, 4 wt% BFF-50, 0.5 wt% DTBP.

Aggregate Formulation: 76 wt% silica sand - 24 wt% Type III portland cement with additives 0.5 wt% A174, 0.5 wt% 8440, 1.5 wt% acrylamide.

[b]Monomer Formulation: 55 wt% styrene - 36 wt% acrylonitrile - 9 wt% TMPTMA with additives 1 wt% A174, 1 wt% DMA, 4 wt% BFF-50, 0.5 wt% DTBP.

Aggregate Formulation: 70 wt% silica sand - 30 wt% Type III portland cement.

[c]Water absorption is measured by submersing samples in boiling water for 5 hours.

Data provided by Brookhaven National laboratory, Upton, NY.

of corrosion product iron ions with the traces of hydrogen sulfide. A mass calculation based on the iron content of four geothermal fluid samples from the T-H-S well indicate a corrosion rate of at least 7 mpy at full fluid production.

Thus, it appears that the corrosion rate of carbon steel may vary significantly as a result of subtle variations in microstructures or the geothermal fluid environment from this resource. High corrosion rates, approximately 20-30 mpy may be encountered.

Low Alloy Steel

As shown in Table 35-3, the weight-loss results from the 4130 flat coupons were somewhat different than those from the U-bends. The flat specimens had large pits--approximately 30-60 mils in diameter and up to 8 mils deep covering about half of the surface of each coupon. The rest of the surface showed little attack, indicating that this area was cathodically protected by the growing pits. The weight-loss corrosion rate of these coupons was 4.9-7.0 mpy. The U-bends, on the other hand, did not exhibit the distinct pitting shown by the flat coupons, though some faint rings were visible. Rather, the entire surface was roughened, indicating uniform corrosion. The weight-loss corrosion rate was 19 mpy. The transition to "uniform" corrosion, may well be the result of the high stress state of the U-bend material as high applied stresses can provide the energy necessary to cause rupture of protective films. As in the case of the carbon steel, these results suggest that the 4130 has some tendency to form protective films, but that these films do not afford reliable protection.

The 4130 U-bends were fabricated from material of HRC 37-38 hardness. Low alloy steel of this hardness is highly susceptible to sulfide stress cracking ("sour cracking"). One of the two U-bends did crack, demonstrating that the Central Texas geothermal fluids can cause sulfide stress cracking of susceptible materials--high strength alloys with HRC greater than 22. The two cracks also showed evidence of metal-loss corrosion, suggesting that they occured early in the test.

Ni-Resist Type I Cast Iron

This high nickel cast iron is used as impeller material in some electric submersible pumps. It exhibited 4.5-9.2 mpy weight-loss corrosion as uneven graphitization. Graphitization is a corrosion mode of cast iron in which the ferrous matrix is corroded away leaving the graphite flakes. The object does not change shape, but looses strength as the matrix is dissolved.

Galvanized Steel

The three flat galvanized steel coupons and both U-bends were partially corroded away during the 4627 hour test. Almost half of each of two of the flat coupons was missing, and what remained was brittle and fragile to the touch. Apparently all of the zinc was corroded away, as well as most of the steel substrate. As anticipated, these results indicate that galvanizing is not protective in these waters.

Type 304 Stainless Steel

The flat specimen examined by the Radian MSL showed 0.7 mpy weight-loss corrosion and a few scattered pits up to 4.1 mil deep. These pits were 1-7 mils in diameter and were barely visible at 40X. They would not have been visible at the 5-10X magnification used by the INCO. No crevice corrosion was detected. The two U-bends showed 0.5 mpy weight-loss and no cracking. Like the flat specimen, they exhibited roughening of the as-received finish.

The two coupons evaluated by INCO showed no reported weight-loss corrosion (<0.05 mpy) and no signs of pitting or crevice corrosion.

Type 316 Stainless Steel

All of the flat coupons of this material showed less than 0.05 mpy weight-loss corrosion. The specimen examined by the Radian MSL showed no detectable change in the as-received surface finish. This result is consistent with the inspection of the Type 316 plates from one of the T-H-S heat exchangers after its initial seven months of service. That inspection, which included microscopic examination up to 400X, also showed no change in surface finish. (Refer to Appendix D.)

The U-bends showed 0.1-0.2 mpy weight-loss, possibly a result of the applied stress. No evidence of chloride stress corrosion cracking was observed.

Type 317LM, Alloy 904L, Nitronic Alloy 50, Incoloy 825

All of these highly alloyed stainless steels contain additions of alloying elements which would be expected to provide greater pitting resistance than Type 316. Their performance in this test was consistant with this expectation. All showed less than 0.05 mpy weight-loss corrosion and no detectable pitting or crevice corrosion.

Type 410 Stainless Steel

This 12Cr stainless steel showed surprisingly little corrosion, less than 0.05 mpy weight-loss and no pitting when examined at low magnification. It did suffer some crevice corrosion, less than 1 mil deep. 12Cr stainless steels typically have significantly less pitting resistance than Type 304. Therefore, despite the good result in this trial, use of these alloys for large thin-wall applications, such as heat exchanger plates, is inadvisable for this resource.

Monel 400 and K500

These two alloys are compositionally quite similar, containing about 40 percent copper in a nickel base. Monel K500 contains minor additions of aluminum and titanium which produce high strength properties. These alloying additions generally do not produce a significant difference in weight-loss or pitting corrosion performance [Lewis 1979]. In this test, the two Monel K500 coupons analyzed by INCO and the Monel 400 coupon analyzed by Radian all showed weight-loss corrosion rates of 0.1 mpy with no pitting detected at 40X. The two Monel 400 coupons evaluated by INCO also showed no pitting or crevice corrosion, but exhibited 1.2 mpy weight-loss corrosion.

The Copper Alloys

Most copper alloys have performed extremely poorly in low temperature geothermal environments. Copper and brasses have not done well and should generally be avoided, as should cupronickels [Ellis and Conover 1980; 1981]. However, a few copper alloys-- aluminum bronzes and leaded red bronze-- have shown promise [Ellis and Conover 1981; Anliker and Ellis 1981], and were included in this test.

CA 836 (leaded red bronze) showed 0.1-0.2 mpy uniform corrosion with crevice corrosion up to 1.2 mils deep. There was no evidence of pitting.

CA 613 and CA 614 are wrought aluminum bronzes with similar compositions. The CA 613 showed 0.2-0.3 mpy weight-loss corrosion. About one-half of the surface of each coupon was covered with dense microscopic pits less than 0.5 mils deep. Crevice corrosion depth was 1.4 mils. The CA 614 showed no evidence of stress cracking.

The aluminum-nickel bronzes, CA 954, CA 955, and CA 958, all had weight-loss corrosion rates of 0.2 mpy or less. All showed crevice corrosion of about the same severity (0.6-1.5 mil). CA 954 showed no pits, while CA 955 had 5 pinpoint pits on one coupon, and CA 958 had a few tiny pits on each coupon.

Polymer Cements

All of these materials showed a slight but real strength progression as a result of hydration of the Portland cement constituent. The water absorption of the styrene-TMPTMA more than doubled, while the styrene-AN-TMPTMA showed only a 25 percent increase. However, even the highest water absorption was only 2.54 percent, compared to six percent for good Portland cement. The cements were also dimensionally stable. It is the conclusion of BNL that these materials showed no degradation as a result of the test exposure [Kukacka 1983].

Elastomeric O-Rings

As shown in Table 35-6, the average compression set of the Viton was 31.8 percent while the Buna-N (nitrile rubber) was 44.8 percent. Neoprene showed a compression set of 73.9 percent after only 4627 hours. The Neoprene O-rings were conspicuously flattened after removal from the compression test apparatus, and showed no visible signs of recovery even after several days. On the basis of these results, Viton is ranked as best, Buna-N is good, and neoprene is poor.

35.4 Implications for Central Texas Geothermal Development

As shown in Table 35-1, the Central Texas geothermal resource as typified by the fluids of the T-H-S well fall into Geothermal Corrosivity Class Va. In fact, the measured wellhead pH of 6.16 at Marlin may well make this resource one of the most aggressive to steel of any low temperature domestic geothermal resource developed to date.

Experience at other Class Va resources shows that, for steels, weight-loss corrosion rates of 4.8 to 20 mpy are typical, usually with heavy pitting [Ellis 1982]. The average weight-loss corrosion rate of carbon steel in the 4627 hour test was within this range, but four of the six specimens had corrosion rates of 23-28 mpy. The evidence from the 4627 hour test, and other data from the T-H-S geothermal system, indicate that the corrosion behavior of carbon steel can vary widely with minor and subtle variations in environment.

Minor alloying with chromium and molybdenum (4130 steel) did not improve the overall corrosion performance of the steel. Unstressed metal showed pitting at about 15 mpy, while stressed material showed 19 mpy "uniform" corrosion.

Given the variability in steel performance, conservative values of 20-30 mpy should be assumed, as such corrosion rates may well occur even in the absence of oxygen. In addition, the Central Texas geothermal water was demonstrated to cause sulfide stress cracking of high strength low alloy steel. Therefore, the limitations of NACE* Materials Requirement for Sulfide Stress Cracking Resistant Metallic Material for 0.1 Field Equipment (NACE Standard MR-01-75) should be considered in all materials selections. This standard allows a maximum hardness of HRC 22 for low alloy steels.

Whenever possible, alternative materials such as non-metallic piping and well casing should be considered. Table 35-7 summarizes the properties of some non-metallic well casings tested for low temperature geothermal wells. The source reference for Table 35-7 also provides information on design, limitations, and cost of such casing.

Another alternative worthy of consideration is the use of moderately alloyed steels ranging from 2.25Cr - 1Mo to 9Cr - 1Mo. These alloys have apparently not been tested in low temperature applications, but have been shown to be superior to carbon steels in some high temperature trials [McCright 1981].

Galvanizing cannot be relied upon for protection of steel. The galvanized samples tested at T-H-S were partially destroyed. No protection was afforded by the zinc.

Low temperature geothermal experience has shown that copper and many of its alloys, including most brasses and cupronickels, have given almost universally poor performance in actual geothermal systems [Ellis and Conover 1980; 1981]. Therefore, it is likely that virtually all Central Texas geothermal projects

*National Association of Corrosion Engineers

TABLE 35-7. APPROXIMATE MECHANICAL PROPERTIES AND LIMITATIONS ON NON-METALLIC CASING MATERIALS

Material	SpGr (68° F)	Tensile Strength (at 68°F) (ksi)	Tensile Modulus at 68°F) (ksi)[a]	Ceiling Temperature (°F)	Tensile Modulus @ Ceiling Temp (ksi)	Thermal Expansion (10^{-5} in/in/°F)	Depth Limit (ft)
Thermoplastics							
ABS	1.04	4.5	299.9	180	220.4	3.05	1000
CPVC	1.55	8.4	422.4	180	--	3.78	1000
PVC	1.40	8.0	419.6	150	284.4	2.78	1000
SBR	1.06	3.8	320.0	140	284.4	4.17	1000
Thermosets							
Epoxy	1.89	9.5	1351.1	266	--	1.28	--
Polyester	1.80	8.2	1378.1	150	--	1.22	--
Vinylester	1.53	15.2	1041.1	199	--	1.22	--
Fiber-Reinforced Plastics							
Epoxy (continuous wound)	--	--	2190.2	266	1393.8	--	6562
Epoxy (fiber mat)	--	--	1329.8	150	938.7	--	--
Vinylester	--	--	938.7	199	739.6	--	1200
Reinforced Plastic Mortar (RPM)	1.95	27.0	2999.5	140	--	0.50	--
Casing Steel[b]							
API K-55	7.84	75.0	39593.6	1800	--	0.63	--

-- No data available.

[a]ksi = thousand pounds per square inch
[b]Included for comparison purposes.

Abbreviations
ABS - polymerized acrylonitrile, butadiene, and styrene monomers
CPVC - chlorinated polyvinyl chloride
PVC - polyvinyl chloride
SBR - styrene butadiene copolymer resin

Source: Gas, Purdin and Armitage 1979

will require the use of isolation heat exchangers to protect standard HVAC equipment from contact with the geothermal fluid.

Both T-H-S heat exchanger experience and results of the 4627 hour test indicate that Type 316 stainless steel is probably the optimum material for heat exchanger plates in the Central Texas resource. Type 304, which inherently has less pitting resistance than Type 316, was found to have suffered microscopic pitting at about 8 mpy, and therefore it is likely not suitable for heat exchanger service. It may be useful for thick-walled applications. Type 410 (12Cr) likewise usually has lower pitting resistance than Type 304, and should be considered only for thick-walled applications.

More highly alloyed stainless steels, such as Type 317LM, Alloy 904L, Nitronic 50, and Incoloy 825 could be considered if Type 316 should prove inadequate at other Central Texas locations. These alloys may also be useful for other applications in various geothermal components.

Leaded red bronze has proven successful for valve bodies, lineshaft bearings, and pump impellers in other geothermal systems, and these test results support its use in the Central Texas resource. The aluminum-nickel bronzes, CA 954, CA 955, and CA 958, may also be useful and economic for thick-walled applications. Wrought aluminum bronze CA 613 has been considered for plates of plate heat exchangers, but its tendencies toward pitting or surface roughening, as well as crevice corrosion, should be considered carefully prior to its use for such.

Viton was found to be the best elastomer tested and is likely to be worth the extra cost for dynamic seals and for parts which are frequently disassembled. Buna-N was not as resistant to compression set as was Viton, but is also an acceptable material. Neoprene showed severe compression set and should be avoided.

36.0 ENVIRONMENTAL MONITORING OF THE T-H-S MEMORIAL HOSPITAL GEOTHERMAL DISCHARGE*

The Torbett-Hutchings-Smith (T-H-S) Memorial Hospital geothermal project secured appropriate permits allowing surface discharge of the spent geothermal fluids. This disposal technique enjoys both technical and economic advantages over injection of spent geothermal fluids. It is therefore desirable that future geothermal projects having the same or similar fluids also use surface discharge. The primary deterrent to this technique is the potential environmental impact on water quality and/or biota due to these discharges. The purpose of this case study was to monitor and evaluate the actual environmental conditions along the surface discharge route of the spent T-H-S fluids. This route is illustrated in Figure 36-1.

This case study included water quality and biological sampling, analyses, and documentation. Sampling was performed by a water quality analyst and an aquatic ecologist on one-day sampling trips occurring in the months of May, July, and November 1982, and February 1983. Water quality field measurements (pH, temperature, dissolved oxygen, and conductivity) were made during each of the trips at pertinent locations along the discharge

*This section describes an effort which is unique to the T-H-S Hospital project and which is, therefore, in addition to the "standard" DOE PON outline followed for this report.

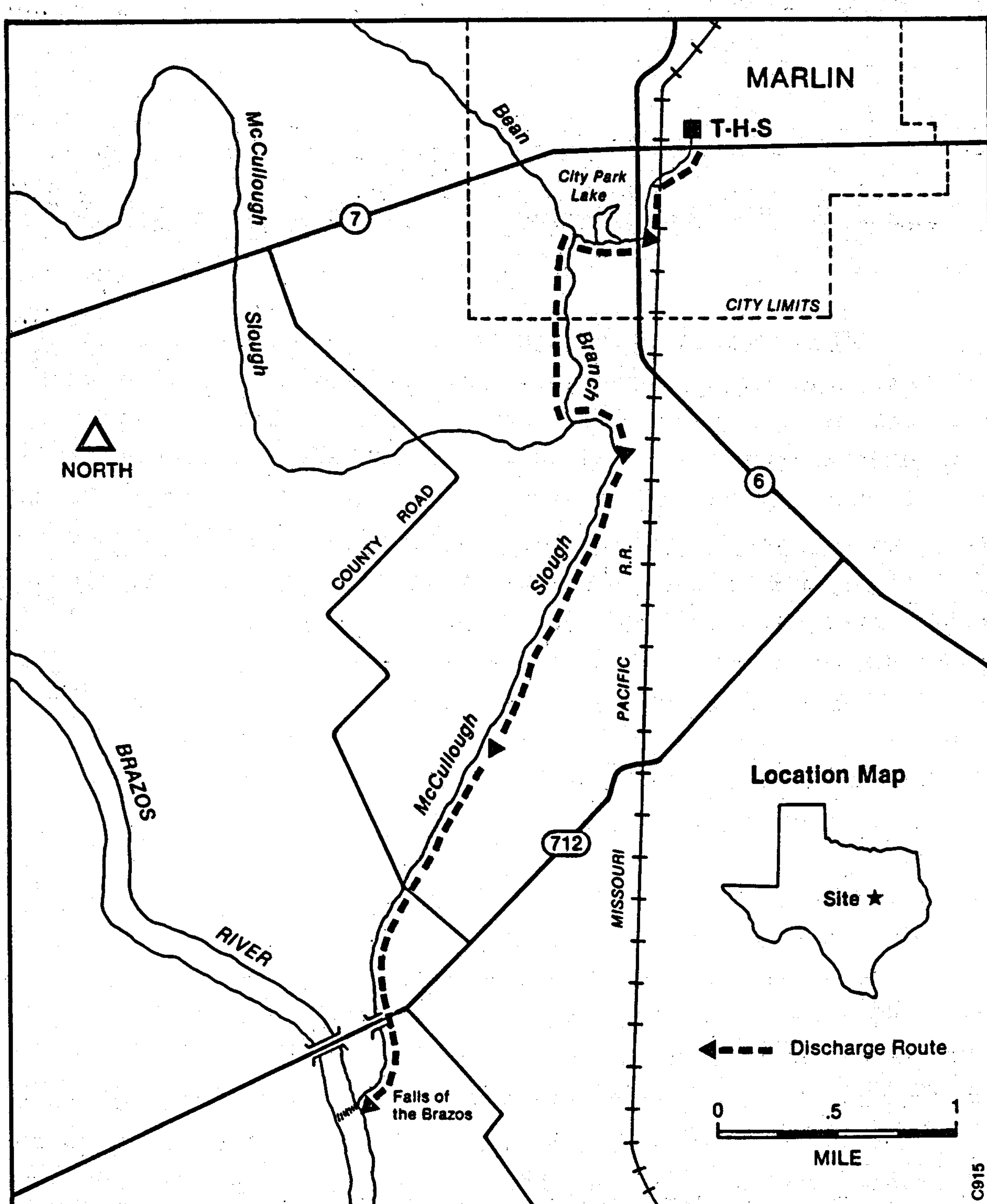


Figure 36-1 Map of the Discharge Route

route. Water quality analyses that determined total dissolved solids (TDS), sulfates, chlorides, and trace metal concentrations were performed for two sample locations during each of the four seasonal visits. Additionally, qualitative and quantitative comparisons of aquatic biota at appropriate locations were made by an aquatic ecologist. Similarly, a terrestrial ecologist assessed the biota near the stream beds of the discharged fluid route.

36.1 Description of the Receiving Water Body

The spent geothermal fluids are discharged to City Park Lake via a storm sewer system which drains the southern portion of the city. The storm sewer outlet is a culvert which empties into a short inlet stream which flows to City Park Lake. Figure 36-2 shows the City Park Lake and its surroundings.

The City Park Lake is a man-made impoundment which serves as a storm-water catchment basin. The pond area is approximately two acres and its average depth is less than two feet. The deepest point found during Radian's 1982-1983 surveys was slightly over three feet. The pond is situated in the City Park and its primary value is scenic. There is no use of the lake for swimming or boating. Fishing has reportedly been limited to catching bait for other lakes and rivers in the area. Such reports are consistent with the finding of no significant game or sport fish while seining the lake during four seasonal visits.

The outlet stream from the lake flows into Bean Branch, a tributary of McCullough Slough. McCullough Slough is a former channel of the Brazos River which drains to the Brazos the agricultural bottomlands in the floodplain between the existing Brazos River channel and the City of Marlin.

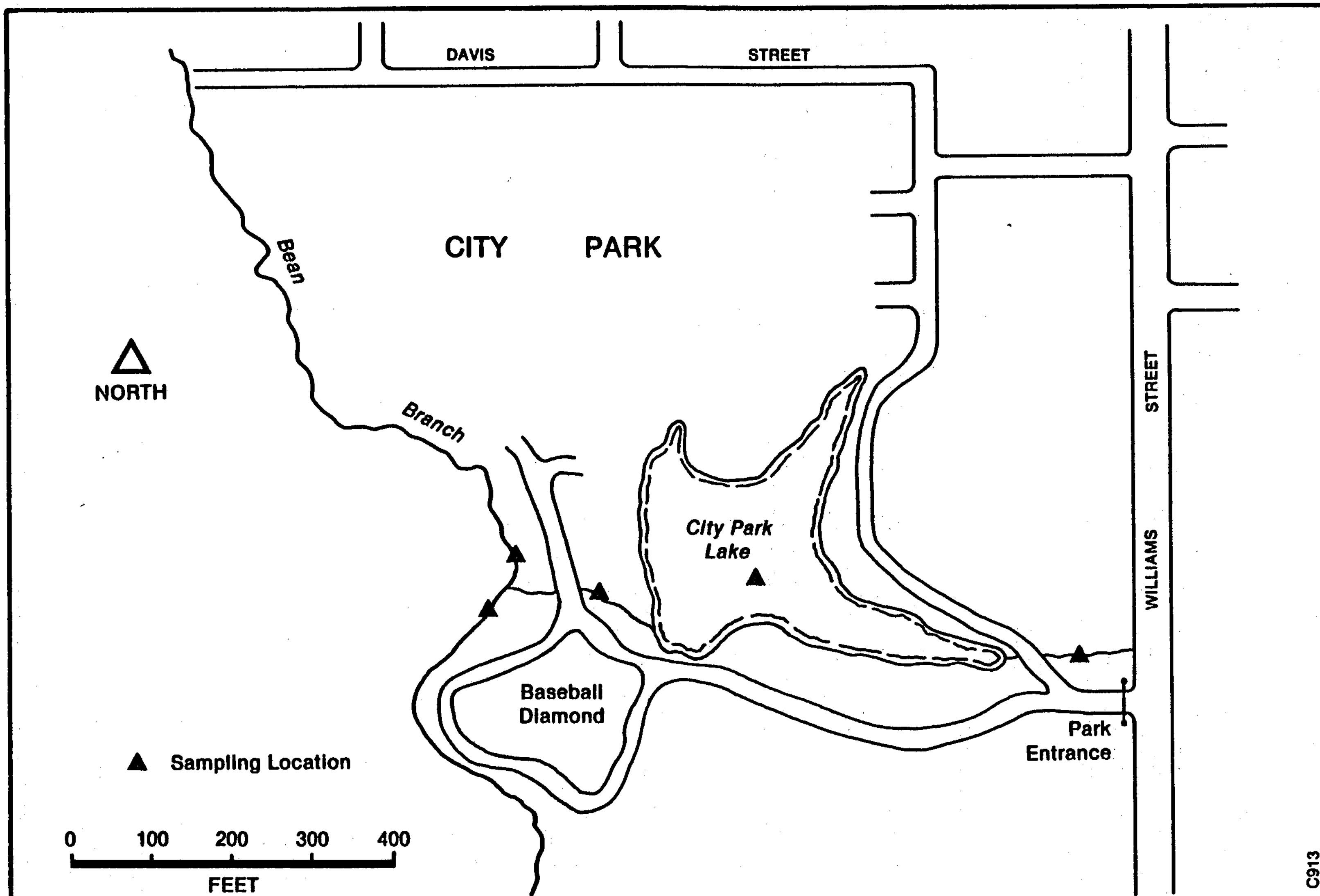


Figure 36-2 Sampling Locations Near City Park Lake

The Brazos River is the third largest river flowing in Texas. It flows southeast and across Texas and enters the Gulf of Mexico. Marlin is located about 3.5 miles (5.6 km) northeast of the confluence of McCullough Slough and the Brazos River.

Baseline water quality data was not collected for the surface waters prior to the initiation of discharges from the T-H-S well. Table 36-1 lists a comparison of pH and TDS values for waters downstream from City Park Lake during a period in which there were on and off well test discharges at low flows of approximately 50 gpm. It is not clear to what extent these test discharges affected the downstream water quality on the day in which these samples were taken. However, this data is consistent with other data taken in December 1981 prior to installation of the production pump (e.g., no discharge occurring). Therefore, these earlier values were used as baseline for assessment purposes both in the original environmental assessment and for this study.

TABLE 36-1. WATER QUALITY DATA FOR CITY PARK LAKE, BEAN BRANCH McCULLOUGH SLOUGH AND BRAZOS RIVER IN MARLIN, TEXAS, AUGUST 1979

Sample Collection Site	pH (units)	TDS (mg/l)
City Park Lake Inlet	8.02	3960
City Park Lake Outlet (Bean Branch Inlet)	7.65	1110
McCullough Slough Outlet	7.57	1460
Brazos River Park	7.69	840

Source: Radian 1979.

36.2 Description of Sampling and Analytical Procedures

All sampling and analytical procedures performed by Radian were standard, approved techniques. A brief description of them follows. Further details can be found in references APHA-AWWA 1981; US EPA 1979; and US EPA 1973.

36.2.1 Sampling Procedures

Water Quality

Sampling trips to the site were made in May, July, and November 1982 and in February 1983. During these trips, physico-chemical data were recorded in the field and samples for water quality analysis were iced and returned to Radian's laboratories in Austin, Texas.

Table 36-2 provides information on the Hydrolab® 8000, the instrument used for field physico-chemical determinations.

TABLE 36-2. HYDROLAB® 8000 TECHNICAL INFORMATION.

Parameter	Probe Type	Calibration	Range Sensitivity
Temperature	Linear thermister	Factory	-5.0 to 45°C ± 0.1°C
Depth	Strain gauge transducer	Factory[a]	0 to 20 m ± 0.1 m
Conductivity	Temperature compensated, four electrode cell	Laboratory[b]	0 to 20,000 µmhos/cm ± 2
pH	Temperature compensated glass electrode, silver/silver chloride reference	Field[c]	0 to 14 su ± 0.02 su
Dissolved oxygen	Temperature compensated membrane filter	Field[c]	0 to 20 ppm ± 0.05 ppm

[a]Field calibrated to zero on local barometric pressure.

[b]Documented calibration before and after each trip.

[c]Documented calibration daily.

Biological

Fish were collected using a 20 ft x 4 ft x 3/16 inch mesh minnow seine and a D-framed dip net. Observing shallow streams and checking fisherman creels were also used where appropriate.

Qualitative plankton samples were taken by towing a 9 cm No. 220 mesh net through the water. Quantitative samples were obtained by collecting one liter of raw water in a wide-mouth bottle. All plankton samples were preserved with three to five percent buffered formalin and labeled.

Benthic (bottom dwelling) invertebrate samples were collected using a 6 inch x 6 inch Ekman dredge. The sample was placed in a No. 30 mesh bottomed wash bucket and the silt and fine debris was rinsed out. The remaining debris and organisms were placed in a one-liter widemouth jar, preserved with five percent formalin, stained with rosebengal and labeled.

Periphyton (plant communities attached to submerged objects) samples were qualitatively sampled by scrapping appropriate substrates at the station site. The samples were preserved with three to five percent formalin and labeled.

Sediment samples were collected using a 6 inch x 6 inch Ekman dredge. The dredge was emptied into a Teflon bucket, allowed to settle, and the supernatant was discarded. The remaining material was placed in a one-quart jar with Teflon lid, labeled, iced, and returned to Radian's Austin laboratories.

36.2.2 Analyses Procedures

Water Quality

Water quality samples returned to the laboratory were analyzed as presented in Table 36-3. Trace elements were analyzed using ICPES (Inductively Coupled Argon Plasma Emission Spectroscopy) scans. The first two sampling trips also used AA (Atomic Absorption) spectroscopy for greater sensitivity. Detection limits of the trace elements scans are presented in Table 36-4.

Biological

Macroinvertebrate samples were rinsed with tap water, placed in a white background pan, sorted from the debris, and preserved in 70 percent ethanol. The samples were then identified to the lowest practical taxon utilizing either a dissecting microscope or a compound microscope, as necessary.

TABLE 36-3: METHODS USED FOR WATER QUALITY CHEMISTRY OF MARLIN SAMPLES

Parameter	Method Cited	Technique	Detection Limit[1]
Chloride	EPA 325.3[2]	Titrimetry	1
	SM 407C[3]	Potentiometric titrimetry	1
Sulfate	EPA 375.4[2]	Nephelometry	1
Total Dissolved Solids	EPA 160.1[2]	Gravo,etru	1

[1]mg/l unless otherwise noted
[2]Source: US EPA, 1979.
[3]Source: APHA, 1980.

TABLE 36-4. METHODS AND DETECTION LIMITS FOR TRACE METAL DETERMINATIONS OF MARLIN SAMPLES

	Detection Limit (mg/l)				
	AAS[1]				
Element	Flame	Graphite Furnace	Hydride Generation	Cold Vapor	ICPES[2]
Aluminum	0.5				0.050
Antimony	0.02	0.005	0.005		0.032
Arsenic	0.01	0.002	0.003		0.057
Barium	10.0	0.1			0.0006
Beryllium	0.04	0.0005			0.0005
Bismuth					0.049
Boron					0.009
Cadmium	0.1	0.0005			0.008
Calcium	0.05				0.045
Chromium	0.2	0.003			0.001
Cobalt	0.05	0.005			0.006
Copper	0.1	0.003			0.001
Gold					0.048
Indium					0.055
Iron	0.02				0.008
Lead	0.4	0.002			0.084
Lithium	0.01				0.004
Magnesium	0.02				0.034
Manganese	0.01				0.001
Mercury				0.0002	0.032
Molybdenum	0.1	0.005			0.002
Nickel	0.2	0.005			0.003
Phosphorus					0.18
Platinum					0.025
Potassium	0.05				0.042
Selenium	0.01	0.003	0.004		0.084
Silicon	1				0.016
Silver	0.06	0.001			0.002
Sodium	0.05				0.006
Strontium	0.02				0.0004
Sulfur					0.030
Tellurium					0.10
Thallium	1	0.003			0.091
Tin					0.12
Titanium					0.005
Tungsten					0.018
Uranium					0.064
Vanadium	1	0.001			0.003
Yttrium	0.02				0.002
Zinc	0.03	0.005			0.003

[1]Atomic absorption spectroscopy
[2]Inductively coupled argon plasma emission spectroscopy

Plankton samples were settled in a one-liter hydrometer cylinder with two to five milliliters (ml) of Lugol's solution and two ml of detergent. After settling for 48 hours, the sample was concentrated by slowly siphoning off and discarding all but 25 ml of fluid. The concentrated plankton were then poured into a beaker, and 25 ml of distilled water were added to the hydrometer cylinder to further rinse out the sample. The rinse water was then added to the plankton, bringing the volume to 50 ml. This concentrate was aggitated before sub-sampling for zooplankton and phytoplankton analyses.

Depending on the density of the zooplankton populations, quantitation was achieved using either a Sedgewick-Rafter (sparse) or Palmer (dense) counting cell. Enumeration was done with either a Bausch and Lomb Stereozoom 5 (Sedgewick-Rafter) or an Olympus CHA (Palmer) compound microscope.

Total algal populations were determined in a two-step method. The first step involved quantifying and identifying the diatom (abundant microscopic siliceous algae) component by dry mount. The second step involved identifying and quantifying the remaining population by wet mount. The final densities of taxonomic (systematic scientific classification-type) units were determined by combining the results of the two methodologies.

Taxonomic composition and abundance of diatoms were determined by placing several drops of the settled concentrate on a microscope slide, thoroughly drying the sample on a warming plate and mounting a coverglass with Hyrax. This procedure allows identification of the diatoms at 100X, 450X, and 1000X utilizing phase and/or oil immersion. From this data all diatoms were identified to the lowest practical taxon. Ratios of small, otherwise unobservable diatoms to the larger individuals were made.

A Palmer counting cell was then prepared (wet mount) and all algal components were identified and enumerated. Only the large diatoms are countable by this technique. The remaining diatoms are then added to count in the same ratio as determined from the dry mount.

36.3 Results of Field Measurements and Sample Analyses

36.3.1 Water Quality Analyses

The parameters chosen for this study can be divided into two categories:

- Field Parameters: temperature, dissolved oxygen, pH, and conductivity,
- Chemical Parameters: total dissolved solids (TDS), chloride (Cl), sulfate (SO_4), and trace metals.

Table 36-5 summarizes the results of both field measurements and water quality analyses at the inlet stream to City Park Lake and at City Park Lake itself. The data indicate that the inlet water is being diluted within the body of the lake. Also it appears that a density gradient or partial stratification may exist in the lake during some periods of the year. During spring and fall sampling, dissolved oxygen concentrations in the lake exceeded the saturation level, indicating a biological "bloom" in the lake. The ratio of conductivity to total dissolved solids ranges from 0.64 to 0.74 which closely corresponds to the mean ratio of 0.65 reported by the U.S. Geological Survey for this area [Welborn 1983].

TABLE 36-5. WATER QUALITY SAMPLING DATA, CITY PARK LAKE, MARLIN, TEXAS

Parameter[1]	5/82 Inflow	5/82 Lake	7/82 Inflow	7/82 Lake	11/82 Inflow	11/82 Lake	2/83 Inflow	2/83 Lake
pH (su)	8.6	8.7	8.2	8.2	8.1	8.0	8.2	8.4
Temperature (°C)	27.4	24.3	30.1	31.3	24.4	15.6	23.8	13.8
Dissolved Oxygen	7.6	8.6	6.7	5.4	7.2	6.6	8.6	12.4
Conductivity[2] (µmhos/cm)	5880	2830 (3090)	4390	3800	5560	2210 (3370)	5950	3330 (4000)
Total Dissolved Solids	4042	1825	3320	2880	4150	1530	4430	2380
Sulfate	2060	456	1510	1280	---	---	2590	1520
Chloride	315	158	370	310	260	141	290	237

[1]Units in mg/l unless shown otherwise.
[2]Data in parenthesis at 1.0 meter depth. Other data at 0.1 meter depth.

Water quality samples were also analyzed for trace metal concentrations at these two locations. These data are included as Appendix G to this report. Analysis of the trace metal data failed to show any seasonal trends or significantly high concentrations of trace metals in lake water, bottom sediment, or fish tissue.

Tables 36-6 through 36-9 present representative field measurements taken along the entire discharge route during the four seasonal visits. Sampling points are roughly indicated on Figure 36-2 and 36-3. Data for two depths at the middle of City Park Lake are included to give a profile of the water column in the lake. As noted earlier, the discharge fluids are more dense than local surface waters, and it appears that a density gradient

TABLE 36-6. REPRESENTATIVE FIELD MEASUREMENTS FROM CITY PARK LAKE TO THE BRAZOS RIVER, 5 MAY 1982

Station	Temperature (°C)	pH	Conductivity (µmhos/cm)	Dissolved Oxygen (mg/l)	Depth (m)
Inlet Stream	27.4	---	5880	7.6	0.1
City Park Lake	24.3 23.9	8.7 8.1	2830 3090	8.6 2.4	0.1 1.0
Outlet Stream	24.6	---	2780	6.5	0.1
Bean Branch (Upstream)	24.5	---	720	5.5	0.1
Bean Branch (Downstream)	25.3	---	1480	9.7	0.1
McCullough Slough (At highway bridge)	24.5	---	1840	6.7	0.1
McCullough Slough (At Brazos River Park)	23.8	---	1880	7.9	0.1
Brazos River (Upstream)	23.3	8.2	1400	9.1	0.2
Brazos River (Mixing zone with McCullough Slough)	23.3	8.2	1430	8.8	0.2

TABLE 36-7. REPRESENTATIVE FIELD MEASUREMENTS FROM CITY PARK LAKE TO THE BRAZOS RIVER, 29 JULY 1982

Station	Temperature (°C)	pH	Conductivity (μmhos/cm)	Dissolved Oxygen (mg/l)	Depth (m)
Inlet Stream	30.1	8.2	4390	6.7	0.1
City Park Lake	31.3	8.2	3800	5.4	0.1
	30.5	7.8	---	1.0	1.0
Outlet Stream	30.6	8.6	3900	7.1	0.1
Bean Branch (Upstream)	32.4	9.2	3750	7.1	0.1
Bean Branch (Downstream)	32.3	10.2	3800	8.5	0.1
McCullough Slough (At highway bridge)	31.4	9.0	2570	8.3	0.1
McCullough Slough (At Brazos River Park)	33.6	9.4	2570	13.6	0.1
Brazos River (Upstream)	31.8	9.0	1100	10.1	0.2
Brazos River (Mixing zone with McCullough Slough)	31.8	9.9	1080	10.1	0.2

TABLE 36-8. REPRESENTATIVE FIELD MEASUREMENTS FROM CITY PARK LAKE TO THE BRAZOS RIVER, 5 NOVEMBER 1982

Station	Temperature (°C)	pH	Conductivity (μmhos/cm)	Dissolved Oxygen (mg/l)	Depth (m)
Inlet Stream	24.4	8.1	5440	7.1	0.5
City Park Lake	15.6	8.0	2210	6.6	0.2
	16.8	7.7	3670	2.5	1.2
Outlet Stream	15.4	8.1	2300	7.8	0.1
Bean Branch (Upstream)	14.3	7.4	1450	4.6	0.2
Bean Branch (Downstream)	13.8	7.52	1300	5.0	0.5
McCullough Slough (At highway bridge)	13.3	7.6	1820	5.4	0.1
McCullough Slough (At Brazos River Park)	15.0	7.8	1990	9.0	0.1
Brazos River (Upstream)	16.7	7.9	1030	9.5	0.2
Brazos River (Mixing zone with McCullough Slough)	16.5	7.9	1060	9.5	0.2

TABLE 36-9. REPRESENTATIVE FIELD MEASUREMENTS FROM CITY PARK LAKE TO THE BRAZOS RIVER, 17 FEBRUARY 1983

Station	Temperature (°C)	pH	Conductivity (μmhos/cm)	Dissolved Oxygen (mg/l)	Depth (m)
Inlet Stream	23.8	8.2	5950	8.6	0.2
City Park Lake	13.8	8.4	3330	12.4	0.1
	14.6	8.1	4000	8.6	1.0
Outlet Stream	13.5	7.9	3280	10.5	0.1
Bean Branch (Upstream)	12.9	7.7	1150	9.5	0.1
Bean Branch (Downstream)	13.6	8.0	2320	10.4	0.1
McCullough Slough (At highway bridge)	12.1	7.5	1440	8.5	0.1
McCullough Slough (At Brazos River Park)	15.3	8.1	1580	16.1	0.1
Brazos River (Upstream)	18.2	9.2	1090	18.0	0.2
Brazos River (Mixing zone with McCullough Slough)	17.6	9.0	1200	18.36	0.2

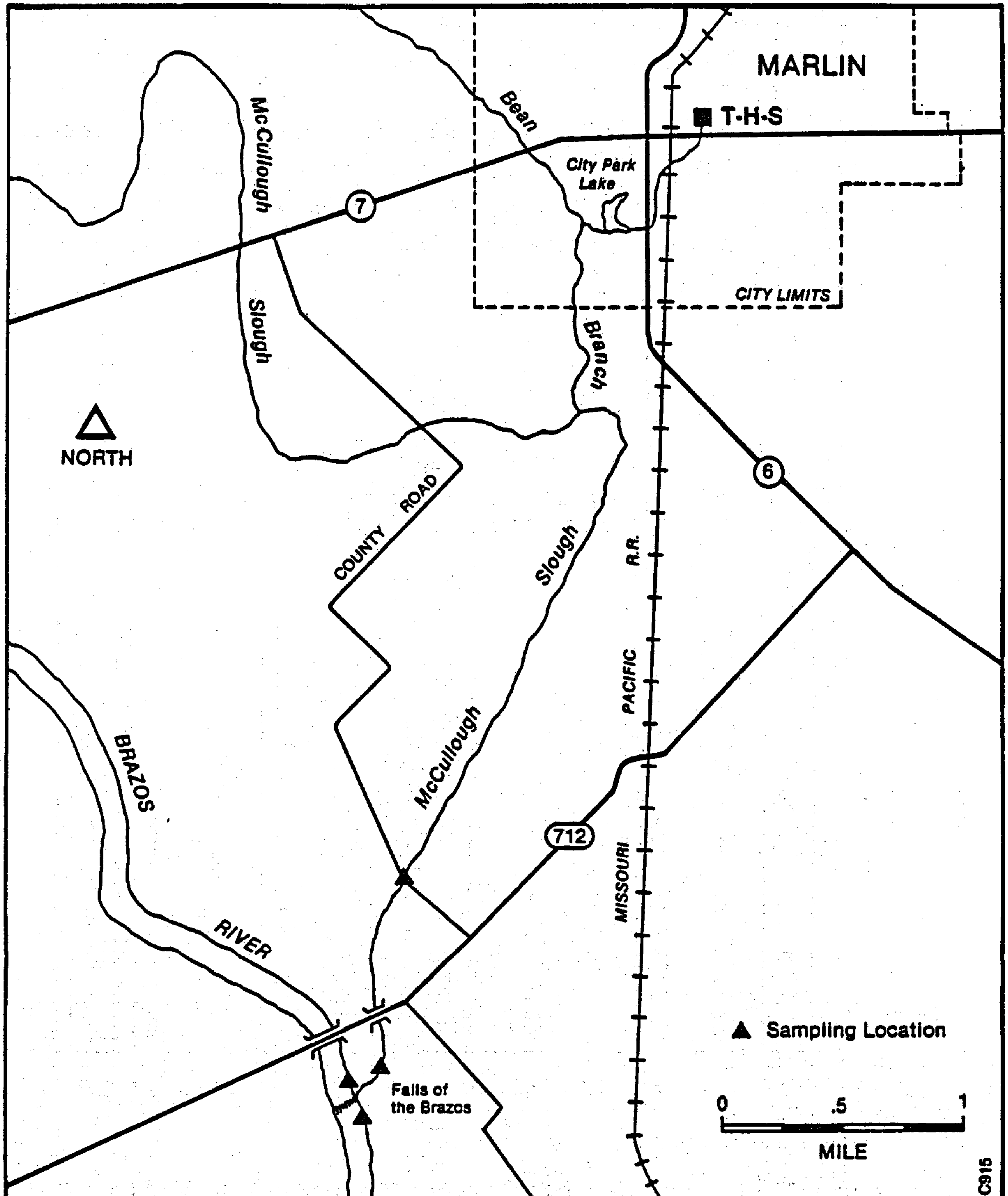


Figure 36-3 Sampling Locations Downstream From City Park Lake

occasionally exists in the lake. This effect was most pronounced during the fall (November 1982) sampling trip.

Figure 36-4 is a chart comparing normal and recorded monthly precipitation for Marlin, Texas. During the monitoring period, the monthly precipitation pattern was at or below normal except for the months of October, November, and February.

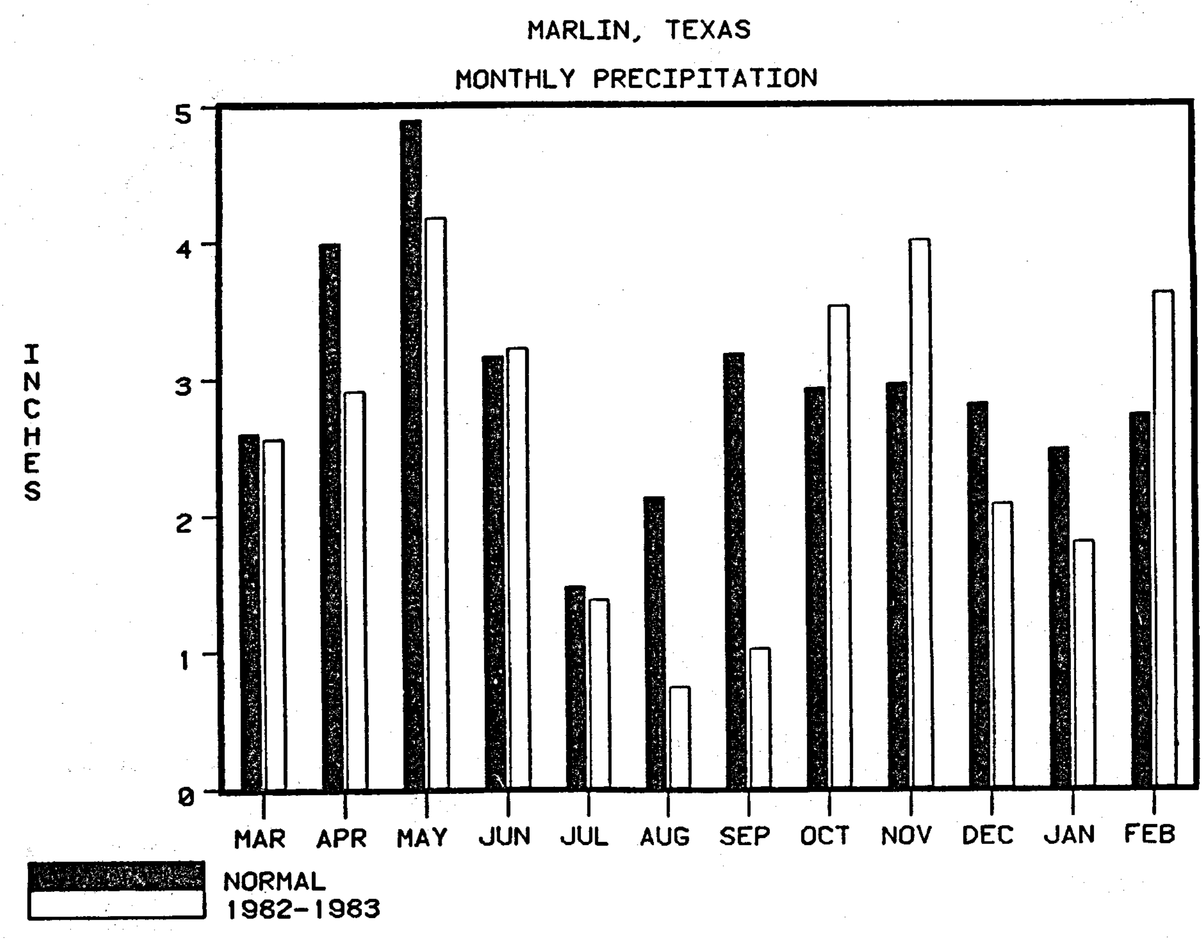


Figure 36-4 Recorded Monthly Precipitation in Marlin, Texas During Study Period Compared to Normal Monthly Precipitation. Source: NCC 1982

Storm catchment water quality can be dependent upon the number of dry days preceding sampling. Conversely, water quality following a wet period may be improved by the dilution of rainfall. Figure 36-5 shows the pattern of daily rainfall for the one year monitoring period with the dates of sampling visits indicated. The spring sampling trip was preceded by a relatively dry period in late April and early May. Similarly the summer sample was also during an extended dry period. Fall and winter samples were preceded by a number of storm events.

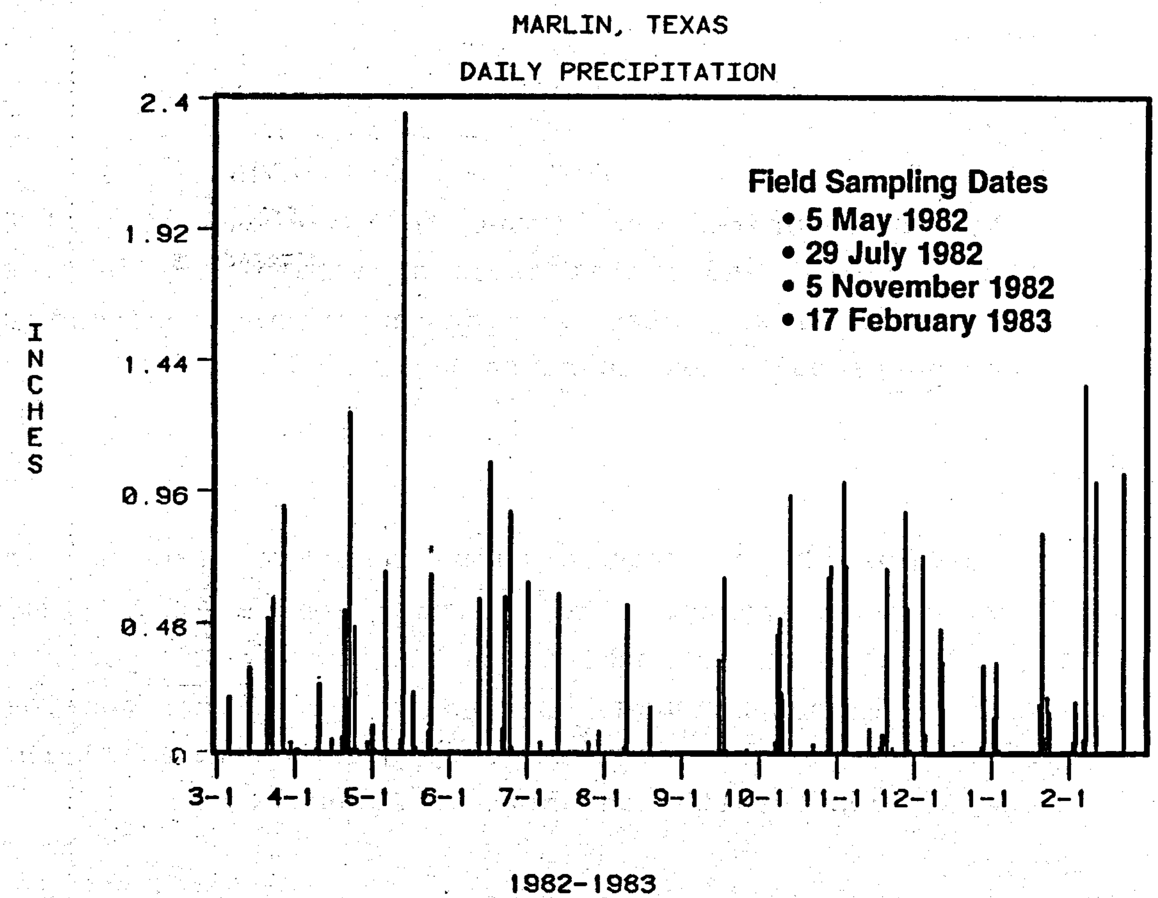


Figure 36-5 Daily Precipitation in Marlin, Texas During the Study Period. Source: NCC 1982

36.3.2 Aquatic Biology

Fish

The only fish collected in the inlet and outlet streams and the lake were green sunfish (*Lepomis cyanellus*) and mosquitofish (*Gambusia affinis*). The mosquitofish were collected in very large numbers. Downstream, in Bean Branch, a fisherman had caught a brown bullhead (*Ictalurus nebulosus*). The only other fish noted were in the mouth of McCullough Slough at the Brazos River where the blacktail shiner (*Notropis venustus*) was abundant.

Macrobenthos

No invertebrates were found in the lake. Casual collections in the inlet and outlet streams yielded very few specimens. Below the lake, most of the organisms observed were dragonflies (odonates) known to be salt-tolerant.

Plankton

Phytoplankton populations demonstrated moderate "blooms" and low diversity. The dominant species (Table 36-10) were all indicative of eutrophication and/or sewage* ponds. In particular, *Enteromorpha* and *Bidulphia* are often considered estuarine organisms. No emergent macrophytes were evident in the pond. All plankton results are shown in Appendix G.

---

*Sewage, as used in this section, refers to sanitary sewage. Although it has not been reported as occurring, typically urban storm sewers may receive overflows of sewage from manholes, liftstations, etc. during wet weather.

TABLE 36-10. DOMINANT ALGAE FOUND DURING THE MARLIN STUDY IN CITY PARK LAKE

Date	Genus (units/ml)	Indicator of[1]
29 July 82	Palmellococcus (2700)	Sewage
	Tetraedron (1700)	Sewage
5 Nov 82	Chlorococcum (2400)	Sewage
	Cyclotella (2500)	Sewage
	Rhaphiopsis (2500)	Sewage
	Enteromorpha (Abundant periphyton)	Organic Pollution
17 Feb 83	Chlorococcum (1400)	Sewage

[1]Source: Palmer, 1977.

Discussion

Mosquitofish and green sunfish are often considered to be among the fish most tolerant of pollution. The abundance of mosquitofish is indicative of the absence of an efficient predator. The moderate blooms of sewage-indicative algae demonstrate eutrophic conditions. The absence of benthic invertebrates in the pond demonstrates a serious environmental pertubation. Some bottom-dwelling pond organisms are usually very tolerant of anaerobic/salinity/thermal influences.

The biological communities present in City Park Lake are indicative of high organic sewage, salinity and environmental stresses. Many freshwater organisms can tolerate salinities up to about 5000 ppm. The stress on this system is probably related to more factors than just salinity and/or to an interaction of several factors.

36.3.3 Terrestial Vegetation

The vegetation occurring adjacent to those streams and impoundments receiving discharged geothermal waters was surveyed on 5 November 1982. Observations were made at five stations along the affected drainage. These included three stations in Marlin City Park, one station at the county road bridge over McCullough Slough and one at the confluence of McCullough Slough and the Brazos River. Observations were made of the macrophytic vegetation adjacent to the affected drainages on a qualitative basis.

Marlin City Park

The three stations included in this park were the stream channel below the park entrance and above City Park Lake (Station 1), City Park Lake (Station 2), and the stream channel below the impoundment to its confluence with Bean Branch. All three stations maintained a disturbed vegetative cover consisting of a mixture of native and introduced plant taxa.

> Station 1. Vegetation adjacent to this section of the creek is a narrow gallery forest predominantly of live oak (*Quercus virginiana*) with infrequent cedar elm (*Ulmus crassicolia*) and bois d'arc (*Maclura pomifera*). Understory consists of several large colonies of giant reed (*Arundo donax*), rough-leaf dogwood (*Cornus drummondii*), and common four-o'clock (*Mirabilis jalapa*). Vines are abundant and are dominantly trumpet-creeper (*Campsis radicans*), and poison ivy (*Rhus toxicodendron*). Herbaceous cover consists of a weedy growth of giant ragweed

(*Ambrosia trifida*), johnson grass (*Sorghum halapense*) and hairy paspalum (*Paspalum pubiflorum*). Isolated sites along this stream segment maintain a ground cover of bermuda grass (*Cynodon dactylon*) and St. Augustine grass (*Stenotaphrum secundatum*).

Station 2. The park impoundment has several live oak trees scattered around its periphery. Several of these, especially those on the south and southeast edges, appear to be dying. This condition appears to have been extant for at least several years and is not attributable to the recently initiated discharge. The most severely affected trees occur in the level park area south of the impoundment. This area maintains a lawn-type ground cover of low grasses and associated weedy forbs. The lake periphery supports a narrow, dense stand of taller weeds, especially sumpweed (*Iva frutescens*), false ragweed (*Parthenium hysterophorus*), fiddle dock (*Rumex pulcher*), johnson grass, giant and western ragweed and aster (*Aster subulatus*). Emergent macrophytes are restricted to several small colonies of common cat-tail (*Typha latifolia*) and knot-weeds (*Polygonum spp.*).

Station 3. The city park impoundment discharges through a concrete spillway and raceway terminated by a three meter fall. At the base of this fall the stream enters a flat open area containing scattered bottom land trees. These include pecan (*Carya illinoininsis*), overcup oak (*Quercus lyrata*), and both American and cedar elm. The channel supports a dense growth of weedy grasses dominated by johnson grass. The stream exits the park area and enters a shallow slough containing numerous dead sugarberry trees (*Celtis laevigata*) and elms.

McCullough Slough

Two stations were located on the drainage channel below Marlin City Park. This channel appears to have been straightened and adjacent woody vegetation removed.

Station 4. The stream passes through a well-formed channel containing no woody vegetation. Associated vegetation consists of weedy forbes and grasses found at stations 2 and 3. The channel is approximately 25 meters wide and 6 meters below the adjacent lands. Southeast of the channel occurs a forest dominated by sugarberry and ceder elm, undisturbed portions of which appear to contain isolated pecan trees and water tolerant hardwoods. Large areas have been cleared north of the channel and an extensive pecan orchard occurs south of this station.

Station 5. This station consists of a maintained channel adjacent to a county park located at the existing falls on the Brazos River. An adjacent forest is permitted to encroach on the channel and developed camping areas and trails occur along the adjacent upland area. This station is characterized by an open woodland of elm, live oak and sugarberry. Shrubs and weedy forbs and grasses are controlled and groundcover consists of scattered low grasses and forbs. The shallow stream flows over a thin bedded sandstone and little vegetation occurs in the channel center.

Discussion

The vegetative communities associated with water resources receiving the spent geothermal fluids are typical of disturbed portions of this region. The channelization of the affected stream below Marlin City Park, and the maintenance of that park and the downstream county park prevent the occurrence of significantly natural communities.

36.4 Conclusions

The comparison of the data collected during the monitoring study to the expected environmental effects of the discharge of the spent geothermal fluids is discussed below. As expected, water quality parameters indicate that the discharge has increased the concentrations of TDS in the lake and waters immediately downstream.

Figure 36-6 illustrates predicted TDS concentrations in the lake arising from the discharge of the spent geothermal fluids [Radian 1979]. Superimposed upon this figure are the four TDS data points collected during the monitoring study. The four TDS data points were instantaneous grab samples while the plotted curves represent predicted monthly average concentrations.

The modeled concentrations were based on a much larger diluting body (5 acres x 5 ft versus 2 acres x 2 ft) and also a

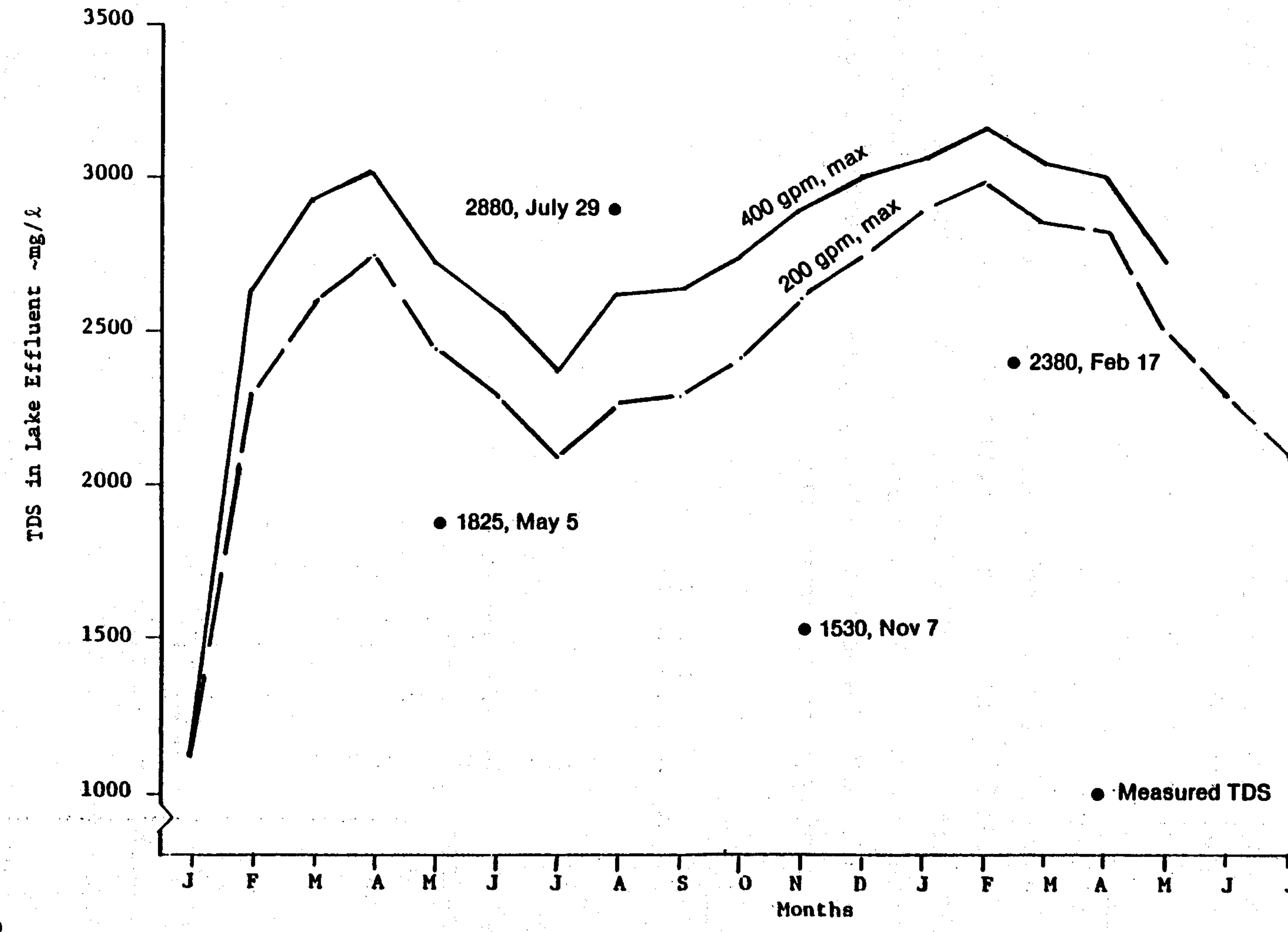


Figure 36-6 Measured Versus Predicted TDS Concentration in City Park Lake

larger discharge (200 gpm max versus 55 gpm avg.). The actual lake concentrations are probably more sensitive to precipitation than modeled since it is smaller than originally thought. This sensitivity is apparent from the July 1982 data point in that this sample was taken after an extended dry period during which both the absence of diluting rainfall and the corresponding solar evaporation tended to increase this concentration. Nevertheless, this comparison indicates that the lake concentration of TDS is in the same range as that which was predicted.

Comparing the July 1982 data (from Table 36-5) for City Park Lake to that reported for the lake outlet in August, 1979 (from Table 36-1) shows an increase in TDS of 159 percent (from 1110 mg/l to 2880 mg/l) in the lake. Using conductivity (from Tables 36-7, 36-8, 36-9, 36-10) for comparison in Bean Branch, the increase between upstream and downstream stations was approximately 100 percent during the spring and winter. Fall and summer samples show an apparent decrease in conductivity from upstream to downstream. This was likely an artifact of the extremely low flow conditions in Bean Branch that allowed mixing in the vicinity of the confluence rather than an indication that there were upstream sources of conductivity. Using the ratio of conductivity to TDS discussed in Section 36.3.1, an estimate of the comparison between McCullough Slough in August 1979 and McCullough Slough in July 1982 shows that the conductivity (or TDS) has increased by 32 percent. The effect on the Brazos River was not significant.

Since the T-H-S discharge is causing no significant change in the water quality of the Brazos River, it is deduced that there is no impact on the river's biota. Although, as expected, the upstream TDS levels (in Bean Branch and McCullough Slough) have increased, any impacts are difficult to discern due to other extensive manmade perturbations. However, no apparent impacts to the biota in these waterways were observed or analyzed during the monitoring.

The impact of the chemical changes on the biota in City Park Lake is difficult to discern in the absence of baseline biological data. City Park Lake has a number of indicators of a stressed aquatic environment (low diversity of fish species, lack of emergent vegetation, absence of benthic organisms). These responses are often representative of some type of toxic response. In addition, the microflora in the lake are indicative of both saline and organically loaded (sewage) aquatic environments. Without adequate pre-discharge (baseline) information, the stressed condition of City Park Lake can not be sufficiently linked to a particular activity. Conclusions concerning potential impacts from the discharged T-H-S Hospital geothermal fluids would therefore be entirely speculative. For future geothermal projects proposing surface discharge, it is strongly recommended that biological sampling be included in preoperational studies so that causal factors for potential stresses can be determined.

REFERENCES

Anliker, D. M. and P.F. Ellis. 1981. Component Failure Analysis Report: Bowls and Impellers of Downhole Lineshaft Pump, Merle West Medical Center, Klamath Falls, OR. DCN 81-212-011-05 DOE Contract DE-AC03-81SF11503, Radian Corporation, Austin, TX, March.

APHA-AWWA, WPFC. 1981. Standard Methods, 16th Edition.

Clusen, R.C. 1980. US DOE Memorandum from R. C. Clusen to Ruth M. Davis on Environmental Assessment, DOE/EA-0117, and Finding of No Significant Impact. US DOE, Washington, DC, August.

Cohen, L.A. 1982. Unpublished memorandum to DOE. ICF, Inc., Washington, DC, February.

Cohen, L.A. 1983. ICF, Inc. Personal communication with T.F. Green of Radian Corporation, Austin, TX, March.

Cronin, J.G., et al. 1973. Reconnaissance Investigation of the Ground-Water Resources of the Brazos River Basin, Texas. Bulletin 6310. Texas Water Commission, Austin, TX, December.

Dillard, J.W. 1978. Personal communication with J.D. Norris, Administrator, T-H-S Memorial Hospital, Marlin, TX, June.

Ellis, P.F. 1981. "A Geothermal Corrosivity Classification System," Transactions Vol. 5, Geothermal Resources Council, October.

Ellis, P.F. 1982. "Critical Assessment of Carbon Steel Corrosion in Low Temperature Geothermal Applications," paper 74, Corrosion/82, Houston, TX, 22-26 March.

Ellis, P.F. and M.F. Conover. 1980. "Corrosion Engineering for Geothermal Heating Systems," Commercial Uses of Geothermal Heat. Geothermal Resources Council, Davis, CA, June.

Ellis, P.F. and M.F. Conover. 1981. Material Selection Guidelines for Geothermal Energy Utilization Systems. NTIS Pub Code DOE/RA/27026-1, Radian Corporation, Austin, TX, January.

Ferguson, A.F., and T.F. Green. 1981. "Variable Frequency Drive (VFD) Application and Benefits for Geothermal Production at Marlin, Texas," Transactions Vol. 5, Geothermal Resources Council, October.

Ferguson, A.F., and T.F. Green. 1982. Volume 1, Torbett-Hutchings-Smith Memorial Hospital Geothermal System (1981) Operating Manual. DCN 82-212-300-17. Radian Corporation, Austin, TX, March.

Gass, T.E., W.H. Purdin, and D. M. Armitage. 1981. Economic Impact of Using Nonmetallic Materials in Low to Intermediate Temperature Geothermal Well Construction. NTIS Pub. Code TID-4500 1.1 and Vol. 2, DOE Contract DE-AC02-76CH00016, National Water Well Association, Worthington, OH, December.

Green, T.F. 1982. Comparison of Two Options for Supplying Geothermal Energy to the Veterans Administration Medical Center of Marlin, Texas. Prepared under DOE Contract DE-AC07-76 ID01570 Report No. EGG-2153, Radian Corporation, Austin, TX, April.

Hall, W.D.. 1976. Hydrogeologic Significance of Depositional Systems and Facies in Lower Cretaceous Sandestones, North-Central Texas. University of Texas, Bureau of Economic Geology, Austin, TX.

Hederman W.F. Jr. and L.A. Cohen. 1981. Economic Assessment of Geothermal Direct Heat Technology: A Review of Five DOE Demonstration Projects. Interim Topical Report under DOE Contract DE-AC07-80ID12099, ICF, Inc., Washington DC, June.

Hederman, W.F. Jr., and L.A. Cohen. 1982. "Commercial Applications of Geothermal Direct Heat Energy," presented to the Ninth Energy Technology Conference and Exposition, Washington DC, February.

Klemt, W.B., R.D. Perkins and H.J. Alvarex. 1975. Ground-Water Resources of Part of Central Texas With Emphasis on the Antlers and Travis Peak Formations, Volume 1. Report 195. Texas Water Development Board, Austin, TX, November.

Klemt, W.B., R.D. Perkins and H.J. Alvarex. 1976. Ground-Water Resources of Part of Central Texas With Emphasis on the Antlers and Travis Peak Formations, Volume 2. Report 195. Texas Water Development Board, Austin, TX, January.

Kukacka, L., 1983. Brookhaven National Laboratory. Personal communication with P.F. Ellis of Radian Corporation, 25 February.

Layne Texas Company. 1979. Completion Report, T-H-S Memorial Hospital Well No. 1. Layne Texas Company, Houston, TX, October.

Lewis, R. 1979. INCO design engineer, personal communication with P.F. Ellis of Radian Corporation, 30 November.

Lowenthal, R.E. and G.V.R. Marais. 1976. Carbonate Chemistry of Aquatic Systems: Theory and Application. Ann Arbor Science, Ann Arbor, MI.

McCright, R.D. 1981. "Corrosion Behavior of Materials Exposed to Hypersaline Geothermal Brine," Paper No 228 presented at Corrosion/81, Toronto, Ontario, Canada, April, NACE, Houston, TX.

National Climatic Center, 1982-83, Climatilogical Data, Texas March 1982 - February 1983, Ashville, NC.

Palmer, C.M. 1977, "Algae and Water Pollution, An Illustrated Manual on the Identification, Significance, and Control of Algae in Water Supplies and in Polluted Water," USEPA, Cincinnati, OH. December.

Radian Corporation. 1978. An Environmental Report for the Geothermal Direct Utilization Project at the Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas. Prepared under Contracts DOE/ET-78-C-08-1554 and TEAC/G-3-1. DCN 78-200-300-02. Austin, TX, August.

Radian Corporation. 1979. An Exhibit for a Special Request to SWR 8 to Permit Off-Lease Discharge of Geothermal Water at the Torbett-Hutchings-Smith Memorial Hospital at Marlin, Texas. prepared under Contract DOE/ET-78-C-08-1554. Austin, TX, November.

Radian Corporation. 1979. Letter from M.F. Conover to W. Staub of Oak Ridge National Laboratory, TN.

Radian Corporation. 1979. Preliminary Design Report for the T-H-S Memorial Hospital Geothermal Heating System at Marlin, Texas. Contracts DOE/ET-78-C-08-1554 and TENRAC/G-3-1. DCN 79-212-300-15. Austin, TX, December.

Radian Corporation. 1980. Preliminary Design Review: Torbett-Hutchings-Smith (THS) Memorial Hospital Geothermal Heating System, Marlin, Texas. DOE Contract No. ET-78-C-08-1554 (A001), Austin, TX, January.

Radian Corporation. 1980. Final Design Report for the T-H-S Memorial Hospital Geothermal Heating System at Marlin, Texas. DOE Contract No. DE-AC08-78 ET27059. DCN 80-212-300-16. Austin, TX, September.

Thompson, G.R. 1972. Ground-Water Resources of Navarro County, Texas. Report 160. Texas Water Development Board, Austin, TX, November.

Torbett-Hutchings-Smith Memorial Hospital. 1977. Proposal for the Direct Utilization of Geothermal Energy for Space and Water Heating at Torbett-Hutchings-Smith Memorial Hospital, Marlin, Texas. Marlin, TX, November.

US DOE. 1980. Environmental Assessment, Geothermal Direct Heat Project, Marlin, Texas. U.S. Department of Energy, Assistant Secretary for Resource Applications, DOE/EA-0117, Washington, DC, August.

US EPA, 1979. Methods for Chemical Analysis of Water and Wastes. US EPA-600/4-79-020.

US EPA, 1973. Biological Field and Laboratory Methods. US EPA-670/4-73-001.

Welborn, C. 1983. USGS, Texas District, Austin, TX. Personal communication with R. Wallace of Radian Corporation.

Wolterink, T. 1979. Internal memorandum to M.F. Conover, Radian Corporation, Austin, TX. October.

Woodruff, C.M. Jr. 1980. Texas Bureau of Economic Geology. Personal communication with R.C. Keeney of Radian Corporation, Austin, TX, September.

Woodruff, C.M. Jr. and M.W. McBride. 1979. Regional Assessment of Geothermal Potential Along the Balcones and Luling-Mexia Talco Fault Zones, Central Texas. Final Report, DOE Contract ET-78-5-05-5864, Texas Bureau of Economic Geology, University of Texas, Austin, TX, May.

APPENDICES

APPENDIX A: WELL DATA

- Permit to Drill (TRC)
- Drilling Plan
- Drillers Log
- Fluid Analyses (DST/Pump Test)
- Pump Test Data
- Injection Test Data
- Inclination Data
- Logging

RAILROAD COMMISSION OF TEXAS
OIL & GAS DIVISION
PERMIT TO DRILL, DEEPEN OR PLUG BACK ON REGULAR LOCATION

MIT NUMBER 045008	DATE OF PERMIT 3/26/79	DISTRICT 05
NUMBER 42 145 30297	FORM W-1 (dated) 3/15/79	COUNTY FALLS
E OF OPERATION DRILL		ACRES 4
RATOR 834103 T-H-S MEMORIAL HOSPITAL, INC. BOX 60 MARLIN TX 76661		NOTICE NO ALLOWABLE WILL BE ASSIGNED unless well protects all fresh water sands with sufficient surface casing. Where Commission rules do not specify surface casing requirements, contact the Texas Department of Water Resources for depth to which fresh water sands must be protected. PERMIT SUBJECT TO CONDITIONS ON BACK OF FORM District Office Telephone No.: AC 214 984-3026
SE NAME T-H-S MEMORIAL HOSPITAL INC.		WELL NUMBER 1
ATION MILES 000000 FROM MARLIN		TOTAL DEPTH 3,400
TION, BLOCK and/or SURVEY T. J. CHAMBERS A-12 SUR.		
TANCE -- LEASE LINES FSL & 140 FEL	-- SURVEY LINES 5310 FEL & 12,020 FNL	-- NEAREST WELL ON LEASE N/A

D(S)

WILDCAT

** LIMITATIONS **

WILDCAT ABOVE 3400.
REGULAR FOR GEOTHERMAL USE ONLY.

Based upon the representations made on the above FORM W-1 and those made on any plat or plats filed therewith, it is believed that the peration indicated, when carried out at that point which you have represented to be the location of the above designated Well, complies as of e date thereof, with the provisions of the applicable spacing rule SUBJECT TO THE LIMITATIONS, IF ANY, SET OUT ABOVE. Compliance ith the applicable Commission spacing rule renders it unnecessary that you secure a special Commission permit to cover this indicated peration at the location shown, the same being classed as regular.

If there are outstanding permits covering operations which have not actually been started as of the date of filing of FORM W-1 above scribed and which, if started, would impair the regularity of this operation, then the permit covering that location on which the actual peration is first begun shall prevail, and all other such outstanding permits shall be nullified.

PHONE:
(512) 475-2458

DIRECT INQUIRIES TO: ADMINISTRATIVE SERVICES DIVISION
DRILLING PERMIT SECTION

MAIL:
Capitol Station–P. O. Drawer 12967
Austin, Texas 78711

DRILLING PLAN

T-H-S GEOTHERMAL WELL NO.1

GENERAL:

The general scope of work on this project is to drill an exploratory hole to the Travis Peak Formation, estimated at 3400 feet and determine the quality and temperature of the water from the formation.

The site of the well will be as shown on the attached drawing number 1.

A 9-7/8" hole will be drilled to approximately 2900 feet. At this point the hole will be reduced to 7-7/8" through the Glen Rose. The base of the Glen Rose is estimated at 3100 feet. From driller's log and on site inspection of cuttings it will be decided where to take a drill stem test (DST) in the Glen Rose. After DST complete, drill ahead through Travis Peak to approximately 3400 feet.

An induction, micro density and gamma ray density log will be made of the hole. A DST will be made in the Travis Peak.

All drilling will be by straight mud rotary. If all tests prove satisfactory, the well will be completed according to diagram number 2.

Drill cutting samples will be obtained, on 20 foot intervals, washed, sacked and stored at the site.

DRILLING FLUIDS:

Drilling mud will be used to total depth and until completion of the well. From surface to 2000 feet mud will be composed of natural mud and Quick-gel with a weight of 9.5 to 9.8#/gal., viscosity of 34-36 and water loss of 10-20 cc in 30 minutes. From 2000 to 3100 feet mud weight of 9.5 to 9.8#/gal., viscosity of 34 to 38 and water loss of 5 to 12 cc in 30 minutes. CMC will be added as needed. During drilling of anhydrite sections between 2200 and 2800 feet, the mud may need conditioning with Super-treat several times.

DRILL STEM TESTING PROGRAM:

Near base of Glen Rose a Haliburton drill stem test tool will be set and opened. The sampled interval will be allowed to flow. A sample will be obtained for chemical analysis. The water temperature at the surface will be measured as well as shut-in-pressure. Instruments in the tool will measure bottom hole temperature and pressure.

DRILL STEM TESTING PROGRAM - CONTINUED:

The process will be repeated in the Travis Peak after the hole is drilled and electric logs are made.

CASING PROGRAM:

A string of 7" O.D. J-55 23#/ft. casing will be set to the top of the Travis Peak estimated at 3100 feet. The casing will be cemented in place in an eleven inch hole from the casing float shoe to the surface with Portland Type H cement with 8 percent bentonite gel for a slurry of 1.7 cu.ft./sack. Cementing will be by Dowell or Haliburton.

Below the 7" casing in the Travis Peak a 5" liner-screen will be set, which will include 200 feet of mill-slotted liner and 100 feet of blank pipe.

SURFACE EQUIPMENT:

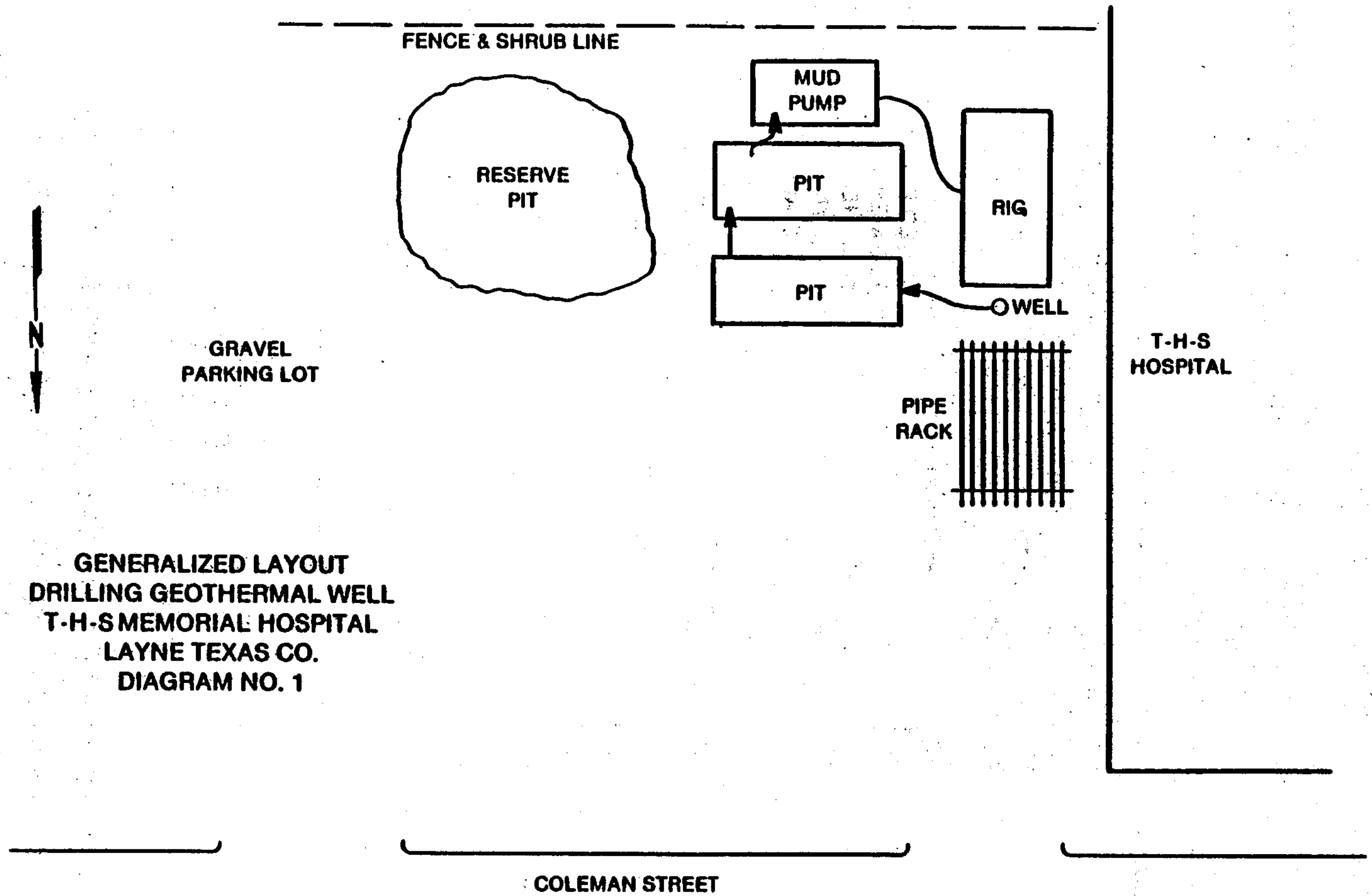
No blow out preventer will be required as no gas or high hydrostatic heads will be encountered. The casing will be capped with a valve on completion of the well which will allow the well to flow when desired.

DRILLING OPERATIONS SEQUENCE:

1. Move in drilling rig and set up.
2. Construct pits.
3. Drill 9-7/8" hole to 2900 feet. Monitor mud weight, etc. Run Eastman single shot each 100 feet. Maintain one (1) degree or less deviation. Cutting samples each 20 feet.
4. Drill 7-7/8" hole to 3100 feet or near base of Glen Rose. Cutting samples each 20 feet.
5. Make drill stem test of Glen Rose, determine hydrostatic head, water temperature and quality.
6. Continue 7-7/8" hole to 3400 feet. Cutting samples each 20 feet.
7. Run GO International or Schlumberger induction, micro density and gamma density logs. Determine from logs the interval to make next DST.
8. Run DST obtaining water quality, temperature and pressures.
9. Ream 11" hole to 3100 feet.
10. Set 3100 feet of 7" O.D. casing and cement to surface.
11. Wait on cement 24 hours. Drill plug and clean out hole to 3400 feet.
12. Set 200 feet of 5" mill-slotted screen and 100 feet of blank liner.
13. Develop well by agitating and washing.

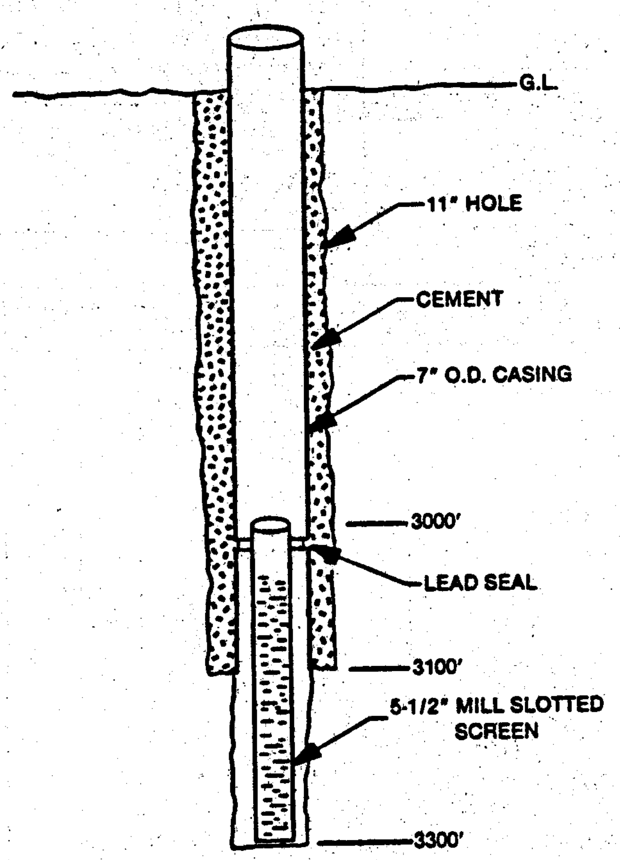
DRILLING OPERATIONS SEQUENCE-CONTINUED:

14. Set pump and pump for 24 hours at rate of 200± gpm. Measure discharge rate, water level, water temperature at least each 30 minutes.
15. Pull pump and cap well.
16. Move rig from site and clean up.



GENERALIZED LAYOUT
DRILLING GEOTHERMAL WELL
T-H-S MEMORIAL HOSPITAL
LAYNE TEXAS CO.
DIAGRAM NO. 1

70A3301



PLANNED PRODUCTION WELL
T-H-S MEMORIAL HOSPITAL
GEOTHERMAL PROJECT
LAYNE TEXAS CO.
DIAGRAM NO. 2

70A3300

LAYNE TEXAS COMPANY,
HOUSTON -:- DALLAS

WELL LOG

REPORT NO.
S. O. 1202-8527
PAGE 1 of 2
FILE NO. 3934
DATE 6-13-79

CUSTOMER LOCATION	WELL DATA
FOR T.H. S. Memorial Hospital	NAME WELL WELL NO. 1
LOCATION WELL East Parking lot at 322 Colman St. Marlin, Texas	ELEVATION 400' DATUM RT C GR
SURVEY FIELD	TEST HOLE SIZE 9-7/8"+7-7/8"
COUNTY Falls STATE Texas	DATE STARTED DRILLING 4-17-79
OTHER LAND MARKS	DATE FINISHED DRILLING 6- -79
	DRILLER L.S.Luthringer RIG NO. 4
	TYPE MUD Gel-Cellex NO. SACKS 260
	ELECTRIC LOG Yes TYPE Schlumberger
	SURVEY Eastman TYPE Single Shot
	OTHER

DEPTH STRATA	EACH STRATUM	DESCRIPTION FORMATION	SAMPLES DEPTH	SAMPLES TYPE	SAMPLES NUMBER
0		Surface			
2'	2'	Surface Soil			
17'	15'	Grey & Red Clay			
21'	4'	Sand			
36'	15'	Gray Clay			
63'	27'	Blue & Grey Clay			
162'	99'	Blue Shale			
169'	7'	Gray Shale			
197'	28'	Soft Black Shale			
320'	123'	Gray Shale			
378'	58'	Gray Shale & Gravel Stks.			
408'	30'	Gray Shale & Sand Stks.			
673'	265'	Gray Shale & Black Shale			
900'	227'	Gray Shale			
952'	52'	Gray Shale W/Sand Stks.			
968'	16'	Gray Shale			
1168'	200'	Hard Black Shale			
1201'	33'	Limestone			
1252'	51'	Lime & Shale Stks.			
1270'	18'	Blue Shale W/Sand Stks.			
1397'	127'	Lime & Shale			
1404'	7'	Hard Shale			
1492'	88'	Black Shale W/Lime & Gravel Stks.			
1500'	8'	Black Sand			
1568'	68'	Black Shale			
1585'	17'	Lime W/Black Shale Stks.			
1621'	36'	Black Shale W/Lime Stks.			
1655'	34'	Lime Stone W/Shale Stks.			
1670'	15'	Black Shale W/Lime Stks.			
1753'	83'	Lime & Shale			
1798'	45'	Shale & Lime			
1841'	43'	Lime & Shale			
1896'	55'	Shale & Lime			
2042'	146'	Lime & Shale			
2124'	82'	Gray Shale & Lime Stks.			
2195'	71'	Lime, Gray & Black Shale			
2260'	65'	Shale & Lime			
2336'	76'	Lime & Shale			
2372'	36'	Blue & Gray Shale			

LAYNE TEXAS COMPANY,

HOUSTON -:- DALLAS

WELL LOG

REPORT NO.
S. O. 1202-8527
PAGE 2 of 2
FILE NO. 3934
DATE 6-13-79

CUSTOMER LOCATION		WELL DATA	
FOR T.H.S. Memorial Hospital		NAME WELL	WELL NO.
LOCATION WELL		ELEVATION	DATUM
		RT C	GR
SURVEY	FIELD	TEST HOLE SIZE	TD
		DATE STARTED DRILLING	
		DATE FINISHED DRILLING	
COUNTY	STATE	DRILLER	RIG NO.
		TYPE MUD	NO. SACKS
OTHER LAND MARKS		ELECTRIC LOG	TYPE
		SURVEY	TYPE
		OTHER	

DEPTH STRATA	EACH STRATUM	DESCRIPTION FORMATION	SAMPLES DEPTH	SAMPLES TYPE	SAMPLES NUMBER
2384'	12'	Blue Shale & Sand Stks.			
2404'	20'	Lime Stone			
2414'	10'	Lime & Shale			
2489'	75'	Shale & Lime			
2510'	21'	Lime & Shale Stks.			
2529'	19'	Shale W/Lime & Sand Stks.			
2630'	101'	Lime & Shale			
2647'	17'	Shale & Lime Stks.			
2724'	77'	Lime & Shale W/Sand Stks.			
2861'	137'	Black Shale W/Lime Stks.			
2873'	12'	Soft Lime & Shale Stks.			
2905'	32'	Shale & Hard Lime			
3023'	118'	Lime & Shale			
3052'	29'	Soft Lime & Shale			
3108'	56'	Lime & Shale			
3122'	14'	Lime, Shale & Sand Lyrs.			
3133'	11'	Hard Lime & Shale			
3170'	37'	Black Shale & Lime			
3206'	36'	Soft Sandy Shale			
3276'	70'	Shale, Lime & Sand Stks.			
3305'	29'	Shale & Sand Lyrs.			
3318'	13'	Hard Gray Shale & Lime			
3388'	70'	Sandy Lime W/Black & Gray Shale Stks.			
3407'	19'	Grey Shale			
3438'	31'	Pink Shale W/Lime & Sand Lyrs.			
3493'	55'	Sandy Lime & Black Shale Lyrs.			
3562'	69'	Sand, Sandstone & Shale Lyrs.			
3604'	42'	Sandstone & Shale, Red & Black			
3612'	8'	Shale & Sandy Lime			
3618'	6'	Sandstone W/Red & Black Shale			
3620'	2'	Sand Rock			
3639'	19'	Sandstone, Red & Black Shale			
3688'	49'	Red, Black Shale W/Sandstone Lyrs.			
3705'	17'	Red, Black, White Shale W/Very Hard Lyrs.			
3879'	174'	Sand & Sandstone w/Shale Stks.			
3885'	6'	Shale			

EDNA WOOD LABORATORIES, INC.

WATER TECHNOLOGISTS . . CHEMISTS . . MICROBIOLOGISTS

19 June 1979

To: Layne Texas Company
P. O. Box 9469
Houston, Texas 77011

SO #1102-8527

Sample marked: THS Memorial Hosp., Marlin, Texas - Sample taken from Drill Pipe. Packer at 3615'. Screened: 3620' - 3705'.

Received: 6-18-79. Turbid sample, filtered for analysis.

WATER ANALYSIS

results in parts per million (mg/1) except as noted

Dissolved Residue at 350°C		*3,492	Conductance, micromhos/cm, 25°C	4,040
Total Dissolved Solids, actual†		*3,605	Color, units	25
Total Dissolved Solids, calc.		3,492	Turbidity, units	105
Silica	SiO_2	31	As Calcium Carbonate, $CaCO_3$:	
Calcium	Ca	268	Phenolphthalein Alkalinity	0
Magnesium	Mg	37	Total Alkalinity	182
Sodium (diff.) Na + K as	Na	765	Total Hardness	820
Carbonate	CO_3	0	Free Carbon Dioxide CO_2	20
Bicarbonate	HCO_3	222	pH . . . 7.25	
Sulfate	SO_4	2,054	**HYPOTHETICAL COMBINATIONS**	
Chloride	Cl	114	Calcium Bicarbonate	295
			Calcium Sulfate	663
			Magnesium Sulfate	181
Total Fluoride	F	1.0	Sodium Sulfate	2,132
Total Nitrate	NO_3	< 0.1	Sodium Chloride	188
			Sodium Fluoride	2
Total Manganese	Mn	0.55	Silica	31
Total Iron	Fe	5.5	Total Dissolved Solids, Calc.	3,492
Iron, filtered sample	Fe	< 0.05		
*Includes organic matter				

†Total Dissolved Solids, actual = Dissolved Residue + 50.8% of bicarbonate (HCO_3) ion

EDNA WOOD LABORATORIES, INC.

By: *Edna Wood*
Edna Wood

5127
pm

EDNA WOOD LABORATORIES, INC.

WATER TECHNOLOGISTS . . CHEMISTS . . MICROBIOLOGISTS

7 August 1979

To: Layne Texas Company
P. O. Box 969
Houston, Texas 77011

SO #1202-8527

Sample marked: T.H.S. Memorial Hospital. Taken: 7-28-79 after 23 hrs. pumping at 307 gpm. 10 min. static head: +14.86'. Pumping level: 198'. Screened: 3615' - 3882'. H_2O Temp. 152.6°F.

Received: 8-3-79. Turbid sample; filtered for analysis.

WATER ANALYSIS

results in parts per million (mg/1) except as noted

Dissolved Residue at 350°C	*3840	Conductance, micromhos/cm, 25°C	3930
Total Dissolved Solids, actual†	*3925	Color, units	3
Total Dissolved Solids, calc.	3680	Turbidity, units	6
Silica SiO_2	40	As Calcium Carbonate, $CaCO_3$:	
Calcium Ca	278	Phenolphthalein Alkalinity	0
Magnesium Mg	35	Total Alkalinity	138
Sodium (diff.) Na + K as Na	815	Total Hardness	840
Carbonate CO_3	0	Free Carbon Dioxide CO_2	13
Bicarbonate HCO_3	168	pH . . . 7.33	
Sulfate SO_4	2256	**HYPOTHETICAL COMBINATIONS**	
Chloride Cl	87	Calcium Bicarbonate	223
Total Fluoride F	0.8	Calcium Sulfate	757
Total Nitrate NO_3	< 0.1	Magnesium Sulfate	175
Total Manganese Mn	0.05	Sodium Sulfate	2340
Total Iron Fe	1.8	Sodium Chloride	143
Iron, filtered sample Fe	0.14	Sodium Fluoride	2
*Sample hygroscopic; gains weight on balance - includes organic matter.		Silica	40
		Total Dissolved Solids, Calc.	3680

†Total Dissolved Solids, actual = Dissolved Residue + 50.8% of bicarbonate (HCO_3) ion

EDNA WOOD LABORATORIES, INC.

By: Edna Wood
Edna Wood

5544
pm - cc: Mr. Joe Dillard - Dallas, Texas 75228

LAYNE TEXAS COMPANY

HOUSTON -:- DALLAS

WATER WELL TEST

REPORT NO.
S. O. 1202-8527
PAGE 1 of 2
FILE NO. 3934
DATE 7-27-79

CUSTOMER LOCATION

TEST FOR T.H.S. Memorial Hospital

LOCATION OF WELL 322 Coleman St.

SURVEY FIELD

COUNTY Falls STATE Texas

DESCRIPTION OF LAND MARKS East side of T.H.S. Memorial Hospital

WELL DATA

NAME WELL WELL NO. 1

ELEVATION 391.50' DATUM

WELL SIZE 10-3/4" x 8-5/8" x 5½"

TOTAL DEPTH 3885' TOP SCREEN 3613'-3883'

GRAVEL WELL No STRAIGHT WELL Yes

TYPE SCREEN Mill Slot GAGE 3/32"

TEMPERATURE OF WATER 156°F

WATER CONDITION Clear

WATER MEASURING DEVICE

ORIFICE SIZE 6" x 4" LENGTH

OTHER

TEST PUMP DATA

DEPTH SETTING TOP OF BOWL 200'

LENGTH AIR LINE 200' SIZE ¼"

TYPE BOWL NO. STAGES 10

LENGTH BOWL SUCTION LT.

SAND CONTENT OZ. PER 100 GAL.

ACTIVE STATIC HEAD AFTER PUMP STOPPED

5 MIN. FT. 20 MIN. FT.
10 MIN. FT. 25 MIN. FT.
15 MIN. FT. 30 MIN. FT.

WATER SAMPLE TAKEN Yes NO. SAMPLES 1

BACTERIOLOGICAL SAMPLE TAKEN

DRAWDOWN SPECIFIC CAPACITY

DATE HOUR	AIR LINE GAGE	PUMPING LEVEL	DISCH. PRESS.	HEAD ON ORIFICE INCHES	GPM	RPM	OPERATOR	REMARKS
7-27-79								
1:45 PM		Pump On						+14.85
2:45		150'		15.5				
3:00		157'		15				
3:30		190'		24	Speeded	Pump Up		
3:45		194'		24				
4:00		195'		24				
4:30		196'		23.5				
5:00		196'		23.5				
5:30		196'		23.5				
6:00		196'		23.5				
6:30		196'		23.5				
7:00		196'		23.5				
7:30		196'		23.5				
8:00		196'		23.5				
8:30		196'		23.5				
9:00		196'		23.5				
9:30		196'		23.5				
10:00		196'		23.5				
10:30		196'		23.5				
11:00		196'		23.5				
11:30		196'		23.5				
12:00		196'		23.5				
12:30 AM	7-28-79	196'		23.5				
1:00		196'		23.5				
1:30		198'		23.5				
2:00		198'		23.5				

OBSERVERS

FOR OWNER ______ FOR LAYNE TEXAS CO. ______

T.H.S. Memorial Hospital

S.O. 1202-8527
File No. 3934

Date 7-27-79

DATE HOUR	AIR LINE GAGE	PUMPING LEVEL	DISCH PRESS	HEAD ON ORIFICE INCHES	GPM	RPM	OPERATOR	REMARKS
2:30		198'		23.5				
3:00		198'		23.5				
3:30		198'		23.5				
4:00		198'		23.5				
4:30		198'		23.5				
5:00		198'		23.5				
5:30		198'		23.5				
6:00		198'		23.5				
6:30		198'		23.5				
7:00		198'		23.5	307			
7:30		198'		23.5	307			
8:00		198'		23.5	307			
8:30		198'		23.5	307			
9:00		198'		23.5	307			
9:30		198'		23.5	307			
10:00		198'		23.5	307			
10:30		198'		23.5	307			
11:00		198'		23.5	307			
11:30		198'		23.5	307			
12:00		198'		23.5	307			
12:30 PM		198'		23.5	307		Temp. ~~156° F.~~	
1:00		198'		23.5	307		153° F ✓	
1:30		198'		23.5	307			
1:45		198'		23.5	307		Pump Off	
	RECOVERY							
1:46		96'						
1:47		56'						
1:48		34'						
1:49		21'						
1:50		15'						
1:51		14'						
1:52		0 Flowing						

Well will flow 75 to 80 GPM
Shut in Static Level 14.85' above G.L.

OBSERVERS

FOR OWNER

FOR LAYNE TEXAS CO.

LAYNE TEXAS COMPANY

HOUSTON -:- DALLAS

WATER WELL TEST

REPORT NO.
S. O. 1202-8527
PAGE 1 of 1
FILE NO. 3934
DATE 7-30-79

CUSTOMER LOCATION

TEST FOR T.H.S. Hospital

LOCATION OF WELL 322 Coleman St., Marlin

SURVEY FIELD

COUNTY Falls STATE Texas

DESCRIPTION OF LAND MARKS

WELL DATA

NAME WELL WELL NO.

ELEVATION DATUM

WELL SIZE X X

TOTAL DEPTH TOP SCREEN

GRAVEL WELL STRAIGHT WELL

TYPE SCREEN GAGE

TEMPERATURE OF WATER

WATER CONDITION

WATER MEASURING DEVICE

ORIFICE SIZE LENGTH

OTHER

TEST PUMP DATA

DEPTH SETTING TOP OF BOWL

LENGTH AIR LINE SIZE

TYPE BOWL NO. STAGES

LENGTH BOWL SUCTION LT.

SAND CONTENT OZ. PER 100 GAL.

ACTIVE STATIC HEAD AFTER PUMP STOPPED

5 MIN.	FT.	20 MIN.	FT.
10 MIN.	FT.	25 MIN.	FT.
15 MIN.	FT.	30 MIN.	FT.

WATER SAMPLE TAKEN NO. SAMPLES

BACTERIOLOGICAL SAMPLE TAKEN

DRAWDOWN SPECIFIC CAPACITY

DATE HOUR	AIR LINE GAGE	PUMPING LEVEL	DISCH. PRESS.	HEAD ON ORIFICE INCHES	GPM	RPM	OPERATOR	REMARKS

7-31-79 Injection in old well with Halliburton

23 Min. @ 21 gpm @ 175 PSI
1 Hr. 50 Min. @ 10 gpm @ 175 PSI

7-30-79 Injection in new well with Halliburton

12 Min. @ 231.66 GPM @ 200 PSI and up to 240 PSI slowed pump down
10 Min. @ 168.48 GPM @ 200 PSI and up to 240 PSI
33 Min. @ 147.42 GPM @ 220 PSI
10 Min. @ 126.36 GPM @ 340 PSI

OBSERVERS

FOR OWNER FOR LAYNE TEXAS CO.

FORM NO. 25 -

Layne Texas Company
Box 9469, Houston, Texas 77011 • (713) 928-5741

June 25, 1979

Re: T.H.S. Memorial Hospital
Marlin, Texas
S.O. 1202-8527
Well #1

Below is a tabulation of depths and their corresponding drift angles which we have read and recorded from the Eastman drift indicator discs run in above-referenced well:

Inclination

Depth	Deg.	Min.	Depth	Deg.	Min.
30'	00°	15'	1500'	00°	15'
60'	00°	15'	1600'	00°	30'
100'	00°	10'	1700'	00°	10'
200'	00°	10'	1800'	00°	10'
300'	00°	10'	1900'	00°	05'
400'	00°	10'	2000'	00°	10'
500'	00°	05'	2100'	00°	10'
600'	00°	10'	2200'	00°	10'
700'	00°	40'	2300'	00°	10'
800'	00°	45'	2400'	00°	10'
900'	00°	30'	2500'	00°	10'
1000'	00°	20'	2600'	00°	10'
1100'	00°	15'	2700'	00°	05'
1200'	00°	15'	2800'	00°	10'
1300'	00°	15'	2900'	00°	05'
1400'	00°	10'	3000'	00°	10'

LAYNE TEXAS COMPANY

C. D. Amy

CDA/tm

Logging*

Log	Depth Interval (ft)
Electric	0-3885
Induction Electric	0-3885
Lateral Log	0-3885
Microlog	0-3885
SP	0-3885
Gamma	3386-3885
Gamma Gamma	0-3885
Caliper	0-3885
Directional	30-3000
Temperature	3386-3885

---

*Individual logs are on file with Mr. J.D. Norris, Administrator, T-H-S Memorial Hospital and with the Texas Railroad Commission, Austin, Texas.

APPENDIX B: INSTITUTIONAL PERMITS AND APPROVALS

Included in this Appendix are copies of the following items:

- DOE Finding of No Significant Impact (FNSI)
- Texas Railroad Commission (TRC) discharge permit for Exception to Statewide Rule No. 8 (SWR8)
- Texas Air Control Board (TACB) Permit Exemption
- EPA New Source Determination
- EPA NPDES Permit Determination
- Texas Department of Health Construction Approval

Department of Energy
Washington, D.C. 20585

AUG 8 1980

MEMORANDUM FOR RUTH M. DAVIS
ASSISTANT SECRETARY FOR RESOURCE APPLICATIONS

FROM: RUTH C. CLUSEN
ASSISTANT SECRETARY FOR ENVIRONMENT

SUBJECT: ENVIRONMENTAL ASSESSMENT, DOE/EA-0117, GEOTHERMAL ENERGY, DIRECT HEAT APPLICATIONS PROGRAM, TORBETT-HUTCHINGS-SMITH MEMORIAL HOSPITAL, MARLIN, FALLS COUNTY, TEXAS (JULY 1980) AND FINDING OF NO SIGNIFICANT IMPACT

In response to your memorandum of July 23, 1980, the Office of Environment has reviewed the subject draft environmental assessment prepared in support of the Department's proposal to jointly fund the retrofitting of the Torbett-Hutchings-Smith Memorial Hospital heating and hot water system to use low-temperature geothermal fluid as a supplementary energy source. Comments previously provided by this office have been accommodated, and the document is now adequate for publication.

In accordance with the Department of Energy's responsibilities under the National Environmental Policy Act (NEPA), the Council on Environmental Quality's NEPA regulations (40 CFR Parts 1500-1508), and the Department of Energy's NEPA guidelines (45 FR 20694), we have determined, after consultation with the Office of the General Counsel, that the proposed action is not a major Federal action significantly affecting the quality of the human environment. Therefore, an environmental impact statement is not required.

The basis for our determination is summarized in the attached "Finding of No Significant Impact," which must be made available to the public as specified in Section 1506.6 of the

Council on Environmental Quality regulations, placed in appropriate Department of Energy locations for public inspection, and distributed to Federal, state, and local agencies as well as to other parties who have expressed an interest in the proposed action. Please provide us with a listing of those to whom these documents were provided so that we may have a record of our public involvement efforts.

Attachments

Office of the General Counsel

Concur ____________________ Date 8.5.80

Nonconcur ____________________ Date ____________

Finding of No Significant Impact

Geothermal Energy
Direct Heat Applications Program
Torbett-Hutchings-Smith Memorial Hospital
Marlin, Falls County, Texas

The Department of Energy has prepared an environmental assessment, DOE/EA-0117, for a proposed action to jointly fund the retrofitting of the Torbett-Hutchings-Smith Memorial Hospital heating and hot water system to use low-temperature geothermal fluid as a supplemental energy source. The proposed site for the geothermal well is in a parking lot adjacent to, and owned by the hospital in downtown Marlin, Texas.

A solicitation for proposals for the joint funding of geothermal direct heat application projects was issued by the former Energy Research and Development Agency in the summer of 1977. Twenty-two responses were received and evaluated using established criteria for their ability to meet the geothermal direct heat applications program objectives. This project was one of the eight considered to meet the program objectives and selected for further contract negotiations.

The existing system at the Torbett-Hutchings-Smith Memorial Hospital uses natural gas-fired boilers to produce steam which, in turn, passes through heat exchangers into hot water storage tanks. These tanks are thermostatically controlled for space heating application, and additional heat exchangers are used to heat the water for laundry and dishwashing applications.

The new system utilizes a geothermal well southeast of the boiler room, a settling tank for the geothermal fluid, and associated pumps, piping, heat exchangers, and controls. A heating demand in the hospital will result in 65°C (150°F) geothermal fluid flowing through new heat exchangers in the heating system prior to circulating through the existing heat exchangers of the hospital heating system. In this way the geothermal system acts as either preheat, supplemental heat, or replacement heat for the existing system, depending on the heating demand and desired mode of operation. Operation is automatically regulated by the temperature of the water going into the hospital to maintain a 54°C (130°F) output temperature to the building. The geothermal system will provide preheat only for the domestic hot water system and is expected to displace 85% of the hospital's current natural gas consumption. The estimated annual savings is about 10.5×10^6 cubic feet of natural gas.

The environmental issues related to direct heat applications were identified and evaluated in an environmental assessment prepared by the former Energy Research and Development Administration (ERDA/EIA/GE/77-2, Hydrothermal Subprogram, March 1977). These included water use, surface and groundwater contamination, and noise. These and other potential site specific environmental issues associated with this project were analyzed for the well drilling, pipeline construction, heating system modification, and fluid disposal aspects of the project.

A well was drilled to a depth of approximately 1040 m (3400 ft) using conventional mud rotary drilling methods. It was necessary to drill the well prior to completion of this environmental assessment in order to obtain fluids for analysis to assess the environmental effects of fluid disposal.

After drilling, the well was production-tested for 48 hours, during which time a total flow of approximately 2.3×10^6 liters (6.0×10^5 gal) of geothermal fluid was produced. The Texas Railroad Commission granted the hospital a special temporary permit to discharge the produced geothermal fluid directly into the city storm sewer which discharges to a small pond in the city park in southwest Marlin.

For the actual operation of the retrofit system, the applicant identified five alternative methods of fluid disposal: (1) discharge into the city storm sewer, (2) pretreatment of the fluid, followed by release of the treated effluent into the city's entrapment lakes, where it would become part of the city's water supply, (4) discharge into the city's sanitary sewers, (5) subsurface injection. These alternatives were evaluated on the basis of economics, technical feasibility, and environmental effects. Alternative #1 was preferred, and the applicant applied to the Texas Railroad Commission for a surface discharge permit. The Commission determined that surface disposal was environmentally acceptable and granted the permit. Accordingly, the spent geothermal fluid will be discharged into the city storm sewer which empties into City Park Lake, which empties into Bean Branch and McCullough Slough, which eventually flow into the Brazos River.

The proposed activities could result in some minor impacts; however, these are not considered significant for the following reasons:

- The low withdrawal rate (200 gallons per minute) and the location of the producing formations are below well-consolidated rock, reducing the possibility of subsidence and seismic activity during operation.

- No significant effects on water quality in the project area were noticed during flow testing, or are expected during operation. Geothermal fluid will be disposed of by discharging it into the Marlin City storm sewer. Surface disposal activities will be conducted in accordance with the Texas Railroad Commission discharge permit, which requires that discharged geothermal resource waters be monitored and meet appropriate Texas Water Development Board/EPA-approved water quality standards at all times.

- Park Lake will be chemically degraded by surface discharge of geothermal water; however, the environmental effect of this degradation is of no consequence since Park Lake is designed as a catchment basin and no aquatic life is deliberately maintained in it.

- Air quality impacts resulting from construction activities were slight and brief and not detectable over those for the urban setting of the site.

- Hydrogen sulfide emissions should not occur during operation since there will be no flashing or venting of gases.

- There are no impacts expected from noise during operation because there will be no flashing or venting.
- There will be no change in current land use practices.
- There will be no negative impact on water use. The municipal water supply was adequate to meet needs during the construction phase, and no water will be required for the geothermal system during the operational phase.
- No historical sites or natural landmarks would be affected by the project.

Alternatives considered in the environmental assessment include abandoning the project, delaying the project, or moving to another location.

Single copies of the environmental assessment, DOE/EA-0117, are available from:

Mr. Robert Oliver
Division of Geothermal Energy
Office of the Assistant Secretary
for Resource Applications
U.S. Department of Energy
Mail Stop 3344, FED
Washington, D.C. ~~20583~~ 20461
(202) 633-8755

For further information about the environmental assessment contact:

Mr. F. A. Leone
NEPA Affairs Division
Office of Environmental Compliance
and Overview
Office of the Assistant Secretary
for Environment
Room 4G-064, Forrestal Building
1000 Independence Avenue, SW
Washington, DC 20585
(202) 252-4610

Date 8/8/80

Ruth C. Clusen
Ruth C. Clusen
Assistant Secretary
for Environment

RAILROAD COMMISSION OF TEXAS
OIL AND GAS DIVISION

1124 S. IH 35 • CAPITOL STATION – P. O. DRAWER 12967 • AUSTIN, TEXAS 78711

March 17, 1980

J. D. Norris, Jr.
Torbett-Hutchings-Smith Memorial Hospital
322 Coleman St.
Marlin, TX 76661

Re: DOCKET NO. 5-74,042
Disposal of Geothermal
Discharge Water
Falls County, Texas

Gentlemen:

At a formal conference held March 17, 1980, the Commission approved the application of Torbett-Hutchings-Smith Memorial Hospital for surface disposal of geothermal water from the T-H-S Well No. 1.

A formal order is attached.

Yours very truly,

Willis C. Steed

Willis C. Steed
Senior Staff Engineer

WCS:bs
cc: RRC-Kilgore
Proration - 5
Phillip R. Russell
Jack Welch
Mike McCloskey

RAILROAD COMMISSION OF TEXAS
OIL AND GAS DIVISION

OIL AND GAS DOCKET
NO. 5-74,042

FALLS COUNTY, TEXAS

FINAL ORDER
APPROVING THE APPLICATION OF TORBETT-HUTCHINGS-SMITH MEMORIAL
HOSPITAL FOR SURFACE DISPOSAL OF GEOTHERMAL
DISCHARGE WATER
IN FALLS COUNTY, TEXAS

The Commission finds that, after statutory notice in the above-numbered docket, heard on November 13, 1979, the presiding examiners have made and filed a report and proposal for decision containing findings of fact and conclusions of law, for which service was waived by parties of record; that the proposed application is in compliance with all statutory requirements; and that this proceeding was duly submitted to the Railroad Commission of Texas at conference held in its offices in Austin, Texas.

The Commission, after review and due consideration of the proposal for decision, the findings of fact and conclusions of law contained therein, hereby adopts as its own the findings of fact and conclusions of law contained therein, and incorporates said findings of fact and conclusions of law as if fully set out and separately stated herein.

Therefore, it is ordered by the Railroad Commission of Texas that effective March 17, 19 80, the application of Torbett-Hutchings-Smith Memorial Hospital, City of Marlin, Falls County, Texas for an exception to Statewide Rule 8 (c) (1) (C) be and is hereby approved. This exception will permit the discharge of geothermal resource waters into the Brazos River and is subject to the condition that at all times discharged geothermal resource waters will comply with the water quality standards established by the Texas Water Development Board or its successor.

Done this 17th day of March, 1980.

RAILROAD COMMISSION OF TEXAS

CHAIRMAN

COMMISSIONER

COMMISSIONER

ATTEST:

Elizabeth Mavropoulos
Secretary

TEXAS AIR CONTROL BOARD

6330 HWY. 290 EAST
AUSTIN, TEXAS 78723
512/451-5711

August 3, 1981

Mr. J. D. Norris, Jr., Administrator
TORBETT-HUTCHINGS-SMITH MEMORIAL
HOSPITAL
Post Office Box 60
Marlin, Texas 76661

Re: Permit Exemption X-2672
Geothermal Heating Facility
Marlin, Falls County

Dear Mr. Norris:

This is in response to Mr. Ronald Keeney's recent letter concerning the proposed construction of a geothermal heating facility. We understand that the emission of hydrogen sulfide to the atmosphere from the discharged fluid will be less than 50 pounds per year.

Pursuant to Section 3.27(a) of the Texas Clean Air Act, I have determined to exempt your proposed facility from the permit procedures of this Agency because it will not make a significant contribution of air contaminants to the atmosphere if constructed and operated as described in your letter. You are reminded that regardless of whether a construction permit is required, this facility must be in compliance with all Rules and Regulations of the Texas Air Control Board at all times.

Thank you for providing the information necessary for our evaluation of your proposal. If you have further questions concerning this exemption, please contact Mrs. Tammy Meyer of our Permits Section.

Sincerely,

E L Bell
for Bill Stewart, P.E.
Executive Director

cc: Mr. Eugene Fulton, Regional Supervisor, Waco

PUBLIC NOTICE

OF

DEC 13 1980 NEW SOURCE DETERMINATION

Applicant:

Torbett-Hutchings-Smith
Memorial Hospital
P.O. Box 60
322 Coleman Street
Marlin, Texas 76661

Proposed Facility:

supplement hospital's heat derived from natural gas combustion with heat derived from geothermal fluids

Location: Marlin, Falls County, Texas

This proposed facility will require a National Pollutant Discharge Elimination System (NPDES) permit to discharge wastewater to waters of the United States. EPA has made an initial determination that this facility will not be a new source as defined in Section 306 of the Clean Water Act. Consequently, the applicant will not be required to comply with the environmental review procedures of 40 CFR Part 6, Subpart F. Although the environmental impacts of the proposed discharge will be carefully considered before action is taken on the permit application, this facility will not be subject to environmental impact statement requirements and procedures. Any interested person may challenge EPA's initial determination that the facility is not a new source by requesting an evidentiary hearing under 40 CFR 122.53(h) within 30 days of the date of this public notice. For further information, please contact:

Ms. Kathleen Robinson
Environmental Protection Agency
Administrative Branch (6AEP)
1201 Elm Street
First International Building
Dallas, Texas 75270
Phone: (214) 767-2765

1-23-81

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VI
1201 ELM STREET
DALLAS, TEXAS 75270

5-14-81
Copy -

NPDES DETERMINATION

After considering the facts and the requirements and policies expressed in Public Law 95-217 and implementing regulations, I have determined that Permit No. TX0086321, Torbett-Hutchings-Smith, be issued and effective as proposed in Public Notice dated March 14, 1981, subject to timely certification (or waiver thereof) by the state certifying agency, provided however, that any condition(s) contested in a request for an Evidentiary Hearing submitted within 30 days from receipt of this determination as in accordance with new 40 CFR 124.74 (45 Fed. Reg. 33498, May 19, 1980) may be stayed if the request for a Hearing is granted.

Dated: May 13, 1981

for Bill Hathaway
Diana Dutton
Director
Enforcement Division (6AE)

Permit No. TX0086321
Application No. TX0086321

AUTHORIZATION TO DISCHARGE UNDER THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C. 1251 et. seq; the "Act"),

Torbett-Hutchings-Smith
Memorial Hospital
Marlin, Texas

is authorized to discharge from a facility located at

322 Coleman Street
Marlin, Texas

to receiving waters named

Brazos River

in accordance with effluent limitations, monitoring requirements and other conditions set forth in Parts I, II, and III hereof.

This permit shall become effective on June 14, 1981

This permit and the authorization to discharge shall expire at midnight, June 13, 1986

Signed this 13th day of May 1981

for Bill Hathaway
Diana Dutton
Director
Enforcement Division (6AE)

EPA Form 3560-2 (2-74) REPLACES EPA FORM 3320-4 (10-73) WHICH MAY BE USED UNTIL SUPPLY IS EXHAUSTED

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

During the period beginning effective date and lasting through the date of expiration the permittee is authorized to discharge from outfall(s) serial number(s) 001

Such discharges shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations				Monitoring Requirements	
	kg/day (lbs/day)		Other Units (Specify)			
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow—m^3/Day (MGD)	N/A	N/A	N/A	N/A	1/day	Estimate
Oil and Grease	N/A	N/A	N/A	15 mg/l	1/month	Grab
COD	N/A	N/A	N/A	200 mg/l	1/month	Grab

The pH shall not be less than 6.0 standard units nor greater than 9.0 standard units and shall be monitored 1/month by grab sample.

There shall be no discharge of floating solids or visible foam in other than trace amounts.

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): At discharge point 001.

B. SCHEDULE OF COMPLIANCE

1. The permittee shall achieve compliance with the effluent limitations specified for discharges in accordance with the following schedule:

   None

2. No later than 14 calendar days following a date identified in the above schedule of compliance, the permittee shall submit either a report of progress or, in the case of specific actions being required by identified dates, a written notice of compliance or noncompliance. In the latter case, the notice shall include the cause of noncompliance, any remedial actions taken, and the probability of meeting the next scheduled requirement.

C. MONITORING AND REPORTING

1. *Representative Sampling*

Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

2. *Reporting*

Monitoring results obtained during the previous 3 months shall be summarized for each month and reported on a Discharge Monitoring Report Form (EPA No. 3320-1), postmarked no later than the 28th day of the month following the completed reporting period. The first report is due on July 28, 1981 Duplicate signed copies of these, and all other reports required herein, shall be submitted to the Regional Administrator and the State at the following addresses:

Diana Dutton, Director
Enforcement Division (6AE)
U.S. Environmental Protection Agency
First International Building
1201 Elm Street
Dallas, Texas 75270

Mr. Harvey D. Davis, Exec. Director
Texas Department of Water Resources
P. O. Box 13087, Capitol Station
Austin, Texas 78711

3. *Definitions* See Part III

~~a. The daily average discharge means the total discharge by weight during a calendar month divided by the number of days in the month that the production or commercial facility was operating. Where less than daily sampling is required by this permit, the daily average discharge shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar month when the measurements were made.~~

~~b. The daily maximum discharge means the total discharge by weight during any calendar day.~~

4. *Test Procedures*

Test procedures for the analysis of pollutants shall conform to regulations published pursuant to Section 304(g) of the Act, under which such procedures may be required.

5. *Recording of Results*

For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information:

a. The exact place, date, and time of sampling;

b. The dates the analyses were performed;

c. The person(s) who performed the analyses;

d. The analytical techniques or methods used; and

e. The results of all required analyses.

6. *Additional Monitoring by Permittee*

If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in the calculation and reporting of the values required in the Discharge Monitoring Report Form (EPA No. 3320-1). Such increased frequency shall also be indicated.

7. *Records Retention*

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation and recordings from continuous monitoring instrumentation shall be retained for a minimum of three (3) years, or longer if requested by the Regional Administrator or the State water pollution control agency.

A. MANAGEMENT REQUIREMENTS

1. *Change in Discharge*

All discharges authorized herein shall be consistent with the terms and conditions of this permit. The discharge of any pollutant identified in this permit more frequently than or at a level in excess of that authorized shall constitute a violation of the permit. Any anticipated facility expansions, production increases, or process modifications which will result in new, different, or increased discharges of pollutants must be reported by submission of a new NPDES application or, if such changes will not violate the effluent limitations specified in this permit, by notice to the permit issuing authority of such changes. Following such notice, the permit may be modified to specify and limit any pollutants not previously limited.

2. *Noncompliance Notification*

If, for any reason, the permittee does not comply with or will be unable to comply with any daily maximum effluent limitation specified in this permit, the permittee shall provide the Regional Administrator and the State with the following information, in writing, within five (5) days of becoming aware of such condition:

a. A description of the discharge and cause of noncompliance; and

b. The period of noncompliance, including exact dates and times; or, if not corrected, the anticipated time the noncompliance is expected to continue, and steps being taken to reduce, eliminate and prevent recurrence of the noncomplying discharge.

3. *Facilities Operation*

The permittee shall at all times maintain in good working order and operate as efficiently as possible all treatment or control facilities or systems installed or used by the permittee to achieve compliance with the terms and conditions of this permit.

4. *Adverse Impact*

The permittee shall take all reasonable steps to minimize any adverse impact to navigable waters resulting from noncompliance with any effluent limitations specified in this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge.

5. *Bypassing*

Any diversion from or bypass of facilities necessary to maintain compliance with the terms and conditions of this permit is prohibited, except (i) where unavoidable to prevent loss of life or severe property damage, or (ii) where excessive storm drainage or runoff would damage any facilities necessary for compliance with the effluent limitations and prohibitions of this permit. The permittee shall promptly notify the Regional Administrator and the State in writing of each such diversion or bypass.

6. *Removed Substances*

Solids, sludges, filter backwash, or other pollutants removed in the course of treatment or control of wastewaters shall be disposed of in a manner such as to prevent any pollutant from such materials from entering navigable waters.

7. *Power Failures*

In order to maintain compliance with the effluent limitations and prohibitions of this permit, the permittee shall either:

a. In accordance with the Schedule of Compliance contained in Part I, provide an alternative power source sufficient to operate the wastewater control facilities;

or, if such alternative power source is not in existence, and no date for its implementation appears in Part I,

b. Halt, reduce or otherwise control production and/or all discharges upon the reduction, loss, or failure of the primary source of power to the wastewater control facilities.

B. RESPONSIBILITIES

1. *Right of Entry*

The permittee shall allow the head of the State water pollution control agency, the Regional Administrator, and/or their authorized representatives, upon the presentation of credentials:

a. To enter upon the permittee's premises where an effluent source is located or in which any records are required to be kept under the terms and conditions of this permit; and

b. At reasonable times to have access to and copy any records required to be kept under the terms and conditions of this permit; to inspect any monitoring equipment or monitoring method required in this permit; and to sample any discharge of pollutants.

2. *Transfer of Ownership or Control*

In the event of any change in control or ownership of facilities from which the authorized discharges emanate, the permittee shall notify the succeeding owner or controller of the existence of this permit by letter, a copy of which shall be forwarded to the Regional Administrator and the State water pollution control agency.

3. *Availability of Reports*

Except for data determined to be confidential under Section 308 of the Act, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the State water pollution control agency and the Regional Administrator. As required by the Act, effluent data shall not be considered confidential. Knowingly making any false statement on any such report may result in the imposition of criminal penalties as provided for in Section 309 of the Act.

4. *Permit Modification*

After notice and opportunity for a hearing, this permit may be modified, suspended, or revoked in whole or in part during its term for cause including, but not limited to, the following:

a. Violation of any terms or conditions of this permit;

b. Obtaining this permit by misrepresentation or failure to disclose fully all relevant facts; or

c. A change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge.

5. *Toxic Pollutants*

Notwithstanding Part II, B-4 above, if a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under Section 307(a) of the Act for a toxic pollutant which is present in the discharge and such standard or prohibition is more stringent than any limitation for such pollutant in this permit, this permit shall be revised or modified in accordance with the toxic effluent standard or prohibition and the permittee so notified.

6. *Civil and Criminal Liability*

Except as provided in permit conditions on "Bypassing" (Part II, A-5) an "Power Failures" (Part II, A-7), nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance.

7. *Oil and Hazardous Substance Liability*

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under Section 311 of the Act.

8. *State Laws*

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation under authority preserved by Section 510 of the Act.

9. *Property Rights*

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of Federal, State or local laws or regulations.

10. *Severability*

The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

PART III

OTHER REQUIREMENTS

The "daily average" concentration means the arithmetic average (weighted by flow value) of all the daily determinations of concentration made during a calendar month. Daily determinations of concentration made using a composite sample shall be the concentration of the composite sample. When grab samples are used, the daily determination of concentration shall be the arithmetic average (weighted by flow value) of all the samples collected during that calendar day.

The "daily maximum" concentration means the daily determination of concentration for any calendar day.

The conditions applicable to all permits under 40 CFR 122.7, 122.15, 122.60, 122.61 and 122.62 (as promulgated in the May 19, 1980, Federal Register) are hereby incorporated into this permit and prevail over any inconsistent requirements of this permit.

Texas Department of Health

Robert Bernstein, M.D., F.A.C.P.
Commissioner

1100 West 49th Street
Austin, Texas 78756
(512) 458-7111

A. M. Donnell, Jr., M.D., M.P.H., F.A.C.P.
Deputy Commissioner

May 15, 1981

Mr. Tom Green
Radian Corporation
P. O. Box 9948
Austin, Texas 78766

Subject: Torbett-Hutchings-Smith Hospital #517
Marlin, Texas
HFC - AH80-0401-021

Scope: Geothermal Heating System Project
and Energy Management System

Dear Mr. Green:

Your letter of disposition dated May 11, 1981, submitted to this office for Torbett-Hutchings-Smith Hospital, Marlin, Texas, has been reviewed by Mr. Zenon A. Pihut, Engineer, and appears to meet the requirements of the Hospital Licensing Standards. This letter will serve as the approval from this office as required under Article 4437f, Vernon's Civil Statutes.

This review is based upon the Hospital Licensing Standards and Life Safety Code Standards. In no way should this review be construed to mean the approval of the structural stability or mechanical integrity of this facility, nor should it mean that appropriate action from the Health Facilities Commission is unnecessary for this project. Any item not covered by this review that is contrary to the above mentioned standards does not mean the waiver of these standards.

Please advise this agency in writing when construction of this project began and also inform us when the project will be complete for a final inspection. It will be necessary to inform us three weeks in advance of the completion date for the inspection. We also request that you submit quarterly reports showing work in progress and the work plan for the ensuing quarter.

Any changes relative to the structural, mechanical, electrical, plumbing and heating, ventilating and air conditioning shall be submitted to this office for approval. If you have any questions regarding the standards relating to this project, please contact Mr. Zenon A. Pihut.

Sincerely,

Walter L. Dick, Director
Hospital Licensure & Certification Division

WLD/jlm

cc: Mr. J. D. Norris, Jr., Administrator
Mr. Ben Markowski, Fire Marshal
Texas Health Facilities Commission
State Health Planning & Resource Development
Public Health Region 6

APPENDIX C: ACCEPTANCE TEST REPORT

Included herein is a copy of the Acceptance Test report for the T-H-S Memorial Hospital Geothermal Heating System. The report details the procedures and results of the final inspection conducted by Radian Corporation engineers. Also included are communications between Radian Corporation and T-H-S explaining the Acceptance Test.

RADIAN

82-212-300-X

27 April 1982

Mr. J. D. Norris, Jr., Administrator
T-H-S Memorial Hospital
P.O. Box 60
Marlin, TX 76661

RE: Geothermal System Acceptance Test Procedure

Dear J.D.:

Since the originally-contracted portion of the geothermal system is completed and Lochridge-Priest has been paid (establishing a Beneficial Use Date of January 26, 1982 and a one-year warranty period), it is time to accomplish the formal acceptance by the T-H-S Hospital of the constructed system. As your geothermal consulting engineers, it is our job to show you that your geothermal system has been constructed and operates per the specifications. This procedure is analogous to an engineer's certification that a monthly construction invoice is valid before you sign it off for payment.

We will work with you to accomplish this necessary effort via the referenced procedure. Tom Green has prepared the procedure and he and Al Ferguson have already taken much of the actual data. Tom will sit down and discuss the procedure with you on April 28th. We need you to accompany Tom throughout the entire system so he can show you that it is all installed and operates properly. Radian will certify through these tests that the system is operational. This procedure will provide the basis for you to sign off thus accepting the installed system. We will note any deficiencies that need correcting. It is the responsibility of Lochridge-Priest to correct these deficiencies as they have since your Beneficial Use Date.

Naturally, any Change Orders not yet accomplished--such as the Btu Meter--will be addressed separately. This Acceptance Test Procedure does not affect the warranty period. When our additional funding request is approved, we will be able to provide some 130 man-hours of assistance to you to solve operating problems, orientation and instruction of your maintenance men, etc. up until the end of our subcontract in January 1983.

8501 Mo-Pac Blvd. / P.O. Box 9948 / Austin, Texas 78766 / (512)454-4797

Let me also call to your attention that the EPA discharge permit requires monthly measuring of the chemical oxygen demand (COD) as well as oil and grease levels in the geothermal discharge. If the City or the Texas Department of Health cannot do this for you, I believe your own lab could set up to do it.

If I can answer any questions, please give me a call.

Best regards,

Marshall

Marshall F. Conover, P.E.
Program Manager

MFC/lmd

RADIAN CORPORATION

ACCEPTANCE TEST CERTIFICATION FOR T-H-S MEMORIAL HOSPITAL GEOTHERMAL HEATING SYSTEM

During April 1982, Radian conducted a thorough examination of the installation and operation of the T-H-S Memorial Hospital Geothermal Heating System. These Acceptance Tests were performed by Radian's Tom Green and Alan Ferguson with assistance being provided by Lochridge-Priest's Steve Hennick and Johnson Controls' Charlie Miller. T.E. Alexander (T-H-S Hospital engineer) was periodically apprised of the procedures and was present during some of the tests. Additionally, a step by step verbal orientation of the geothermal system, including maintenance and troubleshooting tips, was provided for the T-H-S engineering personnel.

As documented in the attached Tables 1, 2, 3, and 4, the following items were included in the Acceptance Test inspection:

- Geothermal Well Head
- Variable Frequency Drive (VFD), all modes of operation
- Backpressure valve
- Geothermal piping pressure relief valve
- Geothermal overpressure alarm and automatic system shutdown
- BTU meter
- Adequacy of CPVC (plastic) piping supports
- Installation of suitable dielectric coupler on PHX-1 to prevent galvanic corrosion

- SHW override controls for geothermal heating bypass on Converter 2
- SHW flow rates under heating conditions
- Sequencing of PHW control valves with backup heating (steam, electric, or gas) in all ten AHU
- Flow balancing in entire PHW system, including all ten AHU
- Automatic makeup to PHW system
- Automatic controls for PHW pumps F, G, H, I

Based on this Acceptance Test procedure and Radian's previous inspection during the installation of the equipment, we certify that the following actions are the only ones which need to be accomplished by Lochridge-Priest in order to complete proper installation of the geothermal system.

1. Remove and calibrate all existing thermometers installed as part of geothermal system (replace broken one), and reinstall using glycerine in the thermowells. Consult Radian for quick calibration procedure.

2. Remove and calibrate all existing pressure gauges installed for geothermal system and reinstall. Consult Radian for calibration procedure. Replace inoperable and absent gauges at PHX-4.

3. Replace broken handle or appropriate valve parts to valve 268 (automatic air vent valve near PHX-4).

4. Return faulty circuit board(s) from VFD spare parts kit to factory for repair or replacement. Deliver replacement(s) to job site.

RADIAN CORPORATION

5. Install three additional CPVC piping supports. Consult Radian for locations.

6. Label all controls in G.E. room.

7. Bell and Gossett differential pressure meters (Model RO-5) supplied with project give neither satisfactory accuracy nor repeatability. These meters should be returned and replaced with a meter such as Dwyer Capsuhelic Differential Pressure Gauge, Model 4300. Retain pressure needle insert assembly from RO-5 meter for use with Dwyer meter.

8. Label conductance monitor alarm signal (light) above G.E. room door.

9. Eagle Eye meter is not sufficiently sensitive to measure SHW flows. Provide two other suitable meters such as Dwyer Flex Tube U-Tube Manometers with 16 in water column (WC) range, Model 1223-16-W.

10. Readjust AHUs 2 and 6 (steam valve spring range or control settings) so that a 0.5 to 1.0 psig "dead band" exists between the PHW valve full open position and the steam valve just opening.

11. Recheck AHU-1 control pressure sequencing. The 7 psig dead band appears out of sync when comparing with other dead bands.

12. Check problem reported by operator (TEA) on 4/22/82 with AHU-9 second stage heating.

RADIAN
CORPORATION

Additional documentation for these action items is available in the attached tables. These tables also present supplemental O&M data for the T-H-S Hospital engineering personnel.

With the exception of items 10, 11, and 12, Radian is satisfied and therefore certifies that the geothermal system is operating as designed and as intended. Items 1 through 9, while they will not impact system operation, are vital steps which should be taken to assist future maintenance and troubleshooting.

Radian recommends that the T-H-S Memorial Hospital officially accept the Geothermal Heating System via signing the system acceptance below and forwarding a copy to Lochridge-Priest. It is understood by all parties that this acceptance is contingent upon Lochridge-Priest's timely completion of the twelve aforementioned actions. Of course, T-H-S's acceptance does not impact outstanding ECOs (such as the BTU meter), the Lochridge-Priest warranty, or outstanding Records for Owner.

Certified by: Tom Green 4/27/82

Tom Green — Date
Project Director
Radian Corporation

Accepted by: J.D. Norris, Jr.

J.D. Norris, Jr. — Date
Administrator
T-H-S Memorial Hospital

TABLE 1. GEOTHERMAL EQUIPMENT ROOM ACCEPTANCE TEST SUMMARY (ADDITIONAL G.E. ROOM DATA IN TABLES 2, 3, and 4)

DATE	COMPONENTS	PROCEDURE	RESULTS	ACTION ITEMS
4/23/82	Thermometers	Conducted rough calibration of all thermometers in G.E. room	Some thermometers several degrees (5°F) out of calibration. True calibration not achievable because thermometer sockets could not be removed from thermowells (one thermometer broke when trying). Thermometers and thermowells do not appear to mate properly, and thermometers used do not conform to specs (see p. 1502-3 in specs).	Remove and calibrate all existing thermometers installed as part of geothermal system (replace broken one), and reinstall using glycerine in the thermowells. Consult Radian for quick calibration procedure.
4/23/82	Pressure Gauges	Conducted rough calibration of all pressure gauges	Pressure gauges were generally close and were set so pressure differential could be accurately read. On PHX-4, one gauge missing and one not working: the one not working probably due to either bad gauge or bad diaphragm seal. Replace or repair as appropriate. Calibrate replacements.	Remove and calibrate all existing pressure gauges installed for geothermal system and reinstall. Consult Radian for calibration procedure. Replace inoperable and absent gauges at PHX-4.
4/23/82	VFD Automatic Control	Verified temperature for minimum speed control	VFD achieves minimum speed at the 126 to 130°F range. More precise control settings are not possible until thermometers are calibrated. (Maximum speed control temperature cannot be verified without large heating loads.)	VFD minimum speed control acceptable as in current operation. No further action recommended.
4/8/82	Geothermal Pressure Relief Control	Checked to see that PRV opened at approximately 60 psig and that it simultaneously triggered overpressure alarm system	Readjusted PRV to open and trigger alarm at 65 psig. PRV had been incorrectly set at approximately 85 to 90 psig. PRV did not properly reset after adjustment. Lochridge-Priest has since remedied.	PRV setting and system override operating acceptably. No further action required.
4/23/82	BTU Meter	Verified planned repair action (previously checked operation of BTU meter on 4/8/82 and 4/14/82)	BTU meter has not worked since installed. Apparently problem is with hardware shipped from factory. Once appropriate parts are received from factory, BTU meter will be removed from system and returned for warranty repair. Calibration curves for BTU meter still not received.	Obtain certified BTU meter calibration curves and submit for approval. Further action to be determined at time of reinstallation and checkout.
4/23/82	Ball Valve to Automatic Air Vent	AAV valve near PHX-4 has broken handle (valve no. 268)		Replace broken handle or appropriate valve parts. to valve 268 (automatic air vent valve near PHX-4).

TABLE 1. GEOTHERMAL EQUIPMENT ROOM ACCEPTANCE TEST SUMMARY (ADDITIONAL G.E. ROOM DATA IN TABLES 2, 3, and 4)

(Continued)

DATE	COMPONENT	PROCEDURE	RESULTS	ACTION ITEMS
4/8/82	Dielectric Coupler for PHX-1	Verified installation of flange kit to prevent galvanic contact between copper pipe and stainless steel heat exchanger	Dielectric flange installed.	No further action required.
4/8/82	Claval Back-pressure Valve	Reset backpressure setting	Adjusted valve to provide approximately 9 psig backpressure at the discharge of PHX-4 at flow rate of 40 gpm as determined by the BTU meter (previously set for 15 psig backpressure).	No further action required.
4/8/82	VFD Amperage	Checked VFD amps cross-line and at 60 Hz.	VFD amps cross-line = 18 VFD amps @ 60 Hz = 20	No further action required.
4/8/82	VFD Automatic Operation	Checked reasons for VFD not working in AUTO position	Determined that proper control signal was being received by VFD, and that problem was in VFD. Lochridge-Priest has since remedied problem.	Return faulty circuit board from VFD spare parts kit to factory for repair or replacement. Deliver replacement(s) to job site.
4/8/82	Geofluid Sampling Valve	Placed note on pipe adjacent to sampling valve	Note reminds operator to purge valve prior to taking geofluid sample.	No further action required.
4/8/82	Wellhead J-Box	Checked for H_2S corrosion of copper wire	Found no evidence of corrosion. Placed short bare piece of copper wire in J-Box. Wire should be checked periodically by operator for evidence of corrosion.	Periodic operator checks are only further action required.
4/8/82	CPVC Piping Supports	Checked for possible need for additional CPVC piping supports	CPVC lines discharging PHX-2,3, and 4 could probably benefit from additional support at the "elbows".	Install three additional CPVC piping supports. Consult Radian for locations.
4/28/82	VFD	Checked all modes of VFD operation	All modes working properly. Under AUTO control, VFD speed follows heating demand. Manual and cross-line operation also proper.	No further action required. (Note spare parts replacement above.)
4/28/82	Controls	Controls labels in G.E. room	Several control instruments in G.E. room were not labeled. Instructed Johnson Controls to label appropriately.	Label all controls in G.E. room
4/28/82	Geothermal Well Head	Checked for completed installation	All necessary equipment installed and operating.	No further action required.

TABLE 2. DHW SYSTEM ACCEPTANCE TEST SUMMARY (BOILER ROOM AND GEOTHERMAL EQUIPMENT ROOM)

DATE	COMPONENT	PROCEDURE	RESULTS	ACTION ITEMS
4/28/82	Steam Valves to Hot Water Generators	Set steam valves for HWG-1 and HWG-2	HWG-1 steam valve setting = 0. HWG-1 temperature at 0 setting = 114°F (Pump E OFF). HWG-2 steam valve setting = 9 HWG-2 temperature at 9 setting = 124°F (Pump E OFF).	Suitable control. No further action required. NOTE: HWG steam valves should be reset only in "emergency" conditions.
4/23/82	DHW Circulation Pump E	Verified set point and results	Pump E set point at 135°F. HWG-1 temperature = 134°F (steam valve OFF). HWG-2 temperature = 132°F (steam valve OFF).	Suitable set point and control. No further action required.
4/23/82	DHW Circulation Pump E	Reset circuit setter balance valve	Balance valve setting = 38°F. Balance valve pressure drop = 15.5 ft of H_2O. GPM = 38. Instructed operator (T.E.A.) on how to reset if hot water infiltration into cold lines continued. Future resetting by operator should be documented herein.	Bell and Gossett differential pressure meters (Model RO-5) supplied with project give neither satisfactory accuracy nor repeatability. These meters should be returned and replaced with a meter such as a Dwyer Capsuhelic Differential Pressure Gauge, Model 4300. Retain pressure needle insert assembly from RO-5 meter for use with replacement meter.
4/8/82 & 4/23/82	"Uniloc" Conductance Monitor	Verified calibration and checked operation	DHW make up conductivity per Uniloc = 290 μmho-cm. DHW makeup conductivity per Radian instrument = 285 μmho-cm. Activated Uniloc on high alarm: all three alarm lights functioned, Pumps E and D shut down, and valves in G.E. room bypassed PHX-1. Label on high alarm light at G.E. room is missing. Activated low alarm: single alarm light on panel came on. Set high alarm for 620 μmho-cm, low alarm for 120 μmho-cm. Operation satisfactory.	Label conductance monitor alarm signal above G.E. room door. Operation satisfactory.

TABLE 3. SHW SYSTEM ACCEPTANCE TEST SUMMARY (PENTHOUSE AND GEOTHERMAL EQUIPMENT ROOM)

DATE	COMPONENT	PROCEDURE	RESULTS	ACTION ITEMS
4/23/82	Control Valve for SHW-2 Circuit (2-Pipe) to PHX-2	Checked sequencing of SHW control valve and steam valve via checking pneumatic control pressures	Control pressure when SHW valve just opening = 4 psig. Control pressure when SHW valve full open = 8 psig. Control pressure when steam valve just opening = 8.5 psig.	Control pressures show that steam is being properly sequenced only after geothermal cannot maintain load. No further action required.
4/23/82	SHW-2 Control Valve Override	Check to ensure override was functional (override controls bypass PHX-2 if SHW return temperature is greater than GF supply temperature)	Override controls had been improperly wired. Johnson Controls rewired and checked operation. Johnson reported proper operation.	No further action required.
4/23/82	Annubar Flow Sensor on SHW Line to PHX-2	Checked flow rate in SHW-2 circuit with all flow going to PHX-2	Although flow detected via observing equalization of SHW temperatures at PHX-2, no flow could be detected using Annubar and portable Eagle-Eye meter. (Controls overridden to produce flow.) On 4/28/82, Radian checked flow with manometer. Results below. Pump on / Annubar Diff. Pressure / Flow Rate 3 only / 2.5 in H_2O / 90 gpm 3 and 4 / 4.25 in H_2O / 120 gpm	Eagle Eye meter is not sufficiently sensitive to measure SHW flows. Provide two other suitable meters such as Dwyer Flex Tube U-Tube Manometers with 16 in in water column range, Model 1223-16-W.
4/23/82	Control Valve for SHW-1 Circuit (3-Pipe to PHX-3	Checked sequencing of SHW control valve and steam valve via checking pneumatic control pressures	Control pressure when SHW valve just opening = 3 psig. Control pressure when SHW valve full open = 7 psig. Control pressure when steam valve just opening = 8 psig.	Control pressures show that steam is being properly sequenced only after geothermal cannot maintain load. No further action required.
4/22/82	Annubar Flow Sensor in SHW Line to PHX-3	Checked flow rate in SHW-1 circuit	No results since all (or most) valves at induction units are closed to heating, resulting in no heating water circulation. Data to be taken by operators beginning next fall.	Because Eagle Eye meter is not sensitive enough, the second (Dwyer) manometer above should be installed to measure SHW-1 flow rates.

TABLE 4. PHW SYSTEM ACCEPTANCE TEST SUMMARY (PENTHOUSE AND GEOTHERMAL EQUIPMENT ROOM)

DATE	COMPONENT	PROCEDURE	AHU	Control Pressure When PHW Valve Just Opening	Control Pressure When PHW Valve Full Open	Control Pressure When Steam Valve Just Opening	ACTION ITEMS
4/8/82	All primary heating water (PHW) control valves	Checked for proper controls sequencing between PHW valves and backup heating (either steam, natural gas, or electric)	1	16.5 psig	13.5 psig	6.5 psig	Readjust AHUs 2 and 6 (steam valve spring range or control settings) so that a 0.5 to 1.0 psig "dead band" exists between the PHW valve full open position and the steam valve just opening.
			2	13	9	9	
			3	13	9	8	
			4	13	9	7	Recheck AHU-1 control pressure sequencing. The 7 psig dead band appears out of sync when comparing with other dead bands.
			5(4/23)	16	13	11 (stm reheat) 7 (stm preheat)	
			6	13	9	9.5	
			8	14	10	7	
			AHU 7:	PHW valve opened on first stage heating			Check problem reported by operator (TEA) on 4/22/82 with AHU-9 second stage heating.
			AHU 9:	PHW valve opened on first stage heating, gas furnace activated on second stage heating			
			AHU 10:	PHW valve opened on first stage heating, gas furnace activated on second stage heating			

DATE	COMPONENT	PROCEDURE	AHU	Circuit Setter Position	Circuit Setter Pressure Drop	Flow Rate	ACTION ITEMS
4/8/82 & 4/23/82	All primary heating water heating coils	With contractor's help (Steve H., Lochridge-Priest) balanced PHW flow to all heating coils via checking circuit setter balancing valve and balancing cock. (Steve H. with L-P balanced AHUs 1, 4, 8, 9, 10 and reported results to Tom G. with Radian)	1	19°	3 ft H_2O	41 gpm	NOTE: Balance cock (currently painted blue in most PHW circuits) should not be reset.
			2	34°	16	45	
			3	33°	16	47	If circuit setters ever need to be closed, reset according to schedule at left.
			4	14°	3	47	
			5	37°	21	45	
			6	14°	23	70	
			7	2°	1.7	19	Resulting flows are satisfactory. No further action required.
			8	23°	6	46	
			9	18°	6	33	
			10	10°	12	34 bypassing AHU-10 (18 gpm to AHU-10)	

TABLE 4. PHW SYSTEM ACCEPTANCE TEST SUMMARY (PENTHOUSE AND GEOTHERMAL EQUIPMENT ROOM) (Continued)

DATE	COMPONENT	PROCEDURE	RESULTS	ACTION ITEMS
4/23/82	PHW automatic makeup pump	Verified control pressure settings for automatic makeup into PHW system	Pump cycles on if compression tank pressure falls to 22 psig. Pump cycles off when pressure reaches 25 psig.	Controls operating satisfactorily. No further action required.
4/28/82	Automatic pump start controls for PHW pumps F, G, H, and I	Reset OA temperatures which start pumps	Pump Controls reset to accommodate system operation under energy conservation control system. Pump G now operates below approximately 50 F OA, and Pumps F, H, and I operate below approximately 65 F. Actual settings below.	Because AHU 2,3,5, and 6 operate with different discharge temperatures under energy conservation controls (55°F rather than previous 65°F), the control sequence was reset as shown to left. This control satisfactory. No further action required (NOTE: This control is sequence is different than that shown in Radian's Operating Manual and system specs. Disregard old sequence.)

Pump	OA Temp On	OA Temp Off	P-E Setting
F,H,I	66 (OA falling)	68 (OA rising)	12
G	49 (OA falling)	52 (OA rising)	10

APPENDIX D:

PLATE HEAT EXCHANGER INSPECTION REPORTS

RADIAN CORPORATION

Radian Contract No. 212-300

GEOTHERMAL FACILITY INSPECTION REPORT

Where: THS Memorial Hospital - Marlin, TX
What: Geothermal Fluid/Domestic Hot Water Plate and Frame Heat Exchanger
When: 15 July 1982
Inspector: Peter F. Ellis

The HX is a Trantor Superchanger with washboard configuration Type 316 stainless steel plates. The unit was placed in service in mid-January 1982 and was shut down on 15 July for the inspection. After the HX temperature had dropped to 100°F the HX was drained and opened.

Gross Examination Results

The geothermal side of the plates was found to be essentially free of deposits and shiny (metallic) in appearance. There was an extremely thin gray-black film or discoloration in a "trickle down" pattern from the inlet ports. This film was slightly tenaceous--but rubbed off easily with a sampling stick. A very small sample was collected for EDS examination.

Small flakes of blue material--it looked like paint--were also found on the geothermal sides of a number of plates. A small sample was collected.

The domestic water (DW) surfaces were covered with a thin tan film. The metallic sheen of the HX plates was visible through this film. The film wiped off easily with the fingertip and had an oily or slippery feel when wet. Some sand particles were also found, and there was a small amount--perhaps a gram or two--of particulate crud lodged against the gaskets at the bottom of the DW side of the HX plates. A sample was collected for further examination. It was tentatively concluded that the tan film was silt from the city water supply.

Detailed Examination of One Plate

A single plate was removed at random for detailed examination. Whole-face and close-up photographs were taken of each side. The DW side photographs should have a tannish cast due to the silt deposits.

On each side of the plate, an area of about one square foot was cleaned with detergent and water. With this cleaning treatment, both the black geothermal film and the tan DW film wiped off readily with a soft cloth.

Locations on each side of the plate were then examined microscopically using Radian's portable metallograph. Magnifications of 50X to 400X were used. The metallograph was also equipped with an optical depth gauge capable of measuring height differences of 0.1 mil.

On the geothermal side, loading or contact points--where the ridges of one plate press on ridges (at right angles) on the next plate--were readily apparent to the eye. These points were about the size of a period. Close visual examination of the plate surface revealed no other features. Four contact points were washed with 15% HNO_3 and examined microscopically:

Point 1: There was much mechanical smearing of the plate surface at the contact point. One area remained darker than the surrounds after the HNO_3 wash. This area showed a depth of less than 0.1 mil, though slight depth was evident at 400X. It could represent a point of incipient crevice corrosion, or may be only a region of differing albedo due to difference in surface texture.

Points 2, 3, and 4: Like Point 1, there was a mechanically smeared area and dark spot at each contact point. The dark spots--which were resistant to HNO_3 cleaning--had no visible depth even at 400X.

Several spots of black film were visualized. They had a thickness of 0.1-0.5 mil.

Away from the contact points, the surface had an "orange peel" appearance typical of rolled stainless steel. Examination of a non-wetted surface of the plate showed an identical surface.

On the DW side, close visual examination showed distinctive marks at the contact points. The appearance was similar to the geothermal side. The close visual examination showed no other features.

Four contact points were cleaned with HNO_3 and examined microscopically. All were quite similar in appearance. Each showed a dark spot with no detectable depth even at 400X, and some mechanically smeared metal.

Away from the contact points, the plate surface showed an "orange peel" texture identical with a non-wetted portion of the plate.

Conclusions:

- No evidence of mineral deposition (scaling) was found.

- No corrosion of the plates was evident. In particular:

  --Microscopic examination at 400X disclosed no persuasive evidence of localized corrosion even at the interplate contact points; an area of maximum risk for this form of corrosion.

  --The microscopic appearance of the plate surfaces was typical of rolled stainless steel. The appearances of the plate surfaces which had been wetted with geothermal fluid or domestic water were no different than areas which had remained dry.

RADIAN
CORPORATION

Radian Contract No. 212-300
9 August 1982

THS GEOTHERMAL HEAT EXCHANGER INSPECTION
DEPOSIT ANALYSIS REPORT
by Peter Ellis

During the inspection of 15 July 1981, deposit samples were collected from the geothermal and domestic hot water surfaces of the plates of HX 1. The geothermal side sample consisted of two black flakes, each about the size of a period punctuation mark. These particles were not magnetic. The sample from the domestic hot water surface consisted of about one (1) gram of flakey particulate matter, tan in color. Some of this material was magnetic, some was not.

The two deposits were analyzed by Energy Dispersive (X-Ray) Spectroscopy (EDS) in Radian's Scanning Electron Microscope. This technology provides a semi-quantitative analysis of those elements with atomic numbers greater than 9 (fluorine). Hydrogen, lithium, beryllium, boron, oxygen, and fluorine are undetectable by this technique.

GEOTHERMAL SIDE DEPOSITS

Results

Figures 1 and 2 show the EDS spectra for the two black particles from the geothermal side of the HX plates. One of these particles was smooth in appearance (Figure 1). It contained major amounts of calcium, sulfur, silicon, and iron; minor amounts of titanium and aluminum; and traces of chlorine.

The other particle was rough (Figure 2) and contained major amounts of sulfur and iron, and traces of aluminum, silicon, calcium, copper, and zinc.

Interpretation

The data indicates that the black deposits are composed largely of iron sulfide corrosion products, probably derived from the casing. The absence of gross ferromagnetic activity indicates that magnetite is not a significant constituent.

The other constituents, silicon, calcium, aluminum, and titanium are characteristic constituents of many clays or silts, and it is suggested that they are derived from suspended solids in the produced fluid.

The traces of copper and zinc are probably copper and zinc sulfide corrosion products from bronze pump components.

SECONDARY (DOMESTIC WATER) SIDE DEPOSITS

Results

Figure 3 is the EDS spectrum for a bulk sample of the secondary side deposit. This sample contained major amounts of copper and iron, minor amounts of silicon and aluminum; and traces of magnesium, sulfur, chlorine, calcium and titanium

Interpretation

The sample appears to be composed largely of iron and copper corrosion products, probably oxides. The observed gross ferromagnetic activity of some of the particles of the sample indicate magnetite (magnetic iron oxide), supporting the above hypothesis. These oxide corrosion products are the result of corrosion elsewhere in the domestic hot water system. Their presence may indicate persistent oxygen inleakage into the domestic water supply. One likely source of oxygen is air inleakage at faulty pump packings and seals. For the long term health of the domestic water system, more intensive maintenance of these seals and packings may be in order.

The trace elements observed are those typical of clays and silts and are most likely derived from suspended solids in the domestic water supply.

Figure 1. EDS SPECTRUM OF SMOOTH BLACK PARTICLE FROM GEOTHERMAL SIDE OF HX 1 OF THE THS GEOTHERMAL SYSTEM (Full Scale = 468 cnts.)

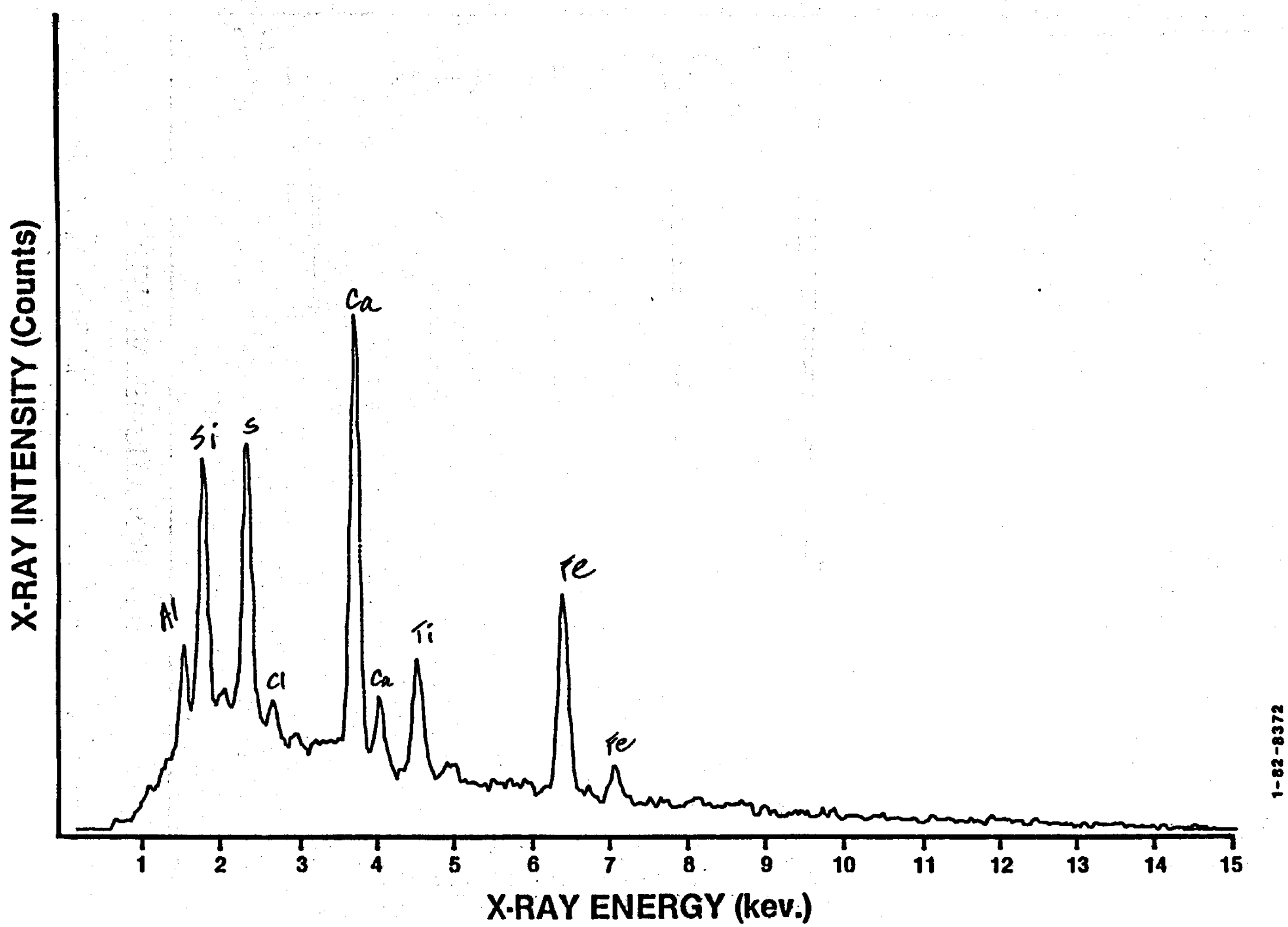


Figure 3. EDS SPECTRUM OF DOMESTIC WATER SUPPLY SIDE DEPOSITS FROM HX 1 OF THE THS GEOTHERMAL SYSTEM (full scale = 968 cnts).

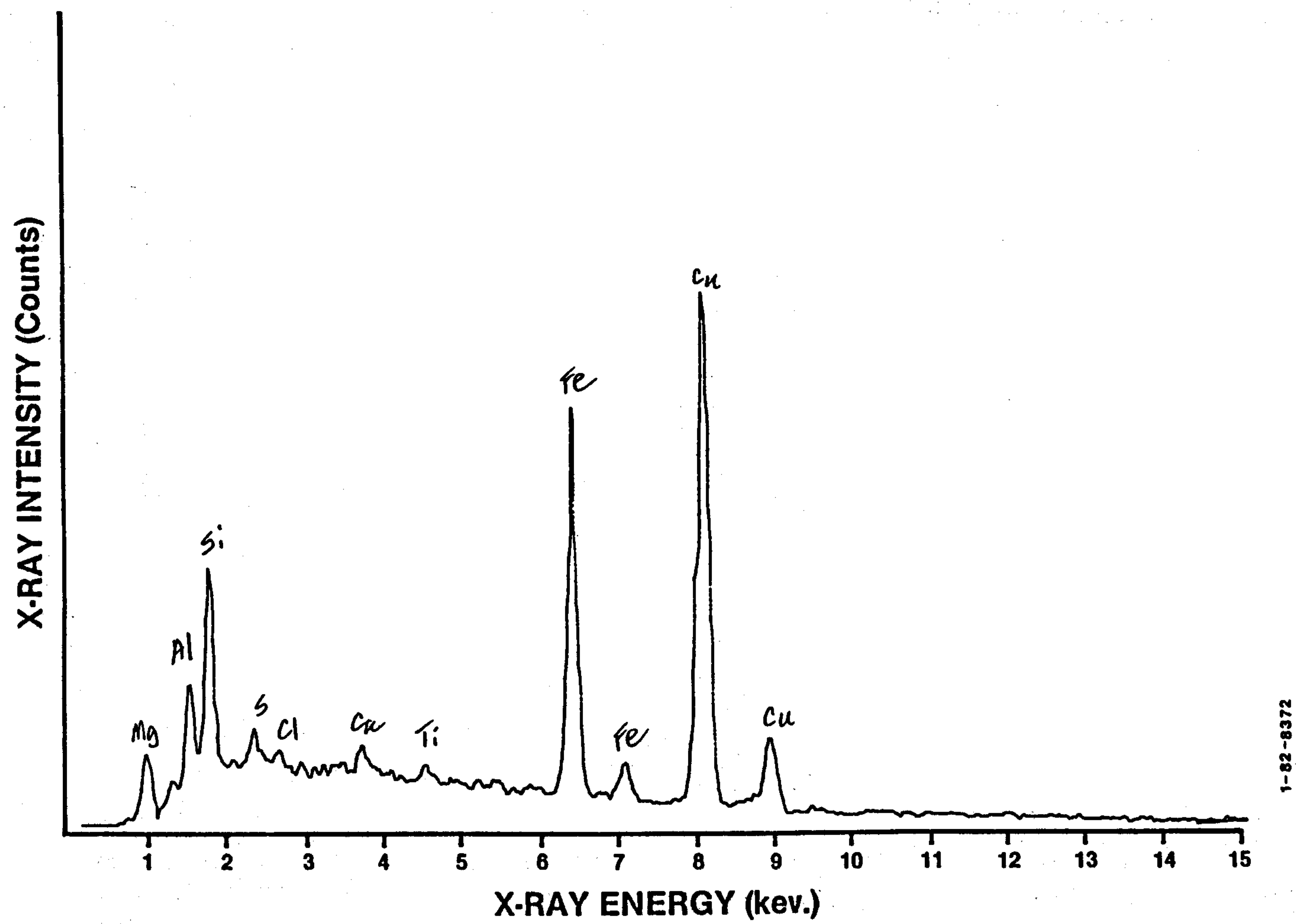
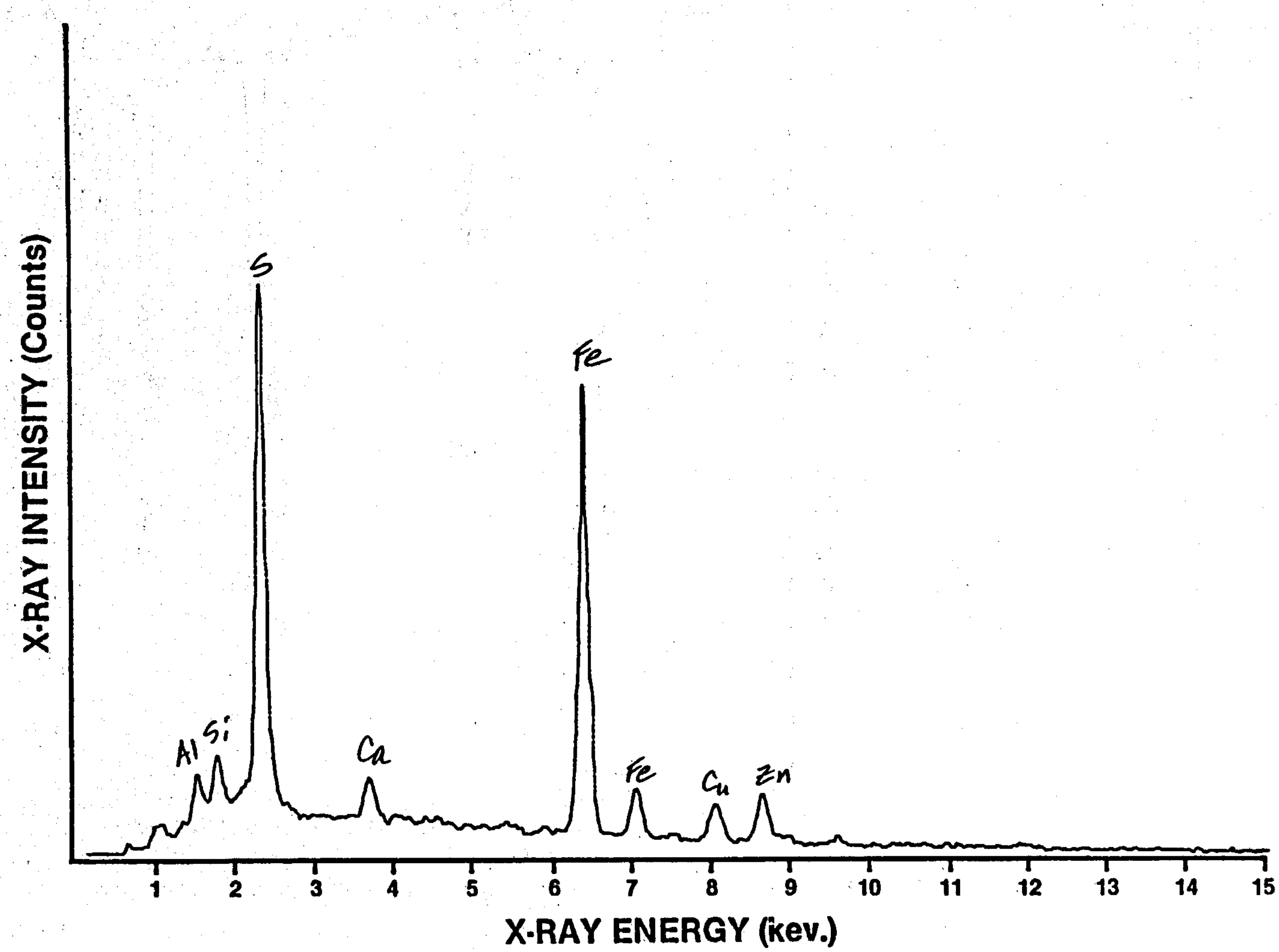
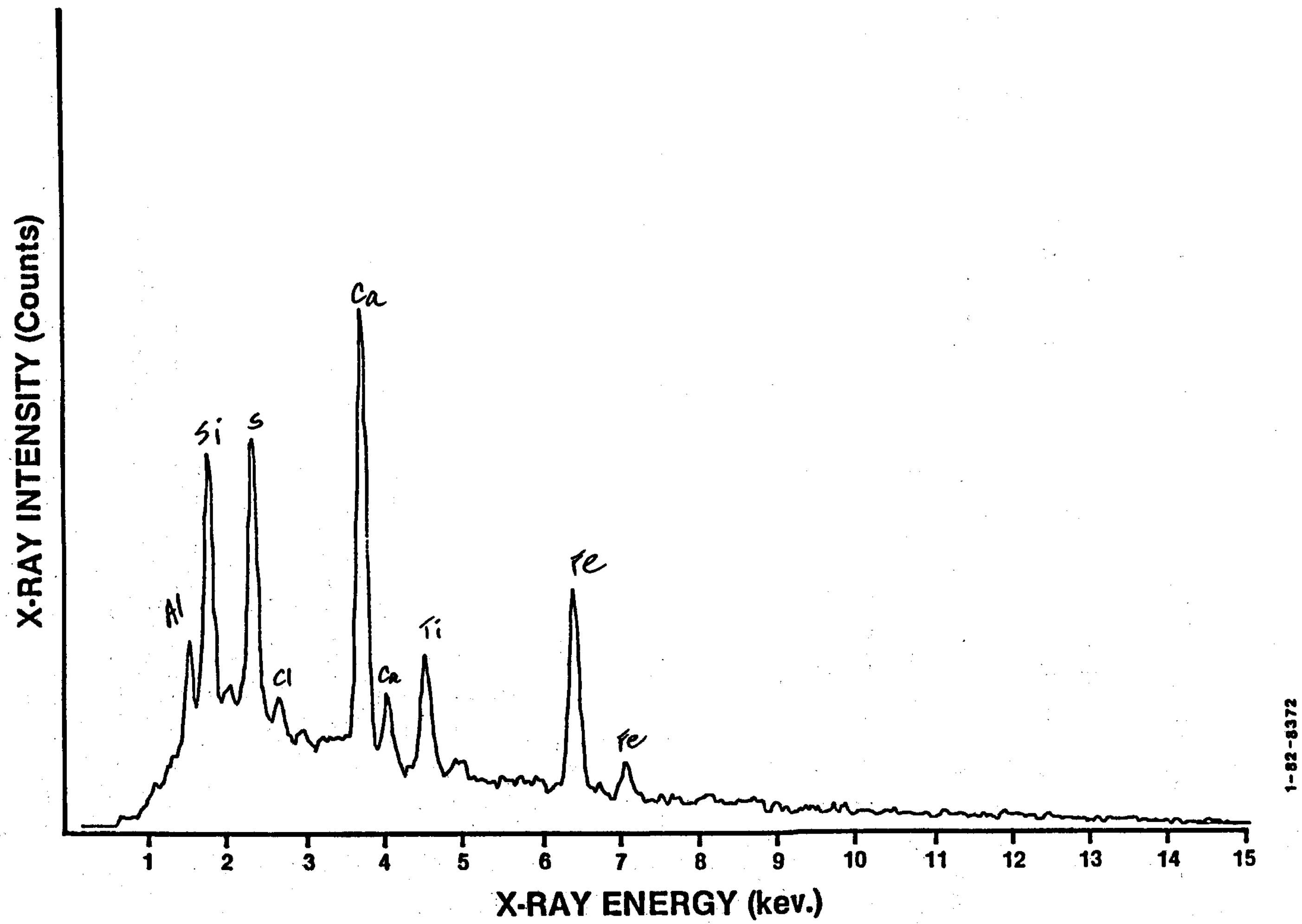


Figure 2. EDS SPECTRUM OF ROUGH BLACK PARTICLE FROM GEOTHERMAL SIDE OF HX 1 OF THE THS GEOTHERMAL SYSTEM (full scale = 1031 cnts)



1-82-8372

Figure 1. EDS SPECTRUM OF SMOOTH BLACK PARTICLE FROM GEOTHERMAL SIDE OF HX 1 OF THE THS GEOTHERMAL SYSTEM (Full Scale = 468 cnts.)



APPENDIX E:

CAPITAL COST ANALYSIS FOR AN EQUIVALENT GEOTHERMAL HEATING SYSTEM

This appendix details the derivation of the capital costs for a geothermal system "equivalent" to T-H-S, except that this equivalent system does not incur the development and reporting costs associated with the T-H-S project. The resulting costs are therefore representative of future development of the Central Texas geothermal resource. Note that the costs, expressed in 1982 dollars, are based on actual T-H-S project experience and not on engineering estimates.

A. Subtract costs which would not be accounted in future projects.

1.	Total Project Costs		$1,144,174
2.	Less Central Texas Savings and Loan Contribution (injection well, not used)	(100,000)	
3.	Less T-H-S Hospital In-Kind Contributions	(88,722)	
4.	Remaining Costs contributed by DOE/TENRAC/City of Marlin		$ 955,452
5.	Less Project Reporting Costs	(26,125)	
6.	Less Environmental Assessment (Permitting costs remain)	(12,462)	
7.	Less Public Awareness	(24,086)	
8.	Less O&M Manual Prepared by Engineers	(5,026)	
9.	Less System Monitoring by Engineers	(9,810)	
10.	Less Environmental Monitoring	(12,500)	
11.	Less Materials Testing	(10,000)	
12.	Base Costs not accounting for year spent		$ 855,443

B. Determine equivalent costs occurring before 1982.

1.	Base costs (from A.10 above)		$ 855,443
2.	Less 1982 construction costs	(385,700)	
3.	Less 1982 construction costs acceptance testing (by Engineers)	(23,374)	
4.	Costs occurring before 1982		$ 441,369

C. Escalate pre-1982 costs to 1982 dollars.

1.	Costs occurring before 1982 (from B.4 above)		$ 441,369
2.	Less 1979 well costs	(224,300)	
3.	1980 Engineering, Architecture, Permitting, etc. costs.		$ 217,069
4.	Less 50% of 1980 Engr. costs (accounting for development engineering)	(34,462)	
5.	1980 Engr., Arch., permitting, etc., costs for equivalent system		$ 182,607
6.	1980 Engr., etc. costs escalated to 1982, using 8.5% inflation ($182,607 \times 1.085^2$)	214,966	
7.	1979 well costs escalated to 1982 using 8.5% inflation ($224,300 \times 1.085^3$)	286,495	
8.	Pre 1982 costs in 1982 dollars		$ 501,464

D. Determine Equivalent System Capital in 1982 dollars.

1.	Pre 1982 costs in 1982 dollars (from C.8 above)	$ 501,464
2.	Plus 1982 construction costs (from B.2 above)	$ 385,700
3.	Plus 1982 construction oversight and acceptance testing costs (from B.3 above)	$ 23,374
4.	Equivalent system capital expressed in 1982 dollars	$ 910,538

APPENDIX F:

PUBLIC AWARENESS DOCUMENTATION

- Press Releases
- Fact Sheets
- System Brochure

Media Contact: J. D. Norris
817-883-3561

FOR IMMEDIATE RELEASE
August 31, 1978

Torbett-Hutchings-Smith Memorial Hospital

322 Coleman Street Telephone: 817-883-3561
Marlin, Texas 76661

GEOTHERMAL CONTRACT SIGNING

MARLIN--Congressman W. R. "Bob" Poage (D-Waco) heads up a list of federal, state and local officials here today to observe the signing of contracts initiating work on the State's first geothermal heating project.

The project calls for using Marlin's hot underground waters as a source of space and domestic water heating at the Torbett-Hutchings-Smith Memorial Hospital here.

Federal funds in the amount of $437,000 are being matched by a grant from the Texas Energy Advisory Council (TEAC) and in-kind service contributions from local groups for a total project cost of more than $600,000.

Environmental assessments, performed by Radian Corporation of Austin, the hospital's geothermal engineering consultant, indicate there are no significant environmental impacts associated with the project.

According to current plans, a well will be drilled some 3,400 feet down to the geothermal reservoir in February 1979. Completion of the project is scheduled for mid-1980. The well is expected to produce nearly 200 gallons per minute of 150°F water to replace an estimated 85 percent of the hospital's current demand for natural gas.

The contract-signing ceremonies are being held Friday at 10:30 a.m. in the Sun Room at the Falls Hotel. Several dozen state and local elected officials and representatives of federal and state agencies have been invited for the event.

Media Contact: J.D. Norris
817-883-3561

FOR IMMEDIATE RELEASE
2/17/78

Torbett-Hutchings-Smith
Memorial Hospital

322 Coleman Street Telephone: 817-883-3561

Marlin, Texas 76661

MARLIN HOSPITAL SELECTED TO NEGOTIATE GEOTHERMAL CONTRACT

U.S. Congressman W.R. (Bob) Poage (D-Waco) announced this week that the U.S. Department of Energy has selected the Torbett-Hutchings-Smith Memorial Hospital (T-H-S) of Marlin, Texas, to enter into contract negotiations for field experiments to demonstrate direct utilization of geothermal energy resources.

The program -- the first of its kind in Texas -- calls for using Marlin's hot mineral water as a source of energy for space and water heating in the hospital. Marlin is one of several Central Texas cities that overlie pockets of hot mineralized water which have percolated into faults which in turn are heated by the earth's hot interior. Rising to the surface under their own pressure, these waters have been used in Marlin health spas since the late 1800's.

The estimated cost of the project is $588,834. The proposed federal funding totals $379,464. Local "in-kind" service contributions will amount to $134,370 and another $75,000 has been requested from the Texas Energy Development Fund.

State Representative Dan Kubiak of Rockdale, who last year sponsored legislation establishing the $1.5 million Texas

Energy Development Fund, strongly supports Marlin community leaders in their efforts to secure state and federal funding. The Texas Energy Advisory Council administers the fund and will meet in early March to make initial project awards.

According to Project Director and T-H-S Hospital Administrator, J.D. Norris, Jr., Radian Corporation, an Austin based energy and environmental research and development firm, is the hospital's geothermal consultant and will provide overall project guidance, engineering design and installation, environmental assessment and technology transfer functions. Spencer Associates of Austin, the hospital's architect, will oversee all structural modifications and the hospital's continuing energy conservation program. Ham-Mer Consulting Engineers, also of Austin, will produce an operations and maintenance manual and perform an economic analysis. The Houston firm of Layne Texas Co. will drill and complete the well.

The new hot well to be drilled in the T-H-S complex is expected to produce near 200 gallons of water per minute at a temperature of near 150°F. Preliminary estimates are that the geothermal system will replace 85 percent of the hospital's current demand for natural gas. Presently, T-H-S consumes approximately 12 million cubic feet of gas per year.

The geothermal energy demonstration proposed for T-H-S calls for circulating hot water through heat exchangers which in turn will supply space heat and domestic hot water in the existing system. Project plans call for a 5-month drilling phase followed by a 13-month design and construction phase. A twelve month operational phase will be focused on attracting the general public and potential users of direct geothermal heat.

Norris states that the geothermal water is anticipated to be injected into the producing formation through an existing well located on the property of Central Texas Savings and Loan about 800 feet east of the T-H-S Complex.

The $134,370 "local in-kind services share" will be contributed by the community. The Central Texas Savings & Loan Association injection well will count as $100,000. The hospital will contribute $28,850 and the City of Marlin's share will be $5,520.

Geothermal energy -- literally "heat from the earth" -- is a renewable energy source currently supplying heat for whole communities and industries in Iceland, Hungary, New Zealand, and the Soviet Union. At higher pressures and temperatures, geothermal energy is used to generate electric power. One-third of San Francisco's electric power needs are met by geothermal energy.

If the Marlin project is successful, can other institutions, perhaps even a community-wide system and industrial complex, benefit from the geothermal resources?

The answer depends largely on the economic analysis of the project and a separate study assessing geothermal potential in the

Central Texas Region. The Texas Bureau of Economic Geology (BEG) in Austin and Baylor University in Waco will conduct this regional assessment.

The BEG is also involved in the multimillion dollar assessment of the Gulf Coast geopressured-geothermal resource in Texas and Louisiana and another geothermal study in far West Texas.

# # # # #

Media Contact: J.D. Norris
817-883-3561

FOR IMMEDIATE RELEASE
April 6, 1979

Turbett-Hutchings-Smith
Memorial Hospital

322 Coleman Street Telephone: 817-883-3561

Marlin, Texas 76661

MARLIN GEOTHERMAL WELL DRILLING DATE SET

MARLIN--Ceremonies marking the "spud-in", or the beginning of drilling operations, of one of the state's first geothermal wells are scheduled for Friday, April 13 at 3:30 P.M. here at the site of the drilling operations -- the grounds of the Turbett-Hutchings-Smith Memorial Hospital.

Guests for the spud-in ceremonies will include U.S. Congressman Marvin Leath, former Congressman W. R. Poage and State Representative Dan Kubiak. Representatives from the United States Department of Energy (DOE), the Texas Energy Advisory Council (TEAC) and other state and local offices will attend.

The drilling operation is the first major milestone in the two and a half year project designed to provide geothermal heating for the T-H-S Hospital.

The U.S. Department of Energy (DOE), which is funding approximately two-thirds of the total project costs, gave the go-ahead for drilling after reviewing an environmental assessment of the project prepared by Radian Corporation of Austin, geothermal consultant for the hospital. In addition to the DOE funds, the Texas Energy Advisory Council is contributing $75,000 toward the total project costs of about $600,000. Other sponsors include the T-H-S Hospital, Central Texas Savings and Loan, and the City of Marlin -- all of which are contributing materials, labor or other services toward the project.

The drilling contractor is Layne Texas Co. headquartered in Houston. Two four-man crews and a supervisor from the Dallas office of the company are expected to be on site for six to eight weeks.

Other subcontractors include Spencer Associates of Austin, which will oversee all structural modifications, and Ham-Mer Consulting Engineers of Austin, which will produce an operations and maintenance manual and perform an economic analysis of the project.

Based on other wells in the area--many of which provided hot mineral baths for health spas in the early 20th century--the T-H-S well is expected to produce 150 degree F water at 200 gallons per minute from a depth of about 3,400 feet. The water will rise to the surface under artesian pressure and be circulated through heat exchangers. The geothermal energy could reduce hospital gas use by 85 percent. Depending upon the quality of the water, the spent geothermal fluids will either be injected into the ground formation or utilized for other purposes.

The hospital also is considering using the water prior to injection, to heat greenhouses. The temperature of the water even then will probably be in excess of 100 degrees F. Hospital Administrator and Project Director, J.D. Norris, feels that the greenhouses can be used by volunteer workers to grow flowers and fresh vegetables for the patients.

The Marlin project has sparked interest among several institutional, industrial, and commercial users such as large scale greenhouse operators and industrial process heat users.

# # # # # # # #

Media Contact - J. D. Norris, Jr.
817/883-3561

FOR IMMEDIATE RELEASE

Torbett-Hutchings-Smith
Memorial Hospital

322 Coleman Street Telephone: 817-883-3561
Marlin, Texas 76661

J. D. NORRIS, JR.
ADMINISTRATOR

MARLIN GEOTHERMAL WELL COMPLETED

MARLIN, TEXAS - - A 3,885 foot deep geothermal well here is a success based on the results of the well pump tests.

The test indicates that the well will supply more than twice the space heating and water heating needs of Marlin's 130-bed Torbett-Hutchings-Smith Memorial Hospital.

The completion and testing of the well marks a major milestone in the $662,000 two-and-a-half year project designed to demonstrate the economic and technical feasibility of using locally available low-temperature geothermal energy.

Drilling of the well, located on the grounds of the T-H-S Hospital, ended in late July. The driller, Layne Texas Co., Inc. of Dallas, last week performed a pump test to determine the well's long-term production capability. Drawing from a reservoir ranging from 3615 to 3885 feet below the surface, the well is capable of producing more than 100 gallons per minute (gpm) at more than 140 degrees F under its own artesian pressure.

With a pump applied, the well can produce over 300 gpm at more than 150 degrees--a temperature and volume combination which is more than double the peak demands of the hospital.

According to Hospital Administrator and Project Director J. D. Norris, Jr., this 300 gpm flow rate indicates that other institutional or industrial Marlin users may be able to hook into the geothermal supply and thereby benefit from this constantly available and renewable source of heat which underlies many parts of Central and North Central Texas.

The test also indicates that the producing waters contain about 4,000 parts per million total dissolved solids content--a level defined by the federal government as "slightly saline." However, the geothermal water will not be consumed directly by hospital users. The second phase of the project involves the development of a preliminary engineering design of a system using heat exchangers coupled to the hospital's existing heating system.

Radian Corp. of Austin, the hospital's geothermal consultant, is analyzing the results of the water chemistry tests in order to select materials for the project which will best resist scaling and corrosion. Scaling and corrosion are significant concerns in the development and use of mineralized geothermal water.

Present plans call for the geothermal system to be in place by the winter of 1980-81. The system is estimated to reduce the hospital's annual consumption of natural gas by about 85 percent.

The U.S. Department of Energy is funding approximately two-thirds of the total project costs. The remaining third is comprised of a grant from the Texas Energy Development Fund and local in-kind service contributions.

# # #

MAR 29 1983

RELEASE: Upon Receipt
CONTACT: J. D. Norris, Jr. 817/883-3561
Administrator, Torbett, Hutchings, Smith Memorial Hospital
Marlin, Texas 76661

NATION'S MOST ADVANCED GEOTHERMAL PROJECT TO BE CHRISTENED IN MARLIN

Proven Success for Alternate Energy

Marlin, Texas; March 25, 1982 -- The nation's most advanced geothermal project will become fully operational in the midst of a full-blown celebration during a noon ceremony April 14 in Marlin.

The successful alternate energy project is highly significant not only regionally but also nationally because of its demonstrated capability to reduce heating costs of Marlin's Torbett, Hutchings, Smith Memorial Hospital to one fourth its previous cost. Four years in its planning and construction, the $1 million project will pay for itself through the radical cost savings created.

Preliminary design work for the project began in 1978 with financing secured through a combination of grants from the U.S. Department of Energy (DOE) and the Texas Energy and Natural Resources Advisory Council (TENRAC) and a loan from the Farmers Home Administration (FmHA). The pioneering project gained additional support from the City of Marlin, the Marlin Chamber of Commerce, Central Texas Savings and Loan Association and the Torbett, Hutchings, Smith Memorial Hospital.

Armed with these combined resources and a broad base of enthusiastic support by alternate energy proponents across the state and nation, the geothermal heating project has been essentially completed in the past year and has undergone a fine-tuning toward 100% capacity. Yet under this testing phase and not fully operational, the geothermal waters that convert to heat for the entire hospital complex have already demonstrated a 72% cost savings in natural gas. Gas bills actually dropped from $9,829.01 in January and February 1981 to $2,717.79 in January and February 1982. Further, the geothermal well has a capacity to meet more than three times the hospital's peak demands.

The basic principle of the alternate energy project is quite simple. Coursing beneath this beautiful Central Texas community is a natural formation of hot water, one of several such formations in areas ranging from Laredo to the Dallas-Ft. Worth area. Used in the early years of the century to fill the city's thriving spas, the water's benefits were virtually ignored after advances of modern medicine. Now rediscovered as a useful benefit to health care in Marlin, the water is piped through heat exchangers that provide domestic hot water and heat to warm the hospital complex.

A well that taps the hot water formation supplies underground water as needed for the desired temperature, with a capacity to pump over 400 gallons per minute of 155 F. water.

Radian Corporation of Austin, the consulting engineers, have revealed an economic analysis that says that a commercial user in the Marlin area could pay for the cost of a well and heating system in about three years, based on projected gas cost increases and using the proven technology of this initial prototype.

"It's obvious that we're delighted with the cost savings," said Torbett, Hutchings, Smith Memorial Hospital Administrator, J. D. Norris, Jr. "But moreover, we are extremely excited over what this means to the future energy resouces in the face of declining petro-fuel sources."

A large gathering of officials, advocates, and the public is expected for the April 14 christening, including Lieutenant Governor Bill Hobby, U.S. Congressman Marvin Leath, State Representative Dan Kubiak, representatives from DOE, TENRAC, and FmHA.

The noon ceremony will include a short program, a demonstration and a barbeque sandwich lunch. There will be no charge and the public is invited.

-30-

NOTE TO NEWS EDITORS: The hospital administrator, architect and engineers will be available one hour prior to the public event, at 11 a.m. on April 14 to explain the project and demonstrate its workings. Visual depictions will also be available. PLEASE RSVP your plans to attend along with ANY SPECIAL NEEDS OR EQUIPMENT which we may assist in providing. Radio stations and others who desire audio feeds following the event, please respond also.

CONTACT J. D. NORRIS, HOSPITAL ADMINISTRATOR AND PROJECT DIRECTOR AT 817/883-3561 for reservations or more information.

April 1979

MARLIN T-H-S HOSPITAL GEOTHERMAL PROJECT
FACT SHEET NUMBER 1*

PURPOSE

To demonstrate the technical and economic feasibility of using local geothermal waters for space and water heating.

SITE

The Torbett-Hutchings-Smith (T-H-S) Memorial Hospital in Marlin, Texas. Marlin is 30 miles southeast of Waco.

METHOD

A well will be drilled to a depth of about 3,400 feet into the Trinity sands which contain water of about 150°F. Based on the experience of nearby wells, this water should flow under artesian pressure at about 200 gallons per minute. The hot water--or geothermal fluids--will circulate through heat exchangers in the hospital. The geothermal system will supplement the existing space and water heating system which uses a natural gas-fired boiler and heat exchangers. Preliminary estimates are that the geothermal system may replace about 85 percent of the hospital's natural gas demand. The geothermal waters will remain in a closed system from production through disposal.

CONTRIBUTORS

• U.S. Department of Energy	$436,800
• Texas Energy Advisory Council	75,000
• T-H-S Memorial Hospital	33,600
• City of Marlin	11,600
• Central Texas Savings and Loan Assn.	100,000
Total	$657,000

PROJECT DIRECTOR

J. D. Norris, Jr., T-H-S Hospital Administrator

PARTICIPANTS

- Radian Corporation, Austin--Overall geothermal consultant, engineering design, geochemical analysis, system installation, technology transfer, public awareness and environmental analysis.
- Layne Texas Co., Inc., Dallas--Well drilling and completion, disposal and permitting.
- Ham-Mer Consulting Engineers, Inc., Austin--Engineering design review, economic assessment and operation and maintenance manual.
- Spencer Associates, Austin--Architectural overview
- W. M. Parrish, Jr., Marlin--Accountant
- Jack Welch, Marlin--Attorney
- Marlin Chamber of Commerce--Community coordination

PROJECT TIMETABLE

	Start	Complete
• Prepare environmental report	6/78	8/78
• DOE review and environment consent	8/78	1/79
• Preliminary design	11/78	8/79
• Drill and test production well	4/79	6/79
• Final design	10/79	12/79
• Construction	2/80	7/80
• Project acceptance test	7/80	8/80
• User attraction and demonstration	8/80	7/81

*This fact sheet is based on conceptual design and early plans.

FREQUENTLY ASKED QUESTIONS AND ANSWERS

Q. *How extensive is the resource area? Is it likely that this project will deplete the resource locally?*

A. This resource extends over a large area of Central Texas. Heating takes place by deep circulation of water in large cracks in deep rocks. The aquifer is not likely to be depleted since it receives new water continuously from rainfall and run-off far to the northwest of Marlin.

Q. *Are other geothermal projects planned for this area?*

A. Yes. A similar demonstration project has been funded by the U.S. Department of Energy to provide space and water heating for a hospital and a college building in Corsicana, 70 miles north of Marlin. A district heating feasibility study is being considered for downtown Marlin. Several commercial and institutional users are considering use of water, space heating and industrial process heat. Commercial greenhouses appear to be a particularly attractive use.

Q. *How will corrosion problems be controlled?*

A. Corrosion of metal is best solved by selecting those metals that are immune to certain constituents in the geothermal fluid. The selection of materials for the heating system will be based on tests conducted in the well water.

Q. *What happens to the used geothermal water?*

A. Although this is the first time these waters have been used for space and water heating purposes, this same producing formation supplied hot mineral baths for health spas which flourished in Marlin during the first half of the 1900's. Although highly mineralized, these geothermal waters are still used for drinking purposes. Nevertheless, the project plans call for a closed system in which the water will not commingle with drinking water or the existing heating system. The disposal method will comply with state regulations and, depending on the actual water quality, will be disposed of either by injection into the ground via another well or stream run-off.

Q. *What are the economics of this heating system?*

A. One of the purposes of this project is to determine the economic feasibility of geothermal energy use in this part of the country. Based on preliminary calculations and very rough estimates, it appears that the system is competitive with present intra-state natural gas prices.

FOR MORE INFORMATION

Contact J. D. Norris, Jr., Administrator, T-H-S Memorial Hospital, 322 Coleman Street, P.O. Box 60, Marlin, Texas 76661, (817-883-3561). As the project progresses, updated fact sheets will be published.

Marlin T-H-S Hospital Geothermal Project

Fact Sheet Number 2

April 1980

Purpose: To demonstrate the technical and economic feasibility of using local geothermal waters for space and water heating.

Site: The Torbett-Hutchings-Smith (T-H-S) Memorial Hospital in Marlin, Texas. Marlin is 30 miles southeast of Waco.

Method: A production well has been drilled and completed to a depth of 3885 feet into the Trinity Sands which contain water at a temperature of more than 150°F. Under artesian pressure, the well produces about 75 gallons per minute of 140° F water. The hot water — or geothermal fluids — will circulate through heat exchangers in the hospital. The geothermal system will supplement the existing space and water heating system which uses a natural gas-fired boiler and heat exchangers. Preliminary design estimates are that the geothermal system will replace over 80 percent of the hospital's annual natural gas demand. The geothermal waters will remain in a closed system from production through utilization. After the useful heat has been extracted, the spent fluid will be discharged via surface waters under the terms of a state discharge permit.

Contributors:

U.S. Department of Energy	$436,800
Texas Energy and Natural Resources Advisory Council	80,000
T-H-S Memorial Hospital	33,600
City of Marlin	11,600
	$562,000

Project Director: J.D. Norris, Jr., T-H-S Hospital Administrator

Participants:

Radian Corporation, Austin — Overall geothermal consultant, engineering design, geochemical analysis, system installation, technology transfer, public awareness and environmental analysis.

Layne Texas Co., Inc., Dallas — Well design, drilling, completion, and development.

Ham-Mer Consulting Engineers, Inc., Austin — Engineering design review, economic assessment and operation and maintenance manual.

Spencer Associates, Austin — Architectural overview.

City of Marlin — Surface disposal provisions.

W.M. Parrish and Co., Marlin — Accountant

Jack Welch, Marlin — Attorney

Marlin Chamber of Commerce — Community coordination.

Project Timetable:

	START	COMPLETE
• Prepare environmental report	6/78	8/78
• DOE review and environmental consent	8/78	1/79
• Preliminary design	12/78	12/79
• Drill and test production well	4/79	7/79
• Final design	1/80	9/80
• Construction	11/80	4/81
• Project acceptance test	4/81	5/81
• User attraction and demonstration	5/81	4/82

Frequently Asked Questions & Answers:

Q. *How extensive is the resource area? Is it likely that this project will deplete the resource locally?*

A. This resource extends over a large area of Central Texas. Heating takes place by deep circulation of water in large cracks in deep rocks. The aquifer is not likely to be depleted since it receives new water continuously from rainfall and run-off far to the northwest of Marlin.

Q. *Are other geothermal projects planned for this area?*

A. Yes. A similar demonstration project has been funded by the U.S. Department of Energy to provide space and water heating for a hospital and a college building in Corsicana, 70 miles north of Marlin. There is also a plan to heat the Marlin Chamber of Commerce offices. In addition, several commercial and institutional users are considering use of water, space heating and industrial process heat. Commercial greenhouses appear to be a particularly attractive use.

Q. *How will corrosion problems be controlled?*

A. Corrosion of metal is best solved by selecting those metals that are immune to certain constituents in the geothermal fluid. The selection of materials for the heating system will be based on tests conducted in the well water.

Q. *How much energy will be saved by this project?*

A. Approximately 9.5 million cubic feet of gas per year will be saved. This is the equivalent of 1700 barrels of oil.

Q. *What happens to the used geothermal water?*

A. This is the first time that these geothermal waters have been used for space and water heating purposes. Wells tapping fluid from part of this same producing formation, however, supplied hot mineral baths for health spas which flourished in Marlin during the first half of the 1900's. These geothermal waters, which are much more highly mineralized than the hospital well fluid, are still used for drinking purposes. Nevertheless, the project plans call for a closed system in which the water will not commingle with city drinking water or the existing heating system. The surface disposal method that will be used complies with state regulations set forth by the Texas Railroad Commission and other state agencies.

Q. *What are the economics of this heating system?*

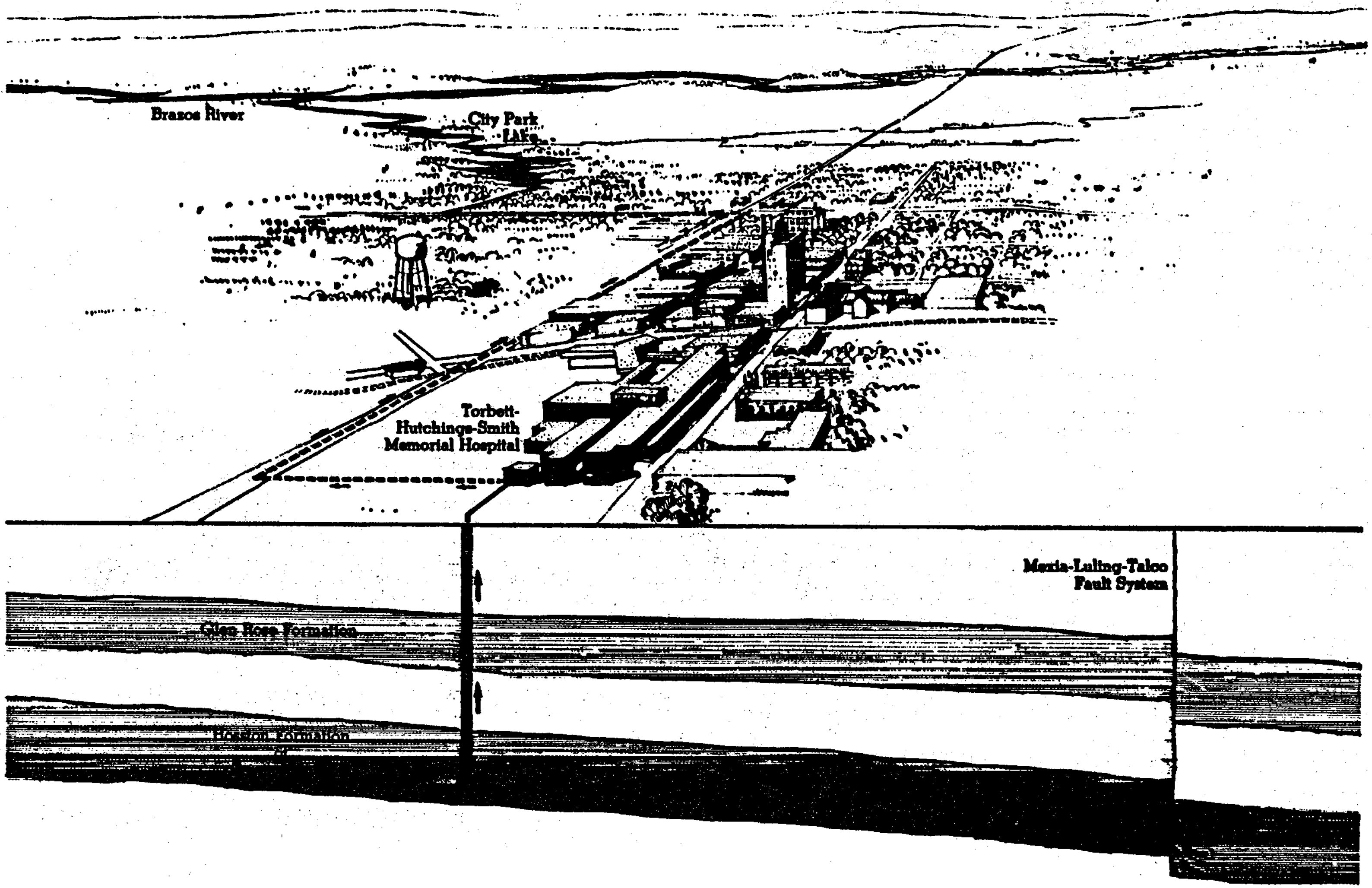
A. One of the purposes of this project is to determine the economic feasibility of geothermal energy use in this part of the country. Return on investment, payback and other economic factors will be determined in late 1980. Based on preliminary calculations and rough estimates, it appears that the system will be competitive compared to the cost of new natural gas prices. It is also likely that the well will be used to provide heating for other users and thus generate additional revenues.

For More Information:

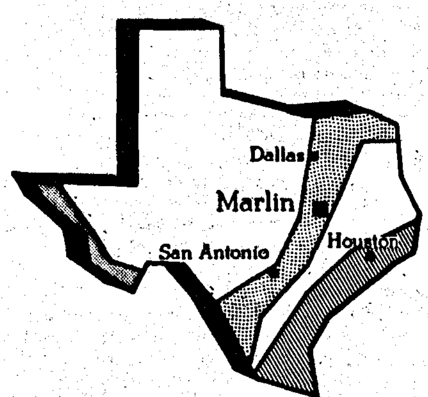
Contact J.D. Norris, Jr., Administrator, T-H-S Memorial Hospital, 322 Coleman Street, P.O. Box 60, Marlin, Texas 76661, (817-883-3561). As the project progresses, updated fact sheets will be published.

*This fact sheet is based on current preliminary design and plans.

T-H-S Memorial Hospital
Geothermal Demonstration Project
Marlin, Texas



Central Texas Hydrothermal Region



Geothermal Regions in Texas

Sources of geothermal energy–which is literally heat from the earth–can be found throughout the United States. This energy exists in the form of hot water, dry steam, pressurized water and methane, or hot dry rock formations. Some geothermal sources are close to the surface and thus easy to tap; others are less accessible.

Texas has three distinct geothermal regions. The relatively unexplored Trans-Pecos Region underlies a sparsely populated area of far West Texas. The Gulf Coast Region is made up of two- to three-mile deep bands of high pressure hot waters which contain methane, or natural gas. It is the third region–the Central Texas Hydrothermal Region–that is closest to commercial development. Although this region lacks the higher heat and pressure of the other two, its hot waters can be tapped at shallow depths using conventional water wells. Sitting above the widely dispersed pockets of the Central Texas resource is a region containing an estimated 4.5 million people living in a few of the state's largest cities and hundreds of smaller communities.

It is estimated that the Central Texas geothermal resources could provide up to one-fourth of a quadrillion British Thermal Units (Btu) of heat energy annually by the year 2000. Although small compared to the nation's annual energy appetite of about 80 quadrillion Btu, this resource could provide energy for space and water heating at many sites. Greenhouse heating and industrial processes are other possible uses for this resource.

Geologically, the Central Texas resource is believed to be caused by hot waters from deep within the earth circulating through cracks created by a fault line (shifting in the earth's crust). These waters come in contact with shallow water reservoirs and in a few places, the pressure is sufficient to bring the water to the surface. In the Central Texas region the hottest known geothermal waters occur in Marlin, a ranching and farming community (county seat) in Falls County. The 155°F water temperature makes Marlin an ideal site for commercial geothermal energy development.

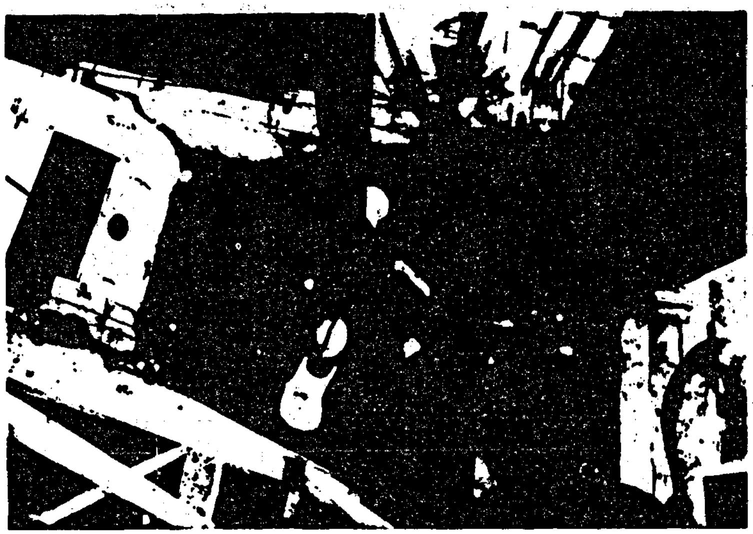
Marlin's Famous Mineral Water Spas

In an attempt to locate fresh water in 1891, the City of Marlin drilled a well to a depth of more than 3,000 feet. They didn't find any fresh water but did tap two sources of hot mineral-laden artesian water. At first the water was discharged to the surface but soon the City began using it for fire fighting and street sprinkling and selling it to public bath houses and a few private residences. Local citizens who drank and bathed in the water reported its healing effect for a variety of ailments from rheumatism to skin disorders.

Stories of the mineral water cures spread throughout the state and even the nation. By the late 1890s a flourishing health spa business attracted trainloads of tourists and patients–the latter often arriving on stretchers and crutches. At its peak in the 1920s, Marlin was the permanent training site of the New York Giants and a fashionable resort. It supported a prosperous industry of hotels, clinics, bath houses, and boarding rooms. This industry had all but disappeared shortly after the second world war as America's fascination with mineral baths was replaced by the advent of the so-called "wonder drugs."

By the mid-1970s, the architectural reminders of Marlin's heyday were still in evidence but the mineral baths were no longer a commercial attraction. However, with energy shortages and rapidly increasing prices for oil and natural gas, community interest in the "hot mineral waters" was revived–this time as a potential energy source for space and water heating.

Majestic Hotel and Spa in the mid 1930s.



Production well drilling during the summer of 1979.

T-H-S Project: Facts and Figures

Purpose: To demonstrate the technical feasibility of using geothermal energy for space and water heating.

Site: The Torbett-Hutchings-Smith Memorial Hospital in Marlin, Texas.

Resource: Under artesian pressure, the 3900-foot production well yields 75 gallons per minute (gpm) of 140°F water from the Hosston Formation. With the addition of a large pump, the well can produce up to 600 gpm at 155°F.

Environment: The geothermal waters remain in a closed system from production to disposal—yielding their heat through a series of heat exchangers. A thorough environmental study determined that the fluids could be discharged to surface waterways without an unacceptable impact on the environment.

Economics: It is estimated that the costs of the production well, engineering, and construction will be offset by natural gas savings in 11-14 years. This payback period is a result of the pioneering nature of the project and the hospital's non-profit status. For a similar commercial geothermal project, taking advantage of tax incentives, the payback could be reduced to less than five years.

Participants

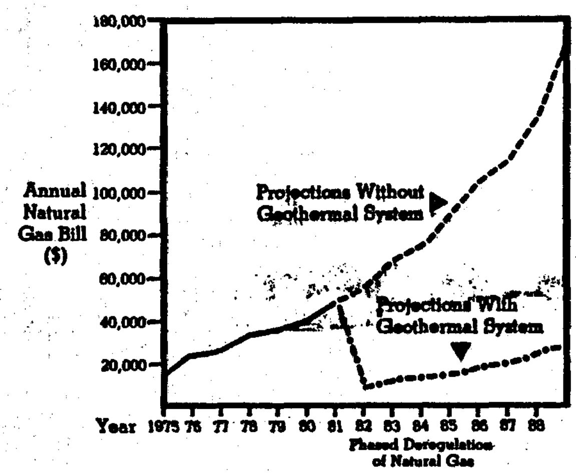
T-H-S Memorial Hospital, Marlin	– In-kind services including accounting and legal services
U.S. Department of Energy, Las Vegas, NV	– Funding $821,600
Texas Energy and Natural Resources Advisory Council, Austin	– Funding $ 81,500
City of Marlin	– Funding $ 5,000
Radian Corporation, Austin	– Overall geothermal consultants for resource development, system design, construction oversight, environment, permits, and public awareness
Layne Texas Company, Dallas	– Well drilling and completion
Ham-Mar Consulting Engineers, Inc., Austin	– Design review, energy conservation and construction coordination
Spencer & Associates, Austin	– Architectural design and oversight
Lockridge-Priest, Inc., Waco	– System construction
Central Texas Savings & Loan Association, Marlin	– Sponsor
Jack Welch, Marlin	– Legal advisor
William Parrish, Jr., Marlin	– CPA
Marlin Chamber of Commerce	– Coordination

T-H-S Project: Background

The Torbett-Hutchings-Smith (T-H-S) Memorial Hospital is the first institution in Marlin to benefit from revived interest in the local hot water resource. The hospital's origin dates back to the early 1900s when, as the Torbett Clinic, it used the hot mineral waters as a supplemental treatment for as many as 40,000 patients a year.

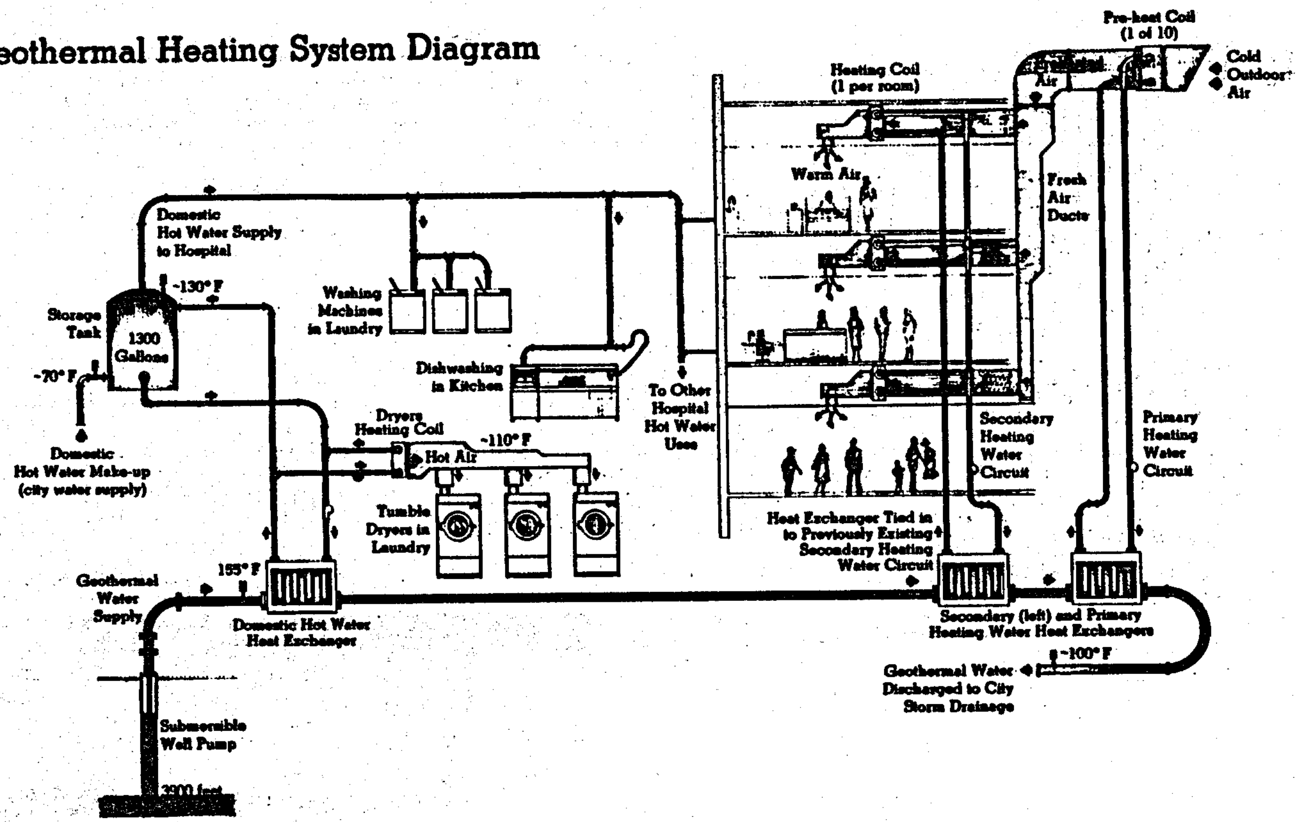
The clinic was relocated, modernized, and later renamed. By the mid-1970s, the 130-bed hospital, like many other natural gas users, began using energy conservation measures and searching for other means of reducing soaring gas costs. Aware of the resource beneath them, hospital and civic leaders, together with a team of contractors and consultants, applied for funds from the U.S. Department of Energy and the Texas Energy and Natural Resources Advisory Council. Working through elected state and federal representatives, the hospital obtained $821,600 in federal and $81,500 in state funds and a loan from the Farmers Home Administration (FmHA) to help cover the cost of the project. The objective is to demonstrate the technical feasibility of using a geothermal resource to meet the hospital's space and water heating needs.

Environmental assessments and preliminary design work were begun in 1978; a production well was drilled and completed in the spring of 1979. Construction to link the geothermal system to existing space and water heating systems through a series of heat exchangers was completed in late 1981. Preliminary start-up tests during the winter of 1981 – 1982 indicate that the use of geothermal energy will reduce the hospital's annual consumption of natural gas by 85 percent.



Natural Gas Costs Savings for T-H-S Memorial Hospital

Geothermal Heating System Diagram



The System

The T-H-S Memorial Hospital Geothermal Heating System provides water and space heating. The well supplies the 155°F geothermal waters first to a hot water heat exchanger. Here, the geothermal waters heat city water for use throughout the hospital. This geothermally-heated hot water also heats air for dryers in the hospital laundry.

After yielding some of its heat for the hospital's hot water supply, the geothermal water passes through two more heat exchangers which provide space heating. Although the entire primary heating circuit was added to the hospital's heating system during the project, the secondary heating circuit and ductwork already existed and required only a simple tie-in to the geothermal system.

About the Front Cover ▶

Hot geothermal waters from the Hoston Formation of the Central Texas Hydrothermal Region provide heat for the T-H-S hospital. The Hoston waters are heated by deeper, hotter water that migrates up through a fault system to the shallower formations. Near the hospital a 3900-foot well taps these hot waters.

For more information contact J.D. Norris, Jr., Administrator/P.O. Box 60/Marlin, TX 76661/(817)883-3561

APPENDIX G:

ENVIRONMENTAL MONITORING BIOLOGICAL AND CHEMICAL LABORATORY ANALYSIS RECORDS

Tables G-1 through G-4 contain the results of plankton and periphyton sample indentifications. Tables G-5 through G-8 are all the chemical laboratory analysis results.

TABLE G-1. CITY PARK LAKE PHYTOPLANKTON, 29 JULY 1983

Genus	Units/ml
Palmellococcus	2700
Merismopaedonin	1100
Tetraedron lunaris	1700
Cyclotella	2100

TABLE G-2. CITY PARK LAKE PHYTOPLANKTON, 5 NOVEMBER 1982

Genus	Units/ml
Chlorococcus	2400
Raphidiopsis	2600
Cyclotella	2100
Navicula	63
Stauroneis	85
Fragillaria	85
Diploneis	43
Closterium	43
Trachelomonas	21

TABLE G-3. PERIPHYTIC COMMUNITIES, ABOVE CITY PARK LAKE
5 NOVEMBER 1982

Genus	Units/ml
Enteromorpha	abundant
Oscillatoria	abundant
Mougeotia	common
Navicula	common
Lyngbya	common
Syndera	common
Bidulphia	present
Gomphonema	present

TABLE G-4. CITY PARK LAKE PHYTOPLANKTON, 17 FEBRUARY 1983

Genus	Units/ml
Chlorococcum	1425
Amphipora	14
Chlorogonium	172
Microactinium	56
Raphidiopsis	42
Phacus	42
Cyclotella	2
Syndera	28
Navicula	14
Actinastrum	28
Diploneis	14
Tetrastrum	2
Cocconeis	2
Gonium	2
Netrium	2

RADIAN CORPORATION

PAGE 1 Analytical Serv REPORT LAB # 82-05-021

RECEIVED: 05/05/82 03/07/83 15:14:29

REPORT TO: Robert Wallace/Fred Blood, Radian, Building 7

PREPARED BY: Radian Analytical Services, 8501 MoPac Blvd., P.O. Box 9948, Austin, Texas 78766

CERTIFIED BY

ATTEN: Robert Wallace

ATTEN

PHONE (512) 454-4797

CONTACT CONOVER

CLIENT MARLIN GEOT SAMPLES 2

COMPANY Marlin Hospital

FACILITY Geothermal well

Duplicate of report of 06/28/82.

WORK ID May samples

TAKEN 5/5/82

TRANS hand carried

TYPE geothermal well

P.O. # 212-300-27-01

INV. # 82000071

302

SAMPLE IDENTIFICATION

01 Inflow

02 Marlin Lake

Analytical Serv TEST CODES and NAMES used on this report

CL TA	Chloride
COD A	Chemical Oxygen Demand
NPDMET	NPDES metals ICPES
ONG A	Oil and Grease
SO4 NA	Sulfate
TDS A	Total Dissolved Solids

RADIAN CORPORATION

Analytical Serv REPORT

LAB # 82-05-021

RECEIVED: 05/05/82

RESULTS BY TEST

TEST CODE default units	Sample 01 (entered units)	Sample 02 (entered units)
CL_TA mg/L	315	158
COD_A mg/L	61	83
ONG_A mg/L	ND	ND
SO4_NA mg/L	2060	456
TDS_A mg/L	4042	1825

RADIAN CORPORATION

PAGE 3 Analytical Serv REPORT LAB # 82-05-021
RECEIVED: 05/05/82 RESULTS BY SAMPLE

SAMPLE ID Inflow FRACTION 01B TEST CODE NPDMET NAME NPDES metals ICPES

DATE ANALYZED 05/10/82 VERIFIED BY DLH

Part B Metals Analyzed by ICPES			Part C Metals Analyzed by ICPES			Part C Metals Analyzed by AA		
CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AL	Aluminum	.070*	AG	Silver	<.002	AS	Arsenic	<.003
BA	Barium	.15	BE	Beryllium	<.0005	HG	Mercury	<.0002
B	Boron	2.4	CD	Cadmium	<.001	PB	Lead	.005*
CO	Cobalt	<.006	CR	Chromium	<.001	SE	Selenium	<.003
FE	Iron	.59	CU	Copper	<.001	TL	Thallium	<.003
MG	Magnesium	34	NI	Nickel	<.003	SB	Antimony	<.003
MO	Molybdenum	<.002	ZN	Zinc	.017			
MN	Manganese	.036						
SN	Tin	<.120						
TI	Titanium	<.005						

304

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

RADIAN CORPORATION

PAGE 4 | Analytical Serv REPORT | LAB # 82-05-021

RECEIVED: 05/05/82 | RESULTS BY SAMPLE

SAMPLE ID Marlin Lake FRACTION 02B TEST CODE NPDMET NAME NPDES metals ICPES

DATE ANALYZED 05/10/82 VERIFIED BY DLH

Part B Metals
Analyzed by ICPES

CODE	METAL	RESULT
AL	Aluminum	<.050
BA	Barium	.16
B	Boron	.91
CO	Cobalt	<.006
FE	Iron	.20
MG	Magnesium	17
MO	Molybdenum	<.002
MN	Manganese	.19
SN	Tin	<.120
TI	Titanium	<.005

305

Part C Metals
Analyzed by ICPES

CODE	METAL	RESULT
AG	Silver	<.002
BE	Beryllium	<.0005
CD	Cadmium	<.001
CR	Chromium	<.001
CU	Copper	<.001
NI	Nickel	<.003
ZN	Zinc	<.003

Part C Metals
Analyzed by AA

CODE	METAL	RESULT
AS	Arsenic	<.003
HG	Mercury	<.0002
PB	Lead	.007*
SE	Selenium	<.003
TL	Thallium	<.003
SB	Antimony	<.003

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

RADIAN CORPORATION

PAGE 1 Analytical Serv REPORT LAB # 82-07-122
RECEIVED: 07/30/82 08/23/82 11:44:41

REPORT TO Robert Wallace/Fred Blood
Radian
Building 7

ATTEN Robert Wallace

CLIENT MARLIN GEOT SAMPLES 2
COMPANY Marlin Hospital
FACILITY Geothermal well

WORK ID July Samplings
TAKEN 7/82
TRANS Hand delivered
TYPE geothermal well
P.O. # 212-300-27-01
INV. # 82000244

PREPARED BY Radian Analytical Services
8501 MoPac Blvd.
P.O. Box 9948
Austin, Texas 78766
ATTEN
PHONE (512) 454-4797

CERTIFIED BY

CONTACT CONOVER

306

SAMPLE IDENTIFICATION

01 Sample L-2 Marlin Lake
02 Sample I-2

Analytical Serv TEST CODES and NAMES used on this report

CL TA	Chloride
ICP 40	Complete ICPES Analysis
SO4 NA	Sulfate
TDS A	Total Dissolved Solids

RECEIVED: 07/30/82

Analytical Serv REPORT LAB # 82-07-122

RESULTS BY TEST

TEST CODE default units	Sample 01 (entered units)	Sample 02 (entered units)
CL_TA mg/L	310	370
SO4_NA mg/L	1280	1510
TDS_A mg/L	2880	3320

CORPORATION

PAGE 3 Analytical Serv REPORT LAB # 82-07-122
RECEIVED: 07/30/82 RESULTS BY SAMPLE

SAMPLE ID Sample L-2 Marlin Lake FRACTION 01A TEST CODE ICP 40 NAME Complete ICPES Analysis

DATE ANALYZED 08/16/82 VERIFIED BY DLH

308

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	M.002	HG	Mercury	<.0002	SE	Selenium	<.003
AL	Aluminum	0.140	IN	Indium	<.05	SI	Silicon	6.8
AS	Arsenic	<.003	K	Potassium	18	SN	Tin	<.12
AU	Gold	NA	LI	Lithium	<.001	SR	Strontium	<.001
B	Boron	1.9	MG	Magnesium	26	TE	Tellurium	<.10
BA	Barium	0.12	MN	Manganese	0.007	TI	Titanium	<.005
BE	Beryllium	<.0005	MO	Molybdenum	0.013	TL	Thallium	<.002
BI	Bismuth	NA	NA	Sodium	800	U	Uranium	<.06
CA	Calcium	150	NI	Nickel	<.003	V	Vanadium	<.003
CD	Cadmium	<.002	P	Phosphorous	NA	W	Tungsten	<.03
CO	Cobalt	<.006	PB	Lead	<.002	Y	Yttrium	<.002
CR	Chromium	<.001	PT	Platinum	<.03	ZN	Zinc	<.003
CU	Copper	<.001	S	Sulfur	NA			NA
FE	Iron	0.030	SB	Antimony	<.003			NA

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

RADIAN CORPORATION

PAGE 4   Analytical Serv   REPORT   LAB # 82-07-122

RECEIVED: 07/30/82   RESULTS BY SAMPLE

SAMPLE ID Sample I-2   FRACTION 02A   TEST CODE ICP 40   NAME Complete ICPES Analysis

DATE ANALYZED 08/16/82   VERIFIED BY DLH

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	<.002	HG	Mercury	<.0002	SE	Selenium	<.003
AL	Aluminum	0.097	IN	Indium	<.05	SI	Silicon	9.7
AS	Arsenic	<.003	K	Potassium	20	SN	Tin	<.12
AU	Gold	NA	LI	Lithium	<.001	SR	Strontium	<.001
B	Boron	2.0	MG	Magnesium	29	TE	Tellurium	<.10
BA	Barium	0.063	MN	Manganese	<.001	TI	Titanium	<.005
BE	Beryllium	<.0005	MO	Molybdenum	<.002	TL	Thallium	<.002
BI	Bismuth	NA	NA	Sodium	900	U	Uranium	<.06
CA	Calcium	170	NI	Nickel	<.003	V	Vanadium	<.003
CD	Cadmium	<.002	P	Phosphorous	NA	W	Tungsten	<.03
CO	Cobalt	<.006	PB	Lead	<.002	Y	Yttrium	<.002
CR	Chromium	<.001	PT	Platinum	<.03	ZN	Zinc	<.003
CU	Copper	<.001	S	Sulfur	NA			NA
FE	Iron	0.019	SB	Antimony	<.003			NA

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

CORPORATION

PAGE 1 Analytical Serv REPORT LAB # 82-11-063

RECEIVED: 11/07/82 11/23/82 09:37:52

REPORT TO	Robert Wallace/Fred Blood Radian Building 7	PREPARED BY	Radian Analytical Services 8501 MoPac Blvd. P.O. Box 9948 Austin, Texas 78766
ATTEN	Robert Wallace	ATTEN	Guy M. Crawford
		PHONE	(512) 454-4797

CERTIFIED BY

CONTACT CONOVER

CLIENT	MARLIN GEOT	SAMPLES	2
COMPANY	Marlin Hospital		
FACILITY	Geothermal well		

WORK ID	November samples
TAKEN	
TRANS	hand carried
TYPE	geothermal well
P.O. #	212-300-27-01
INV. #	94

310

SAMPLE IDENTIFICATION

01	Marlin Lake
02	Marlin outfall

Analytical Serv TEST CODES and NAMES used on this report

CL TA	Chloride
ICP 40	Complete ICPES Analysis
TDS A	Total Dissolved Solids

CORPORATION

RECEIVED: 11/07/82

Analytical Serv REPORT
RESULTS BY SAMPLE

LAB # 82-11-063

SAMPLE ID Marlin Lake SAMPLE # 01 FRACTIONS: A,B

CL_TA	141 mg/L	TDS_A	1530 mg/L

311

CORPORATION

PAGE 3 Analytical Serv REPORT LAB # 82-11-063

RECEIVED: 11/07/82 RESULTS BY SAMPLE

SAMPLE ID Marlin Lake FRACTION 01B TEST CODE ICP 40 NAME Complete ICPES Analysis

DATE ANALYZED 11/17/82 VERIFIED BY DLH

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	<.002	HG	Mercury	<.03	SE	Selenium	<.084
AL	Aluminum	0.055*	IN	Indium	<.05	SI	Silicon	4.2
AS	Arsenic	<.057	K	Potassium	9.7	SN	Tin	<.12
AU	Gold	<.03	LI	Lithium	0.16	SR	Strontium	2.2
B	Boron	0.66	MG	Magnesium	15	TE	Tellurium	<.10
BA	Barium	<.001	MN	Manganese	<.001	TI	Titanium	<.005
BE	Beryllium	<.0005	MO	Molybdenum	0.002*	TL	Thallium	<.091
BI	Bismuth	<.05	NA	Sodium	430	U	Uranium	0.070*
CA	Calcium	98	NI	Nickel	<.003	V	Vanadium	<.003
CD	Cadmium	<.002	P	Phosphorous	<.18	W	Tungsten	<.03
CO	Cobalt	<.006	PB	Lead	<.084	Y	Yttrium	<.002
CR	Chromium	<.001	PT	Platinum	<.03	ZN	Zinc	<.003
CU	Copper	<.001	S	Sulfur	270			NA
FE	Iron	0.095	SB	Antimony	<.032			NA

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

CORPORATION

RECEIVED: 11/07/82

Analytical Serv REPORT
RESULTS BY SAMPLE

LAB # 82-11-063

SAMPLE ID Marlin outfall SAMPLE # 02 FRACTIONS: A,B

CL_TA	260 mg/L	TDS_A	4150 mg/L

313

CORPORATION

PAGE 5 Analytical Serv REPORT LAB # 82-11-063
RECEIVED: 11/07/82 RESULTS BY SAMPLE

SAMPLE ID Marlin outfall FRACTION 02B TEST CODE ICP 40 NAME Complete ICPES Analysis

DATE ANALYZED 11/17/82 VERIFIED BY DLH

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	<.002	HG	Mercury	<.03	SE	Selenium	<.084
AL	Aluminum	<.050	IN	Indium	<.05	SI	Silicon	15
AS	Arsenic	<.057	K	Potassium	17	SN	Tin	<.12
AU	Gold	<.03	LI	Lithium	0.44	SR	Strontium	6.4
B	Boron	1.9	MG	Magnesium	39	TE	Tellurium	<.10
BA	Barium	<.001	MN	Manganese	<.001	TI	Titanium	<.005
BE	Beryllium	<.0005	MO	Molybdenum	0.008*	TL	Thallium	<.091
BI	Bismuth	<.05	NA	Sodium	950	U	Uranium	0.28*
CA	Calcium	240	NI	Nickel	0.007*	V	Vanadium	<.003
CD	Cadmium	<.002	P	Phosphorous	<.18	W	Tungsten	<.03
CO	Cobalt	<.006	PB	Lead	<.084	Y	Yttrium	<.002
CR	Chromium	<.001	PT	Platinum	<.03	ZN	Zinc	<.003
CU	Copper	<.001	S	Sulfur	780			NA
FE	Iron	0.089	SB	Antimony	<.032			NA

314

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

RADIAN CORPORATION

PAGE 1 Analytical Serv REPORT LAB # 83-02-A13

RECEIVED: 02/17/83 03/18/83 09:07:01

REPORT TO Robert Wallace/Fred Blood
Radian
Building 7

ATTEN Robert Wallace

CLIENT MARLIN GEOT SAMPLES 4
COMPANY Marlin Hospital
FACILITY Geothermal well

PREPARED BY Radian Analytical Services
8501 MoPac Blvd.
P.O. Box 9948
Austin, Texas 78766

ATTEN
PHONE (512) 454-4797

CERTIFIED BY

CONTACT CONOVER

WORK ID February samples
TAKEN 2-17-83
TRANS hand
TYPE geothermal well
P.O. # 212-300-27-01
INV. # 514

315

SAMPLE IDENTIFICATION

01 Martin Lake
02 Waterfall M1
03 sediment
04 fish

Analytical Serv TEST CODES and NAMES used on this report

CL IC	Chloride IC
EPAH2O	EPA Water Digestion
EPASED	EPA Sediment Digestion
EPATIS	EPA Tissue Digestion
ICP 40	Complete ICPES Analysis
SO4 IC	Sulfate IC
TDS A	Total Dissolved Solids

CORPORATION

Analytical Serv REPORT LAB # 83-02-A13

RECEIVED: 02/17/83

RESULTS BY TEST

TEST CODE default units	Sample 01 (entered units)	Sample 02 (entered units)	Sample 03 (entered units)	Sample 04 (entered units)
CL_IC mg/L	237	290		
EPAH2O date completed	02/28/83	02/28/83		
EPASED date complete			02/28/83	
EPATIS date complete				02/28/83
SO4_IC mg/L	1520	2590		
TDS_A mg/L	2380	4430		

316

PAGE 3 Analytical Serv REPORT LAB # 83-02-A13
RECEIVED: 02/17/83 RESULTS BY SAMPLE

SAMPLE ID Martin Lake FRACTION 01A TEST CODE ICP 40 NAME Complete ICPES Analysis

DATE ANALYZED 03/01/83 VERIFIED BY DLH

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	<.002	HG	Mercury	<.03	SE	Selenium	<.084
AL	Aluminum	0.42	IN	Indium	<.05	SI	Silicon	6.9
AS	Arsenic	<.057	K	Potassium	10	SN	Tin	<.12
AU	Gold	NA	LI	Lithium	0.26	SR	Strontium	3.3
B	Boron	0.57	MG	Magnesium	19	TE	Tellurium	<.10
BA	Barium	0.036	MN	Manganese	0.11	TI	Titanium	<.005
BE	Beryllium	<.0005	MO	Molybdenum	<.002	TL	Thallium	<.091
BI	Bismuth	<.05	NA	Sodium	590	U	Uranium	<.064
CA	Calcium	134	NI	Nickel	<.003	V	Vanadium	<.003
CD	Cadmium	<.002	P	Phosphorous	<.18	W	Tungsten	<.03
CO	Cobalt	<.006	PB	Lead	<.084	Y	Yttrium	<.002
CR	Chromium	<.001	PT	Platinum	<.03	ZN	Zinc	<.003
CU	Copper	<.001	S	Sulfur	340			NA
FE	Iron	0.20	SB	Antimony	<.032			NA

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

CORPORATION

PAGE 4 | Analytical Serv REPORT | LAB # 83-02-A13
RECEIVED: 02/17/83 | RESULTS BY SAMPLE

SAMPLE ID Waterfall M1 FRACTION 02A TEST CODE ICP 40 NAME Complete ICPES Analysis

DATE ANALYZED 03/01/83 VERIFIED BY DLH

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	0.004*	HG	Mercury	<.03	SE	Selenium	<.084
AL	Aluminum	0.40	IN	Indium	<.05	SI	Silicon	14
AS	Arsenic	2.057	K	Potassium	17	SN	Tin	<.12
AU	Gold	NA	LI	Lithium	0.53	SR	Strontium	6.7
B	Boron	1.5	MG	Magnesium	37	TE	Tellurium	<.10
BA	Barium	<.001	MN	Manganese	0.018	TI	Titanium	<.005
BE	Beryllium	<.0005	MO	Molybdenum	0.008*	TL	Thallium	<.091
BI	Bismuth	<.05	NA	Sodium	1100	U	Uranium	NA
CA	Calcium	250	NI	Nickel	0.004*	V	Vanadium	<.003
CD	Cadmium	<.002	P	Phosphorous	<.18	W	Tungsten	<.03
CO	Cobalt	<.006	PB	Lead	<.084	Y	Yttrium	<.002
CR	Chromium	0.006	PT	Platinum	<.03	ZN	Zinc	<.003
CU	Copper	0.001*	S	Sulfur	700			NA
FE	Iron	0.18	SB	Antimony	<.032			NA

318

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.

NA = not analyzed

* = less than 5 times the detection limit.

PAGE 5 Analytical Serv REPORT LAB # 83-02-A13
RECEIVED: 02/17/83 RESULTS BY SAMPLE

SAMPLE ID sediment FRACTION 03A TEST CODE ICP 40 NAME Complete ICPES Analysis

DATE ANALYZED 03/01/83 VERIFIED BY DLH

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	0.040*	HG	Mercury	<.03	SE	Selenium	<4.3
AL	Aluminum	1200	IN	Indium	<.05	SI	Silicon	13
AS	Arsenic	<.50	K	Potassium	220	SN	Tin	<.12
AU	Gold	NA	LI	Lithium	1.1	SR	Strontium	62
B	Boron	0.83	MG	Magnesium	510	TE	Tellurium	<.10
BA	Barium	34	MN	Manganese	110	TI	Titanium	3.4
BE	Beryllium	<.005	MO	Molybdenum	0.39	TL	Thallium	<.91
BI	Bismuth	<.05	NA	Sodium	740	U	Uranium	NA
CA	Calcium	29000	NI	Nickel	2.5	V	Vanadium	4.5
CD	Cadmium	0.59	P	Phosphorous	190	W	Tungsten	<.03
CO	Cobalt	1.4	PB	Lead	84	Y	Yttrium	<.002
CR	Chromium	4.0	PT	Platinum	<.03	ZN	Zinc	51
CU	Copper	6.7	S	Sulfur	1800			NA
FE	Iron	2700	SB	Antimony	<3.2			NA

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

KRADIAN
CORPORATION

PAGE 6 Analytical Serv REPORT LAB # 83-02-A13
RECEIVED: 02/17/83 RESULTS BY SAMPLE

SAMPLE ID fish FRACTION 04A TEST CODE ICP 40 NAME Complete ICPES Analysis

DATE ANALYZED 03/01/83 VERIFIED BY DLH

CODE	METAL	RESULT	CODE	METAL	RESULT	CODE	METAL	RESULT
AG	Silver	<.02	HG	Mercury	<.03	SE	Selenium	<1.7
AL	Aluminum	7.0	IN	Indium	<.05	SI	Silicon	7.2
AS	Arsenic	<.5	K	Potassium	1600	SN	Tin	<.12
AU	Gold	NA	LI	Lithium	<.009	SR	Strontium	25
B	Boron	<.18	MG	Magnesium	270	TE	Tellurium	<.10
BA	Barium	<.012	MN	Manganese	7.7	TI	Titanium	<.10
BE	Beryllium	<.010	MO	Molybdenum	<.040	TL	Thallium	<.18
BI	Bismuth	<.05	NA	Sodium	690	U	Uranium	NA
CA	Calcium	2900	NI	Nickel	<.060	V	Vanadium	0.16*
CD	Cadmium	<.040	P	Phosphorous	4200	W	Tungsten	<.03
CO	Cobalt	<.12	PB	Lead	<1.7	Y	Yttrium	<.002
CR	Chromium	<.020	PT	Platinum	<.03	ZN	Zinc	25
CU	Copper	0.53	S	Sulfur	N/A			NA
FE	Iron	49	SB	Antimony	<.64			NA

320

NOTES AND DEFINITIONS FOR THIS REPORT.

All results reported in ug/ml unless otherwise specified.
NA = not analyzed
* = less than 5 times the detection limit.

* U.S. GOVERNMENT PRINTING OFFICE: 1983-646-069/855