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Resource Engineering and Economic Studies for Direct Application of Geothermal Energy

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**New York State Energy Research
and Development Authority
Albany, New York**

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RESOURCE ENGINEERING AND ECONOMIC STUDIES FOR
DIRECT APPLICATION OF GEOTHERMAL ENERGY

Draft Final Report

Prepared for

① NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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Holds Cont.

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Table of Contents

<u>Section</u>	<u>Page</u>
Preface	viii
1. <u>Summary and Conclusions</u>	1-1
1.1.0 General	1-1
1.2.0 Economics	1-1
1.3.0 Geothermal Resource Potential	1-3
1.4.0 User Plant Suitability and Interface	1-4
1.5.0 Environmental	1-9
1.6.0 Conclusions	1-9
2. <u>Introduction</u>	2-1
2.1.0 Background	2-1
2.2.0 Objective	2-1
2.3.0 Scope of Work	2-3
3. <u>Feasibility Analysis of Geothermal Resource and User Plant Interface</u>	3-1
3.1.0 Geothermal Resource Investigation	3-1
3.1.1 Existing Geothermal Data	3-1
3.1.2 Site Specific Geothermal Data	3-7
3.1.3 Geothermal Resource Availability	3-8
3.1.3.1 Analysis of Geothermal Formation	3-8
3.1.3.2 Temperatures and Flows Availability	3-27
3.1.3.3 Analysis of the Cambrian Brines with Respect to Corrosion and Scaling	3-31

SectionPage

3.1.4	Assessment of Geothermal Resource Potential and Expansion in N.Y. State	3-38
3.1.5	Geothermal Resource Development	3-39
3.1.5.1	Well Construction	3-39
3.1.5.2	Geofluid Production and Injection	3-43
3.2.0	User Plant Suitability	3-49
3.2.1	Existing Plant Operation	3-49
3.2.2	Available Heat Source	3-56
3.2.3	Process Suitability	3-57
3.2.3.1	Evaporating Process	3-60
3.2.3.2	Pasteurization Process	3-60
3.2.3.3	Cheese Cooking Process	3-61
3.2.3.4	Wash Water	3-62
3.2.3.5	Steam Generation	3-62
3.2.3.6	Space Heating	3-62
3.2.3.7	Incubation	3-62
3.2.3.8	Other Processes	3-63
3.2.4	Process Resource Requirements	3-63
3.2.4.1	Pasteurization Process Requirements	3-64
3.2.4.2	Cheese Cooking Process Requirements	3-65
3.2.4.3	Wash Water Process Requirements	3-67
3.2.4.4	Boiler Feedwater Preheat Process Requirements	3-68

<u>Section</u>	<u>Page</u>
3.2.4.5 Boiler Combustion Air Preheat	3-70
3.2.5 Modes of Operation	3-71
3.3.0 Systems Formulation and Selection	3-74
3.3.1 Preliminary Systems Assessment	3-74
3.3.1.1 Geofluid Subsystem	3-74
3.3.1.2 Hot Water Subsystem	3-80
3.3.1.3 Alternate Energy Utilization Methods	3-82
3.3.2 Candidate Systems Development	
3.3.2.1 Systems Analyses	3-86
3.3.2.1.1 System A1	3-86
3.3.2.1.2 System A2	3-88
3.3.2.1.3 System A3	3-90
3.3.2.1.4 System B	3-92
3.3.2.2 System Selection	3-95
3.3.3 General Arrangement of Selected System	3-95
3.3.3.1 Description of Selected System	3-95
3.3.3.2 Component Selection	3-97
3.3.3.3 Materials Considerations	3-101
3.3.3.4 Energy Utilization	3-110
3.3.3.5 Site Plan and Physical Plant	3-111
References	3-114
4. <u>Environmental Considerations</u>	4-1
4.1.0 Physical Impacts	4-1

<u>Section</u>	<u>Page</u>
4.2.0 Flora and Fauna	4-5
4.3.0 Water Resources Impacts	4-6
4.4.0 Socioeconomic Considerations	4-7
4.5.0 Regulatory Analysis	4-9
4.6.0 Impacts on Facility Costs	4-23
4.7.0 Summary	4-24
5. <u>Economic Analysis</u>	5-1
5.1.0 Capital Cost Estimate	5-1
5.2.0 Estimated Operating Costs and Savings	5-5
5.3.0 Economic/Financial Analysis	5-6

APPENDIX

A - Resource Confirmation, SUNY-Buffalo

B - Institutional Factors, Southern Tier West
Regional Planning and Development Board

LIST OF TABLES

1.1	Computed IRR	1-2
1.2	Computed Simple Payback	1-2
1.3	Plant Processes	1-5
1.4	Hot Water Requirements of Geothermal System	1-7
1.5	Geothermal Utilization System Energy Savings	1-8
3.1	Chemical Analysis of Cambrian Brines in Western New York at Lackawanna	3-26
3.2	Chemical Composition of Various Brines	3-34
3.3	Product List	3-54

	<u>Page</u>
3.4 Present Process Steam Requirements	3-59
3.5 Present Steam Requirements	3-64
3.6 Required Flows of Hot Water For Cheese Cooking Process	3-66
3.7 Steam Displacement Due to Hot Water Utilization	3-69
3.8 Periods of Operation of Suitable Processes	3-71
3.9 Modes of Operation	3-73
3.10 Hot Water Requirements of Geothermal System	3-85
3.11 Definition of Modes System B	3-95
3.12 Heat Exchanger Operating Parameters	3-98
3.13 Heat Pump Operating Parameters	3-99
3.14 Operating Parameter of Air Preheater	3-101
3.15 Estimated Geothermal Resource Properties	3-102
3.16 Materials Selection	3-109
3.17 System Energy Savings	3-110
3.18 Equipment Electric Demands	3-111
5.1 Comparison of Gas Vs Geothermal Energy Costs on a Dollar Per Million BTU Basis	5-17

FIGURES:

Figure 3.1	Contoured Values of Expected Water Temperature in Cambrian Rock Units of Western NY	3-4
Figure 3.2	Extension of the Zone of Probable Deep Faulting Based on Precambrian Basement Gravity Anomaly Patterns	3-9

	<u>Page</u>
Figure 3.3 Interpretation of Vibroseis Line A	3-10
Figure 3.4 Bouguer Gravity Map of Central and Western New York State	3-12
Figure 3.5 Landsat and Drainage Lineaments Near Friendship, N.Y.	3-14
Figure 3.6 Production Well	3-16
Figure 3.7 Stratigraphic Sections from Deep Wells near Friendship, N.Y.	3-21
Figure 3.8 Isopach Map of Rose Run Member (Contour Interval 50 Feet)	3-22
Figure 3.9 Isopach Map of Potsdam Sandstone (Contour Interval 50 Feet)	3-23
Figure 3.10 1976 A.A.P.G. Temperature Gradient Map for New York State	3-28
Figure 3.11 Holding Pond for Storage of Brine	3-42
Figure 3.12 Injection Well	3-47
Figure 3.13a Overall Block Flow Diagram	3-51
Figure 3.13b Overall Block Flow Diagram - Table	3-52
Figure 3.14 Geothermal Resource/Plant Interface System A1	3-87
Figure 3.15 Geothermal Resource Plant Interface System A2	3-89
Figure 3.16 Geothermal Resource/Plant Interface System A3	3-91
Figure 3.17 Geothermal Resource/Plant Interface System B	3-94
Figure 3.18 Area Map	3-112
Figure 3.19 Geothermal Energy For End Use Processes	3-113
Figure 5.1 Cash Flow Analysis	5-18

Figure 5.2 Percent of Total Heat Utilization
 (Btu basis)

5-20

PREFACE

The Resource, Engineering and Economic Studies for Direct Applications of Geothermal Energy was performed by the New York State Energy Research and Development Authority (NYSERDA) for the U.S. Department of Energy, Division of Geothermal Energy, San Francisco Operations Office (DOE).

This document describes the work conducted by NYSERDA under the DOE Program Research and Development Program Announcement PRDA DE-RA03-80RA 50121 and grant contract number DE-FG03-80SF 11441. This study was conducted to determine the feasibility of utilizing geothermal fluids for direct process heat applications in an industrial plant in western New York. This Study will contribute to DOE's national geothermal energy plan which is aimed at establishing near-term commercialization by the industrial sector of the direct use of geothermal resources.

Geological studies conducted by the Department of Geological Sciences of the State University of New York at Buffalo, and certain site specific aspects with regard to regional institutional factors pertaining to geothermal well drilling are appended to this volume.

The following organizations provided information and performed the engineering services for NYSERDA.

Principal A/E contractors performing the study:

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Engineers, Designers, Constructors
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New York, N.Y. 10001

User plant-participating industry:

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Friendship, N.Y. 14739

Geological Consultant:

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Regional Planning & Development Board
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Salamanca, N. Y. 14779

1. SUMMARY AND CONCLUSIONS

1.1.0 General

This study was undertaken to determine the feasibility of utilizing Geothermal Energy at a selected plant in New York State. Existing oil and gas records suggests that geothermal fluid is available in the target area and based on this potential, this study contract was awarded. Friendship Dairies Inc., Friendship, N.Y., selected as a potential user of Geothermal Energy, currently uses natural gas and electricity as its primary energy source.

1.2.0 Economics

Six geothermal system configurations were analyzed based on replacement of gas or oil-fired systems for producing process heat. Each system was evaluated in terms of Internal Rate of Return on Investment (IRR), and simple payback.

The analysis is site specific to Friendship Dairies. However, the results are applicable to other potential New York State geothermal applications. Six system configurations and two replaced fuels, representative of a range of situations found in the State, are analyzed.

Based on the potential geothermal reserves at Friendship, each of the six system configurations are shown to be economically viable, compared to continued gas or oil-firing. The Computed IRR's shown in Table 1.1, are all far in excess of projected average interest rates for long term borrowings: approximately 15 percent for guarantee backed loans or as high as 20 percent for conventional financing.

IRR is computed herein based on the total investment (equity plus debt) and cash flows before financing costs, i.e., before interest expense, but after the tax benefit of the interest deduction. Return on equity, and equity cash flows, i.e., cash flows after interest expenses, are not computed herein.

TABLE 1.1
COMPUTED IRR

Case	IRR (%)	
	geothermal replacing gas	geothermal replacing oil
B/20 yr.	28.5	29.5
MB/20 yr.	43.3	46.0
MG/20 yr.	37.5	39.8
A1/20 yr.	31.1	32.3
B/30 yr.	28.9	-
B/20 yr. D.I.W.	25.9	-

Simple payback, defined as the number of years until cumulative net cash flows equal the net construction period cash flow, is also computed for each case.

TABLE 1.2
COMPUTED SIMPLE PAYBACK

Case	Simple Payback (yr.)	
	geothermal replacing gas	geothermal replacing oil
B/20 yr.	3.4	3.3
MB/20 yr.	2.5	2.3
MG/20 yr.	2.9	2.6
A1/20 yr.	3.2	3.1
B/30 yr.	3.4	-
B.20 yr. DIW	3.7	-

D.I.W. = Deep Injection Well

The base case application for the Friendship analysis is case B/20 yr-gas which produces an IRR of 28.5 percent and payback of 3.4 years. Even better returns could be realized in the cases of oil-avoidance and where greater use of geothermal energy can be made as shown in the other cases considered.

1.3.0 Geothermal Resource Potential

Study of geophysical well logs in the vicinity of Friendship, N.Y. indicates that the Cambrian Theresa and Potsdam Formations are potential sites to obtain geothermal fluids. In the Friendship area, the recommended target zone for the geothermal fluid is 8750 feet to 10,000 feet below the surface.

Average temperature gradients in Allegany County range from 32 to 34 C/km based on evaluation of all bottom-hole temperatures obtained from oil and gas wells in the area and there is very little lateral variation in these gradients. It is expected that the geothermal gradients will change with depth due to thermal conductivity variation. Measured thermal conductivities, and estimates of thermal conductivity from rock units that are not available for measurement, yield a thermal conductivity stratigraphy for the Friendship site that forms the basis of estimates for temperatures in the subsurface. Assuming a heat flow between 60 to 62 mW/m² (milliwatts per square meter), the calculated temperature in the target zone ranges from 167°F to 185°F.

Porosity varies considerably within similar rock types but the bulk porosity of the target zones probably lies between 7 and 12 percent.

Permeability information in the target zone rocks is not available for an area within a 75 mile radius of Friendship, N.Y. and permeability data from the Bethlehem Steel well near Buffalo is the best source of information available. The permeability for the Cambrian formations at the Bethlehem Steel well is 190 gal/day ft², 113 millidarcy (mD). Comparison of estimated porosity from Friendship and the Bethlehem Steel wells show similar values. Pump tests of the Bethlehem well suggested that the permeability, however, was largely due to fractures. Since the

Bethlehem well is located in an area that is not disturbed by folding or faulting, the fractures are assumed to represent an average of non-tectonic fractures in the Cambrian. Because of a similar tectonic setting at Friendship, the permeability of the target zone is estimated to be similar to the Bethlehem Steel well.

Flow rates for geothermal fluids in the confined aquifer at Friendship are dependent on thickness of the target zone, borehole size, and permeability. The maximum borehole length in the target zone is 1,250 ft. Assuming a permeability of 190 gal/day ft² a flow rate of 286 gpm would be expected. These data are based on an unstimulated well.

Hydraulic fracturing of the target zone may increase permeability from 20 to 800 percent. Hydraulic stimulation of the target zone, thus, would increase the expected flow rate of the target zone to at least 345 gpm.

The potential stratigraphic zones for injection of geothermal fluids are the: 1) Cambrian Theresa Formation, 2) Lockport Dolomite and Onondaga Formations. These zones are thought to have sufficient volume, permeability and hydrologic characteristics to accept the disposed fluids.

1.4.0

User Plant Suitability and Interface

The production facility of Friendship Dairies, Inc. at Friendship, New York was selected to serve as the user plant.

This facility produces its own process steam primarily for the production of cottage cheese and other dairy products. The steam is produced by three (3) gas fired boilers capable of producing saturated steam at 125 psig. The steam is applied to the following in-plant processes:

Table 1.3

PLANT PROCESSES

	Steam lb/day	days/year operating
Evaporators	164,150	300
Skim Milk HTST Pasteurizer	56,536	300
Cream HTST Pasteurizer	5,674	300
Cheese Vats	35,640	300
Wash Water	11,055	350
Plant Heating	10,000	150
Skim Milk Preheat	3,893	300
Starter	2,354	300
12.4 Dressing	1,916	300
3.5 Dressing	1,000	300
Cultured Buttermilk	3,121	175
Sour Cream	2,923	250
Yogurt	2,787	150
Total	331,150	-

HTST = High Temperature, Short Time

These processes were analyzed in detail to determine the extent to which the heat from the geothermal resource may be applied to supplement or replace the energy which is currently being generated by the existing boilers.

The primary task was to develop a geothermal production well system which would provide useful geothermal fluid at the well head at a temperature compatible to that used in the Friendship plant processes and then match the available heat source to produce the appropriate quantity of hot water for the in-plant processes. This selection took into account the duration of actual on-line service of processes over a twenty-four hour period to assure optimum utilization of the energy from the available geothermal fluid. On this basis the following operating modes shown in Table 1.4 incorporating the selected processes presented themselves:

Table 1.4

Hot Water Requirements of
Geothermal System

<u>MODE</u>	<u>PROCESS REQUIREMENTS</u>			<u>TOTAL</u> (gpm)
	<u>HTST'S</u> (gpm)	<u>Cheese Vats</u> (gpm)	<u>Filling of Storage</u> (gpm)	
1	178.6	118.1	-	296.7
2	-	118.1	-	118.1
3	178.6	-	6.0	184.6
4	-	-	205.2	205.2
5	178.6	157.6	-	336.2
6	-	157.6	-	157.6
7	178.6	-	7.0	185.6
8	-	-	229.8	229.8

The above data was used to formulate appropriate in-plant systems from which to select the most advantageous overall systems configuration between the available geothermal resource and the user plant.

From these candidates the system most easily assimilated into the present operations of the user plant, and producing significant energy savings was selected for final evaluation (Figure 3.17 Section 3).

The energy and cost savings of the selected system are based on the existing user plant energy cost of \$0.00366 per cubic foot for natural gas. Table 1.5 shows the processes whose energy is substituted by geothermal energy, the equivalent quantity of steam and natural gas, and the cost savings which would result if this system were applied.

Table 1.5

Geothermal Utilization
System Energy Savings

Process	Steam <u>lb/year</u> (x 10 ⁶)	Gas <u>ft³/year</u> (x 10 ⁶)	<u>\$/year</u>
Skim HTST Unit	17.8	27.8	\$101,785
Cream HTST Unit	0.8	1.2	4,341
CIP Units (wash water)	3.3	5.2	19,120
Boiler Feedwater Preheat	-	11.2	40,440
Combustion Air Preheat	<u>-</u>	<u>1.1</u>	<u>5,094</u>
Total	21.9	46.5	\$170,780

The estimated yearly (1981) cost of natural gas at the user plant is \$467,650. The selected geothermal system could reduce this cost to \$351,870 (1981 Dollars).

In addition to the selected system B, the following systems were selected and analyzed.

<u>System</u>	<u>Descriptions</u>
A1	Alternate System 1
A2	Alternate System 2
A3	Alternate System 3
MB	Hypothetical System Based on Using Maximum Available BTU
MG	Hypothetical System Based on Using Maximum Available GPM

System A1 was determined to be economically more attractive than System B but unacceptable to the user.

Systems A2 and A3 were modifications to System A1 but were economically less attractive than System A1.

Systems MB and MG were developed in order to determine the economics of a potential Friendship Plant expansion or an alternate user with larger energy requirements than Friendship.

System MB represents the theoretical maximum utilization of the resource based upon the following:

1. 24 hours/day, 300 days/year operation
2. Utilized flow rate of 345 gpm
3. Injection temperature of 68°F

System MG represents the theoretical maximum utilization of the resource based upon the same assumptions as MB but with an injection temperature of 100°F.

1.5.0

Environmental

Geothermal resource represents a relatively clean energy source, however, environmental effects could occur as a result of development of this resource. Proper development of this facility and compliance with federal and state regulations will mitigate any adverse environmental effects, therefore, the environmental impact of this facility will be favorable.

1.6.0

Conclusions

The results of this study indicate that the utilization of New York State geothermal resources is within the realm of technical feasibility. Economic viability is site specific and would have to depend on the users energy demand and the available geothermal energy flow.

In the event a user meets these requirements, it would be of significant value to proceed with a follow-on project of drilling a confirmation and

production well to demonstrate the possibilities that may exist for geothermal resource utilization in the State of New York.

For the Friendship site, the analysis demonstrates that the use of geothermal resource is economically viable and can provide important savings and large returns on investments.

Although the study suggests a geothermal resource potential with a flow rate of 345 gpm at 174 F at a depth of about 10,000 feet, the reliability of these values could only be established by drilling an exploratory well to confirm these findings. However, it can be stated that if these values can be confirmed, the geofluid production potential could provide a geothermal heat source to supplement certain energy requirements at the user plant.

2. INTRODUCTION

2.1.0 Background

The study to determine the feasibility of utilizing geothermal fluid for direct application at the selected user plant, is principally based on strong indications of the existence of geothermal heat in rock units of the Galway and Potsdam formation in the western region of the State of New York.

This condition is suggested by the interpretation of existing oil and gas records in the study target area, Friendship, New York, in the southwestern part of the State.

On the strength of this suggested potential, the study contract was awarded to investigate the feasibility of utilizing this geothermal energy to replace or reduce the fossil fueled energy base for the production process of the selected user: Friendship Dairies, Inc. This user plant is located in Friendship, New York and currently uses natural gas and purchased electricity as its energy source for processing and general purposes.

The purpose of this investigation is to provide the Division of Geothermal Energy of the Department of Energy further data in its research effort to expand geothermal energy utilization in the northeastern part of the U.S.

2.2.0 Objective

The initial objective is to determine the geothermal resource potential in the vicinity of the user plant, including quality and quantity of the hydrothermal fluids and the anticipated useful life of this resource.

The subsequent objective is to analyze the energy requirements of Friendship Dairies, Inc. to determine whether or not the geothermal energy can effectively be applied for direct use at this plant.

Based on the investigation of geothermal energy availability and the determination of effective utilization of this energy at the user plant, it is also required to establish the technical feasibility of extracting the resource within

environmentally safe limits and sound economics and be compatible with institutional factors.

At the beginning of this study, Friendship Dairies, Inc. was using approximately 3000 gallons of fuel oil to operate their steam producing boilers. For economic reasons and a more reliable source of supply the company has since switched to operating its boilers with natural gas.

2.3.0

Scope of Work

The study was performed by Gibbs & Hill, Inc. under the direction of NYSERDA. The study sequence consisted of the following Scope of Work:

TASK I - Geothermal Resource Investigation

An investigation of existing geothermal data in the target study area, determination of site specific resource availability and the assessment of long term potential.

This task also included establishing the user plant data base in terms of energy requirements and use pattern for the purpose of interfacing the potential geothermal resource with the existing energy system.

TASK II - Geothermal Resource and User Plant

An analysis of site specific geothermal resource availability in terms of temperatures and flows, geofluid production well, injection well; user plant suitability by analysis of existing plant operations and energy requirements, formulation of interface systems between resource and user plant, and general arrangement of selected system and components.

TASK III - Environmental Analysis

An analysis of the environmental constraints and impacts which may affect or result from the potential utilization of the geothermal resource at the user plant. This analysis includes establishing the requirements due to institutional factors and regulatory agency permit limitations, and regional socioeconomic impacts.

TASK IV - Economic Analysis

An analysis of capital and operating costs for the selected overall system and an economic analysis projected over a twenty year period. This analysis establishes effects of energy savings that may result from the direct application of the geothermal energy resource under consideration and draws the final conclusion of the feasibility of the systems interfacing. The analysis considers all aspects of tax credits and legal aspects

specifically applicable to geothermal energy projects.

TASK V - Reports

A detailed report of the analyses performed for Tasks I-IV.

3. FEASIBILITY ANALYSIS OF GEOTHERMAL RESOURCE AND
USER PLANT INTERFACE

3.1.0 Geothermal Resource Investigation

3.1.1 Existing Geothermal Data

3.1.1.1 Introduction

Geothermal energy is derived from the heat of the earth. An average heat of 0.08 watts per square meter flows conductively out through the earth's surface. The total heat flowing from the interior of the earth is estimated at 41,000,000 megawatts. Presently, it is possible to extract only a small fraction of this energy economically. However, local hotspots exist within the earth's crust from which extraction of energy can be economically feasible for direct heat applications or for conversion to electricity.

Geothermal hotspots are expressed in areas associated with one or more of the seven recognized resource types: radiogenic, geopressured, deep sedimentary basin, geothermal gradient, convective hydrothermal, hot dry rock and magma. Within the study area, higher than normal heat flow values have been measured in areas of negative Bouguer anomalies. The source of this heat flow is thought to be radiogenic granites that occur in the crystalline basement rocks.

A few examples of energy obtained from geothermally heated sedimentary basin water are presently in existence. Operations analogous to the conditions of the Appalachian Basin of New York State are found in the Paris Basin. The French have been cycling 70 C (158 F) formation water from a depth of approximately 3000m (9840 ft) and this provides 75 percent of the heating load of a 2500-unit apartment complex. In western Canada Sedimentary Basin, near Regina, Saskatchewan, a feasibility study has been performed to evaluate its subsurface geothermal resource (Jessup, 1976, Vigrass, et al., 1978). In Szeged, Hungary, and in the U.S.S.R., geothermally heated sedimentary formation water is being used for space heating, greenhouses and agricultural processing (Tikhanov and Dvorov, 1970).

The common occurrences of geothermal energy are found in volcanic zones but there is potentially useful heat in saturated porous rock wherever sedimentary sequences occur at a depth of about 2 kilometers (6560 feet) and coincide with geothermal gradients that are equal to or greater than the work average of 20 C/km (14 F/kft). The heat is held in the hot interstitial water of the porous sedimentary formations. These fluids provide the primary medium for heat transfer between the subsurface and the users application. Also, extraction of heat from hot dry rock may be possible in formations that are not porous.

3.1.1.2

Previous Studies - Appalachian Basin

Based on previous work by others, the geothermal energy potential within the Appalachian Basin of New York appears promising. Three valuable geologic elements for hydrothermal energy recovery from the proposed Friendship well are:

- Adequate rock permeability for abundant flow of hot water.

- High water temperature maximizes the energy recovery possible from a given flow.

- Sufficient hydrostatic pressure to bring the resource fluids near the surface for economical recovery.

In the Southern Tier West of New York, the Cambrian age rock formations, the Theresa and the Potsdam, are the targets for geothermal energy recovery.

In 1975, as a portion of a study to review the suitability of subsurface geologic formations in the Appalachian Basin of New York for the disposal of liquid waste, Kreidler examined the porosity and permeability of a number of formations. He identified a pair of deep Cambrian age sandstone formations (Theresa and Potsdam) that possess the hydrologic characteristics favorable for waste injection. The units exhibit ample porosity and permeability for significant fluid injection. These units also possess large volumes of geothermally heated connate waters, usually of high salinity. It is these heated brines that may constitute a significant geothermal resource.

The stratigraphy of this region is well understood due to extensive oil and gas exploration and the research performed by the New York State Geological Survey (Fisher, 1962, McCann, et al., 1968, Rickard, 1973).

The geothermal gradient of the Appalachian Basin in New York has been studied by the AAPG (1976) and most recently by Hodge (1979). Gradient values obtained in the region of interest range from 28 C/km to as high as 30 C/km. Geothermal pore waters with temperatures exceeding 60 C (140 F) are potentially present across a wide section of the southern tier counties of the State (Figure 3.1, Pferd, 1981).

Figure 3.1
 Contoured Values of Expected Water Temperature in Cambrian Rock
 Units of Western NY

The possibilities of subsurface disposal in New York were also studied in 1968 by Wilson. The method, experience, problems and implications of disposal were noted by Piper (1969) and were subjects of symposiums in 1971 (Cook, 1972) and 1973 (Braunstein, 1973). A discussion of deep well disposal by Mokha (1974) covers many aspects of the Friendship project. A technical paper on hydraulics of deep well waste disposal has been studied by van Everdingen, 1974. Creation of seismic effects has been considered as a result of increased fluid pressures in incipient fault fractures (Evans, 1966; Pakiser et al., 1969; Sykes et al., 1972).

Kreidler (1975) described high permeability in basal sandstones of Cambrian age for an evaluation of structures suitable for underground disposal of liquid wastes in New York. Open fracture zones at great depths, which provide channels for extensive circulation of basal brines in the Appalachian Basin sedimentary beds, have been identified by Tillman and Barnes (1980). Solution cavities forming an extensive network within the Middle Ordovician Knox unconformity are reported and contain salt water.

Geologic information for western New York was compiled by the New York State Geological Survey. Detailed site specific subsurface geology was obtained from work by Van Tyne et al. Data was available on deep gas, oil and waste disposal wells that penetrated the target formations. Resource evaluation and analysis for this study was provided by D.S. Hodge and K.G. Hilfiker. Data on drilling, testing and completion of wells by American Industrial Disposal Systems, Inc. (AIDS, Inc., 1968) and numerous other gas and oil wells were obtained from the State Geological Survey files. Consultation for well development technology and completion was provided by B.R. Brown and J. Seymour. J.W. Pferd developed preliminary consultation for resource availability.

3.1.1.3

Geologic Data

Structure and Stratigraphy

The geological structure of the site, which is located within the southwest portion of New York State, consists of typical Appalachian stratigraphy

of alternating Cambrian through Devonian beds of shale, limestone and some sandstone dipping gently to the southeast. In the Southern Tier West of New York, the target for geothermal energy recovery is the Theresa (Galway) Formation of Cambrian age. The Theresa Formation consists of alternating beds of sandstone and sandy dolomite with a few shale layers in the lower section. The older Potsdam, below the Theresa Formation, is a blanket basal sand that lies unconformably on the eroded surface of pre-Cambrian metamorphic and intrusive rocks. This blanket sand is replaced upward by fine to coarse grained quartzose dolostones of the Theresa Formation. The Theresa and the Potsdam Formations thicken from northwest to southeast across the western part of the state and are 1250 feet thick at Friendship. The top of the Theresa Formation, according to Van Tyne and Foster (1979), is interpreted to lie approximately 8750 feet below the surface.

The upper 200 feet of the Theresa Formation includes a porous sand zone containing saltwater. The sands have been treated as a distinct member of the Theresa Formation and called the Rose Run sandstone. Saltwater shows have also been encountered in the dolomite portion of the Theresa Formation. Porosity and permeability have developed in this section from secondary exsolution and fracturing.

Thickness estimates are taken from the work of Van Tyne and Foster's 1979 study of the oil and gas yielding formations of Allegany and Cattaraugus Counties, New York. Gas exploration drill holes within 25 miles provide the closest data. The structural simplicity and lithologic homogeneity of the rock formations allows for ample confidence in these estimates. Rickard (1973) notes that the great thickness of relatively uniform lithologies and subtle lateral changes have made the Ordovician-Cambrian sequence very difficult to subdivide and correlate. The homogeneous character of the geologic materials and their physical properties justifies the qualified extension of values obtained in other portions of western New York to the proposed site.

3.1.2

Site Specific Geothermal Data

In the event the direct application of this resource can be established by this study, it is expected that a drilling program for the determination of the physical resource would be initiated.

The site specific geothermal data are based on interpretation of data obtained from past study reports, such as the temperature gradient map published by the American Association of Petroleum Geologists, in cooperation with USGS, and by interpolation of data obtained from three deep disposal wells which provide geothermal gradient information for the Precambrian formation under consideration.

The details of these data are described in Appendix A of this study.

3.1.3 Geothermal Resource Availability

3.1.3.1 Analysis of Geothermal Formations

3.1.3.1.1 Hydrologic Data

The water contained in the hydrothermal aquifer possesses geothermal energy and serves as a transfer medium of the heat stored in the rock matrix. The porosity of the rock unit determines the volume of fluids present and the permeability determines the ease with which fluids and hence hydrothermal energy can be moved through it.

The porosity present in the Theresa-Potsdam formations may be of primary, secondary and/or fracture origin. Primary porosity or the original intergranular rock space given the depth and age of the target formation is probably of limited extent. However, secondary porosity has been developed to a considerable extent. This porosity may have developed from tectonic fracturing or a variety of chemical processes. Chemical processes during diagenesis may produce shrinkage or dissolution of various rock. Tectonic events may form porosity by fracturing. Indications of the presence of both chemically and mechanically produced porosity are present in the basal Cambrian formations in the region of the site. At least one nearby driller's log notes the presence of loose grained material remaining from exsolution of Cambrian dolomite rock. Deep fracture zones may enhance the porosity and permeability characteristics of the site's hydrothermal aquifer. The proposed site is fortuitously located just south of the projection of a prominent and major tectonic structure, the Clarendon-Linden fault system. Its presently mapped location and the site are shown in Figure 3.2. Seismic wave reflection survey, vibroseis, has clearly shown that the fault trace lies over a subsurface region of multiple faulting, brecciation and disturbed bedding planes. An interpretation of Vibroseis record across the fault zone north of the proposed site is shown in Figure 3.3 (Fakundiny, et al. 1978). The faults and disrupted zones on the cross section imply regions of increased porosity and permeability.

FIGURE 3.2

EXTENSION OF THE ZONE OF PROBABLE
DEEP FAULTING BASED ON PRECAMBRIAN
BASEMENT GRAVITY ANOMALY PATTERNS

Figure 3.3

Interpretation of VIBROSEIS line A. Vertical scale is two-way travel time of seismic waves in seconds. Circular shaded zones are regions of poor data definition. Topographic surface profiles are in meters above sea level.

The extension of the Clarendon-Linden fault system into the region of the proposed site is based on the identification of a boundary in the Precambrian basement rocks that is revealed by the gravity patterns of western New York (Figure 3.4). Figure 3.2 shows the extension of deep faulting, probably associated with the basement juncture. The extension of the fault zone has been difficult to document due to the limited offset along the zone. The maximum displacement observed along the Clarendon-Linden fault to the north is 150 ft from drill hole data by Van Tyne (1975). Without the presence of deep wells in the Friendship area, the deep faulting of the zone tends to lose distinction as a discrete planar surface as it penetrates the upper stratigraphic levels.

Additional zones of deep fracturing may be located by lineament studies for the final drilling phase. Recent research has shown that LANDSAT imagery lineaments correlate with enhanced flow capacity in sandstone aquifers in Arizona (Babcock, 1979). A preliminary lineament study has been performed in the region of the proposed site as a portion of an effort to identify potential zones of deep fracturing (Pferd, 1980).

Figure 3.4 Bouguer gravity map of central and western New York State (after Revetta and Diment, 1971).

Gravity, magnetic, LANDSAT, topographic and drainage data were examined. Lineament sets that are thought to be related to the Appalachian Basin fracture trends are presented in Figure 3.5. The trends are believed to have developed during the crustal warping associated with the formation of the Basin. (Parker, 1972, Price, 1960).

Although previous workers did not identify southward extension of the Clarendon-Linden fault zone, it is conceivable that this system extends into the site area at depth below previous observations. Should fracturing by the Clarendon-Linden fault extend into the Theresa formation at Friendship, permeability and porosity would be enhanced.

The upper zone of the Theresa from 8750 to about 9000 ft depth is sandstone, the Rose Run Member, with high porosity, but good estimates of permeability of this formation are lacking. Based on data from adjoining wells, the Rose Run sandstone has been identified as a clean sand.

FIGURE 3.5 LANDSAT AND DRAINAGE LINEARMENTS NEAR FRIENDSHIP N.Y.

This upper part of the Theresa, including the Rose Run Member and dolomite layers below this layer, is recommended as the primary target zone for geothermal fluids. The basal Cambrian Potsdam Formation may also have good permeability in the zone near the basement and the primary target zone may be extended, if necessary, to this interval to obtain the desired water flow rates (Figure 3.6).

3.1.3.1.2

Porosity Data

Estimates of porosity for the Cambrian formations were based on geophysical logs available from oil and gas operators and the New York State Geological Survey. Calculations from sonic, neutron porosity and formation density logs consistently revealed higher porosities for the upper 200 feet of the Theresa than other intervals of the formation.

The estimates ranged from about 4 percent for dolomites to about 16 percent for sandstones. Porosity varies considerably within similar rock types but the bulk porosity of the target zones probably lies between 7-12 percent.

PRODUCTION WELL

NOT to SCALE

Communications with representatives from Gulf Oil (1980), Consolidated Gas (1980), Rogers (1980) and AIDS (1968), revealed permeability values determined from drill core samples which ranged from 5 to 12 percent for the sandstones and from 2 to 14 percent for the dolomites.

These porosity values suggest that the Cambrian formations do hold sufficient amounts of pore fluids to warrant their consideration as hydrothermal reservoirs.

3.1.3.1.3

Permeability Data

Permeability characteristics of the target formation are anticipated from inferential reasoning based on geologic and well data. During the early 1970's largely in connection with feasibility studies for liquid hazardous waste disposal sites, an interstate commission of technical representatives from New York, Pennsylvania, and Ohio produced a number of documents that deal with the suitability of various porous and permeable formations for waste injection (AIDS 1968). Kreidler (1975) published a survey of stratigraphic units in New York State that possess characteristics favorable for waste injection. He noted that the Theresa and Potsdam units yield flowing connate water.

During this investigation, two test wells for waste inject were evaluated for the pumping characteristics of the Cambrian formation in the Buffalo, New York area. Permeability information for the Cambrian target rocks is not available for an area within a 75-mile radius of Friendship, New York, and permeability from the Bethlehem Steel well near Buffalo is the best source of information available.

Laboratory evaluation of core samples gave values of the rock permeability ranging from less than 1.0 millidarcy (mD) to no more than 10 mD (Waller, et al., 1978). However, pump tests on the wells yielded estimates of bulk rock permeability of 113 mD. This condition suggests that much of the connected pore space is developed on a scale greater than the core samples. Waller, et al. (1978) conclude that fractures and joint planes provide significant permeability in the sandstone and less so in the dolomites. They also note that

"some zones of the dolomite have vuggy permeability."

The permeability for the Cambrian formations at the Bethlehem Steel well is 190 gals/day ft² (113 mD). Comparison of estimated porosity from Friendship and the Bethlehem Steel well shows similar values. Pump tests of the Bethlehem well suggested that the permeability, however, was large due to fractures. Since the Bethlehem well is located in an area that is not disturbed by folding or faulting, the fractures are assumed to represent an average of non-tectonic fractures in the Cambrian. For a conservative approach, because of a similar tectonic setting at Friendship, the permeability of the target zone is estimated to be similar to the Bethlehem Steel well. In the event Clarendon-Linden fault system extends at depth into the site area, the expected fracturing would be more extensive and hence the resulting permeability more favorable.

3.1.3.1.4 Flow Rate Data

The flow rates from existing wells in the area are encouraging although it is found to be highly variable. Data available from Kreidler (1975) and Waller et al. (1978) indicate that unstimulated flow rates can be as high as 30 gallons per minute and the flow rate can be increased to 146 gallons per minute after hydrofracturing.

For areas of high permeability, a smaller well length in the aquifer is needed to meet required flow rates. However, if permeability is low, considerable increases in the well length in the aquifer are required to increase flow rates. Presence of fractures in the Cambrian rocks is expected to enhance the permeability increasing the expected flow rates.

The parameters of importance for flow rates of geothermal fluids in the confined aquifer at Friendship are permeability, borehole size and length of uncased target zone. Assuming the permeability of the rock formation at target zone at the Friendship site is 190 gallons/day/ft² (113 mD) for an unstimulated well and the thickness of the target formation is 1,250 ft, the rate of flow through a 6-5/8 inch diameter well screen

penetrating full depth of target formation will be as follows:

$$Q = K \times A \quad (1)$$

Where Q = flow rate, in gallons per minute,

K = the permeability of rock formation at target zone, in gallons per day per square foot,

A = the area of exposed formation, in square feet.

Substituting K and A values into equation (1)

$$Q = \frac{190}{1440} \times 2 \times \pi \times \frac{6-5/8}{2 \times 12} \times 1250$$
$$= 286 \text{ gallons/minute}$$

Hydraulic fracturing of the target zone may increase permeability from 20 to 800 percent. Assuming that the permeability of rock formation at target zone will be increased 20 percent by hydraulic fracturing, the flow rate will be increased to approximately 345 gallons per minute.

The pressure of injected fluid required to induce hydraulic fracturing at depths of target formations at Friendship have been calculated to be less than 2700 psi of well head pressure.

3.1.3.1.5 Geothermal Reservoir Data

Examination of drilling logs from nearby deep wells show porous sand zones containing salt water which commonly lie below the Knox Unconformity at the base of the Ordovician section (Figure 3.7). The sands have been treated as a distinct member of the Theresa formation and called the Rose Run sand. Kreidler (1975) has presented an isopach map indicating configuration and thickness for the Rose Run sand (Figure 3.8). In addition, the basal Potsdam sands also commonly exhibit water shows during drilling. The isopach map of the Potsdam sands is presented in Figure 3.9. The Friendship, New York site is located in a region where both these sandstones attain nearly their maximum thicknesses. Salt water shows have also been

encountered in the dolomitic portion of the Theresa formation. Porosity and permeability are developed in this section from secondary exsolution and fracturing.

KEY

● 5101

Well No. & Loca.

5400 Depth below surface (ft.)

—? Ord.-Camb. pick

—½ Camb.-Basement pick

LIMESTONE

DOLOMITE

SANDSTONE

BASEMENT

Figure 3.7 Stratigraphic sections from deep wells near Friendship, N.Y.

FIGURE 3.8 ISOPACH MAP OF ROSE RUN MEMBER
(CONTOUR INTERVAL 50 FEET).

Ketler (1975)

FIGURE 3.9 ISOPACH MAP OF POTSDAM SANDSTONE
(CONTOUR INTERVAL 50 FEET)

3.1.3.1.6

Surface Water Level and Drawdown Data

Hydrostatic pressure data from the Cambrian rocks of New York is sparse. Waller, et al. (1978) conclude that the pressure head at the Bethlehem Steel Corp. well (NYS 6668) may be the only true static level of the brine that has been measured. They observe that the Cambrian formation fluids rose to within 380 feet of the surface. Willette (1979) has shown from highly variable drill stem test data that in general, the potentiometric surface of deep aquifers in New York State slopes gently northward and lies at about ground level in the region of Friendship, New York. These studies suggest that the hydrothermal fluids from the Cambrian units will rise to within a few hundred feet of the surface.

The hydrologic characteristics of the hydrothermal aquifers are the least understood aspect of the proposed project. We have confidence that the temperature conditions at depth are adequate and reasonably predictable, whereas the amount of fluids available and the rate at which they can be withdrawn is less well known. However, the data available encourage interest in the hydrothermal energy potential for the Friendship site.

These data are encouraging and the extension of these characteristics to the Friendship site seems justified, if qualified, by the apparent homogeneity of the formation's lithology and the relatively simple geometry of the rock layers. In fact, both greater formation thickness and the effects of possible tectonic fracturing associated with the Clarendon-Linden fault should produce an even better permeability and flow capacity at the Friendship, New York site. Added insurance against low flow may be gained by flow enhancement techniques, such as hydrofracturing within the producing formation.

No reports of geothermal fluid levels from Cambrian boreholes are closer than 25 miles to Friendship. Therefore, estimates of geothermal fluid levels are highly speculative. However, because of frequent use of the Lackawanna well in previous evaluations, it is assumed that its geothermal fluid level at a depth no greater than 500 feet from ground level is valid for Friendship.

The drawdown at Friendship is assumed to be about 9 feet based on permeability information from the Lackawanna well.

3.1.3.1.7 Chemical Data

Depending on permeability of the rock mass; water, gas or oil may occupy most of the voids below the water table at Friendship. Fresh water occurs near the surface, however, by and large, the dissolved solids concentration of ground water increases with depth. Therefore, the deeper formations usually consist of greater concentrations of brines.

By definition the U.S. Geological Survey identifies brine by a concentration above 35,000 mg/L.

The principal concerns in this section of the study are native geothermal fluids in the prospective Cambrian System target zone. Because of concentrations of brine, corrosion is an important consideration in utilizing the hydrothermal resource at the Friendship site.

Documentation of water from the Cambrian System in western New York is limited to a few oil and gas exploration logs on file with the State Survey. However, more detailed data are available from Bethlehem Steel's Well No. 101 near Lackawanna (Table 3.1).

Generally, dissolved solids concentration of water in the Cambrian units ranges from 302,000 to 322,000 parts per million (ppm). Dissolved sodium chloride is the dominating constituent. Chloride concentration ranges from 185,000 to 193,000 ppm, sodium from 80,000 to 85,000 ppm.

In regional terms, because of extensive salt deposits in northwestern New York, the dissolved-solids concentration of Cambrian brine has been found to decrease downdip southward and increase northward and with depth below land surface.

Table 3.1

Chemical Analysis of Cambrian Brines in Western
New York at Lackawanna

Well No. 101 (1968)

	Depth <u>3818 ft</u>
Silica (SiO_2)	1.9 ppm
Calcium (Ca)	30,827 ppm
Magnesium (Mg)	4,640 ppm
Sodium (Na)	84,200 ppm
Potassium (K)	3,030 ppm
Bicarbonate (HCO_2)	14.5 ppm
Sulfate (SO_4)	57 ppm
Chloride (Cl)	192,300 ppm
Dissolved-solids concentration	321,722 ppm
Hardness as CaCO_3	84,676 ppm
pH	7.0

3.1.3.2

Temperatures and Flows Availability

Heat Flow

Along the Atlantic Coastal Plain, higher than normal heat flow values have been measured in unconsolidated sediments in areas of negative Bouguer anomalies. The source of these heat flow anomalies is thought to be radiogenic granites that occur in the crystalline basement rocks.

Heat flow values may exceed 82 mW/m^2 (Milliwatts per square meter) over these radioactive granites and is considerably greater than a typical average value of 50 mW/m^2 . The eastern portion of the U.S. appears to have a lower average heat flow compared to the more tectonically active western U.S. This may in part be a result of few determinations as well as widely scattered source points in the eastern U.S.

Temperature data for the region is available from regional surveys. The AAPG (1976) (Figure 3.10) and D. Hodge, et al. (1979) with LASL have produced a set of maps that provide a broad picture of the geothermal gradients of western New York State. The geometry of the Paleozoic sedimentary rocks may be reasonably approximated by subhorizontal layers of variable thickness and composition. Assuming vertical heat flow, the subsurface temperature profile was simulated by calculation of heat conduction through a multilayered body.

D. Hodge, of the State University of New York at Buffalo, has been investigating the geothermal potential of central and western New York. Hodge's data indicate higher than normal temperature gradients at Friendship with still higher gradients to the north and east, respectively.

Figure 3.10 1976 A.A.P.G. Temperature Gradient Map ($^{\circ}\text{C}/\text{km}$) for New York State.

Mathematical projections of resistivity measurements in Allegany County yield average temperature gradients of 32 C/km for the Friendship site. These calculations are based on temperatures measured in existing wells by Hodge and his associates and on bottom-hole temperatures in wells drilled for oil and gas production. Temperature gradient maps were produced from surface and bottom-hole readings comparing data using corrections for thermal disturbance during drilling and data which provide no correction for drilling disturbance. Correlation of the two gradient maps indicates similar geothermal variation character with differences only in the gradient values. The differences in these values can be considered as the expected upper and lower range of approximations for geothermal gradients of the Friendship site.

The areas of high thermal gradients are sometimes associated with negative gravity anomalies. Temperature gradients may also be strongly affected by thermal conductivity changes in the outer layer of the crust or by water movement. Because of correlation between thermal conductivity and stratigraphic lithology in central and western New York, it was possible to develop a regional heat flow map with measured heat flow sites indicated in good correlation. Lateral variation in geothermal gradients is best described by contour map presentation.

An analysis of estimated conductivity in the Silurian of a well near Lackawanna was found to compare favorably with measured conductivity in Silurian at Oakfield, New York. Correlation of known thermal conductivities with similar site stratigraphy provides the basis for subsurface estimates at Friendship.

Temperature-Depth Modeling

In southwestern New York, temperatures within the zone of geothermal potential are thought to be dependent upon conductive heat flow and thermal conductivity. Therefore, a generalized one-dimensional, steady-state conduction model of temperatures with depth was developed to calculate temperatures within the Theresa and Potsdam Formations. The models apply direct measurements of heat flow, temperature gradients and thermal

conductivities to a multilayer body. Conductivities and geothermal gradients from two wells in the Jamestown and Buffalo areas were assumed not to vary significantly from the Friendship area. Temperature gradient maps suggest that heat flow should also be similar. Using four wells from Allegany County for heat flow and temperature modeling, calculated temperatures at the top of the Theresa were determined to range from 75°C to 77°C. Thus, the expected temperatures within the Theresa-Potsdam (8750-10,000 ft) have been calculated to be between 75°C and 85°C (167°F-185°F). The average temperature is 176°F, and allowing for 2°F loss in the well to the surface yields 174°F, which is the assumed wellhead temperature employed for the purpose of this study.

3.1.3.3

Analysis of the Cambrian Brines with Respect to Corrosion and Scaling

The problem areas of major concern with geothermal brines involve corrosion and scaling. Although these two phenomena are independent, they are not always separable and can very often be supportive of each other. However, problems associated with scaling are relatively more serious due to the predisposing properties of most geothermal fluid resources, and so have commanded the greater attention of investigators.

CORROSION

In terms of corrosion activity, the dominant variables in naturally occurring aqueous streams are high dissolved oxygen, high chloride ion concentrations, relatively high temperatures and low pH (high acidity).

Dissolved oxygen affects corrosion reactions by depolarizing cathodic areas such as by oxidizing ferrous compounds and by changing cell potentials. Within specific solubility limits, the corrosivity of dissolved oxygen interacts directly with increasing temperature and decreasing pH.⁽⁷⁾ But geothermal fluids are inherently low in oxygen ($F = 10^{-45}$ to 10^{-30} atm)⁽²⁾ and so dissolved oxygen in the resource does not appear to present an area of concern here.

Chloride ions derive their corrosive nature from the fact that they readily penetrate protective films, thus enhancing corrosion reactions. This would appear to be an area of serious concern especially when one considers that the Cambrian brines contain large volumes of chloride ions, many times the chloride concentration needed to promote the probability of corrosion of mild steel.⁽⁷⁾ However, the scale deposits expected from geothermal brines are in the nature of layers, as opposed to films, thus less penetrable by chloride ions and making the potential corrosion effect of chloride ions less severe.

The rate of corrosion, like most chemical reactions, is affected by increasing temperature and/or the shifting of various dynamic equilibria, such as the concentrations of carbonates, sulfates

and pH, which are in turn also affected by temperature rises. This is particularly so with the increase in H_2S and O_2 in the steam phase of geothermal brines with rise in temperatures, ⁽⁹⁾ thus promoting corrosion. However, the temperature of the Cambrian brines is expected to be quite moderate (about 174 F at the well head), with relatively low corrosion consequences.

SCALING

Scaling results mainly from the precipitation and deposition of insoluble or suspended components in geothermal brines. The deposits decrease flow diameters, causing decreased fluid productivity and eventual plugging of the well casings. Of more serious consequence is the considerable reduction of heat transfer^{(1 6)(8)(9)} in heat exchanger surfaces. For example, the brine from the Niland area in California deposited a hard, rock-like scale⁽²⁾ in the heat exchanger that required cleaning in about 100 hours of operation.

The four major types of scales are:

1. Silica and silicates
2. Carbonates
3. Sulfates and
4. Sulfides

Silica occurs predominantly in the amorphous form (opal, SiO_2) while the silicates are also amorphous to near-amorphous, the commonest being the silicates of iron (Fe_2SiO_4), magnesium (Mg_2SiO_4), calcium (Ca_2SiO_4), and a variety of metal complexes.

Carbonate scales are predominantly calcite ($CaCO_3$) and low-magnesium calcites, although some high magnesium contents and aragonite⁽²⁾ have been reported. The phases seem to be well crystallized, though probably cation-disordered.

Sulfate scales are predominantly calcium sulfates - anhydrite ($CaSO_4$), bassanite ($CaSO_4 \cdot 1/2 H_2O$), gypsum ($CaSO_4 \cdot 2H_2O$), and barite. Sulfates are formed from sulfate-rich geothermal fluids or when such fluids are contaminated with sulfate-rich

ground waters. They could also be formed from the addition of oxygen to the sulfide bearing geothermal fluids.

Sulfides occur in the form of many phases, usually well crystallized. Predominant are Pb, Zn, Fe, and Cu sulfides such as galena (PbS), sphalerite (ZnS), pyrrhotite (FeS), pyrite (FeS₂), chalcocite (Cu₂S), chalcopyrite (CuFeS₂), covellite (CuS), and others.

There has been relatively little research on precipitation in natural environments of direct interest to geothermal chemistry. Although little is known about scaling reactions, considerable work has been done dealing with precipitation of silica under conditions somewhat different from those expected in geothermal wells. The direct application of these studies is therefore speculative. For instance, some of the studies are based on solubility data,⁽¹⁾ which imply that metastable amorphous silica precipitates from highly concentrated solution (approximately 400 ppm), while the stable form, quartz, precipitates directly only from lower concentrations (approximately 150 ppm).

There are also data on calcite dissolution and precipitation under conditions quite different from geothermal systems. For example, a study⁽¹⁰⁾ gave the solution kinetics of calcite in HCl solutions at room temperature while another⁽¹¹⁾ gave similar studies in less acid environments but still at relatively low temperatures.

Table 3.2 compares the chemical analyses of the four Cambrian brines of Western New York and Canada with those of three other wells with considerable field operating experience: the Magmamax No. 1 brine of the Niland Imperial Valley in California; the well No. M-5 brine of the Cerro Prieto Geothermal Field in Mexico; and the Sinclair No. 4 brine of Salton Sea Geothermal Field in California.

TABLE 3.2

CHEMICAL COMPOSITION OF VARIOUS BRINES

Composition in ppm	WESTERN NEW YORK & CANADA CAMBRIAN BRINES				NILAND IMPERIAL VALLEY BRINE	CEBRO PRIETO BRINE	SINCLAIR
	Well 6073	Well 9235	Well 6668(1)	Well 6668(2)	MAGNAMY NO. 1	Well No. M-5	No. 4 BRINE
SiO ₂	-	28	1.9	2.1	202	1250	421.3
Fe	3.5	2.5	-	-	256	.3	1150.0
Mn	-	.21	-	-	690	-	950
Ca	29,550	36,000	30,827	31,713	20,000	520	22,500
Mg	3,880	5,100	4,640	3,965	80	1	59
Na	60,150	78,000	84,200	80,400	42,000	9,062	50,700
K	60,150	8,200	3,030	3,148	3,600	2,287	11,500
HCO ₃	-	307	14.5	.5	-	74	-
SO ₄	3	-	457.0	443	-	6	180
CL	156,600	200,000	192,300	185,450	121,000	26,442	130,000
TOS	250,550	335,000	321,722	302,080	188,980		217,000
pH	5.1	6.0	7.0	4.5	5.2	7.7	5.5
Temp F	175(3)	175(3)	175(3)	175(3)	370	350	392

Even though the chemical compositions vary widely, some trends do exist, in addition to observations with the three field experiences to indicate expectations with the Cambrian brines, particularly with regard to scaling. As is the case with these experiences, certain corrosion problems may occur. However, because the total dissolved solids contents are higher and the brine temperatures are lower for the Cambrian brines compared to the three field experiences, scaling may be promoted.

With the Niland Imperial Valley brine, a galena crystalline phase scale deposited on the pipe walls immediately downstream of the first flash stage control valve. The galena, a sulfide mineral, was interspersed in an iron-rich amorphous silica matrix with an underlayer, consisting of hematite/magnetite.

The Sinclair No. 4 brines at 390 F indicated that at low pH, SiO_2 , MnO_2 , and iron silicates precipitate. As pH increases, copper and iron sulfides, iron silicates and oxides also precipitate.

In the Cerro Prieto brines, scaling problems were encountered in silencers, cyclone separators, drains, water pipes and even in the turbine blades of the geothermal electric plant. The scales were mostly of calcite (CaCO_3), dolomite (MgCO_3) and silica (SiO_2) with some Fe_2O_3 , FeS and NaCl .

While the causes of scaling are complex, these experiences have served to establish a number of phenomena that are now being predominantly used for scale control, namely:

- Temperature and pressure drops decrease the scaling compound solubility
- Steam loss due to flashing concentrates brine, enhancing precipitation
- pH increase promotes favorable kinetics for scaling
- CO_2 loss increases pH
- Incomplete steam separation results in aerosol carryover of salts

- Presence of certain gases such as CO_2 , H_2S , NH_3 , HCl , H_2 and O_2 influence the pH, thus affecting scaling
- Materials of construction - corrodable materials provide nucleation-growth sites and deposition surfaces.

Based on the above observations, the following recommendations are made if the control of scaling in the Cambrian brines becomes necessary:

- AT THE PRODUCTION WELL

There should be a downhole injection of scale inhibitor such as Dequest 2060 (phosphonate, a registered trademark of Monsanto Company, or equivalent) at a concentration of less than 1.0 ul per liter. (4)

The Dequest molecules would interact by chelating the cations, particularly Ca^{++} to form a phosphonate complex that remains soluble, thus preventing precipitation.

If downhole pumping of the brine is considered the release of CO_2 and consequent CaCO_3 precipitation could be prevented. This would also shield the stream from atmospheric oxygen.

- AT THE PLANT INLET

Here also, further injection of inhibitor (Dequest 2060) should be made with acid injection for pH control to prevent possible CaCO_3 precipitation. The inhibitor concentration here should be less than 10 ul per liter.

- AT THE PLANT

Proper conversion process parameters such as temperature, pressure and pH should be selected to maintain the concentration of salts below solubility limit and thereby prevent crystallization. The inhibitor complex could form a pseudo-scale under some

circumstances, and its solubility could increase with decreasing temperature. This means that the formation of this pseudo-scale would not only be a function of the brine composition and inhibitor concentration, but also of the process temperature.

3.1.4

Assessment of Geothermal Resource Potential and Expansion in N.Y. State

The resource base in New York includes hydrothermal sources in the state's consolidated sedimentary rocks and hot dry sources in both the sedimentary rocks and the underlying crystalline rocks. The hot dry rock (HDR) sources, although technologically less well demonstrated, are larger and have higher temperatures. The possibility exists to develop a well system in the Friendship area to extract energy from hydrothermal sources.

Work by Dr. Dennis Hodge of the State University of New York at Buffalo and his colleagues has shown areas of higher-than-normal geothermal temperature gradients and heat flow near East Aurora in western New York, near Elmira, and near Geneva and Auburn in the Finger Lake district.

In the vicinity of the New York capital district, Dunn Geoscience has performed investigations for possible energy sources associated with thermal springs and carbonated water.

The high gradients at East Aurora, Elmira and Geneva are associated with gravity low anomalies which may be caused by granitic intrusions in the basement rocks and the high heat flow near Auburn is associated with an elongated magnetic anomaly which may reflect a deep basement fault zone.

3.1.5 Geothermal Resource Development

3.1.5.1 Well Construction

Drilling Depth

In the event the overall results of this feasibility study warrant proceeding with a confirmation determination of the potential resource, a hole may be drilled through the sedimentary rock at a point near Friendship, New York and to a depth of approximately 9,500-10,000 feet through the Basal Cambrian formations (Theresa and Potsdam).

Anticipated Casing Needs

The well could consist of three strings of casing to approximate depths of about 100 ft., 1,000 ft., and 8,750 ft., respectively.

Surface Casing

Surface casing to about 100 foot depth and 20" nominal diameter, set into bedrock and cemented as may be necessary.

Fresh Water Casing

A fresh water casing string to about 1,000 ft. depth and 13 1/8" nominal diameter, cemented as necessary, would be required.

Salt Water Casing

Casing of 9-5/8" nominal diameter may be hung from the 13-3/8" casing from about 1000-foot depth to about 8750-foot depth and cemented as necessary to prevent possible salt water or gas intrusion.

Well Screen

A 6 5/8" nominal diameter well screen should be hung from the 9 5/8" casing through the Rose Run member as required. The screen should be No. 316 stainless steel of continuous wrapped construction with 0.10 inch slot size.

Hole Diameter

Specified bit and casing sizes are nominal. Modifications of these guidelines should be considered to make use of advantages in cost and availability as long as the series remains self consistent and meets the needs of the project.

In the cased portions, the hole should be drilled with the appropriate diameter to receive the casing of the specified size. Below the 9 5/8" casing, the hole should be drilled with a 8 1/2" bit to the final depth. (See Figure 3.6.)

Deviation

Deviations from vertical should not exceed 5° from the surface to the top of the Theresa formation and should not exceed 3° per 100 feet below the top of the Theresa formation.

Drilling Method

The drilling may be done with conventional techniques above the Knox Unconformity. Below this depth, drilling should be done with reverse water flow, biodegradable organic mud, or air.

Coring

Core samples should be obtained from the production well at each of the following four horizons:

- 1) Onondaga
- 2) Lockport
- 3) Theresa, Rose Run member
- 4) Potsdam, basal sands

Drill Cuttings

Drill cuttings should be collected at ten foot intervals, bagged and appropriately labeled for the entire length of the hole.

Water Shows

The interval and type should be noted for all water shows.

Gas Flows

Any significant gas flows should be noted and sealed out when necessary.

Permits

All applicable permits should be obtained as specified in Section 4, 5.

Water Impoundment

Any salt water that issues from the hole during drilling should be impounded in a temporary clay lined pond with a holding capacity of 450,000 cubic feet. (See Figure 3.11.)

Preliminary Geophysical Logging

Preliminary geophysical logging should be performed immediately after drilling and prior to casing installation. Logging techniques should include temperature, resistivity and sonic logs.

HOLDING POND FOR STORAGE OF BRINE

PLAN

SECTION A-A

SECTION B-B

STORAGE VOLUME: 450,000 FT³ (3,366,000 GAL)
AREA: 50,000 SQ. FT.
DEPTH: 15 FT.

SUGGESTED METHOD OF CONSTRUCTION
YD³ OF COMPACTED FILL REQ'D.: 3,560
LINER TYPE: COMPACTED CLAY

FIG. 3.11

Confirmation of Resource Report

Upon completion of drilling, logs, water shows, test results and all other data pertinent to analysis of the geothermal resource potential of the site should be presented in a preliminary report to reach a decision on whether or not to proceed with well development. This preliminary confirmation report should be prepared immediately following the drilling program.

Decision Point

A decision should be made whether to proceed with subsequent tasks or to abandon the hole and impoundment pond.

Additional Logging

If a decision is made to continue the project, additional geophysical logging should be performed to include neutron and gamma ray, formation density, caliper, spontaneous potential and spherically focused induction.

3.1.5.2 Geofluid Production and Injection

3.1.5.2.1 Pump Tests

Pump tests of deep aquifer targets should be performed. Each zone of interest should be isolated with packers for testing. A 10" diameter submersible pump or a vertical line-shaft turbine pump should then be installed with its intake below the expected dynamic water level. This level should be estimated based on specific capacity values as derived from preliminary tests and analysis of the samples. Water from the pump tests should be stored in the pond.

Step Drawdown Test

A series of 1/2-hour pump steps should be conducted at flow rates of 25, 50, 100, 200, and 400, and 800 GPM or as warranted, while monitoring pressure and temperature at the bottom of the zone, and respective drawdowns of the potentiometric level.

Long Term Constant Discharge Test

A constant discharge test will be performed at the maximum desired flow rate of at least 350 GPM, as warranted by the results of the step flow tests. Duration of the test should be approximately 7 days pumping phase, or as warranted by the hydrologic behavior of the producing formation. Following shut off of the pump, the water level recovery will be monitored for a suitable period of time.

The geofluid pumped from the well should be discharged for storage into the holding pond.

In addition to monitoring of flow rates and potentiometric levels, samples of the produced fluid will be collected periodically to be analyzed by a certified chemical laboratory for its chemical composition.

Stimulation

Enhancement of the flow from one or more of the deep aquifers could be attempted as may be required. The choice of stimulation techniques if required should be based on data obtained during the drilling and testing phase, and will take into account eventual findings concerning the favorable relation of the drilling site to an extension of the Clarendon-Linden fault zone.

Evaluation of Stimulation

The effectiveness of the best suited flow enhancement techniques should be examined. Pump tests of the stimulated aquifers should be repeated to confirm their modified hydrologic characteristics.

3.1.5.2.2 Injection of Geofluid

Drilling Depth (3600 - 10,000) Feet

In the event the overall results from pump tests warrant proceeding with completion of the project, a hole for injection of geofluids may be drilled through the sedimentary rock to a depth of approximately 3,600 feet through Onondaga limestone, 4800 feet through the Lockport

formation, or 10,000 feet through the Potsdam formation. (See Figure 3.12.)

The choice of the formation to be used for injection will be substantially based on permeability data obtained from the production well drilling, coring, testing, and analysis program. A well for injection into the Onondaga or Lockport will be located approximately 200 feet from the production well. For injection into Cambrian formations it will be about 3,000 feet from the production well.

Anticipated Casing Needs

The well could be constructed with two strings of casing to approximate depths of 1,000 feet and 3,600 feet, respectively.

Fresh Water Casing

The fresh-water casing should have a 13 3/8" nominal diameter and will be set to a depth of approximately 1,000 feet and cemented as necessary.

Inner Casing

An inner 9 5/8" nominal diameter casing string, should be installed to a depth just seated in or above the Onondaga injection formation at about 3,600 feet, and cemented as necessary to surface.

Injection Tubing

Fiberglass injection tubing to prevent possible salt water intrusion into fresh water aquifer may be extended from surface to about 3,600 feet depth through bottom hole packers, preventing the noncorrosive fluids from circulating in the annulus.

Hole Diameter

Specified bit and casing sizes are nominal. Modifications of these specifications should be considered to make use of advantages in cost and availability as long as the series remains self consistent and meets the needs of the project.

In the cased portions, the hole should be drilled with the appropriate diameter to receive the casing

of the specified size. Below the casing, the hole should be drilled with a 8" bit to the final depth. (See Figure 3.12.)

INJECTION WELL

NOT to SCALE

Deviation

Deviation from vertical should not exceed 5° from the surface to the top of the Onondaga formation and should not exceed 3° per 100 feet below the top of the Onondaga formation.

Drilling Method

The drilling may be done with conventional techniques above the Onondaga formation. Below this depth, drilling should be done with reverse circulation, biodegradable organic mud or air.

Drill Cuttings

Drill cuttings should be collected at ten foot intervals, bagged and appropriately labeled for the entire length of the hole.

Step Injection Pump Tests

A series of approximately 1/2-hour injection steps would be conducted at flow rates of 25, 50, 100, 300 and 400 GPM, or higher as required.

Prior to testing, well should be cleaned out by developing and pumping.

Twenty-Four Hour Injection Test

The water should be allowed to recover its equilibrium level after the initial series and then a 24-hour injection test would be conducted at a flow rate of 350 GPM or as required.

3.1.5.2.3

Final Confirmation

All existing geological and geophysical data pertinent to the drill site should be collected. This data should include results of examination and description of the cuttings from the test hole, evaluation, interpretation and correlation of all existing logs of the subject hole and of nearby holes; seismic, magnetic, gravity and any other existing geophysical and geological data, and analysis of the hydrologic tests. The information should be compiled, analyzed and interpreted and the results presented in a final report.

3.2.0 User Plant Suitability

3.2.1 Existing Plant Operation

PRODUCT DESCRIPTION

Friendship Dairies produces a wide variety of milk products. The following list includes those products that have been or are presently produced (the production of certain items is a function of market demand and/or quantities of available raw milk):

- Butter
- Buttermilk
- Buttermilk Powder
- Cottage Cheese
- Cream
- Farmer Cheese
- Skim Milk Powder
- Sour Cream
- Whey Condensate
- Whey Powder
- Yogurt

Each of the above products is formed from skim milk, cream or a mixture of both.

Butter is produced entirely from cream, and the by-product of the butter process is buttermilk. Buttermilk is either sold as such or dried into a powdered form (buttermilk is also formed in tanks by mixing certain proportions of skim milk and cream; this product is referred to as cultured buttermilk).

Cottage cheese and farmer cheese are produced from skim milk. Cottage cheese is manufactured by cooking a mixture of skim (from this point on skim milk will be referred to as "skim") and starter (cultured skim) in a vat until the curds have achieved the desired firmness. Whey is then drained from the bottom of the vat and the curds are washed several times to remove entrained whey. The clean curds are blended with dressing (a cooked mixture of skim and cream) and packaged. The process of making farmer cheese is very similar to that of cottage cheese production, but the skim-starter mixture is incubated at ambient temperature, not heated.

The whey wash (a mixture of water and whey, approximately 5 percent solids) that has been produced as a result of cheese manufacturing is passed through an evaporator. Enough water is removed so that whey condensate (about 50 percent solids) is produced. Most of this condensate is sold as is and the remainder is transformed into powder.

Sour cream and yogurt are mixtures of skim and cream that have been heated to a specific temperature, cooled, then incubated. More detailed descriptions of these processes and the process of all the other products are outlined on Figure 3.13a.

The source of the skim and cream required for the many products produced by the dairy is raw milk supplied by farmers in the area. This raw milk is stored in refrigerated silos before it is separated into skim and cream. Separation is performed by a mechanical centrifuge, which delivers continuous flows of skim and cream to respective pasteurizers.

PASTEURIZATION PROCESS

Pasteurization is accomplished by heating the skim and cream to their legal minimum pasteurization temperatures. These temperatures are selected so that the pasteurized product achieves a specified maximum bacteria count.

NOTE

1. EITHER CHILLED WATER OR WELL WATER CAN BE USED TO COOL CREAM.
2. OPERATION BEGINS AT 10 A.M. 4 DAYS/NEEK. AVERAGE RUNNING TIME: 16.10 MRS. PEAK RUNNING TIME: 10.54 MRS.
3. 1000 GALL./DAY (AVERAGE & PEAK) @ 150 F
4. 1500 GALL./DAY (AVERAGE & PEAK) @ 180 F
5. A) VAT FILLED W/ SKIN MILK @ 80 F AND STARTER MIX
B) VAT FULL FILLED W/ WATER @ 80 F
C) STEAM ROSES SO THAT VAT WILL BE 15 F GREATER THAN MILK TEMP.
D) CUBES & WHEY REACH 150 F AFTER APPROXIMATELY 2 HOURS.
E) TEMPERATURE HELD @ 150 F FOR 5 MINUTES.
F) WHEY IS DRAINED THEN CUBES ARE WASHED THREE TIMES; FIRST WITH WELL WATER (PUMPED TO STORAGE) THEN TWICE WITH CHILLED WATER (TO REMOVE TREATMENT).
HEATING: 5 P.M. - 5 A.M. 4 DAYS/NEEK; AVG. 1 1/2 VATS HEATING AT ONCE. PEAK 1 VATS
6. A) MIXTURE OF SKIN AND CREAM HEATED TO 180 F (1 HR - 1 1/2 HR) IN TANK.
B) HELD AT 180 F FOR 1/2 HOUR.
C) COOLED TO 70 F IN TANK WITH CHILLED WATER.
D) INCUBATED FOR 10 HOURS.
E) COOLED TO 40 F IN TANK WITH CHILLED WATER.
HEATING: 10 P.M. 80 F 5 OR 4 DAYS/NEEK SO: 5 DAYS/NEEK.

7. A) MIXTURE OF SKIN AND CREAM HEATED TO 180 F (1 HR - 1-1/2 HR)
IN TANK.
B) HELD AT 180 F FOR 1/2 HOUR.
C) COOLED TO 40 F THROUGH PLATE HEAT EXCHANGER (CHILLED WATER).
D) STORED IN TANK AT 40 F.
E) HEATED TO 180 F BEFORE PUMPED TO COP ROOM.
HEATING AT 5 A.M. 3 DAYS/WEEK.
8. A) MIXTURE OF SKIN AND CREAM HEATED TO 180 F (1 HR - 1-1/2 HR)
IN TANK.
B) HELD AT 180 F FOR 1/2 HOUR.
C) COOLED TO 40 F IN TANK WITH CHILLED WATER.
HEATING: 10 P.M. 6 DAYS/WEEK.
9. (SAME PROCESS AS DESCRIBED IN NOTE 8)
5 OUT OF 4 BATCHES OF STARTER ARE HALF WATER AND HALF POWDERED
MIX. ONE OUT OF FOUR BATCHES ARE HALF SKIN AND THE REMAINDER MIX
AND WATER.
HEATING: 10 P.M. 14 1 P.M. AT PEAK, 6 DAYS/WEEK.
42% OF PRODUCT IN CHEESE VATS IS STARTER.

10. SKIN IS EVAPORATED AT 5 P.M. FOR 5 HOURS, 5 DAYS/WEEK.
MONEY IS EVAPORATED AT 7 A.M. FOR 13.4 HOURS (15 HOURS PERMO
8 DAYS/WEEK. BUTTERMILK IS EVAPORATED OCCASIONALLY (ONCE A WEEK)
(SAFE PROCESS AS SKIN).
11. ST-18 IS STEAM FLOW FOR SKIN EVAPORATION.
ST-19 IS STEAM FLOW FOR MONEY EVAPORATION.
12. OPERATES 24 HOURS/DAY 8 DAYS/WEEK.
13. POWER IS SUSPENDED IN OIL. MACH 35 PSK OF FINAL PRODUCT.
14. OPERATES 21 HOURS/DAY, ANY TIME OF DAY, 8 DAYS/WEEK.
15. ALL FIGURES REPRESENT QUANTITIES FOR AN AVERAGE DAY.
FIGURES IN PARENTHESIS REPRESENT QUANTITIES FOR A PEAK DAY.
WHERE NO PEAK FIGURE IS GIVEN, THE AVERAGE VALUE IS ALSO THE
PEAK VALUE (THIS ALSO APPLIES TO THE NOTES).

16. (37) REPRESENTS AN AVERAGE FOR A PEAK DAY.
(70) REPRESENTS AN ABSOLUTE PEAK (ALL PROCESSES OPERATING AT ONCE).
17. (18,500) REPRESENTS AN AVERAGE FOR A PEAK DAY.
18. NATURAL GAS HEAT USED IN EVAPORATION PROCESS.
19. CHILLED WATER ASSUMED TO BE 50 F AT INLETS TO ALL PROCESSES.
20. STEAM ASSUMED TO BE @ 127 PSIA, 345 F.
21. WELL WATER ASSUMED TO BE 55 F AT INLETS TO ALL PROCESSES.
22. (3) 10,000LBS, (5) 12,000LBS, (3) 15,000LBS, (11) 17,000LBS,
(2) 17,500LBS, (2) 25,000LBS, (4) 26,000LBS.

NO. NOTE IS MATERIAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BOM MILK LB/DAY	885.00 (1,131,273)	885.00 (1,131,273)																						
BOM MILK LB/HOUR	61.000	61.000																						
SKIM MILK LB/DAY	780.000 (1,020,000)	780.000 (1,020,000)							520.000 (780,000)	26,615	18,572	14,729	13,037 (16,080)	8,868 (11,080)		38,417 CONDENSATE	19,505 POWDER	220.000						
SKIM MILK LB/HOUR	55.000	55.000														1,877 CONDENSATE	829 POWDER	44.000						
CREAM LB/DAY		85.00 (111,273)	85.00 (111,273)							1855	10,715	518	5,283 (7,280)	731 (1011)										
CREAM LB/HOUR		6.000	6.000																					
WATER LB/DAY	11,860,588 (11,788,882)		120,632 (157,888)		36,578 (38,976)	18,545 (18,126)				786,718 (187,585)							18,912 GAL/HR							
WATER GAL/DAY	186.791 (218,887)		14,884 (18,821)	3,888 (4,885)	4,887 (6,788)	2,088 (2,820)	3,880	38,117 (83,818)																
WATER GAL/MIN	181		18	8 (12)	8 (13)	5 1/2 (8)	5 1/2 (8)	NOTE 18 30 (37) (78)																
STEAM LB/DAY	58,538 (73,958)		5,517 (7,214)	2,888 (3,388)	3,888 (4,824)	1,831 (2,034)	2,988	317,984 (386,218)	35,780 (48,150)	4,818	4,714	5,958	2,887 (3,580)	2,882 (3,382)	2,885 (3,478)	5,187		48,988	111,288 (124,156)		4,519			
STEAM LB/HOUR	3,887		388	387 (388)	480 (788)	388 (388)	288 (388)	NOTE 17 18,880 (18,580)	3,570 (4,780)	2,877	3,313	3,888	1,730	1,730	1,333	245		9,288	9,288		180			
CORN LB/DAY									78,880 (103,580)															
MET LB/DAY									488,880 (388,580)												32,558 (4,128)	18,880 (23,275) POWDER		38,200 (48,810)
MET WASH LB/DAY									581,518 (880,080)										581,518 (880,080)					
MET WASH LB/HOUR																			44,000					
BA CULTURED LB/DAY										28,737														
CHEESE LB/DAY																						113,180 (152,250)		
SOUR CREAM LB/DAY											28,537													
TRELLIT LB/DAY												15,288												
DRESS-3.5 LB/DAY														18,782 (25,178)								37,780 (50,750)		
DRESS-12.6 LB/DAY													18,888 (25,574)											
STARTER LB/DAY															28,880 (38,880)									
OIL GAL/DAY								2,988 (2,780)																
GAS FT ³ /DAY																	1,838							
BUTTERMILK LB/DAY																4,130 (8,380)	2,835 (3,888)	28,823 WGT. 518						

LEGEND

BMC	BUTTERFLY LK	SCAL TUNED
BM	BUTTERFLY LK	
BH	BUTTER	
CD	CHUD	
CR	CHEERIN	
CH	CHEESE	
CM	CHILLED WATER WOTE 19	
DS	DRESSING	
HN	HOT WATER	
YS	PEWEE NO SOLIDS	

BN	BAK MILK
SC	SOUR CREAM
SN	SKIM MILK
SNP	SKIM MILK POWDER
SR	STARTER
ST	STEAM (NOTE 20)
STC	STEAM CONDENSATE
VP	VAPOR
WC	WHEY CONDENSATE
WM	WHEY

UP WHEY POWDER
 HS WHEY WASH
 HW WELL WATER (NOTE 2))
 VS VIBRANT
 ↓
 TO CLEAR WATER DRAIN
 ↓
 TO SEWAGE TREATMENT
 S T

FOR BIRMINGHAM SEE 716.3.198

FRIENDSHIP DAIRIES, INC. PLANT
FRIENDSHIP, NEW YORK

OVERALL BLOCK
FLOW DIAGRAM
TABLE

Oliver & Hill Inc.

3CH-2	NONE
-------	------

FIGURE 3.13

JOB NO. : 1-3035-20

3-51

Friendship Dairies operates high temperature, short time (HTST) pasteurizers. This method of pasteurization is a continuous one in which the skim and cream are heated to 163.5 F and 190 F, respectively, and held at those temperatures for 15 seconds.

Heating is done with stainless steel plate heat exchangers. These units are designed with plates arranged so that the product flows between two plates, and the heating medium (in this case hot water) flows in the opposite direction between alternate pairs of plates. These plates are formed with corrugations to produce turbulence in the flow to increase the rate of heat transfer. Ports in the plates are arranged to direct flow where desired, and gaskets are arranged so that any leakage will be outside the press. The capacity of the heat exchanger can be increased by increasing the area of heat transfer (i.e., increasing the number of plates).

The current level of pasteurization that the Friendship plant is operating at is 55,000 lb/hr of skim and 6,000 lb/hr of cream. The hot water required for each pasteurizer is heated with steam in an instantaneous water heater. This is a closed system in which the cooled water is returned to the water heater to be reheated.

After the skim has been heated to 163.5 F and held at that temperature for 15 seconds it is passed through another stainless steel plate heat exchanger (these plates along with the plates used for skim pasteurization and further cooling, if necessary, are all incorporated into one frame) where it is cooled by the flow of raw milk (@ 40 F) on its way to the separator. (See Figure 3.13 for the pasteurization/separation process and all processes to be described.) The raw milk, by cooling the skim, has been heated to 110 F so that separation and subsequent pasteurization are more efficient.

The cream HTST unit also employs regeneration. Pasteurized cream (@ 190 F) is cooled by the flow of cream from the separator (@ 110 F) to 170 F. The cream from the separator has been heated to 130 F by the pasteurized cream, therefore less hot water is required to heat the cream to pasteurization temperature. In turn, due to

regeneration, less chilled water is required to cool the pasteurized cream to storage temperature.

PRODUCT SKIM AND CREAM REQUIREMENTS

After the skim leaves the HTST unit it is pumped directly to the cheese vats, evaporator and dressing tanks. Three days per week, skim is also pumped to the yogurt, buttermilk, and sour cream tanks (this frequency fluctuates as demand for the various products fluctuate). Most of the cream is pumped to refrigerated storage tanks from where it is distributed to the churning equipment and tank trucks. The remaining cream is pumped to the dressing, buttermilk, sour cream, and yogurt tanks.

Cream is mixed with skim in varying degrees such that the desired percentage of milk fat for each product is achieved. The following is a list of each product and the percentage of cream of each:

Table 3.3 - Product List

	<u>Skim</u> <u>lb/day</u>	<u>Cream</u> <u>lb/day</u>	<u>% Cream</u>
Buttermilk	28,615	1,055	3.6
Sour Cream	18,572	10,753	36.7
Yogurt	14,723	516	3.4
12.4 Dressing	13,837	5,263	27.5
3.5 Dressing*	8,866	731	7.8

*blended with curds to produce "low-fat"
cottage cheese

The products listed above are manufactured in relatively small quantities when compared to other products produced. Of the 865,000 lb of raw milk entering the plant on an average day, the majority is processed into cottage cheese and skim powder. Raw milk is separated into 780,000 lb of skim and 85,000 lb of cream per day.

The largest percentage of skim is processed in cheese vats, 520,000 lb/day (66.7 percent). The product that consumes the next largest amount of

skim is skim powder, 220,000 lb/day (28.2 percent). Of the remaining skim (40,000 lb/day), 22,500 lb/day is required for the manufacture of dressings to blend with the curds to form cottage cheese. The remainder, 17,500 lb/day, is processed into either yogurt, sour cream or buttermilk (usually one product per day).

STEAM SYSTEM

Friendship operates three gas-fired boilers to produce steam for the plant. These boilers have 400-hp, 500-hp and 600-hp capacities, respectively. Steam is produced by, usually, two of the three boilers, at 125 psig at an efficiency of 82 percent. It is assumed that the steam exhibits a 10 percent to 15 percent loss en route to the various processes.

Feedwater to the boilers is drawn from three water wells serving the plant. This water is at a constant year-round temperature of approximately 55 F. The only condensate returned to the boiler is from the plant heating system; all other condensate is dumped to waste.

Steam is required directly and indirectly for the manufacturing of all Friendship products with the exception of butter (although cream must be pasteurized before it is churned into butter). Steam is also used to heat the plant through unit heaters. However, Friendship's heating requirement is a small percentage of their total steam use. This is due to the many processes that radiate heat (the cooking of cheese and other products) and large refrigerated storage areas that do not require heating. The plant's steam requirement to heat wash water is relatively large because of the high temperatures and large volumes required. Most equipment in the plant must be washed daily with water near the pasteurization temperature of the product it was in contact with.

The Friendship plant operates 24 hours per day, year-round. Six days of the week are devoted to manufacturing products, the remaining day per week is for cleaning, minor production, maintenance, etc. For approximately two months of the year, in the spring, the amount of raw milk processed by Friendship is significantly larger than any other time of the year. This period is referred to as

the "flush" and the increase is due to increased cow lactation levels.

For the purpose of this study, the yearly operating period of the dairy was assumed to be 300 days of full operation per year, 252 at average levels and 48 at peak operation (during the "flush").

3.2.2

Available Heat Source

In order to determine the suitability of the plant to the available resource, it is necessary to define the resource parameters. The resource is assumed to be a geothermal fluid available at a continuous flow rate of 345 gpm and a constant temperature of 174 F. The chemical composition of the geothermal fluid, hereinafter called "geofluid", is expected to be such that close (i.e., single barrier) contact with milk products will not be legally allowed. The expected characteristics and concentration of total dissolved solids (TDS) in the geofluid (assumed to be approximately 30 percent) would dictate a minimum exposure of the resource to any and all pieces of equipment. Any equipment that comes in contact with the geofluid, by necessity, will have to be especially erosion- and corrosion-resistant, reflecting higher capital cost of equipment and more frequent and costly maintenance requirements.

Considering these points, the practicality of having geofluid pumped through the plant to each process is doubtful. The most sensible approach would be to immediately, as the geofluid leaves the well, transfer its heat to a secondary fluid. This secondary fluid, considering the application and volumes required, is assumed to be water.

To determine the approximate temperature of the water after it is heated, the performance of heat transfer equipment must be considered. Heat transfer equipment has evolved to a level where units with two-degree Fahrenheit approach differences* are commercially available. Although available, these units are extremely expensive. A unit with an eight to ten degree approach can

* The approach of a heat exchanger is the difference between the inlet temperature of the "hot" medium and the outlet temperature of the "cold" medium.

transfer far more heat for each dollar of its capital cost when compared with a two degree approach unit.

Assuming that water is the "working" fluid and that a heat exchanger with an eight degree approach is employed, the available resource temperature becomes 166 F. The assumptions made concerning the heat exchanger approach are based on equal flows of water and geofluid.

3.2.3

Process Suitability

The most suitable processes are those that are most easily interfaced with the available hot water (@ 166 F). Just as important as the ease of interface is the expected displacement of natural gas. The processes that could save the most natural gas by taking advantage of the hot water available are those that currently consume the most steam.

The Friendship plant produces, on an average day, approximately 331,150 lbs of steam (under peak conditions 388,570 lb/day are produced). Of the 331,150 lb/day, nearly half is consumed by the evaporation process. The Weigand evaporator requires approximately 143,400 lb/day and the Carver-Greenfield evaporator, 20,700 lb/day. The total steam requirement for evaporation, 164,100 lb/day, represents 49.6 percent of the total daily requirement for the entire plant.

The process that consumes the next largest amount of steam is pasteurization. The skim HTST unit requires 56,536 lb/day (17.1 percent of daily total) and the cream HTST unit requires 5,674 lb/day (1.7 percent of daily total). Steam in this process heats water that subsequently heats either the skim or cream to pasteurization temperature.

The three remaining processes that require more than 2 percent of the daily steam production are the cheese vats, plant heating, and wash water. The cheese vats use 35,640 lb/day which represents 10.8 percent of the daily total. Wash water consumes 11,055 lb/day or 3.3 percent of the daily total. Steam required to heat the plant is approximately 10,000-20,000 lb/day. All other processes in the plant require significantly

smaller amounts of steam and do not operate every day that the plant is in operation. Table 3.4 lists steam consumption values for each process.

Table 3.4

Present Process Steam Requirements

	<u>Steam*</u> <u>lb/day</u>	<u>days/year</u> <u>operating</u>
Evaporators	164,150	300
Skim HTST Pasteurization	56,536	300
Cream HTST Pasteurization	5,674	300
Cheese Vats	35,640	300
Wash Water	11,055**	350
Plant Heating	10,000	150
Skim Preheat	3,893	300
Starter	2,354	300
12.4 Dressing	1,916	300
3.5 Dressing	1,000	300
Cultured Buttermilk	3,121	175
Sour Cream	2,923	250
Yogurt	2,787	150
Total***	331,150	-

* lb/day for average operation, values for peak operation are slightly higher.

** value represents total for week (7 days of operation) averaged over six days.

*** total is actual value from boiler records. This value is approximately 10 percent greater than itemized total due to losses in steam system.

3.2.3.1

Evaporating Process

Even if a process is a large steam consumer it might be able to utilize the low temperature hot water available to interface with the geothermal system. The evaporators, although consuming half of the plant's steam, require a high enthalpy heat transfer medium to operate with the present equipment.

Discussions with evaporator manufacturers indicated that a "hot water" evaporator would require tremendous heat transfer area and extremely large pumps and piping. These factors along with "first time" development costs would produce an evaporator with twice the cost of a conventional unit. Conventional, triple effect evaporators, similar to the unit employed by Friendship, have a total, installed, cost of approximately \$600,000.

Secondary fluids (i.e., other condensable media) with higher enthalpies than hot water could be used in a system that recirculates condensate. However, systems for evaporating milk using alternative condensable media for heat transfer are currently not commercially available, at least not on an off-the-shelf basis. If the necessary equipment should become commercially available and this were added to the applications for the geothermal heat, the plant could make full use of the geothermal resource with its present capacity.

The evaporation of milk with hot water, either directly or by means of a secondary medium, is technically possible. However, the cost of an evaporator designed to perform such a task is presently too high, with respect to the system under consideration, to be economically justified.

3.2.3.2

Pasteurization Process

The pasteurization process is perfectly suited to the available resource. Presently, 175 F and 198 F hot water is required, respectively, for the skim HTST unit and cream HTST unit. The temperature required for the pasteurization of cream is considerably higher than the available 166 F but the outlet stream of the HTST unit is at 158 F, which could be preheated before being reheated to 198 F. The temperatures of the skim pasteurization process, and the potential for savings, are such

that boosting the available 166 F water to the required 175 F might be justified. The flow rates required for both the cream and skim pasteurizers are also well below the available flow rate (10 gpm for the cream HTST unit and 161 gpm for the skim HTST unit).

3.2.3.3 Cheese Cooking Process

The third largest steam consumer, the cheese cooking process, is also ideally suited to the available resource. The present cheese cooking process is as follows:

- 1) A vat* is filled with skim (@ 86 F) and starter
- 2) The vat wall is filled with water and steam so that the vat wall temp is 86 F
- 3) Steam is periodically added to the water in the wall of the vat** so that the water temperature is six degrees higher than the skim being cooked.
- 4) The curds and whey eventually reach 130 F after approximately 2 hours of heating and are held at 130 F for 5 minutes.
- 5) Whey is drained from the bottom of the vat and the curds are washed with well water and chilled water to remove entrained whey and to stop the curds from cooking.

The maximum water temperature required during this process is 136 F. The flow of water required would be a function of the temperature of the heating medium. If 166 F water replaces steam, 118 gpm would be required to provide heat to the six cheese vats that are usually cooking at any one time. This flow is much less than the 345 gpm available.

* Vats vary in capacity from 10,000 lbs to 28,000 lbs. (See Figure 3.13 for exact breakdown.)

** In the larger vats, culinary steam, injected directly into the skim, supplements jacket heating.

3.2.3.4

Wash Water

Nearly all of the wash water used at the plant is either 150 F or 160 F. Presently, this water is heated, by steam, from 55 F (this is accomplished by three CIP units). Equipment and production areas are constantly being washed, 24 hours per day, seven days per week. The washing process consumes approximately 9 to 10 gpm* of water. Therefore the available resource is an ideal replacement of the CIP units now being used.

3.2.3.5

Steam Generation

There exist two possible applications of 166 F hot water to the present steam generating process. The first is to replace the present 55 F boiler feedwater with the available hot water, and the second; preheat the boiler combustion air (presently at 80 F). Even though these measures seem relatively small, the savings are substantial due to the large quantities of feedwater and combustion air used.

3.2.3.6

Space Heating

Space heating is usually an attractive application for systems utilizing a low quality heat source. The nature of Friendship's operations, however, diminishes the appeal of such an application. Virtually all of the processes in the plant radiate large amounts of heat, which severely reduces the steam required for space heating. The lower than expected steam requirement coupled with the comparatively small, yearly operating period and the cost of replacing existing units leads one to dismiss any interface with the heat source as economically not feasible.

3.2.3.7

Incubation

The incubating room of the plant faces the same argument as space heating. The only difference is that the incubating room operates year round. This is more than offset by the extremely small amount of steam required for this operation. The amortized cost of installing a system to heat the

* A 24-hour, six-day average. Peak demand might be significantly greater.

incubating room with hot water far exceeds the expected annual savings from such a system.

3.2.3.8

Other Processes

The remaining steam consuming processes at the plant are batch (not continuous) and relatively minor. These include the production of cultured buttermilk, yogurt, sour cream, dressing, and starter. These processes aside from being small also require a high enthalpy heating medium, with the present equipment, in order to heat the products to a specific temperature within a minimum required time. The available 166 F hot water cannot economically replace the steam presently used to perform these processes.

3.2.4

Process Resource Requirements

The processes most suitable to the available resources are:

1. Skim and Cream HTST Pasteurization
2. Cheese Cooking
3. Wash Water Heating (CIP Units)
4. Boiler Feedwater Preheat
5. Boiler Combustion Air Preheat

In order to determine the amounts of hot water required to replace the present use of each process, steam consumption must be analyzed. The present daily average, daily peak, and yearly steam consumption of the first three processes are listed in Table 3.5.

Table 3.5

Present Steam Requirements

	<u>Avg lb/day</u>	<u>Peak lb/day</u>	<u>lb/year</u>
Skim HTST	56,535	73,959	20,510,000
Cream HTST	5,674	7,423	2,060,000
Cheese Cooking	35,640	48,114	13,000,000
Wash Water	11,055	11,853	3,880,000

The quantities of hot water required to displace the steam consumption of the processes in Table 3.5 are a function of the available hot water temperature. Each process will not necessarily receive 166 F water. Long lengths of pipe to various washing areas might result in a drop in temperature and the HTST units, as previously mentioned, require temperatures higher than 166 F. The final system arrangement will ultimately dictate the exact temperatures of hot water available to each process. However, to arrive at a final design, some approximate values for hot water requirements have been determined.

3.2.4.1

Pasteurization Process Requirements

The skim HTST pasteurization process requires hot water at a temperature of not less than 175 F. Since the available hot water must be boosted in order to reach this temperature, boosting the water temperature higher than 175 F would be unjustified. Therefore, it is expected that the hot water available to the skim HTST unit will be 175 F.

Assuming the flow and temperatures of skim remain constant, 160.6 gallons per minute of 175 F hot water are required to perform pasteurization. This flow of hot water would replace all steam currently required for skim pasteurization. This value does not vary during peak operation since the hourly rate of skim being processed remains constant. During peak operation, the pasteurization process operates for a longer period of time to handle the larger volumes of raw milk entering the plant.

The cream HTST unit requires approximately 18.0 gallons per minute of 198 F hot water in order to achieve pasteurization. The cream HTST pasteurization process is about one-tenth the size of the skim HTST pasteurization process, therefore, the energy expended to boost the 166 F water to 198 F would not be warranted.

However, the water leaving the cream HTST unit at 158 F could be boosted, along with the inlet water to the skim HTST, to 175 F before it is reheated to 198 F. The savings from preheating the cream HTST pasteurizing water would be small, but incorporating such a procedure into the skim HTST unit water system is very easy. The savings are equal to almost half of the steam now consumed by the process. This is a large percentage, but in absolute terms it amounts to only 2411 lb steam per day (3154 lb/day during peak operation) and 874,692 lb per year.

The boosting of the hot water required for the skim and cream HTST pasteurization processes can be accomplished by one of several methods. The simplest method would be to employ the steam water heaters now being used, but this would consume approximately 5,800,000 lb of steam per year (@ \$.366/ccf this would cost \$33,000/yr). A much more economical approach would be to utilize a heat pump to boost the water temperature; if a warm enough heat source (>110 F) could be tapped, the cost of operating a heat pump, at Friendship's electric rate (about 3.6¢/kWh), would be less than half that of employing the steam heater.

3.2.4.2

Cheese Cooking Process Requirements

As previously mentioned, the minimum water temperature required for cooking cheese is 136 F, but at this temperature the maximum flow is required to supply the necessary Btu. As the available water temperature increases the required flow decreases.

Illustrated in Table 3.6 is the range of required flows of hot water to the cheese vats as the available temperature varies. The temperatures selected, 136 F, 166 F, and 175 F, are the most relevant in the light of previous discussions. Regardless of the flow required, all of the steam

presently consumed by the cheese vats would be displaced by the available hot water.

Table 3.6

Required Flows of Hot Water
For Cheese Cooking Process

<u>Water Temperature (°F)</u>	<u>Average Operation (gpm)</u>	<u>Peak Operation (gpm)</u>
136	168.5	224.4
166	118.1	157.6
175	100.0	133.5

The values displayed in Table 3.6 must be viewed in the context of the entire system. At any one time, the total required flow of hot water cannot exceed 345 gpm. Since the cheese vat and HTST units operations overlap, special attention must be given to required flows of the cheese cooking process.

The flow of water required by the HTST units is constant at 178.6 gpm (160.6 gpm for the skim HTST unit, 18.0 gpm for the cream HTST unit). In order to remain within the limit of available supply, during peak operation, the requirement of the cheese vats cannot exceed 166.4 gpm (345 gpm less 178.6 gpm). This flow reflects an available water temperature of 162.7 F. Therefore, a water temperature of 166 F is within the bounds of the maximum available flow of hot water (see Table 3.6).

If 166 F is an adequate temperature, then any higher temperature, namely 175 F, is also within the allowable limits. However, the cost of raising more 166 F water to 175 F must be compared to the cost of pumping the additional gallons of 166 F water. The comparison will be determined when the performances of the system components are discussed in greater detail in subsequent sections of this report.

3.2.4.3

Wash Water Process Requirements

The majority of the washing at the plant requires 150 F or 160 F hot water. Requirements greater than 160 F are extremely small. Approximately two percent of the total water consumed is hotter than 160 F (0.5 percent @ 170 F and 1.5 percent @ 180 F). This higher temperature water can be heated from the available water temperature to 170 F or 180 F by the existing CIP units (steam water heaters presently heating wash water).

Regardless of the temperatures involved, the same volumes of wash water are required. Presently, the wash water consumption, averaged over 24 hours for a six-day week, is 9.0 gpm. When the plant is operating at peak levels, the wash water consumption is assumed to be slightly higher, approximately 9.8 gpm. These figures represent an average consumption assuming the washing of equipment occurs every minute of every hour, six days per week. This is obviously not the case, but in order to assimilate the wash water requirements into any system it is necessary to place them in the same context as the requirements of other processes.

The demand for wash water during any given day could range from 0 gpm to 50 gpm. If the demand for wash water was at its peak while both the HTST units and cheese vats were operating, the hot water supply could possibly be taxed beyond its capacity. Therefore, it is apparent that some form of a buffer must be placed between the wash water demand and the available flow of hot water. A buffer would levelize the wash water demand so that an averaged demand becomes valid.

Nearly all the steam now consumed by wash water heating, 11,055 lb/day, can be eliminated by utilizing the available hot water for washing. It is reasonable to assume that 160 F water will be available for washing if piping losses are taken into account. Therefore, the steam displaced is equal to the present consumption less the steam required to heat 2 percent of the 160 F water to 170 F and 180 F. This requirement is 38 lb/day for an average day and 44 lb/day under peak conditions. These values are extremely small and represent a yearly steam requirement of 13,512 lb/year, which

is less than the amount presently required for a two days' supply of wash water.

3.2.4.4 Boiler Feedwater Preheat Process Requirements

Boiler feedwater preheating is presently nonexistent, therefore no steam is consumed. By utilizing the available hot water, the quantities of gas required to produce steam can be significantly reduced. Gas savings would be a function of the reduction in heat currently required to generate steam. Presently, feedwater is at 55 F as it enters the boilers; any increase in this temperature translates into less heat required to produce steam. The total heat displaced by preheating is the product of the increase in feedwater temperature (from preheating) and the flow of feedwater.

The quantity of feedwater is equal to the quantity of steam produced. However, steam production varies a great deal depending on which processes are operating. This variation is similar to that of the wash water demand and can be dealt with in the same manner. When based upon a 24-hour day and a six-day week, the feedwater demand becomes 27.6 gpm (32.4 gpm during peak operation). This value, however, must be corrected to account for the expected steam displaced once a geothermal utilization system is in operation.

Steam displaced by utilizing hot water, in the four processes previously discussed, is summarized in Table 3.7. The total displacement of 105,603 lb/day (137,036 lb/day during peak operation) reflects a reduction of the feedwater requirement of 8.4 gpm (peak 9.9 gpm). Therefore, the amount of feedwater (e.g., steam) required to operate the processes not utilizing hot water is 19.2 gpm for average conditions, and 21.5 gpm during peak periods.

Table 3.7

Steam Displacement Due to Hot Water Utilization

<u>Process</u>	<u>lb/day</u> <u>(Avg)</u>	<u>lb/day</u> <u>(Peak)</u>
Skim HTST Pasteurization	56,535	73,959
Cream HTST Pasteurization	2,411	3,154
Cheese Cooking	35,640	48,114
Wash Water Heating	<u>11,017</u>	<u>11,809</u>
Total	105,603	137,036
<u>Steam Consumption</u>		
Current	331,150	388,570
w/Geothermal Interface	225,547	251,534

The determination of the preheated feedwater temperature requires the postulation of two operating conditions. The first assumption is that the available hot water will be employed directly as feedwater. The second is that the buffer system employed to levelize wash water demand will also be used for feedwater, since the demand for feedwater is as variable as that of wash water. These assumptions establish a feedwater temperature of 160 F, the same temperature as the wash water.

The quantity of heat saved by preheating feedwater is equal to the product of the temperature rise, 105 F (160 F - 55 F), and the pounds of steam produced, 225,547 lb/day (peak: 251,534 lb/day); for every 913.1 Btu displaced due to feedwater preheating, one less cubic foot of gas is required to produce the equivalent amount of steam. For the temperatures and flows described above, 9,663,809 cubic feet of gas per year is displaced (assuming an efficiency of 82 percent). Based on a rate of \$.00366/cf, this value represents an expected savings of \$35,370/year.

3.2.4.5

Boiler Combustion Air Preheat

In order for the combustion of gas to occur, a specific percentage of air must be present in the boilers. Presently, the combustion air drawn into the boilers is at ambient temperature (i.e., 80 F, the air temperature in the boiler room). If the air temperature were to be increased, less gas would be required to heat the air to combustion temperature.

Assuming that 160 F water is available to heat the combustion air before it enters the boiler, the gas displaced by preheating can be calculated. The gas displaced is a function of the heat displaced, which is a function of the quantity and temperature of the preheated air.

The performance of water-to-air heat exchangers is such that an approach of 40 F is a conservative assumption. An approach of 40 F (hot water inlet: 160 F, heated air outlet: 120 F) reflects a temperature increase of 40 F (heated air: 120 F, ambient air: 80 F). This figure is only an approximate value; the performance of an actual unit might result in a higher or lower air outlet temperature.

In order to ascertain the mass of air to be preheated, the stoichiometry of the combustion of gas must be determined. Assuming that gas is composed entirely of methane (CH_4), 9.53 cubic feet of air is required to burn one cubic foot of gas. If the excess air necessary to insure complete combustion is accounted for, the ratio of air to gas becomes 10.5. Based upon a yearly gas consumption of 98,020,000 cubic feet*, a density of air of .07655 lb/ft³, and an air specific heat of .24 Btu/lb F, 8.1×10^8 Btu/year are displaced due to preheating. This quantity of heat translates into 889,000 cubic feet of gas displaced per year (or \$3,250/yr @ \$.00366/ft³).

* 3.2.4.4 (calculated from yearly steam consumption)

3.2.5

Modes of Operation

With the exception of the CIP units and the boilers, which operate continuously, all the processes at the Friendship plant operate based on a specific schedule. In determining the demand on the available resource, process schedules must be evaluated so that the operation of a geothermal system can be identified. Table 3.8 lists the operational periods of processes that have been identified as suitable to a geothermal system.

Table 3.8

Periods of Operation of Suitable Processes

	<u>Average Operation</u>	<u>Peak Operation</u>
Skim HTST and Cream HTST Units	10 am - 12:11 am	10 am - 4:33 am
Cheese Vats	6 pm - 6 am	6 pm - 6 am
Wash Water	24 hrs/day	24 hrs/day
Feedwater & Combustion Air Preheat	24 hrs/day	24 hrs/day

Relative to the periods of operation depicted in Table 3.8, four basic operational modes exist. The mode with the largest tax on the available resource is that during which all four processes are operating. (Skim/Cream pasteurization and feedwater and combustion air preheat processes each considered a single process). This mode begins at 6 pm and ends at 12:11 am. Since feedwater/combustion air preheat and wash water heating are 24-hour processes, the three remaining modes are the periods of sole operation of either the HTST units or cheese vats, and the period when neither is operating.

Although the four modes described above encompass all permutations of operation, eight modes are necessary to characterize the plant's operation. Four additional modes are required to define peak operation. Table 3.9 lists each mode, the

processes operating, period of operation, and
length of operation.

Table 3.9

Modes of Operation

<u>Mode</u>	<u>Processes in Operation*</u>	<u>Average or Peak Operation</u>	<u>Period of Operation</u>	<u>Length of Operation</u>	
				<u>hrs/day</u>	<u>hrs/year</u>
1	HTST Units Cheese Vats	Avg	6 pm to 12:11 am	6.18	1557
2	Cheese Vats	Avg	12:11 am to 6 am	5.82	1467
3	HTST Units	Avg	10 am to 6 pm	8.00	2016
4	-	Avg	6 am to 10 am	4.00	1008
5	HTST Units Cheese Vats	Peak	6 pm to 4:33 am	10.55	506
6	Cheese Vats	Peak	4:33 am to 6 am	1.45	70
7	HTST Units	Peak	10 am to 6 pm	8.00	384
8	-	Peak	6 am to 10 am	4.00	192

* feedwater/combustion air preheat and wash water heating are always operating

Now that the operation of the plant has been defined in terms of those processes most suitable to the available heat source, a preliminary system arrangement can be defined. This definition is presented in the next sections of this report.

3.3.0 Systems Formulation and Selection

3.3.1 Preliminary Systems Assessment

The system components, regardless of their exact arrangement, can be identified as either geofluid or hot water components. Those components that constitute the geofluid subsystem, i.e., heat exchanger, production and injection pumps, are components that have direct contact with the geothermal resource. The remaining components comprise the hot water subsystem that supplies geothermal heat to the various processes determined to be suitable.

In order to determine a specific system arrangement, the characteristics and constraints of the two subsystems and the individual system components must be assessed. The overall geofluid subsystem constraints and operating parameters are a function of the geothermal resource properties. The hot water subsystem's make-up is a function of the hot water flow and the individual process requirements.

3.3.1.1 Geofluid subsystem

The basic geofluid cycle would be as follows:

- the geofluid is pumped from the production well to the plant
- in the plant, the geofluid passes through a heat exchanger where it is cooled by well water
- the cooled geofluid is pumped into the injection well

As previously stated, the expected flow of geofluid is 345 gpm and the estimated temperature is 174 F, at the well head. A temperature as low as 174 F should not place any restrictions on equipment selection; however, the maximum flow rate will dictate equipment capacities.

PRODUCTION PUMP

The parameters that govern the selection of a pump for the production well of the proposed geothermal system are:

- the maximum flow
- the maximum pressure or head encountered by the pump
- the pump setting (the depth of the pump in the well)
- the well diameter at the expected setting
- expected required pump variability (will the pump be constant or variable speed?)
- the temperature and composition of the medium being pumped

Once these parameters are determined the following items must be considered:

- type of pump
- capital cost of pump
- maintenance requirements (and costs) of pump
- pump longevity
- pump reliability

These items must be addressed in order to select the pump that will provide the least expensive, most reliable service.

Based upon geologists' estimates of the expected static head of the geofluid in the production well and the calculated drawdown under anticipated operating loads, the production pump must be placed 500 ft below ground level. This location, referred to as the pump setting, represents a head of 500 ft. The expected pressure drop across the heat exchanger, approximately 50 ft, when combined with the pressure losses in piping and valves, amounts

to about 75 ft of head. To be conservative, the pump head is expected to be 600 ft.

The greatest flow that would be encountered by a pump in the proposed production well would be 345 gpm. Assuming that a thirty percent salt solution fairly represents the expected geofluid with respect to fluid density, the production pump would expend 87 kw while pumping 345 gpm under 600 ft of head. The latter determination was performed assuming a pump efficiency of 60 percent and a motor efficiency of 90 percent.

The pump selected to satisfy the above operational conditions must also be small enough to fit inside the casing that lines the well at the setting depth. This casing would most likely be 13-3/8 inches in diameter (O.D.). Therefore, allowing for the thickness of the casing, approximately 4/5 of an inch, the diameter of the pump bowls must be less than 12-1/2 inches. This restriction on pump diameter is well within the range of available pumps large enough to handle the expected load.

Due to the nature of the process demands on the available resource, the selected pump must be able to efficiently handle 345 gpm as well as much smaller flows. A suitable pump, therefore, would have to possess a variable speed capability. Achieving variable speed capability is a relatively simple task for most types of pump and does not significantly increase their cost.

The pump types applicable to the aforementioned operational parameters and constraints are employed by the oil industry and certain businesses that rely, to some degree upon well pumping. This is to say that pumps are available, to a large degree, as "off the shelf" items for the specific duty being discussed. The two pump types considered suitable are the submersible motor type and the vertical lineshaft turbine type. The difference between these two types lies in the location of the motor. The submersible motor pump employs a motor that is in place beneath the pump bowls, submersed below fluid level. The vertical lineshaft turbine pump is powered by a motor located at the wellhead that rotates a shaft that turns the pump bowls.

The advantage that the submersible motor pump has over the lineshaft pump is the absence of a 500 ft

lineshaft. A 500 ft lineshaft requires bearings every ten feet for alignment. If the lineshaft is not in near perfect alignment the bearings wear out rapidly and necessitate replacement. Although the operation of a 500 ft lineshaft pump appears to be difficult, lineshaft pumps, operating successfully, often exceed this setting (1000 ft lineshafts have been employed successfully).

The disadvantages of the submersible motor pump are far more numerous than those of the lineshaft pump for this application. The advantage of a motor placed beneath the pump bowls is diminished by the short life of the motor. The fact that the motor, by being placed in the well, is exposed to a hostile environment, results in frequent motor failure. The frequency of failure could be 18 months to 24 months and the cost of repair might be as much as 80 percent of the downhole equipment cost. Comparatively, the lineshaft pump motor, situated above ground, should last 20 years with minimum maintenance.

As previously stated, the proposed application requires a pump with variable speed capability. The submersible motor pump has this capability but it is very expensive. In order to vary the speed of the submersed motor, a variable frequency drive unit with microprocessor control is required (an additional expense of nearly \$40,000). The vertical lineshaft turbine pump motor, on the other hand, can employ a variety of conventional methods to vary the shaft speed without a significant increase in cost.

Lastly, submersible motor pumps are more suited to much shallower settings and have yet to prove themselves at settings as deep as 500 ft. Vertical lineshaft turbine pumps are much more common at 500 ft and have shown that they are reliable. In light of this fact and previously mentioned factors, the vertical lineshaft turbine pump appears to be the pump type most appropriate to the production well application.

(Pump materials selection considerations with respect to the composition of the geofluid will be addressed in later sections of this report.)

INJECTION PUMP

The selection of an injection pump is a much simpler task than selecting a production pump. An injection pump need not be placed in the well; this reduces the constraints on the selection process considerably.

The operational parameters of injecting the geofluid into the ground are similar to the conditions of production pumping. Since the geofluid subsystem is a closed system, the maximum flow rate for injection is identical to that of production, 345 gallons per minute. The injection pump must also have a variable speed capability similar to that of the production pump.

The injection of geofluid is expected to encounter a significant amount of resistance from the injection well. The injection of the geofluid is aided, to some degree, by gravity but the formations where injection takes place might have too low of a porosity level to absorb all of the fluid pumped into it. It is assumed that the injection pump must be large enough to accommodate 500 ft. of head.

A horizontal split case pump, sized accordingly, would satisfy all the constraints concerning reinjection. A split case pump is relatively easy to maintain and clean and is also lower in cost than other pump types.

HEAT EXCHANGER

The transferring of heat from the geofluid to the potable well water is part of both the geofluid and hot water subsystems. Due to the nature of the geofluid, the operational constraints of the heat exchanger are dependent upon the geofluid parameters. The parameters of concern are the flow rate, temperature, chemical composition, and the desired approach.

Two types of heat exchangers would be capable of performing the required heat transfer; shell and tube, and plate type. The shell and tube heat exchanger is generally more economical than a plate exchanger, when mild steel, copper, or silicon bronze tubes can be utilized. But with respect to

the proposed application, the nature of the geofluid dictates the use of a more corrosion resistant material (several manufacturers recommend titanium). The cost of fashioning tubes from titanium, or other special materials, reduces the cost advantage of the shell and tube exchanger. In addition to the economics, the plate exchanger offers several other advantages:

- Ease of disassembly for cleaning.

Especially in this application, cleaning to reduce fouling from scaling is very important. A shell and tube exchanger is much more difficult to clean.

- Easy to expand for increased loads

To increase the heat transfer area of a plate exchanger additional plates can be added to the frame. Whereas a shell and tube exchanger is designed for one and only one duty and cannot be readily expanded.

- Less floor space required

This is important when the production area is as cramped for space as Friendship's is. Series or parallel systems can be incorporated onto one frame to save additional space.

- Excellent performance

Since the flow is pure counter-flow, log mean temperature difference correction factors approach unity. High turbulence is also achieved, which improves the heat transfer coefficient, through specific plate corrugating.

Several unconventional heat exchanger designs have been utilized in specialized geothermal applications. These designs, direct-contact and fluidized-bed types, however, are not suited to the system being investigated. For the expected service, a plate heat exchanger appears to be the most logical choice.

3.3.1.2

Hot Water Subsystem

The hot water subsystem consists of the following components:

- heat exchangers (discussed in Section 3.3.1.1)
- heat pump (discussed in Section 3.3.1.2)
- storage tanks (as a buffer for continuously operating process)
- water-to-air heat exchanger (for preheating boiler combustion air)

The subsystem cycle can be broken down into this sequence:

- well water is heated by geofluid as it passes through plate heat exchangers
- well water, now hot water, is split into two streams
- one stream is heated to a higher temperature by a heat pump and piped to the pasteurizers
- the other stream is piped to the cheese vats directly. (This water is subsequently disposed of through a clear water drain.)
- the water exiting the pasteurizers is returned to the heat exchanger to be reheated.
- at some point, most likely when the pasteurizer demand is zero, the hot water exiting the heat pump is directed to storage tanks
- hot water from the storage tanks is continuously piped to wash water units, to boilers as feedwater, and to a water-to-air heat exchanger for preheating combustion air

HEAT PUMP

The requirement of a selected heat pump will be to heat water from 166°F to 175°F.

The maximum amount of water to be heated (for the pasteurization process) would be 178.6 gpm (See 3.2.4.1). This flow dictates a heat pump capacity of 1,076,000 BTU/hr. The remaining parameters to be determined are the temperature and flow of the heat source. These parameters directly effect the coefficient of performance (COP) of the heat pump. The COP is a measure of the heat pump's efficiency of operation and increases (reflecting higher efficiency) as the heat source temperature and flow increases. A heat pump unit with a high COP draws less electricity to power its compressor, thereby operating more economically.

The most suitable and convenient heat source available to the heat pump would be the exit stream from the pasteurizers. The temperature of this stream is 137°F and the flow rate is identical to that of the 175°F flow through the heat pump. The only drawback in utilizing this stream as a heat source is that it is only available when the pasteurizers are operating. An alternative heat source will be required for the periods when the heat pump is operating to supply hot water to the storage tanks. (One alternate source could be created by heating additional hot water with geofluid.)

A heat pump that satisfies the determined operational requirements is commercially available. The Westinghouse Templifier Heat Pump is specifically designed as a "waste heat", water-to-water heat pump and is ideally suited to the proposed application.

STORAGE TANKS

Due to the fact that these tanks will store hot water only two parameters need be considered: the volume of the tanks, and the allowable heat loss. Heat loss can be reduced with proper amounts of insulation and by employing large tanks to reduce the surface area to volume ratio.

The selection of tanks is fairly routine and the tank application of the hot water subsystem should not present any special considerations. The required tank volume will be determined in later sections of this report, after system operation has been defined more precisely.

WATER-TO-AIR HEAT EXCHANGER

The proposed function of this unit is as an air heater which would preheat combustion air consumed by the plant's boilers (more than one unit might be required). Formation of equipment specifications is a function of air flow and hot water flow. The air flow can be determined by evaluating the stoichiometry of the combustion of gas. The hot water flow can be ascertained once the flow and temperature increase of air is known.

Based upon determinations made in Section 3.2.4.5, approximately 262,600 lb/day of air are consumed by the boilers. Assuming a relatively efficient unit was employed, 6gpm (7gpm during peak modes) of hot water would be required to heat the air to 120 F.

3.3.1.3

Alternate Energy Utilization Methods

Although the proposed geothermal utilization system would displace substantial quantities of conventionally produced energy, alternate methods of energy production (and utilization) were considered. These methods were cogeneration, refrigeration waste heat, use of an organic Rankine cycle, and cascading.

COGENERATION

Cogeneration is the simultaneous generation of heat and electric power. The three prime movers are a fired boiler and back pressure steam turbine, a gas turbine generator with a waste heat boiler, or a diesel generator with a waste heat boiler. An investigation of cogeneration was performed in order to determine the economic feasibility of generating electricity to sustain equipment necessary to operate a geothermal system, while providing waste heat to various processes.

The result of the investigation revealed that cogeneration was not feasible with respect to the proposed system for the following reasons:

- savings in electric costs were minimal due to relatively low electric rates in the Friendship area.
- small quantities of available waste heat due to small size of unit (due to limited electrical demand of applicable equipment)
- extremely high capital cost with respect to anticipated savings because of the small size of the unit.

Although not feasible for the geothermal system, the applicability of cogeneration to the total Friendship plant would warrant further study. (The feasibility of cogeneration on this scale is outside the scope of this report.)

REFRIGERATION WASTE HEAT

The nature of Friendship's operation necessitates the use of large water chillers which produce substantial quantities of waste heat. At present fossil fuel price levels, some industries have been able to economically utilize the waste heat generated by refrigeration equipment. However, at Friendship Dairies, in light of the proposed geothermal system, the plant's recent conversion to gas, and the logistics of tapping the waste heat source economically, the implementation of this energy utilization method does not appear to be justified.

One of the most common uses of refrigeration waste heat is the heating of wash water. But water-to-water heating, as employed by the proposed geothermal system, is much more efficient than the utilization of refrigeration waste heat would be. Certain temperatures of wash water required (to meet certain food processing codes) might also be beyond the capability of the waste heat source.

The high cost of recuperating the waste heat of refrigeration, when compared to the ease with which a geothermal system could satisfy the same demand, indicates that such a method is uneconomical.

ALTERNATE HEAT PUMP CONFIGURATION

Certain Rankine cycle heat pumps are capable of producing low pressure steam by utilizing the process fluid as the working fluid. The advantage of such a unit is that either the evaporator or condenser or both can be eliminated which would eliminate the penalty of the temperature drops across these components. However, such a unit would require a large flow of hot water and larger and more expensive compressor trains. In the case of the Friendship plant and the expected geofluid characteristics, the required heat source flow is not available.

CASCADING

Cascading usually refers to a total system that incorporates many heat recovery schemes, where the waste heat from one process becomes the heat source of another, whose waste heat, in turn, is fed to another process. The previously mentioned energy utilization methods, cogeneration and refrigeration waste heat are all examples of cascading to some degree. Cascading can be employed in a number of applications at the Friendship Plant.

The "waste" geothermal fluid from heating feed water for the cheese vats and heat pump condenser can then be used to preheat well water. "Waste" heat from the boiler combustion air preheaters and from the pasteurizers can warm the heat pump evaporator.

3.3.2

Candidate Systems Development

From the descriptions of the geofluid and hot water subsystems a basic system arrangement has been defined. The exact combinations and interactions of each component, however, are not clear. A closer look at the system requirements, on a mode by mode basis, is the next step toward a definite system arrangement.

Based upon Sections 3.2.4 and 2.5, Table 3.10 depicts the hot water, and hence the geofluid, requirements of each mode of operation.* The values shown in Table 3.10 are formulated on the assumption that storage tanks are filled during modes 4 and 8 (while the pasteurizers and cheese vats are not operating).

Some filling of storage takes place during modes 3 and 7 when the return from the air preheater is cycled through the system.

Table 3.10

Hot Water Requirements of
Geothermal System

<u>MODE</u>	<u>PROCESS REQUIREMENTS</u>			<u>TOTAL</u> (gpm)
	<u>HTST Units</u> (gpm)	<u>Cheese Vats</u> (gpm)	<u>Filling of Storage</u> (gpm)	
1	178.6	118.1	-	296.7
2	-	118.1	-	118.1
3	178.6	-	6.0	184.6
4	-	-	205.2	205.2
5	178.6	157.6	-	336.2
6	-	157.6	-	157.6
7	178.6	-	7.0	185.6
8	-	-	229.8	229.8

The flow requirements during modes 4 and 8 (filling of storage) were determined by dividing the total daily requirements of the CIP units, boiler feedwater, and air preheater by the length of time each respective mode was in effect. Due to the larger individual process requirements during peak operation, the filling of storage in mode 8 is larger than that of mode 4 (both modes have equal lengths of operation).

* See Table 3.9 for mode definitions.

The mode requirements of Table 3.10, when combined with the basic system arrangement result in the formation of specific systems. These systems, each supplying the required flows to the respective processes with slightly different techniques, are described in the next sections of this report.

3.3.2.1 Systems Analyses

3.3.2.1.1 System A1

The flow diagram of System A1 is depicted in Figure 3.14. As shown, this system utilizes a secondary heat exchanger. The purpose of this heat exchanger is to supply a heat source to the heat pump during modes 4 and 8. During these modes the flow from the heat pump fills the storage tanks, therefore, there is no return flow. When the pasteurizers are operating, in modes 1, 3, 5, and 7, the return from that process (at 137°F) is employed as the heat pump heat source. During modes 2 and 6 the heat pump does not operate since the cheese vats do not require 175°F water, therefore, no heat source is required.

MODE	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U
1	298.7 (184)	298.7 (184)	298.7 (184)	112.1 (45)	112.1 (45)	112.1 (130)	298.7 (131)	298.7	178.6	118.1	178.6	160.6	18.0	0	178.6	178.6 (137)	0	184.6 (131)	0
2	121.0 (123)	121.0 (123)	121.0 (123)	112.1 (45)	112.1 (45)	112.1 (111)	118.1 (111)	118.1	0	118.1	0	0	0	0	0	0	0	184.6 (137)	0
3	185.9 (134)	185.9 (134)	185.9 (134)	0	0	0	184.6 (131)	184.6	184.6	0	184.6	160.6	18.0	6	178.6	178.6 (137)	0	184.6 (131)	0
4	345.0 (117)	345.0 (117)	345.0 (117)	199.2 (78)	345.0 (73)	345.0 (110)	205.2 (110)	205.2	205.2	0	205.2	0	0	205.2	0	199.8 (110)	199.8 (110)	0	145.8 (100)
5	338.2 (128)	338.2 (128)	338.2 (128)	150.6 (60)	150.6 (55)	150.6 (128)	338.2 (129)	338.2	178.6	157.6	178.6	160.6	18.0	0	178.6	178.6 (137)	0	185.8 (131)	0
6	181.0 (123)	181.0 (123)	181.0 (123)	150.6 (60)	150.6 (55)	150.6 (111)	157.6 (111)	157.6	0	157.6	0	0	0	0	0	0	0	7 (137)	0
7	185.9 (134)	185.9 (134)	185.9 (134)	0	0	0	185.8 (131)	185.8	185.8	0	185.8	160.6	18.0	7	178.6	178.6 (137)	0	185.8 (131)	0
8	333.4 (118)	333.4 (118)	333.4 (118)	222.8 (81)	345.0 (70)	345.0 (110)	229.8 (110)	229.8	229.8	0	229.8	0	0	229.8	0	121.2 (110)	121.2 (110)	0	128.2 (58)

NOTE:
TEMPERATURES
DEPICTED ON FLOW
DIAG DO NOT VARY
(REGARDLESS OF
MODE)

LEGEND

GEOTHERMAL FLUID

AIR

WATER

PH=PRODUCTION WELL

IN=INJECTION WELL

MW=WATER WELL

A=AVERAGE OPERATION

(MODES 1, 2, 3, 4)

P=PEAK OPERATION

(MODES 5, 6, 7, 8)

(VALUES W/O A OR P SUFFIX DO
NOT VARY FROM AVERAGE DURING
PEAK OPERATION)

G=GALLONS PER MINUTE

F=FAHRENHEIT

COND=CONDENSER

EVAP=EVAPORATOR

↓ DRAIN

HOURS OF OPERATION

PROCESS

SKIN HTST

CREAM HTST

CHEESE VATS

FILLING STORAGE

CIP UNITS

FEEDWATER

COMBUSTION AIR
PREHEAT

ADDITIONAL
OPERATING
HOURS DURING
PEAK DAYS
(60 DAYS/YR)

OPERATING
HOURS

MODE

12AM

6:30AM

8AM

10AM

12PM

6PM

12AM

12AM

12AM

12AM

12AM

12AM

12AM

12AM

12AM

GEOTHERMAL RESOURCE/PLANT INTERFACE
SYSTEM A1

Gibbs & Hill, Inc.

ENGINEERS, DESIGNERS, CONSTRUCTORS

New York

JOB NO. 11-3005-001

SCALE: NONE

FIGURE 3.14

01/08/82

CADRE/MISC, 3001

The table shown on Figure 3.14 reveals the temperatures and flows of the geofluid and hot water at all points of interest within the system. Those values not included in the table are constant throughout all modes of operation and are shown on the figure.

3.3.2.1.2

System A2

The heat source to the heat pump of System A1, modes 4 and 8, is preheated water from the secondary heat exchanger. Another possible source of heat to the heat pump evaporator could be from the primary heat exchanger, as shown in Figure 3.15.

Essentially, in System A2, the exit stream of hot water from the primary heat exchanger is split into two streams during modes 4 and 8. One stream is piped to the heat pump condenser, the other to the heat pump evaporator. The advantage of such a system is reduced load upon the heat pump resulting from a higher temperature heat source. A higher temperature heat source increases the COP which translates into a smaller compressor electrical demand.

SYSTEM A2 IS A VARIATION OF SYSTEM A1. THE DIFFERENCE BETWEEN THE TWO SYSTEMS IS THE SOURCE OF HEAT PUMP EVAPORATOR INLET DURING MODES 4 & 8. THIS SOURCE FOR SYSTEM A2 IS THE OUTLET OF THE PRIMARY HEAT EXCHANGER (SEE --- ABOVE). FOR SYSTEM A1 THE EVAPORATOR INLET SOURCE IS THE OUTLET OF THE SECONDARY HEAT EXCHANGER (SEE [S] OF SYSTEM A1 FLOW DIAGRAM).

LEGEND

GEOTHERMAL FLUID

AIR

WATER

PH-PRODUCTION WELL

IN-INJECTION WELL

HW-WATER WELL

A-AVERAGE OPERATION

(MODES 1,2,3,4)

P-PEAK OPERATION

(MODES 5,6,7,8)

(VALUES W/O A OR P SUFFIX DO

NOT VARY FROM AVERAGE DURING

PEAK OPERATION)

G-GALLONS PER MINUTE

F-°FAHRENHEIT

COND-CONDENSER

EVAP-EVAPORATOR

↓ DRAIN

HOURS OF OPERATION

PROCESS

SKIM HTST

CREAM HTST

CHEESE VATS

FILLING STORAGE

CIP UNITS

FEEDWATER

COMBUSTION AIR

PREHEAT

ADDITIONAL

OPERATING

HOURS

MODE

12AM

9:30AM

6AM

10AM

12PM

6PM

12AM

OPERATING HOURS

ADDITIONAL

OPERATING

HOURS

MODE

12AM

9:30AM

6AM

10AM

12PM

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OPERATING HOURS

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9:30AM

6AM

10AM

12PM

6PM

12AM

OPERATING HOURS

ADDITIONAL

OPERATING

HOURS

MODE

12AM

9:30AM

6AM

10

However, the savings in electrical costs due to a decrease in compressor demand must be weighed against the increased geofluid pumping costs. In order to heat water destined for the heat pump evaporator in the primary heat exchanger, additional geofluid must be provided to meet the increased demand. An economical comparison determined that the cost of additional pumping was greater than the anticipated savings from increased heat pump COP. The conclusion is that system A1 operates more efficiently than system A2.

3.3.2.1.3

System A3

System A3, Figure 3.16 is basically the same system as A1 with a minor difference. System A3 utilizes a storage tank between the cheese vats and the heat pump. The advantage of this configuration is the ability to level the cheese vat demand over all eight modes, thereby reducing the maximum demands. This levelization is advantageous in the event that the quantity of geofluid available has been overestimated and the presently accepted maximum value of 345 gpm is no longer valid. The level of confidence associated with an available geofluid flow rate necessitates the formulation of an alternate system arrangement such as A3.

SYSTEM A3 IS A VARIATION OF SYSTEM A1. THE DIFFERENCE BETWEEN THE SYSTEMS IS THE SOURCE OF HOT WATER TO THE CHEESE VATS. THIS SOURCE FOR SYSTEM A3 IS A STORAGE TANK THAT HAS BEEN FILLED WITH 175F WATER FROM THE HEAT PUMP CONDENSER. (SEE --- ABOVE). FOR SYSTEM A1, THE SOURCE OF HOT WATER TO THE CHEESE VATS IS THE OUTLET OF THE PRIMARY HEAT EXCHANGER. (SEE [K] OF SYSTEM A1 FLOW DIAGRAM).

LEGEND

GEOTHERMAL FLUID

AIR

WATER

PH=PRODUCTION WELL

IW=INJECTION WELL

HW=WATER WELL

A=AVERAGE OPERATION

(MODES 1,2,344)

P=PEAK OPERATION

(MODES 5,6,748)

(VALUES W/O A OR P SUFFIX DO

NOT VARY FROM AVERAGE DURING

PEAK OPERATION)

G=GALLONS PER MINUTE

F=°FAHRENHEIT

COND=CONDENSER

EVAP=EVAPORATOR

↓ DRAIN

HOURS OF OPERATION

PROCESS	12AM	6AM	10AM	12PM	6PM	12AM
SKIM HTST						
CREAM HTST						
CHEESE VATS						
FILLING STORAGE						
CIP UNITS						
FEEDWATER						
COMBUSTION AIR PREHEAT						
ADDITIONAL OPERATING HOURS DURING PEAK DAYS (NO DAYS/HR)						
OPERATING HOURS						

GEOTHERMAL RESOURCE/PLANT INTERFACE
SYSTEM A3

Gibbs & Hill, Inc.
ENGINEERS, ARCHITECTS, CONSTRUCTORS
New York

SCALE: NONE

JOB NO. 11-3005-001

FIGURE 3.16

01/08/82

CADRE #15C, 3001

The disadvantages of system A3 are as follows:

- Increased capital cost of equipment due to an additional storage tank.
- Increased demand on heat pump resulting from larger flows of 175 F water required by system.
- Additional pumping of geofluid required to produce an available heat source for modes 2 and 6 (increasing electrical costs).

It is clear that System A3 is much less economical than either System A1 or A2.

3.3.2.1.4

System B

Although the previously described systems are thermodynamically correct, with respect to the process requirements, Friendship Dairies raised some doubts as to the logistics of the inclusion of the cheese cooking process into a geothermal system. The primary objection was the piping and disposal of the hot water.

Presently, the cheese vat area has reached the saturation point with respect to space for piping. In order to supply hot water to all of the vats, much larger pipes would be required to accommodate the voluminous flows. The management at Friendship Dairies feels that larger piping would interfere with the efficient operation of the process.

The drains now employed in the cheese vat area are designed to handle the approximately 36,000 lb/day (4,300 gal/day) of wash water used to clean the vats and steam condensate. By comparison, the proposed system interface calls for 85,000 gal/day of hot water (twenty times the condensate currently requiring disposal). Clearly, the present drainage system would be severely overtaxed and the cost of installing a system large enough would be high.

Considering the objections to the cheese vat interface, System B, Figure 3.17, was developed. Due to the absence of the cheese vats the modes of operation of System B are reduced to four. The definition of each mode is included on the figure and in Table 3.11. Due to the fact that the

storage demand is relatively small (68.4 gpm), the heat pump condenser can accommodate both the pasteurizer and storage loads.

LEGEND

GEOTHERMAL FLUID

AIR

WATER

PN=PRODUCTION WELL
IN=INJECTION WELL
WH=WATER WELL
G=GALLONS PER MINUTE
F=FAHRENHEIT
COND=CONDENSER
EVAP=EVAPORATOR

ORAIN

ADDITIONAL
OPERATING
HOURS DURING
PEAK DAYS
NO DAYS/IN

OPERATING
HOURS

HOURS OF OPERATION

PROCESS	12AM	4:30AM	6AM	10AM	12PM	6PM	12AM
SKIN MILK HTST							
CREAM HTST							
FILLING STORAGE							
CIP UNITS							
FEEDWATER							
COMBUSTION AIR PREHEAT							

DEFINITION OF MODES

MODE	PROCESSES OPERATING	HOURS	AVG OR PEAK OPERATION
1	HTST'S BLR FOWTR CIP UNITS AIR PREHEAT	10AM-12AM	AVG
2	BLR FOWTR CIP UNITS AIR PREHEAT	12AM-10AM	AVG
3	SAME AS 1	10AM-4:30AM	PEAK
4	SAME AS 2	4:30AM-10AM	PEAK

GEOTHERMAL RESOURCE/PLANT INTERFACE
SYSTEM B

Gibbs & Hill, Inc.
ENGINEERS, DESIGNERS, CONSTRUCTORS
New York

SCALE: NONE

JOB NO. 11-3005-001

FIGURE 3.17

01/08/82

CADRE/NTSC, 3001

NOTE:
TEMPERATURES
DEPICTED ON
FLOW DIAG DO
NOT VARY
(REGARDLESS
OF MODE)

MODE	A	B	BI	C	CI	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U
1	247	247	247	59.3	59.3	247	247	247	160.6	18.0	68.4	0	9.1	178.6	187.6	187.6	18.0	40.4	9.0	22.3	9.1
2	0	0	0	0	0	0	0	0	0	0	0	9.1	0	0	0	0	0	40.4	9.0	22.3	9.1
3	237.9	237.9	237.9	48.9	48.9	237.9	237.9	237.9	160.6	18.0	59.3	0	10.4	178.6	189.0	189.0	18.0	45.8	9.8	25.6	10.4
4	0	0	0	0	0	0	0	0	0	0	0	10.4	0	0	0	0	0	45.8	9.8	25.6	10.4

During these modes the heat pump operates by employing the pasteurizer return as a heat source.

System B does not achieve the gas savings that systems A1, A2, or A3 could have, but the electrical costs of operating system B are lower since less pumping of geofluid is required.

3.3.2.2 System Selection

Based upon Sections 3.3.2.1.1 - 3.3.2.1.4, System B is the most acceptable system arrangement. Although not the system with the largest savings, it is the system most easily assimilated into the present operations of the Friendship plant.

3.3.3 General Arrangement of Selected System

3.3.3.1 Description of Selected System

The operation of system B, Figure 3.17 is divided into four operational modes. These modes are described in Table 3.11.

Table 3.11

Definition of Modes System B

<u>MODE</u>	<u>PROCESS OPERATING</u>	<u>TIMES OF OPERATION</u>	<u>HOURS PER DAY</u>	<u>PEAK OR AVG</u>	<u>DAYS PER YEAR</u>
1	HTST Units Filling Storage CIP Units Boiler Feedwater Air Preheat	10 AM to 12:11 AM	14.18	AVG	252
2	CIP Units Boiler Feedwater Air Preheat	12:11 AM to 10 AM	9.82	AVG	252
3	HTST Units Filling Storage CIP Units Boiler Feedwater Air Preheat	10 AM to 4:33 AM	18.55	PEAK	48
4	CIP Units Boiler Feedwater Air Preheat	4:33 AM to 10 AM	5.45	PEAK	48

During mode 1 and 3, 174 F geofluid is pumped from the production well, through the heat exchangers, then pumped into the injection well (see Figure 3.17). The heat exchangers cool the geofluid with water which is thereby heated to 164 F. This hot water is piped to the heat pump condenser where it is boosted to 175 F. The 175 F water is directed to three locations; the skim milk HTST pasteurizer, the water heater for the cream HTST unit, and the storage tanks.

The flow of water leaving the cream HTST unit water heater has been heated with steam to 198 F and enters the cream HTST unit. The exit stream of water from the cream HTST unit (at 158 F) is combined with the stream of water cooled in the skim HTST unit to 135 F, and the exit flow of the boiler air preheater, to form one stream at 137 F. This stream enters the heat pump evaporator and is cooled to 122 F. This evaporator outlet is combined with well water and directed to the primary heat exchanger to be reheated by the hot geofluid.

While the storage tanks are being filled with the flow from the heat pump condenser (at 175 F), the CIP units, boilers and air preheater draw water from the storage tank. The total combined load of these three processes are less than that of the flow filling the storage tank such that enough hot water will be available during modes 2 and 4. The only flow recycled is that of the air preheater; boiler feedwater becomes steam, and wash water ultimately enters the plant drainage system.

(All flows at each point of system B are shown in the table of Figure 3.17. The flows of modes 1 and 3 differ slightly because mode 3 represents peak operation and is approximately 4 hours/day longer).

The pasteurizers do not operate during modes 2 and 4. However, the CIP units, boilers, and air preheater do operate and are supplied by the storage tanks (filled in modes 1 and 3). The flows to these processes vary depending on mode and are listed in the table on Figure 3.17. The temperature of the water available to each process, however, is constant at 160 F. This figure is based upon the assumption that hot water in the tanks, and piping to the processes, will transfer

some heat to the surroundings thereby reducing its temperature 15 F.

The filling of the storage tanks does not occur during modes 2 and 4 for two reasons: the absence of a heat source for the heat pump and the need to allow time for cleaning those components in contact with the geofluid. The heat exchangers, valves and piping that constitute the geofluid subsystem require frequent cleaning in order to insure reliable performance. However, production and injection pumps are maintained on a less frequent basis due to the nature of the equipment and relative inaccessibility of their locations.

3.3.3.2

Component Selection

In order to perform the selection of system B components the operational parameters of each component must be considered. The geofluid and hot water flows and temperatures were obtained from Figure 3.17. Capital costs of the selected units were furnished by manufacturers. (The total project cost is formulated in Section 5.1.0).

HEAT EXCHANGERS

The heat exchangers must be selected with respect to the largest load incurred. (This load occurs during mode 1.) Applicable data is listed in Table 3.12.

TABLE 3.12

Heat Exchanger Operating Parameters

PRIMARY HEAT EXCHANGER

Fluid	GEOFLUID	WATER
Flow (gpm)	247.0	247.0
Inlet Temp (F)	174.	122
Outlet Temp (F)	129	164
Btu/hr Transferred	5.06 x 10 ⁶	

SECONDARY HEAT EXCHANGER

Fluid	GEOFLUID	WATER
Flow (gpm)	247	59.3
Inlet Temp (F)	129	55
Outlet Temp (F)	112	122
Btu/hr Transferred	1.95 x 10 ⁶	

The units selected for this service would be counter current plate heat exchangers fabricated from titanium, (plates and nozzles) with gaskets of resin cured Butyl. The total area of the plates would be approximately 965 square feet which would contribute to a pressure drop of about 20 psi.

HEAT PUMP

Mode 1 operating conditions are the largest encountered by the heat pump and are shown in Table 3.13.

TABLE 3.13

Heat Pump Operating Parameters

	CONDENSER	EVAPORATOR
Inlet Temp (F)	164	137
Outlet Temp (F)	175	122
Flow (gpm)	247	178.6
Btu/hr Transferred	1.315 x 10 ⁶	

A single stage centrifugal heat pump employing refrigerant R-114 would be best suited to the temperatures and flows of Table 3.13. Under the above conditions, such a unit would possess a COP of approximately 4.3 and exhibit almost equal pressure drops across the evaporator and condenser of 10 psi.

PRODUCTION PUMP

The maximum duty of a production pump would be during mode 1. A flow of 247 gpm of geofluid, under 600 ft of head, is required to meet the demands of mode 1. Mode 3 has approximately the same requirement (237.9 gpm), therefore, a variable speed capability is not necessary.

A vertical lineshaft turbine pump consisting of 10-15 stages, depending upon impeller design and bowl diameter, would be required (most likely, the downhole assembly diameter would be 10 or 12 inches). In addition, to obtain the desired flow, an 85 hp electric motor or a similar sized gas driven motor would be necessary.

The maintenance requirements of the aforementioned pump are minimal. According to manufacturers, the pump should be pulled from the well every 18 to 24 months for inspection. Some bearings would probably need replacement but the bowls and impellers should last for 20 years.

The cost of "pulling the pump" would include the rental for a large enough rig, supervision, and bearing costs. The total downtime for an inspection would be approximately 7 to 10 days.

INJECTION PUMP

The injection pump would encounter the same flows as the production pump but under a pressure of 500 ft. Since a downhole setting would not be necessary to accomplish injection, a horizontal split case pump would be suitable. This pump would most likely have 3 stages and a 100 hp motor. Maintenance on such a pump would be much easier than on a production pump and would consist of occasional cleaning. No major parts would be expected to require replacement.

STORAGE TANKS

In order to select proper sized storage tanks the expected maximum tank storage must be determined. During mode 1 the tanks would fill at a rate of 68.4 gpm, and would simultaneously be depleted at an average rate of 40.4 gpm, for 14.18 hours. At the end of mode 1, 23,822 gal would be stored for mode 2. However, the fluctuations in the rate of depletion must be considered. (The demands of the CIP units, feedwater, and air preheater are not constant). Assuming that depletion of storage might be 60 percent above average, the required tank storage must total 37,571 gal.

Included in the capital cost of the tanks would be insulation and foundations. These tanks would be located inside the Friendship plant.

AIR PREHEATER

The performance of an air preheater would be continuous and for average operation would function under the following conditions (Table 3.14):

Table 3.14

Operating Parameter of Air Preheater

(two identical units)

Fluid	Water	Air
Inlet temp (F)	160	80
Outlet temp (F)	137	123
Flow	6 gpm	1100 cfm

Assuming that plant operation, employing a geothermal utilization system, would have two boilers in operation, two units, each with a 1500 cfm capacity, would be required. These units would be of typical fan-coil design and each would consist of a fan (1/3 hp), coil, filter box, and assorted ductwork.

Component selection is, for the most part, based upon operational parameters. But considering the nature of the proposed system (i.e., the composition of the geofluid) special attention must be given to materials selection. Much work and research has been performed on this topic but usually on a specific, case by case, basis because geofluid characteristics vary widely from location to location.

Material selection considerations will be addressed in the following section.

3.3.3.3

Materials Considerations

This Section provides recommendations for the selection of pump, valve, piping and heat exchanger materials for this project.

The methods used in this investigation included the determination of environmental and operating parameters by consultation with the geological consultant and project engineers, discussions with equipment and materials suppliers, and a review of the literature. Materials were selected based upon site environment and operating parameters, previous experience and engineering judgment.

The corrosion and scaling of materials in geothermal brines is strongly dependent upon both the site specific properties of the geofluid, Table 3.15, and the engineering design parameters. Where only incomplete data were available, assumptions have been made based on prior desalting experience (1), the chemical composition of nearby and similar geological fluids (2), and estimates of noncondensable gases contained in the resource (3).

TABLE 3.15

Estimated Geothermal Resource Properties

SiO ₂	< 25	mg/l
Fe	< 3.5	mg/l
Mn	< .25	mg/l
Ca	25,000 - 35,000	mg/l
Mg	3,000 - 5,000	mg/l
Total Na + K	75,000 - 85,000	mg/l
HCO ₃	25	mg/l
SO ₄	3 - 500	mg/l
Cl	62,000 - 200,000	mg/l
TDS	25,000 - 335,000	mg/l
CH ₄	Present	
H ₂ S	Present	
CO ₂	Trace	
O ₂	Nil	
pH	4.5 - 7 (Ref. 2)	
pH	7 - 8.5 (Ref. 3)	
Temperature	175°F (Max.)	
System design flow rates	5 - 7 ft/sec	

The resource is similar to most geothermal fluids in that the oxygen levels are extremely low and the conditions are chemically reducing. The resource is atypical with respect to the extremely high chloride and total dissolved solids (TDS) content. There is the potential for both scaling and corrosion, and a good probability of erosion/corrosion in regions of high velocity, turbulent flow, throttling flow, and impingement.

The design calls for non-continuous operation of the plant; the evening hours being used for maintenance and repair. Because the system would be periodically opened to the atmosphere, the mechanical components would alternately be exposed to brine that is reducing and brine that contains oxygen picked up from the atmosphere. The harmful effects of this exposure (tendency to remove protective films and increase corrosion) can be reduced by draining the geothermal fluid and flushing with fresh water. This flushing is important because the introduction of oxygen into the system can increase the general corrosion rate by a factor of 10 and contribute to accelerated pitting and crevice corrosion (5). Material selection must consider protection internally, against the corrosive geothermal brine and the potential damage to the materials by cleaning procedures, and in addition the external protection of the system against atmospheric corrosion and corrosion due to leaking valves and fittings. Candidate materials include:

- Carbon steel, alloy steel and cast iron
- The austenitic stainless steels
- The ferritic and martensitic stainless steels
- Copper alloys
- Nickel base and "superalloys"
- Titanium
- Non-metallic materials

3.3.3.3.1

Carbon Steel, Alloy Steel, and Cast Irons

The resistance of these alloys to corrosions from the resource is very low. High rates of both general and localized (pitting & crevice) corrosion are expected. In addition, depending upon alloy content, heat treatment, and inclusion content, the carbon and alloy steels can suffer from sulfide stress cracking and hydrogen induced cracking (6) (7).

The cladding of corrosion resistant metals to carbon steel, and the coating or lining of carbon steel with non-metallic materials to provide both strength and corrosion resistance can be effective in geothermal systems. The use of epoxy-, polyurethane-, and fluoro-coatings has had mixed results in geothermal systems. Coatings have cracked or have been completely or partially removed by the actions of the fluids or during cleaning. The suitability of a coating system is highly dependent upon the metal surface preparation and correct coating application, and inspection procedures.

The use of cast irons pose several problems. Weld repair, if required, is difficult. The corrosion-resistance of cast irons is initially about the same as that of wrought carbon steels, but, as time goes by and the graphite in the cast structure is more exposed, the graphite can act cathodically toward other metal components, thereby enhancing the corrosion of the cast iron.

3.3.3.3.2

Austenitic Stainless Steels

The 300 series austenitic stainless steels are, in general, susceptible to pitting, crevice corrosion and stress corrosion cracking in high chloride geothermal brines. The rates of attack are accelerated by low velocities or stagnant flow (lay-up for maintenance), and acidic conditions. Increasing the molybdenum content and decreasing the carbon levels in the austenitic alloys will reduce the tendency to crack. It has been reported that the high alloy nickel stainless steels become susceptible to chloride/sulfide stress corrosion cracking at 177 C (351 F). These alloys are expected to be resistant to the ambient environment of the geothermal brine under consideration (8).

Alloys to consider are type 317L or 317LM, alloy 20 Cb-3, Al-6, alloy 904L, and Incoloy 825. It is important, even for these alloys, that the materials be supplied in the properly heat treated condition, and that all welding be in accordance with qualified procedures to avoid sensitization.

3.3.3.3.3

Martensitic and Ferritic Stainless Steels

The 400 series martensitic stainless steels are expected to be less resistant to the geothermal brine than the 300 series austenitic stainless steels. The martensitic stainless steels are expected to show high susceptibility to pitting, and the higher strength alloys will experience stress corrosion cracking.

The lower alloy 400 series ferritic stainless steels show about the same general corrosion resistance as the carbon and alloy steels, but they have increased resistance to pitting and stress corrosion cracking. The higher alloyed ferritic stainless steels (increased chromium with molybdenum additions) show much improved general corrosion resistance and high resistance to pitting, crevice and stress corrosion cracking. Improved melting practice and controlled carbon, nitrogen and stabilizing elements make these alloys possible. The "superferritic" stainless steel alloys to consider are 26-1 (XM-27 and the Titanium stabilized XM-33), 29-4, 29-4-2, and 26-3-2.5 (SC-1).

These alloys, like all ferritic stainless steels, are subject to 885 F embrittlement. This should be of concern only during fabrication or field repair, and will not eliminate these alloys for the intended service. These alloys can be satisfactory with the proper heat treatment (to avoid deleterious phases). The lowest temperatures that the materials would experience during operation and shut-downs must be considered since the ductile-brittle transition temperature of these alloys can be near room temperature.

3.3.3.3.4 Copper Alloys

The copper alloys experience general corrosion, pitting corrosion, dealloying and stress corrosion cracking in geothermal brines. The presence of hydrogen sulfide and low pH severely limits the use of copper alloys. Some aluminum-bronze and nickel-aluminum-bronze alloys have been used with success in the handling of water for injection into oil bearing formations (9) and in handling highly concentrated brines from the Dead Sea (10).

3.3.3.3.5 Nickel Base and "Superalloys"

The resistance of these high nickel alloys to pitting, crevice corrosion, and cracking in the geothermal brine is generally good. The resistance depends upon chemical composition; the nickel-chromium alloys are at the lower end of the resistance to corrosion scale while the nickel-chromium-molybdenum alloys are at the higher end. Alloys containing over 45% nickel are considered resistant to chloride stress corrosion cracking and alloys with high percentages of chromium and molybdenum are highly resistant to pitting and crevice corrosion. Alloys to consider are Inconel 625, Hastelloy G, Hastelloy C-4 and Hastelloy C-276. As with all other alloys considered, metallurgical structure and correct heat treatment are essential for achieving corrosion resistance. These "superalloys" must be used in the solution annealed condition.

3.3.3.3.6 Titanium

Titanium and its alloys show excellent corrosion and corrosion/erosion resistance in geothermal environments. Under extreme conditions of temperature, high chloride, and acidity, Titanium alloys can fail by cracking, pitting, crevice corrosion and embrittlement. For the geothermal brine in question, at temperatures 175 F and below, Titanium is immune to corrosive failure. Compared to steel, Titanium is more prone to mechanical damage by vibration because it has an elastic modulus approximately half that of steel. Careful attention to design will eliminate this source of failure. Alloys to consider are unalloyed Titanium (ASTM GR2), alloy Ti-code 12, and Ti-Pd (ASTM GR7).

3.3.3.3.7

Non-Metallic Materials

The use of polymer concrete materials for piping in geothermal brines or as linings in geothermal systems is presently under investigation. They appear to resist the corrosive effects of the fluids. When used as linings, the polymer concretes can be "pealed" off by aggressive cleaning procedures such as hydrocleaning. Although long term durability has not yet been demonstrated at high temperatures and high TDS, for the geothermal system of interest, the polymer concrete materials should be considered.

Solid plastic and fiber-reinforced plastic materials can be considered when the temperature, pressure and environment are compatible with the plastic. Mechanical limitations of creep and flow at high temperatures and pressures restrict some plastic materials, and low failure strain capability restrict the fiberglass reinforced plastics. When plastic and FRP materials are used in piping systems, they must be designed to withstand the effects of water hammer and 100% vacuum loadings.

Ceramic materials are highly resistant to both abrasion and chemical attack. They are limited by brittleness and lack of bonding agents and techniques, when applied as linings.

3.3.3.3.8

Materials Selection

Table 3.16 lists those materials selected for pumps, valves, piping and heat exchangers, for this project. Solid metals rather than linings or coatings are chosen for components less than 3" in diameter to eliminate the problems involved in fabricating and inspecting linings and coatings in limited access areas. The metals selected would be expected to provide long life for each component under the anticipated service conditions.

Where linings or coatings are specified, the design of the component would allow full inspection during fabrication, and ease of inspection, repair or replacement during planned maintenance.

It is recommended that all linings and coatings be applied in accordance with qualified, manufacturer approved procedures, by qualified experienced

personnel. 100% inspection by an independent inspector is also recommended.

It is further recommended that instrumentation for the detection of brine leakage into the process stream be provided at critical locations (valves and heat exchangers) to allow timely repair to the system without damage to the product.

TABLE 3.16
Materials Selection

Component	less than 3"	greater than 2 1/2"
Pumps	Hastelloy C-276	casings: rubber-lined* shafts: Inconel 625/Hastelloy C-276 impellers: Inconel 625/Hastelloy C-276
Valves (Butterfly)	Inconel 625/ Hastelloy C-276	body: rubber/teflon-lined* disc: Alloy 825/29-4 SS/ Alloy 20-Cb3
Piping	Hastelloy G Hastelloy C-276 Al-6X	Teflon-lined* cement lined/Prekrete G-8 Polymer concrete epoxy FRP polyester FRP
Heat Exchanger Plate		Titanium Grade 2 Titanium Ti-Code 12

* Lining designed for ease of replacement

3.3.3.4 Energy Utilization

3.3.3.4.1 System Energy Savings

Table 3.17 shows on a process basis the expected savings of steam, gas, and dollars due to geothermal system interface. Assumptions made in order to determine gas and dollar equivalents of steam were:

- gas price of \$.00366/cubic foot
- gas specific heat of 913.1 Btu/cubic foot
- boiler efficiency of 82 percent
- saturated steam produced at 125 psig

Table 3.17

System Energy Savings

<u>Process</u>	<u>Steam</u> <u>lb/year</u> <u>(x 10⁶)</u>	<u>Gas</u> <u>ft³/year</u> <u>(x 10⁶)</u>	<u>\$/year</u>
Skim HTST Unit	17.8	27.8	\$101,785
Cream HTST Unit	0.8	1.2	4,341
CIP Units (wash water)	3.3	5.2	19,120
Boiler Feedwater Preheat	-	11.2	40,440
Combustion Air	-	<u>1.1</u>	<u>5,094</u>
Total	21.9	46.5	\$170,780

The estimated present, yearly gas costs (Friendship Dairies recently converted from oil to gas burning boilers) is \$467,650. With a geothermal utilization system operating at the plant this cost would be decreased approximately 36.5 percent to \$296,870. But there are additional costs associated with the operation of such a system and

these are addressed in the following section of this report.

3.3.3.4.2 System Energy Requirements

Various components of the proposed geothermal system require electric power to operate. Each such component is listed in Table 3.18 with its respective demand and yearly kWh load. The values determined are based upon pertinent equipment characteristics developed in previous sections.

Table 3.18

Equipment Electric Demands

	Average kW Demand	hr/year Operating	kWh/year
Production Pump	62	4464	276,753
Injection Pump	52	4464	232,115
Heat Pump	89	4464	397,275
Air Preheater	<u>0.5</u>	7200	<u>3,600</u>
Total	203.5		909,743

Current electric rates for Friendship Dairies are \$.036/kWh (this figure includes tax) and \$3.16/kW/month of demand. The additional electric cost of operating the proposed geothermal system, with respect to these rates, is \$35,000 per year.

3.3.3.5 Site Plan and Physical Plant

Figure 3.18 depicts the proposed locations of the two project wells with respect to the Friendship plant. These locations are very approximate due to the limited scope of this feasibility study pertaining to the production and injection well sites. More detailed geologic investigations of the immediate Friendship site would be required before any geothermal drilling could be initiated.

Figure 3.19 shows the relationship of wells with respect to one another and how the resource interfaces with the surface plant.

GEO THERMAL ENERGY FOR END USE PROCESSES

FIG. 3.19

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4. ENVIRONMENTAL CONSIDERATIONS

4.1.0 Physical Impacts

4.1.1 Geology

4.1.1.1 Regional Geology

In the central and western portions of New York State, the geologic sequence consists of Cambrian through Devonian sandstones, shales, dolomites and limestones, with some evaporites which dip gently to the southeast. The thickness of this sedimentary sequence is about 3000 feet at the shore of Lake Ontario and thickens to over 10,000 in some areas in the south. These Paleozoic sediments overlie unconformably Precambrian crystalline basement rocks. The area is covered mostly by a variously thick veneer of glacial deposits reaching a thickness of 600 feet in some valleys.

4.1.1.2 Site Geology

The sequence of geologic formations in the vicinity of the site consists of paleozoic rocks ranging in age from Cambrian through Devonian, blanketed by varying thicknesses of unconsolidated Pleistocene sediments.

The Pleistocene sediments in the vicinity of the site consist of unconsolidated glacial material ranging in thickness from less than 25 feet to depths of 600 feet in some valleys. In the Van Camden River Valley glacial gravels and till may be several hundred feet thick.

The target formation among the Paleozoic rocks, the Cambrian-age Theresa (Galway) formation, consists of alternating beds of sandstone and sandy dolomite with a few shales in the lower section. Salt water shows have been reported in this formation. The underlying Potsdam formation is a fine to very-coarse-grained sandstone, the color being primarily yellow-grey and the lithology including some dolomite and shale layers.

The construction and operation of the proposed facility should have little, if any, effect on the geology of the area. Most changes are likely to be

associated with the production and use of geothermal fluids rather than during construction.

Geothermal fluids extracted from the Galway will be injected into the overlying, Middle Devonian Age Onondaga. Injection will probably cause local changes in pressure within the receiving formation. The Friendship area does not have a recorded history of earthquake activity. Induced seismic activity is not likely unless injection well pressure fractures the rocks. Of concern in this context is the possibly extension to the site area of the Clarendon-Lyndon Fault Zone, since this zone is associated with the Attica earthquake of 1929 and possibly with recent tremors resulting from a water injection system of salt mining southeast of Attica.

Land surface subsidence has occurred during fluid production at several geothermal fields in several locations. Permanent and non-recoverable subsidence may result from long-term removal of fluids from compressible artesian aquifers. However, given the depth to which the well will be drilled and geothermal fluid removed, surface subsidence is not expected to occur at the Friendship site.

4.1.2

Solid Waste

Safe disposal of solid wastes resulting from geothermal drilling operations is important from an environmental standpoint due to potential toxicity and the large volumes which may be produced as development proceeds. Composition of the waste products will vary according to physical and chemical characteristics of the geothermal resource. Disposal of solid wastes from geothermal facilities to sanitary landfill sites is presently regulated by states and may come under federal requirements pursuant to the Resource Conservation and Recovery Act, as amended.

The principal solid wastes accumulated are drilling muds and formation cuttings. Debris from the well drilling activities is captured and accumulated in storage pits. When drilling is completed the wastes will be dewatered by evaporation and removed to an approved disposal area.

Separation of precipitated solids from spent geothermal fluids is generally considered necessary to prepare for reinjection. Solids consist primarily of silica and heavy metal sulfides. Methods for separation and precipitation are still being refined. Solids could also result from scale buildup and it can be expected that physical methods would be employed to periodically remove scale from critical locations in the facility.

Chemical analysis of Western New York State geothermal resources, however, indicate no significant presence of heavy metals or silicas. For the proposed plant, sufficient descaling chemicals will be added to the geothermal flow to prevent precipitation of solids, hence solid wastes will be negligible.

4.1.3

Air Quality

The complex geochemistry of geothermal resources is exemplified by differences in concentrations of noncondensable gases (ammonia, radon and mercury) between wells within the same area. Hydrogen sulfide (H_2S) appears to be the most troublesome of the gases because of its objectional odor, even at low concentrations. H_2S released at the well head during drilling may be in a sufficiently high concentration to cause discomfort. However, no evidence exists that H_2S released from a geothermal well has caused ambient concentration levels that contribute to endangerment of public health and welfare. The amount of H_2S released at the Friendship site is expected to be very small and no odor or health problem is anticipated.

The only other air quality impact anticipated during construction of the facility is the release of fugitive dust from the movement of construction and well drilling equipment and site preparation. However, fugitive dust can be controlled by sprinkling with water or dust suppression chemicals.

The only effect on air quality anticipated during operation is the possible release of noncondensable gases from well head bleeding or venting.

Using geothermal energy may reduce carbon monoxide, nitrogen oxide, sulfur oxides and non-methane hydrocarbon emissions to the atmosphere from

combustion of fossil fuel which might otherwise be needed to supply the energy.

4.1.4

Noise

During construction, a number of noise sources will be present. These include heavy earth moving and construction equipment, stationary diesel-powered engines, and compressors used in well drilling and the venting of geothermal fluids. These potential noise sources will be controlled by using mufflers to silence engine noise to acceptable levels.

During operation of the facility, any noises from stationary sources will be mitigated utilizing

natural topographic barriers and vegetation as well as noise control technology.

4.2.0

Flora and Fauna

The effects of construction on biological resources as a result of construction facilities such as wells, roads, pipelines and other structures include a relatively small loss of vegetation and wildlife habitat. This loss of habitat could be significant only if the habitat of a rare, threatened or endangered species were involved. The available biological data do not show any rare, threatened or endangered species to inhabit the Friendship site.

Removal of vegetation and disturbance of the soil mantle during construction activities can result in accelerated erosion unless preventive measures are adopted. The deposition of eroded sediments in streambeds can in turn lead to adverse effects on fish spawning and nursery habitat.

Discharge or spills of geothermal fluids or drilling wastes into surface waters can seriously affect aquatic life. These materials often contain small quantities of potentially hazardous substances such as NH_3 , H_2S , heavy metals, or fluoride.

If boric acid is emitted at the geothermal site resulting in vegetation damage, this should be considered a potentially significant environmental impact.

Finally, it is likely that the noise, disturbance, and human intrusion that accompany geothermal development adversely affect wildlife use of adjacent habitat. Species such as nesting raptors and some predators may be particularly sensitive to these factors. Most species, however, seem to adapt to the noise and disturbance.

4.3.0

Water Resources Impacts

The development of geothermal power presents two primary concerns related to water resources:

- the effects resulting from the disposal of fluids withdrawn from deep geothermal reservoirs; and
- the large scale withdrawal and disposal of the geothermal fluids, with ensuing effects on surface and subsurface hydrology of an area.

No evidence exists that geothermal development of any operating facility has altered the area's surface hydrology significantly. The drilling of shallow temperature measuring and observation holes during the exploratory phase of development may create a potential route for mixing shallow and deep water aquifers. This problem will be prevented by proper well construction procedures.

To prevent alteration of the hydrologic balance, most of the withdrawn fluid must be restored through injection. The injection well must be carefully cased and properly constructed to prevent leakage of geothermal brines to shallow aquifers.

Muds used during the early stages of well drilling may contain substances harmful to water quality. To prevent the contamination of surface waters, primarily Van Camden Creek, these substances, together with rock cuttings and the wastewater used in drilling operations will be isolated in a holding basin with an impermeable liner to prevent leakage to surface or ground water.

Erosion and sedimentation associated with the construction of the drilling pads, roads, and structures could degrade the water quality of Van Camden Creek. However, during construction, runoff prevention control measures (diking, straw, berms) will be used.

The production well will be cased and sealed to approximately 8750 feet to prevent the possible contamination of fresh water aquifers with brine.

4.4.0 Socioeconomic Considerations

4.4.1 Economic Factors

The major economic center of Allegany County is Wellsville. The two major manufacturing firms in that community, Air Preheater Corporation and Turbodyne, employ approximately 2,600 persons, or nearly 60 percent of the county's manufacturing work force. The village is the retail and wholesale hub of the county, accounting for nearly 70 percent of wholesale sales. In addition, the village accounts for approximately one-third of service receipts in Allegany County.

Other economic centers of note include: Cuba, Friendship, and the Village/Town of Alfred. In addition to serving as a "bedroom community" to Olean (Cattaraugus County), Cuba has traditionally served as a major agricultural trading center in the Southern Tier. Cuba Cheese and Trading Company, Inc., employing approximately 130 persons, is one of the foremost food processors in the region. Cuba is also the location of Acme Electric Corp., employing approximately 1,200 persons. The Hamlet of Friendship (Town of Friendship) is the location of Friendship Dairies - a major producer of cottage cheese. Friendship Dairies employs approximately 140 persons. Finally, the Village and Town of Alfred is the location of two institutions of higher learning having a combined enrollment of approximately 7,000.

The economic effects on employment and income can be divided into temporary effects due to those workers involved in drilling and constructing the facility and permanent effects due to permanent new employees.

The temporary effects will occur only during the initial construction phases of the project. On completion of the project, temporary workers will either leave the region or compete for existing jobs. Permanent income and employment changes continue for the service life of the facility.

4.4.2

Social Factors

Social effects may be caused by the influx of new residents into an area or by secondary effects of the physical development on present residents of the community. Social effects include population effects, housing and public services, and transportation.

Some small communities and rural areas will experience some disruption by added population, especially if a large work force is used. In general, however, these changes are relatively small and can be absorbed without major problems occurring in most areas.

Permanent population increases result in few effects on housing and public services during the life of a project. However, in individual areas that depend on market conditions, temporary insufficiency of housing and public services will most likely be experienced during facility construction.

Transportation effects are likely to take place because of heavy equipment and commuting traffic. These impacts are usually most intense during construction phase when large pieces of equipment are being transported. Roads not designed or constructed to handle such heavy duty traffic may become congested and be subject to accelerated deterioration.

4.4.3

Cultural Factors

Aesthetic effects at this site could include the visual impacts of the well and pipeline lines. Visual impacts are hard to evaluate because the natural scenic value of the area must be judged as must the desirability of altering that value. The size of the area affected must be estimated as must the effect on the existing landscape, and the degree of scenic disruption.

The major source of offensive odors associated with geothermal development in volcanic areas is hydrogen sulfide. Depending upon local meteorological conditions and terrain, this odor may be perceptible a considerable distance from the facility, and if strong enough to act as a

deterrent to recreational or normal activities. However, Friendship is not a volcanic area and H₂S odor is not expected to present any odor problems. (Refer to Section 4.1.3)

Since the proposed facility will be a closed cycle system, the only time during which hydrogen sulfide gas may be released is during well construction.

Since construction of the proposed geothermal facility will require a small construction work force (approximately 25 persons) and be of relatively short duration, and since no additional workers are anticipated for operation of the facility, the economic, social and cultural effects will be insignificant. Positive effect may be induced on the other hand by potential business expansion favored by the availability and use of the geothermal resource.

4.4.4

Archaeological and Historic Sites

Most of the lake plains and major stream valleys in the three country area are known to have hosted human habitation, probably as long ago as 8,000 to 10,000 years ago. In Allegany County known archaeological concentrations have been identified along the Genessee River, from Caneadea north to the county line; in and around the Village of Belmont and along Angelica Creek and Van Camden Creek. The area around Van Camden Creek, which bisects the project site, is considered to be a secondary archaeological zone indicating the likelihood of prehistoric habitation, but where little or no archaeological work has been done. In some instances these sites contain a few scattered sites that are widely separated.

Prior to the start of construction, an archaeological survey will be conducted to determine if there are any sites which are potentially eligible for inclusion on the National Register of Historic Places.

4.5.0

Regulatory Analysis

4.5.1

State Laws & Regulations

4.5.1.1 SEQRA (State Environmental Quality Review Act) Review

The SEQRA statute is contained in NYS's Environmental Conservation Law - Article 8, and is modelled after NEPA (National Environmental Protection Act). Implementating regulations are contained in 6 NYCRR (New York State Code of Rules and Regulations), Part 617.

"Type I Actions" (listed in Section 617.12) are more likely to require the preparation of EIS's (Environmental Impact Statement) than those not so listed. An example of a "Type I Action" is Section 617.12(7): "any structure exceeding 100 feet above original ground level in a locality without any zoning regulations as to height."

This example of a Type I Action is not intended to define the geothermal project design or site, nor to determine that an EIS is indeed required; rather, it illustrates the kind of projects that generally require EIS's.

The NYSDEC¹ will determine whether an EIS is necessary, after a complete project description has been submitted.

4.5.1.2 Well Drilling Permits

It is assumed that to date there are no New York State laws regulating geothermal drilling. NYS gas well drilling regulations will be applied to geothermal wells. To apply for a well-drilling permit under these regulations, the following must be submitted to DEC:

- Notice of Intention

A "Notice of Intention or Application For Permit to Drill, Deepen, Plug Back or Convert" must be filed for each hole to be drilled.

- Permit

¹DEC = Department of Environmental Conservation

A Well Drilling Permit application must be filed with DEC's Bureau of Mineral Resources, accompanied by a plat certified as to correctness by a licensed surveyor or civil engineer.

A separate permit application is to be filed for each hole to be drilled. A new permit is not required for a well location moved less than 75 feet.

- Organizational Report

An "Organizational Report" must be filed and updated when necessary.

- Individual Well Plugging and Surface Restoration Bond

An "Individual Well Plugging and Surface Restoration Bond" must be filed for each well. The bond will remain in effect until the well is plugged and surface restoration work is certified as completed by DEC.

Under the New York State Real Property Tax Law (NYSRPTL)² certain wells are taxable. Although there have been no tax assessments yet on geothermal wells, a geothermal well could be treated as a gas or oil well, and be taxed based on its depth and/or production rate, or as a property improvement. However, a geothermal well could also be treated as a water well which, historically, has been non-taxable under the NYSRPTL.

4.5.2

Federal Laws

The following are the major federal environmental and conservation laws potentially affecting geothermal development:

- The Geothermal Steam Act of 1970
- The National Environmental Policy Act of 1969
- The Clean Air Act, as Amended (1977)

² See S.102(12) A, F or the NYSRPTL.

- The Federal Water Pollution Control Act,
as Amended (1977)
- The Resource Conservation and Recovery
Act of 1976
- The Safe Drinking Water Act of 1974
- The Noise Control Act of 1972
- Federal Non-nuclear Energy Research and
Development Act of 1974
- Geothermal Energy Research and
Development Act of 1974
- Fish and Wildlife Coordination Act
- Endangered Species Act of 1973
- Wilderness Act
- Marine Protection, Research and
Sanctuaries Act of 1972
- Coastal Zone Management Act of 1972
- Wild and Scenic Rivers Management Act
- Federal Land Policy and Management Act
of 1976
- National Forest Management Act of 1966
- National Historic Preservation Act of
1966

4.5.2.1 Geothermal Steam Act (GSA) of 1970.³

This Act is one of the most significant laws affecting the pace and direction of geothermal energy development. It essentially controls leasing of federal land and all phases of post-lease operations on federal lands (which include a large number of the "known geothermal resource areas" (KGRA's)).

Environmental provisions require preproduction studies, for at least one year, of air and water quality, noise and ecological systems. In addition, the regulations require compliance with all federal and state standards for air, water, land and noise pollution.

GSA-type regs may be issued by NYS under current legislation.⁴

4.5.2.2 National Environmental Policy Act (NEPA) of 1969.

Section 102 of the NEPA requires an environmental impact statement for all major federal actions affecting the quality of the human environment. Therefore, an environmental impact statement can be required prior to construction whether it is on federal, state, or private land.

The impact statement must describe adverse environmental impacts. It must also discuss alternatives to the proposed project and their consequences, and must describe irretrievable resource commitments.

³See S.24 of the GSA, 30 CFR 270 (GSA regs), and GRO (Geothermal Resource Order) No. 4 (issued by the Area Geothermal Supervisor to implement GSA regs).

⁴See Senate Bill No. 6455B/Assembly Bill No. 8475B (introduced as a joint bill to the NYS Legislature on 5/5/81).

4.5.2.3

The Clean Air Act (CAA) as amended (PL 91-604 & PL 95-95).

The CAA has several sections which may affect geothermal energy development.

Section 111 of the CAA and section 109 of the 1977 amendments allow the Administrator of the Environmental Protection Agency (EPA) to establish New Source Performance Standards (NSPS) for air pollutants from stationary source categories. Once established, NSPS become applicable to all new sources in such a category, and further, the states must then establish emission limits for the same constituents from existing sources within that category. This is likely to be the principal route for federal regulation of air emissions, although such standards have not yet been developed for the geothermal industry.

Section 112 of the CAA and Section 110 of the 1977 amendments provide for the establishment of emission standards for hazardous air pollutants from stationary sources. Thus far, standards have been established for specific sources of mercury, asbestos, beryllium and vinyl chloride (40 CFR Part 61). However, these standards do not apply to geothermal sources.

Nevertheless, Section 122 of the CAA Amendments of 1977 provides for the regulation of emissions of radioactive substances, cadmium and arsenic, all of which may be found in geothermal fluids.

4.5.2.4

Federal Water Pollution Control Act Amendments (FWPCA) of 1978 (PL 92-500)

Several sections of this Act apply to geothermal development. Probably the most significant sections are in Title III - Standards and Enforcement. Section 301 calls for the application

³See S.24 of the GSA, 30 CFR 270 (GSA regs), and GRO (Geothermal Resource Order) No. 4 (issued by the Area Geothermal Supervisor to implement GSA regs).

⁴See Senate Bill No. 6455B/Assembly Bill No. 8475B (introduced as a joint bill to the NYS Legislature on 5/5/81).

of "best practicable control technology currently available" by July 1, 1977, for point sources other than publicly owned treatment works. This section also calls for the application of "best available technology economically achievable" by July 1, 1983. Section 301 further requires the elimination of all pollutants where technologically and economically achievable.

Section 304 calls for the definition by the USEPA of such technologies, and effluent limits attainable thereby, through the issuance of "Effluent Guidelines" regulations.⁵ For the geothermal energy industry, those regulations have not yet been developed and are not currently scheduled. However, such regulations may be expected when the industry is firmly established and technologies have been demonstrated.

Section 303 of the FWPCA calls for the establishment and maintenance of receiving water quality standards for both interstate and intrastate surface waters. Such standards have been established by the States and approved by the Administrator (40 CFR Part 120). They are subject to periodic revision. The provisions of this section interact with those of Section 301 and prevail in establishing permit limitations where the application of Effluent Guidelines limits is not sufficient to meet receiving water quality standards. This is likely to be the case in many, if not most, areas of early geothermal energy development.

Section 306 of the FWPCA calls for the establishment of "national standards of performance" for new sources. Past development of such standards indicate that they would be similar to "best available technology economically achievable." There is currently no schedule for establishing new source performance standards for the geothermal industry but they also can be expected in the future.

4.5.2.5

Resource Conservation and Recovery Act (RCRA) of 1976 (PL 94-580)

The provisions of this Act, administered by the Environmental Protection Agency, are principally concerned with solid wastes. Subpart C-Hazardous Waste Management, important to geothermal energy development, involves regulatory control of storage, treatment, and disposal of "potential hazardous" wastes in landfills and surface impoundments. (The potentially hazardous wastes may be liquid, solid, or a combination).

Wastes considered "potentially hazardous" are those which may cause or contribute to adverse effects on human health or the environment when not properly controlled. RCRA regulations are likely to have significant ramifications for the geothermal industry in those cases where spent brine surface impoundments are used and where waste sludges are created, such as in the treatment of waters and noncondensable gases.

4.5.2.6

Safe Drinking Water Act (PL 93-523)

This act is administered by the Environmental Protection Agency and allows and provides for State implementation of its provisions. Part C of the Act, "Protection of Underground Sources of Drinking Water," is of greatest significance to geothermal energy development in that it requires the promulgation of regulations to control underground injection.

Any regulations may be further extended by more restrictive state regulations. Reinjection permits may be required and are likely to be based upon an analysis of geological, hydrological, and injection system design. (See also USEPA May 19, 1970 Consolidated Permit Regulations and Subpart C, Section 122.32ff, as required in 10CFR146.)

The Environmental Protection Agency already has some control over underground injection via NPDES permits using Administrative Order No. 5, which provides for approval of injection systems that are part of any other project subject to EPA regulations.

4.5.2.7 Toxic Substances Control Act (TSCA) (PLO469).

TSCA would apply to any toxic minerals commercially produced from geothermal development.

4.5.2.8 Noise Control Act of 1972 (PL 92-574).

This Act contains broad noise control provisions for regulating and labeling products, many of which are used at geothermal facilities. In addition, EPA has given coordination authority for all programs of other Federal agencies regulating to noise research and noise control.

4.5.2.9 Federal Non-Nuclear Energy Research and Development Act of 1974.

This is the Act which mandated the activities of the Department of Energy, DOE. One of those activities is the active encouragement of geothermal energy technology development through commercial demonstration. The Act also provides for the acceleration of the commercial demonstration of environmental control system for energy technologies.

4.5.2.10 Geothermal Energy Research and Development Act of 1974

This Act authorizes and defines more specifically the responsibilities of the federal government, through the direction of DOE, in developing and demonstrating the commercial viability of geothermal energy conversion. The objectives of the Act are to be accomplished in concert with private developers through grants, contracts, and loan guarantees.

This Act includes a requirement for the development of environmentally acceptable processes. More specifically, it requires that the geothermal research and development program develop and evaluate improved waste control, disposal and monitoring methods; prepare environmental impact statements; and assure compliance with standards and criteria.

- 4.5.2.11-14 Fish and Wildlife Coordination Act; Endangered Species Act; Wilderness Act; and Marine Protection, Research, and Sanctuaries Act.

These federal laws, administered by the U.S. Fish and Wildlife Services, do not directly address pollution control and its requirements. Instead they allow for prohibition of (or advisory action against) certain activities in the interest of preserving wildlife habitats and esthetic values. They also may allow for or require mitigating measures where harm may occur.

- 4.5.2.11-19 Coastal Zone Management Act of 1972; Wild & Scenic Rivers Management Act; Federal Land Policy & Management Act of 1976; National Forest Management Act of 1976; National Historic Preservation Act of 1966.

These federal laws protect coasts, rivers, federal lands, and architecture and archaeology of national significance, and will affect any geothermal project which impacts these areas.

4.5.3 Conclusion

In conclusion, regulation of geothermal projects specific or by extension is increasing, and close monitoring of current New York State legislation is recommended for any geothermal well in New York State. As an example of the increasing regulation, the following legislation is appended:

The Department of Environmental Conservation recently amended sections 554.1 and 556.6 of (Title) 6 NYCRR (Effective date: January 9, 1980, Filing No.: 3081). Notice to the action was published in 2/13/80 New York state Register (Vol. II, Issue 7) and the text is as follows:

"Section 554.1 - Prevention of Pollution and Migration.

- (a) The drilling, casing and completion program adopted for any well shall be such as to prevent pollution.

- (b) Pollution of the land and/or of surface or ground fresh water resulting from exploration or drilling is prohibited.
- (c) Prior to the issuance of a well drilling permit for any operation in which the probability exists that brine, salt water or other polluting fluids will be produced or obtained during drilling operations in sufficient quantities to be deleterious to the surrounding environment, the operator must submit and receive approval for a plan for the environmentally safe and proper ultimate disposal of such fluids. For purposes of this sub-section, drilling muds are not considered to be the polluting fluids. Before requesting a plan for disposal of such fluids, the department will take into consideration the known geology of the area, the sensitivity of the surrounding environment to the polluting fluids and the history of any other drilling operations in the area. Depending on the method of disposal chosen by the applicant, a permit for discharge and/or disposal may be required by the department in addition to the well drilling permit.

An applicant may also be required to submit an acceptable contingency plan, the use of which shall be required if the primary plan is unsafe or impracticable at the time of disposal.

Brine or salt water may be temporarily stored prior to disposal in any watertight tank, container or an earthen pit which is underlaid by soil such as heavy clay or hardpan. Impounding of brine or salt water in an earthen pit is prohibited where the soil underlying the pit is porous and/or is closely underlaid by a gravel, rock or sand stratum unless the pit is lined with watertight material. The tank, container or earthen pit shall be constructed and maintained so as to prevent escape of any fluids therefrom, including any amounts that may be added by natural precipitation.

Storage of brine, salt water or other polluting fluids in such watertight tanks or earthen pits, prior to disposal, shall be for a maximum of 45 days after cessation of drilling operations unless the department approves an extension based on circumstances beyond the operator's control. The department may also approve an extension if the fluid is to be used in subsequent operations according to the submitted plan, and the department has inspected and approved the storage facilities.

- (d) Except as hereinafter provided, sufficient surface casing shall be run in all wells to extend below the deepest potable fresh water level.
- (e) The drilling, casing and completion program adopted for any well shall be such as to prevent migration of oil, gas or other fluids from one pool or stratum to another.
- (f) The drilling, casing and completion program adopted for any well shall be such as to exclude oil, gas or other fluids from any underground mining properties or rights and to protect them in accordance with prudent operations.

"Section 556.5 - Pollution and Disposal"

- (a) Pollution of the land and/or surface or ground fresh water resulting from producing, refining, transportation or processing of oil, gas and products, or in connection with solution mining, is prohibited.
- (b) With reference only to other than existing pools, brine or salt water liquids shall not be stored or disposed of except as follows unless an alternative procedure has been approved by the department after written application therefore and demonstration of good cause, said permission to be granted on administrative basis or after

public hearing at the discretion of the department.

(1) Brine or salt water may be stored prior to disposition in any watertight tank or container including an earthen pit which is underlaid by tight soil such as heavy clay or hardpan. Where the soil underlying the pit is porous and/or is closely underlaid by a gravel or sand stratum, impounding of brine or salt water in such earthen pit is prohibited unless the pit is lined with watertight material. The earthen pit shall be constructed and maintained so as to prevent escape of brine or salt water therefrom including maintenance of the level of the impounded fluid including those added by natural precipitation so that no fluids shall be allowed to escape over or into adjacent lands or into streams or other bodies of water. The department shall have the authority to condemn any pit which does not properly impound such water.

(2) Salt water may be disposed of by injection into the strata from which produced or other proved salt water bearing strata after application for such injection has been approved by the department and under such conditions as may be prescribed. Concurrently, with the filing with department of the application to dispose of salt water by injection, the applicant must send a copy of said application by registered mail to the operators of all leases or units offsetting the lease of unit on which the input well is or will be located and the application must be accompanied by a list of the names and addresses of the offsetting operators and a statement that each has been sent a copy of the application by registered mail,

and the date of such mailing. Upon receipt of the application to dispose of salt water by injection, the department will hold same for 10 days. If within said 10 day period, any offset operator reciting reasonable cause shall file in writing with the department a protest to such disposal, or if the department is not in accord with the proposed injection, the application shall be scheduled for public hearing. If no objection from either an offset operator or the department is interposed within the 10 day period and all other things being in order, the application will be approved and written permission for the injection will be issued by the department prescribing thereon any special conditions that must prevail. The compulsory 10 day waiting period will not be required if the application for permission to dispose of salt water by injection is accompanied by the written consent of the operators of all leases or units offsetting the least or unit containing the well into which it is proposed to inject salt water and the department has no objection."

4.6.0

Impacts on Facility Costs

The facility costs resulting from environmental considerations should be minimal. The major portion of these costs will be associated with well drilling to insure protection of surface and ground waters. Since the adverse environmental effects associated with development of this geothermal resource are negligible, elaborate systems to mitigate adverse effects are not necessary.

Summary

Although geothermal resources represent a relatively clean energy source, environmental effects could occur as a result of the development of this resource. This analysis has reviewed the potential effects resulting from geothermal resource development at Friendship Dairies, Friendship, New York.

During well development, a variety of gases may be released to the atmosphere, the most objectionable being hydrogen sulfide with its disagreeable odor. However, the expected quantity should be small, and therefore impacts should be negligible.

Surface and groundwater pollution will be prevented by the implementation of proper well drilling procedures and from injection of the brine to a rock formation (Onondaga or deeper) sufficiently below, and hydrologically isolated from, fresh water aquifers.

Induced seismicity is considered unlikely if injection pressure is kept below the level at which hydrofracturing would occur.

Compliance with federal, state and local environmental regulations will mitigate any adverse effects of the facility.

The development of this facility presents few adverse environmental effects. Therefore, the environmental impact of this facility will be negligible.

5.

ECONOMIC ANALYSIS

5.1.0

Capital Cost Estimate

Two capital cost estimates were prepared for the Direct Use Geothermal Utilization Systems A & B, as described above. The cost contained in the estimates are as of August, 1981 and were developed as described below;

Equipment Material and Subcontracts

- The cost for the following pieces of equipment were obtained by quotations from the manufacturers.

Production well pump

Injection well pump

Heat pump

Air preheater

- The cost of drilling for the production and injection wells, was obtained from a drilling contractor and adjusted for operator expenditures in accordance with Oil and Gas Journal (May 11, 1981).
- All other material, equipment and subcontracts were developed on a conceptual basis using in house data.

Labor and Indirect Construction Costs

An average wage rate (\$39.50/hr.) was assumed and includes all field indirect construction costs.

Contingency Allowance

A contingency allowance is provided for variations in quantities, cost and labor productivity.

Material and Subcontracts (excluding wells) 15%

Labor and Indirects 25%

Cost Items Not Included

- Land and land rights
- Interest during construction*
- Owners cost
- Taxes*
- Engineering and Design*
- Construction Management
- Escalation*
- Any tear out work required on equipment presently installed at the plant in order to accommodate this new system.

Finally, the estimate for the electrical work is based on the assumption that there is adequate transformer capacity existing at the plant to service the selected system.

System B Summary (1981 Dollars)

Equipment:	\$ 311,500
Labor (installation):	275,000
Subcontracts (including wells):	2,660,000
Contingency:	<u>145,000</u>
Total	<u>\$ 3,391,500</u>

System A1 Summary (1981 Dollars)

Equipment:	\$ 407,000
Labor (installation):	308,000
Subcontracts (including wells):	2,664,000
Contingency:	<u>173,000</u>
Total	<u>\$ 3,552,000</u>

* These items are included in the economic/financial analysis in Section 5.3.2

JOB NO. 11-3005-001 DESCR. Geothermal Utilization

ESTIMATE
SYSTEM B

DATE 1/8/82 APPROVED BY _____
REVISED ESTIMATE

[illegible]

5.2.0

Estimated Operating Costs and Savings

As determined in Section 3.3.3.4.2, the total cost of electricity for operating the proposed geothermal system (System B) at the proposed operating level, is \$35,009/yr (in 1981 Dollars). Additional System B operating costs are estimated to be approximately \$20,000/yr (in 1981 Dollars). These additional costs are broken down as follows:

- production pump maintenance \$ 3,000/yr.*
- general system maintenance and supervision \$17,000/yr.*

*\$6,000 every two years

The cost of general system maintenance and supervision was determined assuming one man working a 30 hour week at a rate of \$8/hour. The total cost to Friendship would be approximately 35 percent higher than the base salary due to the additional cost of social benefits.

Conversion to the proposed geothermal System B is estimated to save 4.26×10^{10} Btu/yr of fuel, compared to the case of continued gas firing at Friendship.

* Expressed in 1981 dollars.

5.3.0 Economical/Financial Analysis

5.3.1 Assumptions

- Six alternative system configurations are analyzed based on Friendship Dairies' thermal demand patterns. Each system is evaluated based on replacement of gas or oil-fired process heating systems. The six system configurations are listed below.

<u>System</u>	<u>Description</u>
B/20 yr.	Base system
MB	Maximum heat utilization on a Btu basis
MG	Maximum utilization on a gpm basis
A1	Alternative system
B 30 yr.	Base System - 30 year life
B DIW	Base System - Deep Injection Well

- Project Life:
20 years. In addition, system B compared to gas fuel is also analyzed over a 30 year life to test the economic results over a longer period. The geothermal reserves are assumed to be sufficient, without additional drilling or extraordinary maintenance expenses, for these project lives.
- Capital Cost Estimate (thousands of 9/29/81 dollars)

	<u>B</u>	<u>B (DIW)</u>	<u>MB, MG, A1</u>
equipment*	891	891	1,052
wells*	2,500	4000	2,500
Total	3,391	4891	3,552

(* includes total system contingency)

- Project Development Factors:

- engineering and construction period 9 months
- straight line cumulative expenditures are assumed
- capital equipment cost escalation 10%
- interest during construction 15%
- begin engineering and construction 4/1/82
- begin operation 1/1/83
- engineering fees (1981 dollars) \$200,000

- Total Investment:

Capital cost including escalation and capitalized interest during construction (thousands of 1/1/83 dollars)

	<u>B</u>	<u>B (DIW)</u>	<u>MB, MG, A1</u>
equipment*	1,221	1221	1,407
wells	<u>2,862</u>	<u>4580</u>	<u>2,862</u>
Total	4,083	5801	4,269

(* includes total system contingency)

- Well Costs:

- tangible costs 25%
- intangible drilling expenses 75%

- Fuel Prices: (1981 dollars)

- natural gas \$4.01/mm Btu
- oil \$6.54/mm Btu

Oil prices are expected to escalate at 15 percent per year through 1990, and at 10 percent per year thereafter.

Gas prices are expected to escalate at 27 percent per year through 1985 when full gas price decontrol is scheduled. On this basis, gas will be selling at a 9 percent discount to oil. After 1985, the oil-gas price differential is expected to remain constant on a nominal dollar basis.

- **Avoided Fuel Consumption:**

<u>System</u>	<u>Avoided consumption (Btu/yr)</u>
B	4.26×10^{10}
MB	12.64×10^{10}
MG	9.65×10^{10}
A1	5.71×10^{10}

- **Electricity Cost:**

The costs that would be applicable to each of the alternative systems are given based on 1981 electric rates. Future escalation is assumed to be 8 percent per year.

<u>System</u>	<u>electricity cost (1981 \$/yr)</u>
B	35,009
MB	79,321
MG	79,321
A1	46,820

- **Operation and Maintenance:**

\$20,000/yr, in 1981 dollars, escalating at 10 percent per year, thereafter.

- **Scale Inhibitor:**

Costs applicable to each of the alternative systems are given in 1981 dollars. Future escalation is assumed to be 10 percent per year.

System	Scale Inhibitor Cost (1981 \$/yr)
B	10,000
MB	22,000
MG	22,000
A1	15,000

- Insurance:

0.5 percent of total investment, escalating at 6 percent per year.

- Debt:

Self-liquidating, mortgage type debt is assumed for 100 percent of total investment at 15 percent annual interest for 20 years. (Alternatively, conventional financing would cover only a portion of the total investment, at an interest rate as high as 20 percent, i.e., above the prime rate. Tax exempt financing would be at an interest rate of about 11 percent or 12 percent. The 15 percent rate used in the analysis is approximately the average of the conventional and tax exempt rates).

- Property Tax:

Assume zero. (based on Section II of the report on Institutional Factors Pertaining to Geothermal Well Drilling, attached as an Appendix to this report.)

- Depreciation of tangible assets:

5 year Accelerated Cost Recovery System class for tangible assets put into service in 1983. This class approximates the 150% declining balance method with zero salvage value.

- Income tax rate:

46%	federal
<u>10%</u>	state & local
56%	total
- Working Capital:

One month's worth of electricity and O & M expenses in the initial year of operation, escalating at 8 percent per year thereafter.
- Investment tax credit:

10%	regular (federal)
15%	energy (federal)
<u>6%</u>	state & local
31%	total

5.3.2

Methodology

The calculations described herein are performed using a Gibbs & Hill computer program for economic analyses of projects for non-regulated, industrial firms. The program computes cash flows over the project operating life, and internal rate of return on investment (IRR). Simple payback, defined as the number of years until cumulative net cash flows equal the net construction period cash flow, is also calculated. Computations for the base geothermal system compared to continued gas firing are shown in Figure 5.1.

Revenues, expenses, and pre-tax income are projected for each year of the plant operating life. Total investment includes the escalated capital cost and capitalized interest during construction. Interest expense is calculated based on self-liquidating, mortgage type debt.

The analyses compare the various geothermal system configurations with the alternative of continued gas or oil-firing at Friendship. Therefore, fuel

consumption that is avoided by the geothermal project is considered as revenue to the project.

The investment in tangible assets is depreciated. Tangible assets include the installed cost of all above ground equipment, as well as tangible drilling costs.

Depletion of the geothermal reserves is computed using the percentage depletion method. The amount allowed is 15% of revenues. The deduction may not exceed 50% of the taxable income from the property, computed without regard to the depletion allowance. Percentage depletion ordinarily permits recovery of much more than would be recovered using the cost method of computing depletion.

It is assumed that the geothermal project owner generates sufficient income from sources other than the project savings to make immediate use of tax benefits generated by the project and to cover the minimum tax on tax preference items. In the case of Friendship, this would be income derived primarily from dairy operations. The tax benefits arise from intangible drilling costs, which may be expensed as incurred during the construction period, investment tax credits, depreciation and depletion. These items are used as tax deductions and credits to shield dairy income from taxes.

Federal, state and local income taxes are computed jointly. Essentially all items allowed as deductions for federal taxes are also allowed for state and local taxes. Therefore, total income taxes are computed at a 56% rate which combines the 46% federal rate and the 10% state and local rate.

Federal and State investment tax credits are also computed jointly. The 25% federal credit is combined with the 6% state and local credit for an overall 31% credit. Investment credits are taken only on tangible, depreciable assets. Investment credits are not allowed for expensed intangible drilling costs, or for geothermal reserves subject to depletion.

Net Income is equal to pre-tax income, less net income tax. "Net income" is actually the net income for tax purposes, not the book income for financial reporting purposes.

For IRR calculations, net cash flows during the operating period are equal to net income, plus interest, depreciation, and depletion, less additions to working capital.

Net cash flow during the construction period is equal to the total investment plus working capital, less the tax benefit of deductible intangible drilling costs, which are incurred during the construction period.

Internal Rate of Return (IRR) is computed based on net cash flows over the construction and operating periods of the project. Cash flows, $CF(t)$, are assumed to occur at the end of each year: construction period cash flows at $t = 0$, and operating cash flows at $t = 1$ through $t = n$, the final year of project life. IRR is computed with the following equation: zero equals the summation from $t=0$ to $t=n$ of $[CF(t)/(1+IRR)^t]$.

IRR is the project return on total investment, expressed in percent, available for all investors: both lenders and equity holders. IRR is computed herein based on cash flows before financing costs, i.e., before interest expense is subtracted, but after the tax benefit of the interest deduction. IRR represents a project's breakeven cost of capital. A project is economically attractive if it can be financed at an interest rate below the IRR.

Alternatively, return on equity (not computed herein) is based on the initial equity investment and cash flows to equity, i.e., cash flows after interest expenses.

5.3.3

Discussion of Results

The six geothermal system configurations are all economically viable, compared to continued gas or oil-firing at Friendship Dairies. The computed Internal Rates of Return, shown below, are all well in excess of current interest rates for long term borrowings: assumed to be 15% for guarantee backed loans or 20% without guarantees. The IRR for even the least economically attractive case (case B replacing gas use) is well in excess of current interest rates.

Case	IRR (%)	
	geothermal replacing gas	geothermal replacing oil
B/20 yr.	28.5	29.5
MB/20 yr.	43.3	46.0
MG/20 yr.	37.5	39.8
A1/20 yr.	31.1	32.3
B/30 yr.	28.9	-
B/20 yr. - DIW	25.9	-

Simple payback, defined as the number of years until cumulative net cash flows equal the net construction period cash flow, is also computed for each case.

Case	Simple Payback (yr.)	
	geothermal replacing gas	geothermal replacing oil
B/20 yr.	3.4	3.3
MB/20 yr.	2.5	2.3
MG/20 yr.	2.9	2.6
A1/20 yr.	3.2	3.1
B/30 yr.	3.4	-
B/20 yr. - DIW	3.7	

The basic case, B/20 yr-gas, yields an IRR of 28.5% which is substantially higher than the projected long-term annual cost of funds (15.0% for guarantee backed loans and 20.0% without guarantees). Payback is a relatively short 3.4 years. Oil avoidance produces even better returns because of the higher price of oil.

Case B Gas/20 yr. and Case B Gas/30 yr show the impact of evaluating the base case over a 20 year versus a 30 year project life. The IRR's and paybacks are essentially equal for these two cases.

Case B/20 DIW-gas shows the economic impact of a deep injection well (10,000 ft vs the base case value of 4800 ft). The computed IRR drops to 25.9% and the payback lengthens to 3.7 years.

The remaining cases show greater returns and shorter paybacks than the base case due to greater utilization of geothermal energy. The most economically attractive case is MB/oil where the IRR is 46.0% and payback 2.3 years.

Two key economic assumptions underlie these results: (1) that sufficient income from dairy operation will be available to utilize tax shelter benefits of the geothermal project, and (2) that a 15% interest rate will be available. However, if these assumptions are not realized, the project would still be economically viable for Friendship as will be shown below.

First, if sufficient income is not available to utilize the tax benefits, they could be sold allowing the project to realize the rates of return shown above less a negotiable discount.

In the unlikely event that the tax losses could not be sold for a favorable return, they would be carried forward to shield future dairy income from income taxes. This delayed shelter use reduces the project return by an amount dependent upon net income levels from dairy operations in future years and the number of years until the loss carry forwards are utilized. For example if Friendship's net taxable income were to average \$600,000 in future years, the IRR for case B/gas would drop to approximately 20%, still above the cost of financing, and therefore still economically viable.

Second, it is assumed that the project will be financed entirely with debt at a 15% interest rate. If Friendship were to utilize conventional financing, the loan would cover about 60% of the total investment, and the interest rate could be as high as 20%, i.e., above the prime rate. However, the project would still be economically viable. For example, using these values the IRR for case B/gas, the least attractive case, would only drop to 26%.

The cost of geothermal energy, expressed in dollars per million Btu, is compared to that of gas for the Friendship B/gas case in which 42,600 mmBtu/yr. is consumed. The comparison is shown in Table 5.1, on both a before-tax and after-tax basis since tax factors have a significant impact on the cost, to the consumer, of geothermal energy. Calculations are based on the gas and geothermal cost components shown in Figure 5.1.

Gas costs are computed based on the cost of gas only. Capital, operating and maintenance costs associated with gas use are not included since the equipment is already in place and would continue to operate.

Geothermal energy costs include capital, operating and maintenance costs since these costs are necessary for utilization of the geothermal resource. Before-tax geothermal costs are computed as total expenses less tax depreciation (per Figure 5.1) and depletion, plus book depreciation

(of total investment, computed by the straight-line method, over 20 years). After tax geothermal costs are computed as net income plus tax depreciation (per Figure 5.1) and depletion; less additions to working capital, after tax gas savings, and book depreciation (of the after-tax amount of the expensed portion of the investment, computed by the straight-line method over 20 years).

The costs of geothermal energy are greatly reduced by tax shelter benefits. On an after-tax basis, the cost of geothermal energy is computed to be lower than that of gas. Although on a before-tax basis, just the opposite is true. For a system using more geothermal energy, the after-tax cost would be even lower.

On an after-tax basis, geothermal energy costs less than gas over the life of the project. Geothermal energy use results in a net after-tax benefit during the first year, due to the combination of investment credit and the intangible drilling cost deduction. Gas costs are about 25 percent greater than geothermal costs in the second year of the project, and this difference is expected to increase. Gas costs are expected to escalate at an average rate in excess of the general inflation rate. Geothermal costs are expected to escalate due to inflationary factors, only during the early years. However, in later years geothermal costs are expected to deescalate, due to the depletion allowance.

Table 5.1

COMPARISON OF GAS VS GEOTHERMAL ENERGY COSTS
ON A DOLLAR PER MILLION BTU BASIS
(for case B/20 yr-gas)

<u>Year</u>	Before Tax Cost (\$/mmBtu)		After Tax Cost (\$/mmBtu)	
	<u>Gas</u>	<u>Geothermal</u>	<u>Gas</u>	<u>Geothermal</u>
1983	6.50	21.46	2.86	(9.44)*
1984	8.26	21.48	3.64	2.91
1985	10.52	21.55	4.63	3.17
1986	12.23	21.57	5.38	3.39
1987	14.20	21.62	6.25	3.20
1988	16.48	21.62	7.25	8.57
1989	19.11	21.62	8.41	7.91
1990	22.11	21.62	9.73	7.08
1991	24.41	21.57	10.74	6.49
1992	26.95	21.53	11.86	6.25
1993	29.72	21.43	13.08	5.99
1994	32.79	21.29	14.43	5.65
1995	36.17	21.13	15.92	5.31
1996	39.88	20.89	17.55	4.87
1997	43.97	20.59	19.35	4.42
1998	48.45	20.19	21.32	3.88
1999	53.38	19.72	23.49	3.25
2000	58.83	19.13	25.88	2.55
2001	64.79	18.40	28.51	1.72
2002	71.38	17.54	31.41	0.14

* Cash inflow

CASH FLOW ANALYSIS
GEOTHERMAL PROJECT
FRIENDSHIP DAIRIES (B-GAS, CASE 1)
(DOLLARS IN THOUSANDS¹)

YEAR	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Revenues										
Gas Savings	277.	352.	448.	521.	605.	702.	814.	942.	1040.	1148.
Total Revenues	277.	352.	448.	521.	605.	702.	814.	942.	1040.	1148.
Expenses										
Electricity	41.	44.	48.	52.	56.	60.	65.	70.	76.	82.
O&M	24.	26.	29.	32.	35.	39.	43.	47.	51.	57.
Scale Inhibitor	12.	13.	15.	16.	18.	19.	21.	23.	26.	28.
Insurance	20.	21.	22.	24.	25.	27.	28.	30.	32.	34.
Interest	612.	606.	600.	592.	583.	572.	560.	546.	530.	512.
Depreciation	291.	425.	407.	407.	407.	0.	0.	0.	0.	0.
Depletion	0.	0.	0.	0.	0.	0.	49.	113.	156.	172.
Total Expenses	1001.	1136.	1121.	1122.	1124.	717.	766.	830.	871.	885.
Pre-Tax Income	-724.	-784.	-673.	-610.	-519.	-15.	48.	112.	169.	263.
Income Tax Liability ²	-405.	-439.	-377.	-337.	-291.	-8.	27.	63.	95.	147.
Investment Credit	600.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Net Income Tax	-1005.	-439.	-377.	-337.	-291.	-8.	27.	63.	134.	147.
Net Income	281.	-345.	-296.	-273.	-228.	-7.	21.	49.	74.	116.
Plus										
Interest ³	612.	606.	600.	592.	583.	572.	560.	546.	530.	512.
Depreciation	291.	425.	407.	407.	407.	0.	0.	0.	0.	0.
Depletion	0.	0.	0.	0.	0.	0.	49.	113.	156.	172.
Less										
Additions to Working Capital	0.	1.	1.	1.	1.	1.	1.	1.	1.	1.
Net Cash Flow	1184.	685.	710.	725.	761.	564.	629.	707.	759.	799.
Construction Period Cash Flow (1/1/83 Basis)								IRR = 28.5%		
Total Investment			4,083							
Working Capital			6							
Subtotal			4,089							
Less: tax benefit of intangible drilling cost deduction (.56x2146)			1,202							
Total			2,887							
								Simple Pay-back 3.4 Years		

- Notes: 1. Numbers are rounded off to nearest thousand and totals may not add up exactly as a result.
2. Negative values indicate cash inflows and positive values indicate outflows. Computation is based on tax deductions generated by the geothermal project being applied against income generated by dairy operations.
3. Interest is added back to cash flow for IRR calculations.

FIGURE 5.1 (Cont'd)

CASH FLOW ANALYSIS
GEOTHERMAL PROJECT
FRIENDSHIP DAIRIES (B-GAS, CASE 1)

(DOLLARS IN THOUSANDS¹)

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Revenues										
Gas Savings	1266.	1397.	1541.	1699.	1873.	2064.	2274.	2506.	2760.	3041.
Total Revenues	1266.	1397.	1541.	1699.	1873.	2064.	2274.	2506.	2760.	3041.
Expenses										
Electricity	89.	96.	103.	112.	120.	130.	140.	152.	164.	177.
O&M	62.	68.	75.	83.	91.	100.	110.	121.	133.	147.
Scale Inhibitor	31.	34.	38.	41.	46.	50.	55.	61.	67.	73.
Insurance	36.	38.	40.	43.	45.	48.	51.	54.	57.	61.
Interest	491.	467.	439.	407.	370.	328.	279.	223.	159.	85.
Depreciation	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Depletion	190.	210.	231.	255.	281.	310.	341.	376.	414.	456.
Total Expenses	899.	913.	927.	941.	954.	966.	977.	987.	994.	999.
Pre-Tax Income	367.	484.	614.	758.	919.	1098.	1297.	1519.	1766.	2042.
Income Tax Liability ²	206.	271.	344.	424.	515.	615.	726.	851.	989.	1144.
Investment Credit	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Net Income Tax	206.	271.	344.	424.	515.	615.	726.	851.	989.	1144.
Net Income	161.	213.	270.	334.	404.	483.	571.	668.	777.	898.
Plus										
Interest ³	491.	467.	439.	407.	370.	328.	279.	223.	159.	85.
Depreciation	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Depletion	190.	210.	231.	255.	281.	310.	341.	376.	414.	456.
Less										
Additions to Working Capital	1.	1.	1.	1.	1.	2.	2.	2.	2.	-26.
Net Cash Flow	841.	889.	939.	995.	1054.	1119.	1189.	1265.	1348.	1465.

5-20

FIGURE 5.2
PERCENT OF TOTAL HEAT UTILIZATION
(Btu basis)

APPENDIX

- A - Resource Confirmation, SUNY-Buffalo
- B - Institutional Factors, Southern Tier
West Regional Planning and Development
Board

APPENDIX A

Resource Confirmation, SUNY-Buffalo

Submitted to: New York State Energy Research and Development Authority
Contract # 362-ET-AES-81

RESOURCE CONFIRMATION FOR RESOURCE ENGINEERING AND ECONOMIC STUDY OF
DIRECT APPLICATION OF GEOTHERMAL ENERGY, FRIENDSHIP DAIRIES

Dennis S. Hodge, Professor
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May 5, 1981

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TABLE OF CONTENTS

Section	Page
I Introduction	1
II Regional Geology	1
III Stratigraphy of the Friendship Area	3
IV Estimated Thicknesses of Rock Units at Friendship .	7
V Previous Heat Flow Studies	13
VI Temperature Gradients	16
VII Thermal Regime of Western New York	21
VIII Temperature-Depth Modelling	25
IX Temperature-Depth Calculations for the Theresa Formation in the Friendship Area	31
X Hydrology	45
XI Porosity From Sonic Logs	45
XII Porosity From Neutron Logs	48
XIII Porosity From Formation Density Logs	50
XIV Permeability Studies	54
XV Estimation of Water Level From the Surface and Drawdown	62
XVI Hydraulic Fracturing	63
XVII Potential Stratigraphic Zones for Reinjection of Geothermal Waters	67
Bibliography	71

FIGURES

Figure		Page
1	Gamma Ray Log	12
2	Cross section location map	8
3	Heat Flow in New York, Pennsylvania, West Virginia .	14
4	A.A.P.G. Geothermal Gradient map, New York	17
5	Uncorrected Geothermal Gradient map, Allegany Co. . .	19
6	Corrected Geothermal Gradient map, Allegany Co. . .	20
7	Multilayer conductive heat flow model	30
8	Plot of Flow rate vs. borehole length	58
9	Plot of Permeability vs. borehole length	59
10	Structure on top of the Oriskany	61a

TABLES

Table		Page
1	Stratigraphic column	10
2	Depth to formations at Friendship	11
3	Conductivities for Nygren Well, Jamestown	22
4	Well analysis of temperature data	25
5	Matrix Velocities	46
6	Porosity from Well 13700 (sonic)	47
7	Porosity from Well 13700 (CNL-FDC)	49
8	Matrix Densities	51
9	Porosity from Well 9235 (FDC)	52
10	Porosity from Well 6668 (Density)	53
11	Porosities by Well and Formation	55
12	Published water flow rates	56
13	Calculation of flow rates	60
14	Drawdown calculation	64
15	Wellhead fracturing pressures	65
16	Water composition analysis	70

I. Introduction

This report summarizes results on the study of "Resource Confirmation for Resource Engineering and Economic Study of Direct Application of Geothermal Energy, Friendship Dairies." The overall objective of the study is to evaluate the commercial feasibility of utilizing hydrothermal fluids directly for a site-specific industrial process heat application.

II. Regional Geology

Within the central and western portion of New York State the geologic structure is relatively simple with Cambrian through Devonian shales and limestones dipping gently to the south. The thickness of this sedimentary sequence is about 2,950 feet at the shore of Lake Ontario and thickens southward to over 10,000 feet at the Pennsylvanian border. Precambrian crystalline basement rocks underlie these Paleozoic sediments and a thin veneer of glacial debris locally covers the area; the glacial deposits reach a thickness of several hundred feet in some valleys.

The Precambrian basement of New York State is exposed in two areas, the Adirondack Mountains and Hudson Highlands. Similar Precambrian rocks are exposed directly to the north of Lake Ontario and gravity and magnetic data suggest that these rock types trend beneath the Paleozoic sedimentary rocks in the study area (Petraske, et al., 1978). The rock types that probably compose the Precambrian basement include metagabbros, meta-

anorthosite, granitic, charnockitic, and syenitic gneisses, amphibolite, and sedimentary marbles, calc-silicates, quartzite, and para-gneisses.

The sedimentary rocks were deposited in the Appalachian basin that generally persisted throughout the Paleozoic. Early Cambrian rocks are absent and Late Cambrian or Early Ordovician rocks lie unconformably on the Precambrian basement. The Late Ordovician Taconic Orogeny (435 mya) resulted in uplift of land in eastern New York while limestones that interfinger with shales and impure sandstones were deposited in western New York. Subsequent deposition in the Upper Ordovician produced thick deltaic deposits. In western New York during the Early Silurian, siltstones and sandstones were formed followed by shales and evaporites.

Subsequently, Early Devonian sandstones were deposited in the Appalachian basin in western New York followed by deposition of the Middle Devonian Onondaga Limestone. This period of deposition was terminated by uplift caused by the Acadian Orogeny (345 mya) which was centered in New England and the Canadian Maritime Provinces. Large amounts of material were eroded from the New Acadian Mountains along the Connecticut-eastern New York area and deposited as shale in a westward prograding delta, the Catskill Delta. The Tully Limestone was formed during a brief interruption in deltaic deposition. Sediment influx in the delta area resumed and these rocks have been divided into eight groups listed here from oldest to youngest: Hamilton, Genesee, Sonyea, West Falls, Java, Canadaway, Conneaut, and Conewango. The four oldest groups extend across the entire state, whereas the younger groups are missing from the Catskills region.

Early Mississippian rocks resemble the underlying Devonian sequences with deposition ending in the Middle Mississippian. Only one brief period of deposition that formed the Olean Conglomerate occurred in Early Pennsylvanian.

In the Mesozoic the dominant geological processes have been vertical uplift and erosion. During the Cenozoic Era the physiographic provinces of New York were shaped, although they have been somewhat obscured by at least four major advances of ice during the Pleistocene.

III. Stratigraphy of the Friendship Area, Allegany County, New York

The following is a general discussion of the stratigraphic rock section at Friendship, New York. The discussion will start with the surface rocks and continue with subsequently deeper and older rock units. The description is based on the projection of lithologic units from wells at nearby locations to Friendship. Because the formations commonly do not show significant changes lithologically over these distances the stratigraphic descriptions should be similar for the site.

III. A. Post-Devonian Rocks

Mississippian and Pennsylvanian rocks occur in isolated areas of Allegany County. These rocks are restricted to areas of high elevation in the southernmost part of western New York and will not be found near the Friendship site.

Pleistocene unconsolidated glacial material covers most of the area; the material is usually less than 25 feet thick but may reach up to 600

feet thick in some valleys. There may be up to several hundred feet of glacial gravels and till in the valley occupied by the Van Camden River on the Friendship property. Glacial unconsolidated deposits may require special drilling and casing techniques for proper well completion and pollution control.

III. B. Devonian Sequence

The upper Devonian rocks in the Friendship area consist of lenses of sandstones that interfinger with shales. The rocks are highly variable in composition and locally a horizon changes lithologically over distances of a mile or less. Correlations of units over a large area is difficult (Van Tyne and Foster, 1979). The break between Upper and Middle Devonian rocks in the Friendship area, however, is distinctive on gamma ray logs with a well defined kick to the right above the Tully Limestone (Figure 1*); the Tully is characterized by low radioactivity. The Tully is a dense, grey-brown limestone and is important in that the limestone is in sharp contrast with the overlying Upper Devonian shales. This contrast makes the Tully an excellent marker horizon.

Below the Tully is the Middle Devonian Hamilton Group; rocks consisting of grey and black shale units with a few interbedded thin limestones. The basal unit of the Hamilton Group is the black Marcellus Shale. The Marcellus Shale is well known as one of the most radioactive shales in western New York State. This radioactivity produces a large kick in gamma ray logs that is in extreme contrast with the low radioactivity of the underlying Onondaga Limestone (Figure 1).

*Figure 1 is a fold-out on page 12.

The Onondaga is a grey fossiliferous limestone that represents the lower part of the Middle Devonian. The Lower Devonian below the Onondaga Limestone is reworked rock material, the upper and lower surfaces of this section being disconformities or erosional surfaces that usually have some relief. This rock material is the Springvale Sandstone Member of the Bois Blanc Formation and contains sand, glauconite, phosphate nodules, and small blocks of dolomite and limestone. Underlying the Springvale is a greyish-white quartzitic sandstone, the Oriskany Sandstone. The Oriskany lies disconformably on the Helderberg Group. In gamma ray logs, the Onondaga has characteristically low radioactivity, whereas the Springvale makes a large kick to the right. The Oriskany is a zone of low radioactivity (Figure 1).

III. C. Silurian Sequence

The Upper Silurian section in the Friendship area consists of a thick sequence of shale, dolomite, salt and gypsum. The top of the Lockport Dolomite is easily picked from gamma ray logs (Figure 1). Often a black water or sulfur water is encountered when drilling into the Lockport. Beneath the Lockport is the Rochester Shale and Irondequoit Limestone of the Clinton Group. The Lower Silurian is comprised of the Sodus Shale, Reynales Limestone, and the Thorold Sandstone of the Clinton Group and the Grimsby Sandstone and Shale of the Medina Group. The Grimsby as described by Van Tyne and Foster (1979) is a series of greyish-red and pink sandstones of medium- to fine-grain interlayered with red and light-green shales. The Silurian-Ordovician boundary is easily distinguished

at the Queenston (top of the Ordovician) and marks a distinct break in lithology and in gamma ray logs (Figure 1).

III. D. Ordovician Sequence

A detailed description of the Ordovician through Precambrian lithology is available from the Bethlehem Steel test disposal well in Erie County (AIDS, 1968). Data for post-Silurian rocks within a 40-mile radius of Friendship is sparse with the Potsdam being penetrated in four wells and the Theresa being penetrated in seven wells. Only two wells have been drilled into the Ordovician in Allegany County.

The Queenston Formation as described by AIDS (1968) is greyish-red shale with interbedded siltstone and localized stringers of sandstone. The transition from Silurian to Ordovician can be recognized by the characteristic change in lithology from greyish-red and pink sandstones of the Grimsby to the red shale of the Queenston. Gamma ray logs show an overall increase in radioactivity (Figure 1).

The Oswego Formation is a medium light grey interbedded shale, siltstone, and sandstone. Color can be variable to dark grey, greyish-red, greyish green, greenish-grey, and pinkish-grey. The Oswego is difficult to identify from gamma ray logs (Figure 1).

Beneath the Oswego is the Lorraine Group, a series of alternating light to dark grey shales and siltstones. Below the Lorraine is the Utica Shale, a dark grey to brownish-black shale and siltstone. It is difficult

to pick the Utica Shale from the Lorraine Shale on gamma rays; however, the overall gamma trace has less variability in the Lorraine-Utica Shale than in the Queenston Shale and Oswego Sandstone (Figure 1).

Middle Ordovician rocks consist of the Trenton and Black River Limestones. The Trenton and Black River are a brown and grey, fossiliferous, hard limestone. These limestones have characteristically low radioactive content that is readily visible on the gamma ray log (Figure 1). The base of the Black River lies disconformably on the Lower Ordovician.

Work by Flagler (1966) indicates that Lower Ordovician Tribes Hill is very difficult to correlate in western New York State. Flagler assigned the Beekmantown Group of the Lower Ordovician to either the Black River or the Little Falls. Van Tyne and Foster (1979) identified the Beekmantown Group in Cattaraugus County (see Figure 1).

III. E. Cambrian Rocks

The Theresa Formation consists of alternating beds of sandstone and sandy dolomite with a few shale layers in the lower section. Salt water shows have been noted in the Theresa by Kreidler et al. (1972).

The Potsdam Formation is a fine- to very coarse-grained sandstone. Color of formation is primarily yellow-grey and the lithology of the units includes some dolomite and shale layers.

IV. Estimated Thickness of Rock Units at Friendship

Figure 2 shows a location map for wells that were used in making two cross sections. Plates 1 and 2 are cross sections A-A' and B-B' respectively

Figure 2. Well location map for cross sections A-A' and B-B'

and the information that was used in making these cross sections is contained in work performed by AIDS (1968), Van Tyne and Foster (1979), and Kreidler et al. (1972). Table 1 presents the geologic periods, groups, rock units, estimated thicknesses, and some notes of gas, oil, or water shows in rock units for the Friendship area.

The depth to the base of the Black River is 6950 feet in cross section B-B' and in A-A' the depth to the Black River would be 6550 feet. Most of the difference in depth can be accounted for in the Salina Group. Plates 1 and 2 illustrate the thinning of this group in a northerly and westerly direction. Plates 1 and 2 also illustrate the thickening of the Theresa-Galaway and the Potsdam in a southeasterly direction.

Because the formations dip in a southeasterly direction and because Friendship is not located on line with cross sections A-A' or B-B', depths to formations important to heat flow studies were determined from work performed in this study and work by Van Tyne and Foster (1979). Table 2 lists the formations of interest for thermal calculations with depths within an accuracy of plus or minus 100 feet.

Plate 1 Cross Section A - A'

Prepared under Contract for the New York State Energy Research Development Administration
 SUNY at Buffalo, Department of Geological Sciences
 D.S. Hodge, Principal Investigator K.G. Hilfiker, Research Associate

1981

* This location on the cross section is 10 miles Northeast of the Village of Friendship.

Plate 2 Cross Section B-B'

Prepared under Contract for the New York State Energy Research Development Administration
 SUNY at Buffalo, Department of Geological Sciences
 K.G. Hilfiker, Research Associate

TABLE 1

	PERIOD	GEOLOGIC TIME N.Y.A.	GROUP	UNITS	THICKNESS A - A'	(FEET) B - B'			
DEVONIAN	UPPER	360	CONEMANGO						
			CONNEAUT	CHADAKOIN Sh. S			oil, gas		
			CANADAWAY	PERRYBURG Sh. Ss			oil, gas		
				PERRYBURG Sh. Ss +			oil, gas		
			WEST FALLS	JAVA Rhinestreet Sh. Ss			oil, gas shows in structural highs		
				RHINESTREET					
	MIDDLE	370	SONTEA	MIDDLESEX Sh	2650	2700	gas		
			GENESSEE	Sh			gas in 3 wells (Allegheny Co.) - fault controlled		
				TULLY Ls					
			HAMILTON	MOSCOW Ludlowville Sh SKANEATELES Sh PARCELLUS Sh			gas - Moughton College 1979		
SILURIAN	LOWER	395	ONONDAGA	Ls	150	100	oil (Chautauque Co.), gas (NW Cattaraugus Co.)		
			TRISTATES	ORISKANY Ss			gas, salt-water 1930's pinchout traps		
	UPPER	423	HELDERBERG	PARLIUS Ls ROCKOFT Dol	850	1100			
				AKRON Dol			gas		
			SALINA	CATILLUS Sh. Gyp SYRACUSE Dol, Sh. Salt VERNON Sh. Salt					
			LOCKPORT	LOCKPORT Dol	200	250	black water, gas shows in other parts of NYS		
			LOWER	435	CLINTON	ROCHESTER Sh IRONDEQUOIT Ls SODUS Sh REYNOLDS Ls THOROLD Ss	200	200	
					MEDINA	GRIPSBY Sh. Ss WHIRLPOOL Ss	125	100	gas shows in Allegheny Co
ORDOVICIAN	UPPER	450		QUEENSTON Sh OSWEGO Ss	1300	1300	gas		
				LORRAINE Sh UTICA Sh	725	750			
	MIDDLE	500	TRENTON- BLACK RIVER	TRENTON Ls BLACK RIVER Ls	350	450	gas production south and west of Adirondack's, shows in southwestern NYS		
			BECKMANTOWN	TRIBES HILL - CHUCTANUNDA Ls	900				
	CAMBRIAN	UPPER	570		LITTLE FALLS Dol THERESA Dol, Ss			gas - shows in S.W. NYS, salt water	
					POTSDAM Ss, Dol			gas - shows in S.W. NYS, salt water	

PRECAMBRIAN

- Glace, Bradford 1st, Chipmunk, Bradford 2nd, Harrisburg Run, Scio, Penny, Richburg
- Bradford 3rd, Humphrey, Clarksville, Nough and Porter, Fulmer Valley

TABLE 2

Formation	Depth (feet)	Depth (meters)
Silurian*	3700	1128
Queenston*	5250	1600
Lorraine	6522	1988
Utica	7149	2179
Trenton*	7250	2210
Theresa*	8750	2667
Basement*	10000	3050

*Based on work by Van Tyne and Foster (1979)

FIGURE 1

031-009-9235

Enterprise #1

Allegany Twp.

Cattaraugus Co.

GAMMA RAY LOG

V. Previous Heat Flow Studies

The relationship between heat flow and heat production measured in igneous rocks bears a linear relationship $q = q^* + DA$ where q is heat flow, q^* is heat flow from the lower crust and mantle, A is the radioactive heat generation and D is depth parameter (Birch et al., 1968). For the eastern U.S. the D parameter has been established to be 7.5 with q^* approximately equal to $0.8 \text{ } \mu\text{cal/cm sec}$ (38 mW/m^2). This relationship suggests that the local variation in heat flow is a result of contrasts in heat production. Costain et al (1980) showed that along the Atlantic Coastal Plain higher than normal heat flow values were measured in unconsolidated sediments in areas of negative Bouguer anomalies. The source of these heat flow anomalies is thought to be radiogenic granites that occur in the crystalline basement rocks. Heat flow values may exceed 82 mW/m^2 ($\sim 2.0 \text{ HFU}$) over these radioactive granites and is considerably greater than a typical average value of $\sim 50 \text{ mW/m}^2$.

The regional heat flow map of the U.S. (Lachenbruch and Sass, 1977) indicates that the eastern U.S. has a lower average heat flow compared to the more tectonically active western U.S. The heat flow map, however, is based on only a few determinations in eastern U.S. In New York, Urban (1970) reported heat flow values of approximately 50 mW/m^2 near Buffalo and two values of 54 mW/m^2 (1.14 HFU) and 67 mW/m^2 (1.67 HFU) in the Finger Lakes region (Fig. 3). In the crystalline rocks of the Adirondacks heat flow values range from 38 mW/m^2 (0.8 HFU) to 54 mW/m^2 (1.2 HFU) with the lowest value found over anorthosite rocks. In an area of sedimentary

Figure 3 - Heat flow values (mW/m^2)

rocks in northern Pennsylvania Joyner (1960) determined near normal values of 55 mW/m^2 (1.3 HFU) and 62 mW/m^2 (1.5 HFU) heat flow. Eckstein (1980), however, reported a heat flow of 82 mW/m^2 in similar sedimentary rocks in Clarion and Venango County, Pennsylvania. Lateral variation in heat flow in New York and Pennsylvania ranges from 0.8 to 2.1 HFU and a more complete description of the regional heat flow and thermal processes within the crust is needed for a comprehensive assessment of our geothermal energy resource.

In regions of gas and oil production temperature estimates of gradients are obtained from bottom-hole and surface temperatures. The American Association of Petroleum Geologists in cooperation with the USGS published a temperature gradient map of the U.S. using about 25,000 temperature gradients; 125 sites were used to establish the gradient map in New York. Hodge et al. (1980) evaluated the temperature gradient using over 1490 sites in western and central New York. Temperature gradients, corrected for a drilling temperature disturbance, range from 24°C/km to over 38°C/km in local areas. The areas of high thermal gradients are associated with negative gravity anomalies (Hodge, et al. 1980). Temperature gradients may be strongly affected by thermal conductivity changes in the outer layer of the crust or locally by water movement. Because there seems to be a distinct correlation between thermal conductivity and stratigraphic lithology in central and western New York, Hilfiker (1981) obtained a representative vertical thermal conductivity variation and showed that a regional heat flow map could be determined from temperature gradients. Comparison of this regional heat flow map with measured heat

flow sites shows good correlation. The heat flow studies suggest that in Allegany County a heat flow value of about $60\text{--}65 \text{ mW/m}^2$ should be expected.

VI. Temperature Gradients

The temperature gradient map (figure 4) prepared by the AAPG (1976) for the geothermal survey of North America made use of bottom-hole temperature from 125 gas and oil wells in New York State. Hodge et al. (1980) reevaluated the gradients for central and western New York State using 1490 new bottom-hole temperatures. The geothermal gradients for an area surrounding Allegany County have been calculated using 146 wells and are presented in this study.

Surface temperatures for gradient calculations were estimated from mean annual temperatures recorded by NOAA at stations located throughout a 7 state area. Because the majority of wells in New York State are gas wells drilled using rotary tools and air, the results from temperatures measured immediately after cessation of drilling indicate that a correction for a thermal disturbance must be made (Hodge et al., 1980). The estimation of this correction is currently being investigated, so in the following section geothermal gradients will be calculated by 1) applying no correction for drilling disturbance giving minimum geothermal gradients from bottom-hole temperatures and 2) applying a corrective factor used by the AAPG (1971) that gives higher values for the geothermal gradients.

The lateral variation in geothermal gradients is best described by contour map presentation. An automated contouring procedure was utilized in producing geothermal gradient contour maps. This method was selected

Figure 4 - 1976 A.A.P.G. Temperature Gradient Map ($^{\circ}\text{C}/\text{Km}$) for New York State.

due to the poor distribution of data (i.e., data points tend not to be randomly located) and because of the inherent variability of the data. Using such a mapping procedure will produce a map that has been "smoothed" thus limiting the variability of extreme data points based on values of the surrounding data points.

Figure 5 is a gradient map produced using well information with depths greater than 500 meters that has not been corrected for drilling disturbances. Geothermal gradients range from $18^{\circ}\text{C}/\text{km}$ to $38^{\circ}\text{C}/\text{km}$. The previously identified geothermal anomaly (Hodge et al., 1980) at East Aurora is again shown in Erie County, New York with a high of $38^{\circ}\text{C}/\text{km}$. Allegany County and the Friendship area has little variability in geothermal gradients with the average gradient being $24^{\circ}\text{C}/\text{km}$. The correlation between the original gradient values in the data set and the smoothed values used in contouring is .75.

Figure 6 is a gradient map produced using temperature data with depths greater than 500 m that has been corrected for drilling disturbance. The minimum gradient value is $28^{\circ}\text{C}/\text{km}$ south of Buffalo to a maximum value of $46^{\circ}\text{C}/\text{km}$ at East Aurora. The area near Friendship in Allegany County still exhibits little variability with the average geothermal gradient about $32^{\circ}\text{C}/\text{km}$.

Comparison of Figures 5 and 6 illustrates that the character of the geothermal variation is similar, only the absolute values of gradients have changed. Because the correction that was applied to the data in Figure 6 was determined from well information collected in Louisiana and Texas (AAPG, 1971) that map must be interpreted as a maximum approximation for geothermal gradients.

Figure 5. Geothermal Gradient ($^{\circ}\text{C}/\text{km}$) for western New York calculated using wells with depths greater than 500 meters and using temperatures not corrected for drilling disturbance.

Figure 6. Geothermal Gradient ($^{\circ}\text{C}/\text{km}$) for western New York calculated using wells with depths greater than 500 meters and using temperatures corrected for drilling disturbances.

VII. Thermal Regime of Western New York

The study flow of heat in one dimension for an isotropic medium can be expressed (Jaeger, 1965):

$$q = K \frac{\partial T}{\partial z} \quad (1)$$

where z is measured vertically downward, T is temperature and q is the constant geothermal flux or heat flow. Conductivity (K), however, is realistically a function of z and can be estimated from the lithology of the stratigraphic section.

Conductivity values were measured for the Devonian and Silurian section in a well near Jamestown, New York (Hilfiker, 1981; see Table 3 and plot of well no. 14310). Unpublished conductivity values for the Silurian section were measured on a U.S. Gypsum well near Oakfield, New York. Since heat flow (q) is constant in a well, any change in geothermal gradient requires a proportional change in conductivity (equation 1). Equation 1 necessitates that the ratio of different gradients in a well be equal to the ratio of the rock conductivities.

There is no thermal conductivity data available for rocks older than Silurian in central and western New York State. However, work by Urban (1970) provides geothermal gradient information for Silurian through Precambrian rocks for the area near Buffalo, New York. Three deep disposal wells (Hooker Chemical Co., Niagara Falls; FMC Corp., Middleport; and Bethlehem Steel Corp., Lackawanna) that were cased and cemented remained undisturbed for approximately a year after drilling had stopped and were logged by Urban in 1969. Temperature depth plots for these three wells, the well near Jamestown, and two wells from Allegany County are included in this report. Table 4 describes the gradient intervals,

Table 3

Depth Meters	Uncorrected Conductivity W/m °C	Rock Chip Density gm/cc	Formation Density gm/cc	Porosity %	Porous Conductivity W/m °C
0	3.570	2.422		.022	3.431
12	2.517	2.711		.022	2.438
27	2.758	2.731		.022	2.666
42	2.804	2.754		.022	3.709
57	2.767	2.765		.022	2.675
73	3.018	2.781		.022	2.911
88	2.782	2.744		.022	2.689
103	3.068	2.805		.022	2.959
118	2.785	2.815		.022	2.692
134	2.805	2.454	2.580	.000	2.805
149	2.678	2.792	2.600	.069	2.416
164	3.086	2.954	2.610	.116	2.549
179	3.896	2.686	2.620	.025	3.721
195	3.596	2.724	2.610	.042	3.336
210	2.687	2.742	2.640	.037	2.541
225	2.917	2.757	2.580	.064	2.635
240	4.440	2.712	2.580	.049	4.027
256	2.738	2.749	2.600	.054	2.521
271	2.348	2.834	2.650	.065	2.148
286	2.110	2.748	2.600	.054	1.972
301	2.062	2.792	2.590	.072	1.886
316	3.492	2.799	2.600	.071	3.081
338	2.292	2.730	2.650	.029	2.204
347	2.770	2.685		.022	2.677
362	2.431	2.775		.022	2.357
377	2.469	2.787		.022	2.392
393	2.563	2.801		.022	2.481
408	2.159	2.716		.022	2.098
423	2.397	2.730		.022	2.324

Table 3 (continued)

Depth Meters	Uncorrected Conductivity W/m °C	Rock Chip Density gm/cc	Formation Density gm/cc	Porosity, %	Porous Conductivity W/m °C
438	3.268	2.938		.022	3.147
454	2.984	2.662		.022	2.880
469	2.635	2.780		.022	2.549
484	2.421	2.765		.022	2.347
499	3.044	2.744		.022	2.936
515	3.051	2.788		.022	2.942
530	3.652	3.050		.022	3.508
545	2.750	2.735		.022	2.659
560	2.628	2.768		.022	2.543
576	2.352	2.717		.022	2.281
591	2.241	2.734		.022	2.177
606	2.482	2.931		.022	2.405
621	2.533	2.742		.022	2.454
637	2.680	2.921		.022	2.592
652	2.487	2.682		.022	2.409
667	3.112	2.773		.022	3.000
682	2.816	2.805		.022	2.721
697	2.513	2.789		.022	2.434
713	2.919	2.741		.022	2.818
728	3.661	2.717		.022	3.516
743	2.710	2.789		.022	2.620
758	2.335	2.691		.022	2.266
789	2.193	2.527		.022	2.131
804	2.008	2.545		.022	1.954
819	2.023	2.457		.022	1.969
835	2.117	2.590		.022	2.059
850	2.492	2.923		.022	2.415
865	2.539	2.782		.022	2.459
880	2.382	2.761		.022	2.310
896	2.600	2.695		.022	2.516
911	2.729	2.795		.022	2.638

Table 3 (continued)

Depth Meters	Uncorrected Conductivity W/m °C	Rock Chip Density gm/cc	Formation Density gm/cc	Porosity %	Porous Conductivity W/m °C
926	2.191	2.772		.022	2.129
941	2.836	2.697	2.590	.040	2.666
957	2.357	2.666	2.640	.010	2.326
972	3.115	2.687	2.620	.025	2.990
987	3.853	2.644	2.540	.039	3.581
1002	4.301	2.647	2.600	.018	4.153
1018	4.140	2.823	2.670	.054	3.728
1033	3.967	2.852		.022	3.804
1048	3.816	2.786		.022	3.663
1063	4.241	2.998		.022	4.061
1078	4.956	2.900		.022	4.729
1094	3.644	2.680		.022	3.501
1109	4.050	2.735		.022	3.882
1124	3.246	2.606		.022	3.126
1139	3.313	2.571		.022	3.190
1155	3.368	2.712		.022	3.241
1170	3.404	2.691		.022	3.275
1185	3.400	2.694	2.830	.000	3.400
1200	3.635	2.853	2.850	.001	3.628
1216	4.266	2.914	2.790	.043	3.924
1231	4.599	2.796	2.810	.000	4.599
1246	4.718	2.746	2.770	.000	4.718
1261	5.330	2.860	2.770	.031	4.975
1277	3.543	2.781	2.730	.018	3.429
1292	3.517	2.747	2.710	.013	3.434
1307	3.337	2.840	2.800	.014	3.257
1322	5.052	2.778	2.680	.035	4.686
1339	5.410	2.922	2.650	.093	4.407
1356	4.968	2.674	2.680	.000	4.968
1370	3.557	2.716	2.730	.000	3.557
1377	2.895	2.750		.022	2.795

TABLE 4

Bethlehem Steel Corp (Well No. 6668)

Formation	Interval (m)	Gradient (°C/km)	Conductivity (W/m°C)	Heat Flow (mW/m ²)	Ratio of formation Gradients to Utica
SILURIAN	200-358	20.11 (.41)	2.40	48.22 (1.19)	.5255
QUEENSTON	358-608	22.17 (.17)	2.18	48.48 (.38)	.5793
LORRAINE	608-767	34.74 (.32)	1.51	53.04 (.45)	.9078
UTICA	767-875	38.27 (.21)	1.26	48.57 (.21)	1.0
TRENTON	875-1058	24.39 (.26)	2.01	49.51 (.49)	.6373
THERESA	1058-1103	17.72 (1.79)	3.01	57.19 (7.49)	.4630
OVERALL	200-1103	28.10 (.24)	1.79	50.17 (.10)	.7343

FMC Corporation (Well No. 6667)

Formation	Interval (m)	Gradient (°C/km)	Conductivity (W/m°C)	Heat Flow (mW/m ²)	Ratio of formation Gradients to Utica
QUEENSTON	200-352	22.93 (.33)	2.46	55.61 (.74)	.5679
LORRAINE	352-502	32.44 (.20)	1.51	48.84 (.33)	.8034
UTICA	502-561	40.38 (.26)	1.26	50.70 (.39)	1.0
TRENTON	561-750	22.78 (.13)	2.18	49.91 (.28)	.5641
THERESA	750-867	17.67 (.31)	3.18	56.45 (1.11)	.4376
OVERALL	200-867	27.88 (.28)	1.83	51.26 (.10)	.6904

TABLE 4 Cont.

Hooker Chemical Corp (Well No. 6669)

Formation	Interval (m)	Gradient ($^{\circ}\text{C}/\text{km}$)	Conductivity ($\text{W}/\text{m}^{\circ}\text{C}$)	Heat Flow (mW/m^2)	Ratio of formation Gradients to Utica
QUEENSTON	200-410	22.66 (.20)	2.15	48.81 (.42)	.5849
LORRAINE	410-578	32.28 (.11)	1.51	48.62 (.17)	.8333
UTICA	578-644	38.74 (.10)	1.26	48.89 (.15)	1.0
TRENTON	644-784	22.19 (.11)	2.18	48.45 (.26)	.5728
HERESA	784-837	17.70 (.31)	2.75	48.81	.4569
OVERALL	200-837	28.97 (.23)	1.69	48.96	.7478

Anderson 1 (Well No. 14310)

Formation	Interval (m)	Gradient ($^{\circ}\text{C}/\text{km}$)	Conductivity ($\text{W}/\text{m}^{\circ}\text{C}$)	Heat Flow (mW/m^2)	Ratio of Devonian and Silurian
DEVONIAN	600-900	26.74 (.33)	2.38	63.55 (.72)	gradi- ents
SILURIAN	900-1020	11.72 (.59)	3.71	43.51 (2.2)	conduc- tivities
SILURIAN	900-1265	16.66 (.98)	3.74	62.34 (3.95)	.4383 (.6415)
OVERALL	600-1265	20.36 (.49)	2.95	60.13 (.96)	.6230 (.6364)

Well No. 11978

Formation	Interval (m)	Gradient ($^{\circ}\text{C}/\text{km}$)	Conductivity ($\text{W}/\text{m}^{\circ}\text{C}$)	Heat Flow (mW/m^2)
DEVONIAN	780-866	25.39 (.41)	2.38	60.43 (1.92)
DEVONIAN	932-1207	34.44 (3.71)	2.38	81.97 (.47)
DEVONIAN	780-1207	28.15 (.19)	2.38	69.00 (1.01)

TABLE 4 Cont.

Well No. 8034

Formation	Interval (m)	Gradient ($^{\circ}\text{C}/\text{km}$)	Conductivity ($\text{W}/\text{m}^{\circ}\text{C}$)	Heat Flow (mW/m^2)
DEVONIAN	73-455	23.39 (.26)	2.38	55.38 (.60)
DEVONIAN	1220-1450	38.96 (.36)	2.38	93.49 (.77)
DEVONIAN	73-1450	26.11 (.12)	2.38	62.07 (.28)

Values in parenthesis are standard errors

ratio of the gradients to the Utica Formation, conductivities, and heat flow. Note that Urban assigned the Utica Formation a conductivity of 1.26 W/m °C and based the conductivity of the other intervals solely on the ratio of the gradients to the gradient of the Utica. Analysis in this study shows that Urban's estimated conductivity in the Silurian of the Bethlehem Steel well compares favorably with our measured conductivity in the Silurian at Oakfield, New York. The following section utilizes this conductivity information in estimating subsurface temperatures at Friendship, New York.

VIII. Temperature-Depth Modelling

Temperatures within a zone of geothermal potential may be dependent upon conductive heat flow, thermal conductivity and convective heat transfer. In southwestern New York the convective heat transfer in deep formations is thought to be negligible.

In this study, therefore, a generalized one-dimensional, steady-state conduction model of temperatures with depth is derived to calculate the temperatures within the Theresa and Potsdam formations. The models employ direct measurements of heat flow, temperature gradients, and thermal conductivities to a multilayer model.

The steady-state, one dimensional conductive, heat transfer equation can be expressed:

$$K \frac{d^2 T}{dz^2} = 0$$

where K is thermal conductivity, T is temperature and z is depth. The

variation of radioactive heat generation in the sedimentary layer contributes to a negligible amount of heat. The equation (2) is subject to the constraints:

$$T(z=0) = T_s$$

and

$$K_i \left. \frac{dT}{dz} \right|_{z=z_i} = Q_i \quad (3)$$

where Q_i is heat flow in the i layer. Under these conditions for constant K_i within a layer and constant K_{i+1} in the bounding layer:

$$Q_i = Q_{i+1}$$

and

$$K_i \frac{dT}{dz} = K_{i+1} \frac{dT}{dz} \quad (4)$$

specifies the boundary condition at the interface between two different thermal layers.

According to equation (3) (see fig. 7) the temperature at the bottom of a layer t_i with conductivity K_i is:

$$T_i = \frac{Q_i}{K} d_i + T_{i-1}$$

where T_{i-1} is the temperature at the top of the i layer and d_i is the thickness of the layer i . For the case where only the bottom-hole temperature (T_{BHT}) and surface temperature is known, then:

$$T_{BHT} = \frac{Q}{K_{av}} \left\{ \sum_{i=1}^{b-1} d_i + f \right\} + T_s = \frac{Q}{K_{av}} Z_{BHT} + T_s \quad (5)$$

$$Q = \frac{K_{av}}{Z_{BHT}} (T_{BHT} - T_s)$$

Figure 7. Model of multilayer conductive heat transfer. G_b is the geothermal gradient calculated from bottom-hole temperature and surface temperature. The temperature-depth profile is calculated to a depth Z_n .

where Q is the heat flow, K_{av} is the length weighed Harmonic mean thermal conductivity, T_s is the surface temperature and f is the portion of layer b between the top of the layer and the Z_{BHT} . The calculation of temperature-depth profile extended below the Z_{BHT} requires either a depth-conductivity profile or estimates of the values of thermal gradients for specific depth intervals. Estimates of temperatures can be obtained if either variable is known because heat flow is constant in a well.

Using the measured bottom-hole temperature and surface temperature and defining a depth-conductivity or gradient-depth profile the temperature at a depth is:

$$T_i = \left\{ \frac{T_{BHT} - T_s}{\sum_{i=1}^{b-1} \frac{d_i}{K_i} + \frac{f}{K_b}} \right\} \cdot \sum_{i=1}^n \frac{d_i}{K_i} + T_s \quad (6)$$

IX. Temperature-Depth Calculations For The Theresa Formation in The Friendship Area

The only equilibrium temperature gradients measured in southwestern New York are in the Anderson well (14310) near Jamestown in Chautauqua County. Geothermal gradients in the Devonian and Silurian sections are 26.77 and 16.66 °C/km respectively.

Only 2 wells (11879, 8034) have temperature-depth information available in Allegany County. The average gradient for the Devonian section in these wells is in the 26.11 - 28.15 °C/km range and compares favorably to the Devonian gradient in Jamestown.

The only known conductivity measurements for southwestern New York State are those of the Silurian and Devonian sections at the Nygren well near Jamestown. Conductivities for the Ordovician through Precambrian section have been determined by Urban (1970) for the Buffalo area. We assume that the conductivities of the Silurian and Devonian and Ordovician through Precambrian do not vary significantly from these two locations to the Friendship area.

Heat flow calculations at Jamestown give an average heat flow of 60.13 mW/m^2 ($\pm .96$). If conductivities and geothermal gradients do not vary from Jamestown to Friendship, then heat flow should also be similar; temperature gradient maps suggest this is a correct assumption. Four wells from Allegany County were selected for heat flow and temperature modelling (11762, 11978, 12927, 13242). The stratigraphic column was used for determining conductivity intervals and conductivities from the Anderson (14310) and Bethlehem Steel wells (6668) were applied to the models. The resulting heat flow values ($56.6 - 62.02 \text{ mW/m}^2$) are in good agreement with determined heat flow at Jamestown (60.13 mW/m^2). From these models, calculated temperatures at the top of the Theresa range from 71.2°C to 76.8°C . Thermal constraints for these calculations along with calculated temperature vs. depth plots are presented at the end of this section.

MEASURED TEMPERATURE-DEPTH INFORMATION
FOR WESTERN NEW YORK

TEMPERATURE-DEPTH CALCULATIONS
FOR THE TOP OF THE THERESA
AT FRIENDSHIP, NEW YORK

OUTPUT FILE = TAPE6

100% SILURIAN K FROM NYGREN K AND K FROM BUFFALO.

WELL ID	11978-NC2
SURFACE HEAT FLOW	62.02 M WATT/M**2
MANTLE HEAT FLOW	62.02 M WATT/M**2
HEAT PROD. COEF.	0. M WATT/M**3
THICKNES OF POTENTIAL HEAT PROD. ZONE	5000.0 M
MAX COMPUTATIONAL DEPTH	3050.0 M

UNIFORM DISTRIBUTION OF RADIOGENS.

SYNOPSIS

	DEPTH	GRADIENT	INTERFACE TEMP	CONDUCTIVITY
DEVONIAN	0.0	26.1	5.2	2.38
SILURIAN	1128.0	16.7	34.6	3.71
QUEENSTON	1600.0	28.5	42.5	2.18
ERRAINE	1988.0	41.1	53.5	1.51
OTICA	2179.0	49.2	61.4	1.26
TRENTON	2210.0	30.9	62.9	2.01
TERESA	2667.0	20.6	77.0	3.01
BASEMENT	3050.0	-----	84.9	1.00

AVERAGE CONDUCTIVITY (IN COVER)
AVG GRADIENT IN SEDIMENTARY COVER

2.37
26.1

NON-RAPG. POST SILURIAN K FROM NYGREN K AND K FROM BUFFALO.

HEAT FLOW MODEL PROGRAM
SUNY AT BUFFALO

OUTPUT FILE = TAPE6

POST SILURIAN K FROM NYGREN K AND K FROM BUFFALO.

WELL ID	12927-NC2
SURFACE HEAT FLOW	60.15 M WATT/M**2
MANTLE HEAT FLOW	60.15 M WATT/M**2
HEAT PROD. COEF.	0. M WATT/M**3
THICKNES OF POTENTIAL HEAT PROD. ZONE	5000.0 M
MAX COMPUTATIONAL DEPTH	3050.0 M

UNIFORM DISTRIBUTION OF RADIOGENS.

SYNOPSIS

	DEPTH	GRADIENT	INTERFACE TEMP	CONDUCTIVITY
D VONIAN	0.0	25.3	7.2	2.38
SILURIAN	1128.0	16.2	35.7	3.71
QUEENSTON	1600.0	27.6	43.4	2.18
L RRRAINE	1988.0	39.8	54.1	1.51
UTICA	2179.0	47.7	61.7	1.26
T ENTON	2210.0	29.9	63.2	2.01
THERESA	2667.0	20.0	76.8	3.01
BASEMENT	3050.0	-----	84.5	1.00

AVERAGE CONDUCTIVITY (IN COVER)
AVG GRADIENT IN SEDIMENTARY COVER

2.37
25.3

NON-AAPG. POST SILURIAN K FROM NYGREN K AND K FROM BUFFALO.

HEAT FLOW MODEL PROGRAM

SUNY AT BUFFALO

X. Hydrology

The hydrologic characteristics of the Cambrian formations are not well known for the Friendship area. Two parameters of importance in hydrologic studies are porosity, the volume of fluids held in the rock unit, and permeability, the ease with which fluids can move through the rock matrix. The following section will discuss porosity information that has been calculated from Sonic, Neutron Porosity, and Formation Density Logs and permeability data that has been evaluated for western New York State.

XI. Porosity from Sonic Logs

The Sonic Log records the variation with depth of the travel time (Δt) required for a compressional sound wave to traverse one foot of formation. The interval transit time (Δt) is the reciprocal of the velocity of the compressional wave and depends on the lithology and porosity of a given formation. Knowing the lithology of a formation makes the Sonic Log useful as a porosity log.

Wyllie et al. (1956, 1958) concluded that there is a linear relationship between porosity and transit time in consolidated formations with uniformly distributed pore space. This relationship solved for porosity (ϕ) is:

$$\phi = \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$$

where

Δt_{log} = reading on the Sonic Log ($\mu\text{sec}/\text{ft}$)

Δt_{ma} = transit time of matrix material (Table 5)

Δt_f = estimated to 189 $\mu\text{sec}/\text{ft}$ (equal to about 5300 ft/sec for fluid velocity)

Table 6 shows porosity calculations made from a Borehole Compensated Sonic Log taken from well number 13700 in Livingston County. Intervals of relatively equal transit times were selected and porosity was calculated for matrix materials of dolomite, limestone, and sandstone.

Table 5

Lithology	Matrix Velocity (ft/sec)	Matrix interval transit time ($\mu\text{sec}/\text{ft}$)
Unconsolidated Sands	18,000	55.5
Consolidated Sands	19,500	51.0
Limestone	21,000-23,000	47.5
Dolomite	23,000	43.5
Anhydrite	20,000	50.0
Salt	15,000	67.0
Iron Casing	17,500	57.0

After Schlumberger (1972a)

Table 6

Well: Wesley M. Hilts (13700)

County: Livingston

Elevation: 873 feet

Log Type: Borehole Compensated Sonic Log

Theresa Interval: 5860-6350 (TD) feet

Interval (feet)	t_{log} (μ sec)	Dolomite		Limestone	Sandstone
		Porosity(%) $t_{ma}=38.5$	Porosity(%) $t_{ma}=43.5$	Porosity(%) $t_{ma}=47.6$	Porosity(%) $t_{ma}=51.2$
5860-5900	47.0	5.6	2.4	-	-
5900-6020	50.0	7.6	4.5	1.7	-
6020-6156	45.0	4.3	1.0	-	-
6156-6180	49.0	7.0	3.8	1.0	-
6180-6210	53.0	9.6	6.5	3.8	1.3
6210-6250	57.0	12.3	9.3	6.7	4.2
6250-6350	61.0	15.0	12.0	9.5	7.1

XII. Porosity from Neutron Logs

In a Neutron Log, high-energy neutrons are emitted from a radioactive source mounted in a sonde; the neutrons collide with the nuclei of formation materials and lose some of their energy. The amount of the slowing-down of neutrons depends on the amount of hydrogen in the formation. If pore space is filled with oil or water, then the Neutron Log reflects the amount of liquid filled porosity by the capture of neutrons and thus a lower counting rate by the detector in the sonde.

Well number 13700 has a compensated Neutron Log-Formation Density Compensated (CNL-FDC). Corrections that may need to be performed on the CNL-FDC Log are for the effects of borehole and formation salinity, mud weight, mud cake thickness, standoff distance, and borehole temperature. Schlumberger (1972b) provides nomograms for the above factors with the combined correction usually being small.

Table 7 shows intervals of relatively uniform porosity determined from a CNL-FDC log for well number 13700. Neutron porosity is calculated assuming a lithology matrix of limestone. Schlumberger (1972b) provides charts to make porosity corrections for other matrix materials and Table 7 lists porosity for limestone, dolomite, and sandstone lithologies.

Table 7

Well: Wesley M. Hilts (13700)

County: Livingston

Elevation: 873 feet

Log Type: Compensated Neutron Log-Formation Density Compensated (CNL-FDC)

Theresa Interval: 5860-6350 (TD) feet

Interval (feet)	Neutron Porosity (%)	Equivalence Porosities (%)		
		Dolomite	Limestone	Sandstone
5860-5900	4	.4	4	7.9
5900-6020	2	0.0	2	5.4
6020-6156	3	0.0	3	6.6
6156-6180	3	0.0	3	6.6
6180-6210	2	0.0	2	5.4
6210-6250	3	0.0	3	6.6
6250-6350	8	2.4	8	12.0

XIII

Porosity from Formation Density Logs

In a Formation Density Log (FDC) medium energy gamma rays are emitted into a formation. These gamma rays lose some of their energy in collisions with electrons in the formation and continue on with lower energies. This interaction between gamma rays and electrons is called Compton scattering. The amount of Compton scattering is directly related to the electron density (number of electrons per cubic centimeter) of the formation. In turn, the electron density is related to formation bulk density (gms/cc) which depends on the density of the rock material, formation porosity, and the density of the pore-filling materials.

Porosity (ϕ) can be solved knowing the bulk density, ρ_b (the bulk density is taken to be the apparent density read from the log) and the density of the matrix material, ρ_{ma} . Porosity can be expressed:

$$\phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

where

ρ_f = density of formation fluid

and ρ_{ma} values for various materials are given in Table 8.

Table 9 shows intervals of relatively equal porosity for well number 9235 in Cattaraugus County. The log was run over the interval 9550-11190 feet with the density of matrix materials set to 2.68 gm/cc (that of sandstone). However, the interval 9820-10810 feet probably is dolomite

and should be calculated with a matrix density of 2.87 gm/cc. Table 9 shows porosities calculated with both sandstone and dolomite matrix densities.

Table 10 shows porosities over selected intervals in well number 6668 in Erie County. Porosities were calculated using matrix density values for sandstone, limestone and dolomite.

Table 8

Compound	Formula	Density (gm/cc)
Quartz	SiO_2	2.654
Calcite	CaCO_3	2.710
Dolomite	$\text{CaCO}_3\text{MgCO}_3$	2.870
Anhydrite	CaSO_4	2.960
Sylvite	KCl	1.984
Halite	NaCl	2.165
Gypsum	$\text{CaSO}_4\cdot 2\text{H}_2\text{O}$	2.320
Fresh Water	H_2O	1.000
Salt Water	200000ppm	1.146
Oil	$n(\text{CH}_2)$	.850

After Schlumberger (1972a)

Table 9

Well: Enterprise Transit State #1 (9235)

County: Cattaraugus

Elevation: 2278 feet

Log Type: Compensated Formation Density Log (FDC)

Theresa Interval: 9270-10610 feet

Potsdam Interval: 10610-11010 feet

Interval (feet)		ρ_b (gm/cc)	porosity (%) for $\rho_{ma}=2.68$ gm/cc	porosity (%) for $\rho_{ma}=2.87$ gm/cc
THERESA	9720- 9750	2.68	3	10.2
	9750- 9820	2.6	5	14.4
	9820- 9920	2.76	-4	5.9
	9920-10320	2.83	-6	2.1
	10320-10400	2.7	0	9.1
	10400-10610	2.8	-4	3.7
POTSDAM	10610-10850	2.75	0	6.4
	10850-10900	2.63	2	12.8
	10900-11010	2.56	8	16.6

Table 10

Well: Bethlehem Steel (6668)

County: Erie

Elevation: 586'

Log Type: Density Log

Theresa Interval: 3810-4100 feet

Potsdam Interval: 4110-4230 feet

	Interval (feet)	(gm/cc)	Sandstone Matrix porosity (%)	Limestone Matrix porosity (%)	Dolomite Matrix porosity (%)
THERESA	3810-3850	2.65	0.0	2.2	7.7
	3850-3900	2.68	--	1.1	6.6
	3900-3930	2.63	1.0	3.0	8.4
	3930-3940	2.75	--	--	4.2
	3947	2.45	7.5	9.6	14.6
	3950-4020	2.7	--	0.0	5.9
	4020-4030	2.5	5.7	7.8	12.9
	4030-4090	2.7	--	0.0	5.9
	4090-4110	2.6	1.9	4.1	9.4
POTSDAM	4110-4190	2.45	7.5	9.6	14.6
	4190-4230	2.5	5.7	7.8	12.9

Examination of tables 6, 7, and 9 shows that the porosity of the upper 200 feet of the Theresa consistently has higher porosities than other intervals of the formation. The upper 200 feet of the Theresa is called the Rose Run sandstone by Kreidler (1975) and was reported in the D.A. Wolfer #1 well (4248) in Allegany County to be a clean sand.*

A formation may have high porosity (a large amount of intergranular space) but low permeability (no communication between void spaces) and thus be a poor aquifer. The following section deals with permeability of the Cambrian rocks.

XIV. Permeability Studies

Permeability information of the Cambrian rocks has been investigated by AIDS (1968), Kreidler (1975), and Waller et al (1978).

Kreidler (1975) evaluated permeability of formations by shows of connate water. Table 12 lists wells with shows of connate water and amount of water reported for central and western New York. Of particular interest is the Tyler well (no. 4593) where 25 gal/minute is reported. The Tyler well is approximately 60 miles north of Friendship. The Veith well (no. 4092) is about 30 miles north of Friendship and has reports of 2 gal/minute flow from the Galway and 4 gal/minute from the Potsdam.

A study by Willette (1979) shows the potentiometric surface of deep aquifers should lie at about ground elevation near Friendship, however, the information is gathered from highly variable drill stem test data on only 14 wells. Table 12 does show that waters from the Slayton 2 well

*Table 11 summarizes the porosity information obtained from the 3 wells used in this study.

TABLE 11

Hilts Well (#13700)			Transit Well (#9235)		Bethlehem Steel (#6668)		
Interval (feet)	Porosity(%) From: Sonic Neutron		Interval (feet)	Porosity(%) from FDC Log	Interval (feet)	Porosity(%) from Density Log	Porosity(%) from AIDS 1968
Rose Run (Sandstone)			Rose Run (Sandstone)		Theresa (Dolomite)		
5860-5900	0.0	7.9	9720-9750	3.0	3810-3850	7.7	5.2
5900-6020	0.0	5.4	9750-9820	5.0	3850-3900	6.6	---
					3900-3930	8.4	6.0
Theresa (Dolomite)					3930-3940	4.2	4.0
6020-6156	4.3	0.0	9820-9920	5.9	3947	14.6	4.6
6156-6180	7.0	0.0	9920-10320	2.1	3950-4020	5.9	3.7
6180-6210	9.6	0.0	10320-10400	9.1	4020-4030	12.9	---
6210-6250	12.3	0.0	10400-10610	3.7	4030-4090	5.9	5.2
6250-6350	15.0	2.4			4090-4110	9.4	6.3
			Potsdam (Sandstone)		Potsdam (Sandstone)		
			10610-10850	0.0	4110-4190	7.5	))) 8.6
			10850-10900	2.0			
			10900-11010	8.0	4190-4230	5.7	

TABLE 12

Well No.	Name	County	Flow Rates (gal/min)	
			Galway	Potsdam
615	Wilson	Wyoming	30	
4092	Veith	Wyoming	115	200
4552	McClury	Livingston	425	
4593	Tyler	Genesee	1488	
3924	Olin	Steuben	5	
3973	Shepard	Tompkins	510	
1003	Slayton 2	Cayuga	Rose to surface	

after Kreidler (1975)

in Cayuga County rose to the surface, but prediction of water level at Friendship would be highly speculative.

The best documentation of Cambrian hydrology comes from Waller et al (1978) and AIDS (1968). After performing a 400 gallon/minute pump test on 527 feet of open hole at Bethlehem Steel Corp. in Lackawanna, New York, the permeability of the Cambrian test formations was determined to be 190 gallons per day per square foot of formation. For a 8 inch diameter hole with 527 feet of exposed surface, the flow rate would be 146 gallon/minute (see Table 13 for calculations). Calculations for another deep test well in Middleport, New York (FMC Corp.) gives a flow rate of 37 gallons/minute (Table 13). Waller et al (1978) reports an unstimulated yield of 2 gallons/minute in 207 feet of open hole in the Cambrian at the Hooker Chemical test well in Niagara Falls.

Although flow rates are highly variable, the data is encouraging. Information available from Kreidler (1975) and Waller et al (1978) shows unstimulated flow rates as high as 30 gallons/minute and upto 146 gallons/minute after hydrofracing (the only available determination of stimulated flow in New York State).

Parameters for flow rates have been plotted on figures 8 and 9. Figure 8 shows flow rate vs. thickness of an 8 inch diameter hole and lines have been plotted for various permeabilities. Figure 9 is a plot of permeability versus length of an 8 inch diameter open borehole with lines of equal flow rates drawn. Notice on Figure 9 that for high

TABLE 13

$$Q = K \times A$$

where Q is flow rate, K is the hydraulic conductivity, and A is the area of the exposed formation.

$$A = 2\pi (\text{radius of borehole}) \times (\text{length of exposed aquifer})$$

$$A = 2\pi (4/12 \text{ feet}) \times (527 \text{ feet})$$

$$A = 1104 \text{ sq. ft.}$$

$$K = 190 \text{ gallons per day per sq. ft.}$$

$$Q = 1104 \times 190 = 209760 \text{ gallons/day} = 146 \text{ gallons/minute}$$

Hooker Chemical (Well #6669)

$$Q = K \times A \qquad A = 2\pi (4/12 \text{ ft}) (207 \text{ ft})$$

$$Q = 122 \text{ gpd/ft}^2 \times 434 \text{ ft}^2$$

$$Q = 52948 \text{ gallons/day} = 37 \text{ gallons/minute}$$

permeabilities, smaller changes in well length in the aquifer are required to increase flow rates. However, if permeability is low, then considerable increases in the well length in the aquifer are required to increase flow rates.

Increased flow rates could be encountered from enhanced permeability and porosity resulting from fractures in the Cambrian rocks. Van Tyne and Wickerham (1981) and Isachsen and McKendree (1977) report on linears observed from satellite imagery. These fractures may be valleys, lakes, or ridges that seem to align on photos and may result from the influence of joints and faults on surficial features. The presence of a linear feature such as the Van Camden River at Friendship does not necessarily indicate deep fracturing and probably is the result of joint control. Engelder and Engelder (1977) and Engelder (1979) describe the strain of the upper Devonian in western New York and shear as a result of strain may increase the permeability and porosity at Friendship.

Work by Van Tyne (1975) delineates the Clarendon-Linden fault zone north of Allegany County, New York. Van Tyne (1975) did not note faulting in the Friendship area, however, faulting in the lower Paleozoic may have occurred and may not be observed in the gas well information due to absorption of fault movement in the more ductile Queenston Formation. Should the fracturing by the Clarendon-Linden fault extend into the Theresa formation at Friendship, then permeability and porosity may be enhanced.

Work by VanTyne and Foster (1979) shows some structure in Devonian rocks for Allegany and Cattaraugus Counties (Figure 10), however these structures are the result of flow in the Silurian Salt section and are not found at greater depths.

Figure 10. Structure on top of the Oriskany

In the Bethlehem Steel well at Lackawanna, flow rates from the Theresa and Potsdam are calculated to be 146 gallons per minute. Because of the tectonic setting at the Friendship site, it is assumed that the flow rate at Friendship may be similar to that at the Bethlehem Steel Well. There is no direct evidence to verify this observation. Other factors that may give higher flow rates at Friendship are 1) Friendship's location south of the Clarendon-Linden structure and the possibility of fault induced permeability and porosity and 2) the presence of a 200 foot thick porous sandstone unit above the Theresa at Friendship that is not present in the Bethlehem Steel Well. These two factors may make flow rates more favorable than the flow rates calculated at Lackawanna.

XV. Estimation of Water Level from the Surface and Drawdown

Data from Waller et al (1978) and Kreidler (1975) indicates that Cambrian wells within a 40 mile radius of Friendship have water that rose from the Theresa to at closest, 1540 feet from ground level and in the Transit Well near the Pennsylvania border in Cattaraugus County, water from the Theresa rose only to 9200 feet below the ground level. There are no reports of water levels from Cambrian boreholes closer than 25 miles to Friendship and estimations of water level would be highly speculative. Other hydrologic calculations in this report are based on the Bethlehem Steel well and a best estimate of water level at Friendship using the Bethlehem information would be a level at a depth no greater than 500 feet from ground level.

The expected drawdown or lowering of the water level during pumping has been calculated in Table 14 using equations from Heath and Trainer (1968). The drawdown would be about 9 feet based on permeability information from the Bethlehem Steel well.

XVI. Hydraulic Fracturing

The pressure of injected fluid required to induce hydraulic fracturing at the depths of the target formations at Friendship have been calculated in Table 11. The required injection pressure depends on the characteristics of the rock material and on the state of underground stress which in turn depends on the tectonic environment of the area. Fractures should form perpendicular to the axis of least principal stress (Hubbert and Willis, 1972) and Waller et al (1978) considers western New York to be a tectonically relaxed state so that induced fractures should be nearly vertical. Because the stress in the area is assumed to be in a relaxed state, injection pressures less than overburden pressures (pressure exerted by the overlying rocks) should induce fractures. The required well head pressure at Friendship should be less than 2621 psi (Table 15).

Davis and De Wiest (1966) state that well stimulation commonly improves the specific capacities of wells by 20 to 800 per cent. Less than 10 percent of stimulation attempts fail to improve well characteristics. Acid treatment, shooting explosives, and hydrofracturing are methods to be considered for well stimulation at Friendship.

TABLE 14

Drawdown calculation

after Heath and Trainer (1968)

$$\text{drawdown} = h_2 - h_1 = \frac{Q}{2\pi bk} (\ln r_2 - \ln r_1)$$

$$h_2 - h_1 = C \ln \frac{r_2}{r_1}$$

$$C = \frac{400 \text{ gal/min} \times 60 \text{ min/hour} \times 24 \text{ hours/day}}{2\pi \times 527 \text{ ft} \times (190 \text{ gal/day/ft}^2)}$$

$$C = .9155$$

$$\text{for } r_1 = 4/12 \text{ ft and } r_2 = 10560 \text{ ft}$$

then

$$h_2 - h_1 = .9155 (\ln \frac{10560}{4/12})$$

$$h_2 - h_1 = 9.5 \text{ ft}$$

TABLE 15

Required Wellhead Pressures to Initiate Fracturing

$$\text{WHP} = P_i - \left[d \times \frac{\partial P}{\partial z} \right]$$

WHP = required wellhead pressure to fracture rocks

P_i = minimum fracture pressure

d = depth to aquifer (8750 ft)

$\frac{\partial P}{\partial z}$ = pressure gradient of fluid injected (.4331 lbs/in²/ft for water)

$$P_i = P + \sigma_a$$

P = pressure exerted by a column of fluid

σ_a = effective horizontal earth stress

$$P = t \times \frac{\partial P}{\partial z}$$

t = thickness of static water level in well (8250 ft)

$\frac{\partial P}{\partial z}$ = pressure gradient of natural brine (.514 lbs/in²/ft)

$$\sigma_a = (S_z - P)/3$$

S_z = total vertical stress exerted by overburden

$$S_z = t \times \frac{\partial P}{\partial z}$$

t = thickness of rock overburden (8750 ft)

$\frac{\partial P}{\partial z}$ = pressure gradient of rock (1.17 lbs/in²/ft)

TABLE 15 CONT'D

$$S_z = 8750 \text{ ft} \times 1.17 \text{ lbs/in}^2/\text{ft}$$

$$S_z = 10238 \text{ lbs/in}^2$$

$$P = 8250 \text{ ft} \times .514 \text{ lbs/in}^2/\text{ft}$$

$$P = 4241 \text{ lbs/in}^2$$

$$\sigma_a = (10238 - 4241)/3$$

$$\sigma_a = 2000 \text{ lbs/in}^2$$

$$P_i = 4241 + 2000$$

$$P_i = 6241 \text{ lbs/in}^2$$

$$\text{WHP} = 6241 - [8750 \text{ ft} \times .4331 \text{ lbs/in}^2/\text{ft}]$$

$$\text{WHP} = 2451 \text{ lbs/in}^2$$

<u>Water depth from surface (ft)</u>	<u>WHP (lbs/in²)</u>
0	2621
500	2451
1000	2279
1500	2107
2000	1936

XVII. Potential Stratigraphic Zones for Reinjection of Geothermal Waters

The disposal of the geothermal waters after heat exchange at the plant site must consider the compatibility of the underground geothermal liquid with 1) fresh-water aquifers, 2) subsurface natural resources, 3) existing oil and gas wells and 4) risks of induced seismic activity. In addition, the rocks in the disposal zone should have 1) proper impermeable beds above and below 2) adequate porosity and permeability, and 3) sufficient pore volume to accept the waste fluid.

The potential zones for disposal at Friendship are the 1) Cambrian Theresa Formation, 2) Lockport and 3) Onondaga. These zones are all below the impermeable Devonian shale that are at least 3000' thick and mixing of fresh-water groundwater with disposal geothermal water is highly unlikely. The Lockport and Onondaga formations are composed of limestones and dolomites which display fracture permeability in many sites in western New York. It must be noted, however, that if the fracture permeability is absent in these rocks, the formations likely would not be able to accept the geothermal disposal discharge at a satisfactory rate of flow. The Cambrian Theresa should be able to accept the volume and rate of flow of the geothermal fluids.

In the Friendship area old oil and gas wells may have penetrated through the Onondaga and Lockport Formations. A thorough check of existing and plugged wells is necessary to determine if leakage of geothermal fluids could migrate up to fresh-water aquifers through old wells. To our knowledge no old oil and gas drilling penetrated to the Theresa in the Friendship region.

Assuming adequate permeability in these formations there should be adequate volume to accept the disposal of geothermal waters. The Friendship area has not suffered earthquake activity in recorded history, so that induced seismic activity is not likely unless reinjection well head pressures exceed the fracturing strength of the rocks.

TABLE 16

ANALYSIS OF WATER FROM CAMBRIAN FORMATIONS
FOR CANADA, NEW YORK, AND OHIO

WATER ANALYSIS FROM SUBTRENTON ROCKS (VALUES IN GRAMS/LITER)

SOURCES: WALLER ET AL (1968) AND LAMBORN (1952)

Well No.	Cl	Br	I	SO ₄	CO ₃	HCO ₃	SiO ₂	Na	K	Ca	Mg	(AlFe) ₂ O ₃	SrO	Ba	Mn	Total Dissolved Solids ppm
Ohio																
271	62.7	.05	.01	.05	---	.17	----	19.29	.93	14.56	2.18	.04	.01	--	.01	302090
257	61.582	.2809	.0037					29.274	1.137	6.201	1.52					161259
252	61.971	.3343	.0038					25.862	.835	9.067	1.770					389417
251	61.547	.3883	.0029					27.747	.708	8.233	1.134					370048
250	61.576	.2584	.0045					29.247	1.321	5.987	1.606					87430
248	61.605	.3828	.0003					27.385	.842	8.656	1.128					181000
236	62.595	.6023	.0057					20.206	1.289	12.521	2.78					227786
235	62.532	.5504	.0063					23.057	1.152	9.733	2.969					204739
234	62.31	.5364	.0047					23.471	1.117	10.058	2.502					187716
233	62.437	.5783	.0054					21.382	1.283	11.724	2.59					220789
224	62.427	.5137	-----					23.329	1.22	9.716	2.794					159017
62	61.86	.38		.7	.03	.07	.04	26.59	.55	6.15	3.29	.06				71500
63	61.96	.33		.27	NONE	.01	.02	21.97	.83	12.24	1.83	.04				180000
New York																
67	156.6			.003			-----			29.55	3.88				---	250550
94ET	200.0			----		.307	.028	78.0	8.0	36.0	5.1				.0002	335000
101	192.3			.057		.0145	.0019	84.2	3.03	30.827	4.64					321722
103	118.0			.136		.02		69.96		27.6	.1					213000
104	61.82			.5		0	.0093	9.84	.892	72.49	14.486					270450
Canada																
7S	164.24			15.13				102.2		71.64	.0007					261300
8	154.447															247800
9H	22.6			.412		.037		10.2		3.32						40900

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APPENDIX B

B - Institutional Factors, Southern Tier
West Regional Planning and Development
Board

INSTITUTIONAL FACTORS PERTAINING
TO
GEOTHERMAL WELL DRILLING

SUMMARY

PREPARED BY

SOUTHERN TIER WEST REGIONAL
PLANNING AND DEVELOPMENT BOARD

DATE

MAY 15, 1981

INSTITUTIONAL FACTORS

- I. Drilling Regulations
 - II. Assessment
 - III. Local Opinions and Questions
 - IV. Environmental Concerns
 - V. Funding Sources
 - VI. Archeological and Historic Sites
 - VII. Community Socio-Economic Factors
- Appendices (Permit Application Forms)

I. DRILLING REGULATIONS

There are currently no specific New York State regulations pertaining to geothermal drilling according to the Department of Environmental Conservation (DEC). In the absence of such regulations, DEC officials have indicated that existing gas well drilling regulations are to be used as an alternative. These regulations are found in the DEC publication entitled "Rules and Regulations for Mineral Resources" (Parts 550-558, June 1975). Key regulatory provisions are outlined below.

Permit Application Procedure

All drilling related application materials are to be submitted to Mr. Robert Chase, Regional Supervisor, Region 9 Bureau of Mineral Resources, New York State Department of Environmental Conservation, 128 South Street, Olean, New York 14760. Telephone (716) 372-5636. Four forms need to be submitted as part of the permit procedure:

A. Notice of Intention

1. "Notice of Intention or Application For Permit to Drill, Deepen, Plug Back or Convert" filed in triplicate.
2. Acknowledgment of receipt of the notice of intention will be provided to the owner or operator of the well(s) by DEC.
3. During the period while drilling operations are in progress, the DEC acknowledgment must be posted in a prominent place at the well site.
4. A separate notice is to be filed for each hole to be drilled.

B. Permit

1. Well Drilling Permit filed in triplicate, each accompanied by a neat, legible plat certified as to correctness by a licensed surveyor or civil engineer.
2. Application accompanied by a fee of \$20.00, check or money order payable to Bureau of Mineral Resources.
3. Actual permit (OG9) must be displayed at drill site.
4. Plat must contain the following information:
 - a. Boundaries of the lease or units
 - b. Distance in feet from the well to the two nearest boundaries
 - c. Distance in feet to the nearest well completed in the objective pool, if within one mile

- d. Latitude and longitude of the well and scaled distance in feet in east-west and north-south directions from nearest corner of U.S.G.S. topographical map
5. Permits good for 180 days
6. New permit not required for location moved less than 75 feet
7. Spacing requirements:
 - a. Well to be located not less than 660 feet from any boundary line of lease or unit
 - b. Well to be no closer than 1,320 feet from any other producing well completed in the same pool or being drilled in the same pool
8. Surface requirements - well to be located no closer than:
 - a. 100 feet from inhabited dwelling without written consent of owner
 - b. 150 feet from any public building, factory, etc
 - c. 75 feet from public road
 - d. 50 feet from any public stream
9. A separate permit application is to be filed for each hole to be drilled.
- C. Organizational Report
 1. "Organizational Report" to be filed in duplicate.
 2. Updated copies of this report to be submitted immediately after any change occurs as to the facts stated in the most recent report.
- D. Individual Well Plugging and Surface Restoration Bond
 1. "Individual Well Plugging and Surface Restoration Bond" filed in duplicate.
 2. For each well to be drilled, a good and sufficient bond in the amount of \$2000 shall be required.
 3. Each bond shall be by a corporate surety authorized to do business in the State of New York. Each bond shall be in favor of the New York State DEC utilizing the appropriate form(s). It will remain in force and effect until the plugging of the applicable well or wells and surface restoration work is complete and approved by the department, or the bond is released by the department or cancelled by the surety.

Issuance of Permit

Upon receipt and review of the various application materials,

1. The DEC Regional Supervisor (Olean Office) will make recommendations to the Buffalo DEC Office.
2. Upon determination that the application is in order and that the appropriate plugging bond is in force, the department shall issue as expeditiously as possible a permit to the owner or operator of the proposed well(s).
3. During the period while operations are in progress, the permit must be posted in a prominent place at the well site so as to be clearly visible and legible at all times.
4. If the operations for which the permit is granted have not commenced and been pursued in a diligent manner within 180 days from the date of issuance of the permit, said permit shall expire.

II. ASSESSMENT

The purpose of this section is to raise a number of issues relative to a geothermal drilling/heat transfer project. Further study and potential legal or legislative action may be necessary to clarify these issues.

New York State Real Property Tax Law, Section 102, Subpart 12, paragraph A provide localities with the authorization to assess, for taxing purposes, "the land itself, above and under water, including trees and undergrowth thereon and mines, minerals, quarries and fossils in and under the same, except mines belonging to the state". Currently in New York State there are no assessment precedents in regard to geothermal wells. It has been stated that a geothermal well could be treated in much the same manner as gas and oil wells. In the Southern Tier, as in other areas of the State, a number of methods are utilized to assess gas and oil wells. Taxation of wells is left up to the individual towns. Wells can be taxed at a fixed rate for producing wells or they can be taxed on the basis of well depth and production. In the case where the gas is consumed on site, some assessors have determined that the well is not taxable, only the value added to the property as a result of the producing well is taxable. Since there has been little drilling activity in the Town of Friendship local experience or precedent does not exist to guide assessment decisions. The Town Assessor has indicated a willingness to be flexible in the matter and rely on the advice of the N.Y.S. Department of Taxation and Finance. In any event the larger issue that may have to be resolved is whether geothermal water is taxable. Water wells in this State have not been taxed and in the opinion of some property tax experts the New York State Real Property Tax Law currently precludes taxation of water wells, regardless of their purpose.

Assessment and taxation of the heat transfer facility is another issue. Section 102, Subpart 12, paragraph f clearly includes this type of facility and equipment as taxable within State law.

III. Local Opinions and Questions

Unlike other portions of the Southern Tier West Region (Allegany, Cattaraugus, and Chautauqua Counties) there has been very little oil and gas drilling activity in the Town of Friendship. The Inventory and Analysis of Oil and Gas Resources in Allegany and Cattaraugus Counties, New York prepared by the New York State Geological Survey Office indicates that only two gas wells have been located in that Town. In that the New York State Department of Environmental Conservation and the Town do not have any records of these wells it has been assumed that the wells were drilled prior to 1930. The lack of drilling activity may have a positive affect on community acceptance of a geothermal facility at Friendship Dairies, Inc. Based on an informal survey of officials of the Town the Dairy is an asset to the Town and there is general support for activities that would enhance the business stability of the firm. While one official voiced some concern about the possible effect of drilling on the water levels of nearby Town wells, there was little concerns for other environmental issues. One official stated, "we are a progressive little town and anything that helps business will help our Town". This official further indicated that in a recent county-wide referendum on a proposal to drill a gas well at a public facility in the County, Friendship had a larger proportional voter turn-out than larger communities in the County and while the referendum was approved county-wide, the margin of acceptance in Friendship was significantly higher than the county-wide vote.

While the above is not meant to conclusively indicate community acceptance of a geothermal drilling and heat recovery project in Friendship, it does suggest a positive attitude. It can be expected that the positive attitude will continue barring significant environmental hazards identified during the drilling process. The community concerns should be addressed as they arise. Perhaps a community information program should be instituted when the project is implemented.

IV. Environmental Concerns

While environmental issue will no doubt be received as part of the DEC Permit Application Process, two questions appear to be of special environmental concern:

1. The impact of geothermal drilling, extraction and injection operations on aquifers. Impact is dependent on a number of factors including: (a) permeability of rock formations, (b) mining technology, (c) "position" of aquifers in relation to geothermal reservoirs; and, (d) depth of the geothermal reservoir. Water loss through permeation in the geothermal reservoir formation may be a strong economic factor, particularly in arid regions and/or in those communities that are especially dependent upon growing water systems.
2. Disposal of effluent. If water chemistry problems such as corosin or scaling exist, some treatment may be required and solid effluents (removed deposits) may result. According to NYS/DEC officials, moreover, there currently is "no approved way of getting rid of salt" which may accumulate in this fashion.

Recent research indicates that the "best method of treating used geothermal water" may be the use of man-made wetlands containing selected aquatic plants. Such plants "grow rapidly and rid the water of harmful chemicals."

(Land Use Planning Report, 3/30/81 p. 104).

V. Funding Sources

Federal, State and local government agencies offer a number of financial incentive programs of possible relevance to this project. It should be noted, however, that this program portfolio is in a state of flux given the proposed budget cuts of the current national administration.

- U.S. Department of Energy Geothermal Loan Guarantees for Small Business or Other Qualified Borrowers.

Objectives: (1) to encourage and assist the private and public sectors to accelerate development of geothermal resources with environmentally acceptable processes by minimizing a lender's financial risk on loans to carry out a geothermal project; and (2) to develop normal borrower-lender relationships which will in time encourage the flow of credit so as to assist in the development of geothermal resources without the need for federal guarantees.

- NYS Energy Research and Development Authority Revenue Bonds.

Objectives: Financing the costs of acquisition, construction, or conversion of facilities that generate fuel from renewable and indigenous energy resources including extraction of heat from geothermal resources. Qualified projects financed through tax-exempt revenue bonds.

- Industrial Development Agencies.

Objectives: To finance business and industrial projects through the sale of tax-exempt revenue bonds. Program uses include facility construction and property acquisition. (Note: Allegany County is served by the Allegany County Industrial Development Agency).

- Southern Tier West Energy Enterprise Revolving Loan Fund.

Objectives: Low interest loans (maximum \$50,000) to area industries for use in making energy related improvements. Eligible activities could include installation of innovative energy related capital improvements.

- New York State Job Development Authority

Objectives: To provide loans for industrial development resulting in job creation. Eligible costs include real estate and machinery/equipment. Loans for real estate cannot exceed 40% of the total project costs, and commitments for the remaining cost must be demonstrated. JDA's 40% is secured by a second mortgage behind an institutional first mortgage of 50%. The typical financing package includes a 50% loan from an institutional lender, a 40% loan from JDA, and a 10% equity investment by the borrower. Loans for machinery and equipment follow the same ratio but the JDA loan is on an equal lien basis with that of the institutional lender.

- New York State Job Incentive Program

Objectives: To stimulate economic development by providing corporate franchise tax and real property tax exemptions. State enabling legislation allows local taxing authorities to enact legislation to exempt all or part of the local tax levies on depreciable real property for up to ten years. Thus, the amount of exemptions allowed and the time such exemption will be effective vary according to locale.

- New York State Investment Tax Credit

Objectives: To provide an incentive for the purchase or improvement of a manufacturing facility. Tax credits of 4% are allowed with respect to qualified tangible personal property and other tangible property, including buildings and structural components of buildings that were acquired, constructed, reconstructed or erected after December 31, 1978. Such property must have a useful life of at least four years and must be principally used in the production of goods by manufacturing, processing, assembling, etc.

Investment tax credits are also available for increased manufacturing employment which results from the acquisition, construction, reconstruction or erection of real property as specified above.

- New York State Business Investment Exemption

Objectives: To encourage business development by providing a real property tax exemption for the improvement of real property for commercial and industrial use. Facilities may be eligible if they were constructed after January 1, 1976 at a cost of more than \$10,000. Exemptions apply to new or improved real property used primarily for manufacturing, assembly, or processing. If eligible for this graduated exemption, firms may be exempt from paying a percentage of the increase in real property taxes each year for ten years. (Exemption ceases in the event the property ceases to be used for eligible purposes.)

VI. ARCHEOLOGICAL AND HISTORIC SITES

Most of the lake plains and major stream valleys in the three county area are known to have hosted human habitation, probably as long ago as 8,000 to 10,000 years ago. In Allegany County known archeological concentrations have been identified along the Genessee River, from Caneadea north to the county line; in and around the Village of Belmont and along Angelica Creek and Van Campen Creek. The area around Van Campen Creek, which bisects the project site, is considered to be a secondary archeological zone indicating the likelihood of pre-historic habitation, but where little or no archeological work has been done. In some instances these sites contain a few scattered sites that are widely separated. (See attached Archeological Sites Map, prepared by the Southern Tier West Regional Planning and Development Board.)

VII. Community Socio-Economic Factors

A. Economy Factors

The major economic center of Allegany County is Wellsville. The two major manufacturing firms in that community-Air Preheater Corporation and Turbodyne-employ approximately 2,600 persons, or nearly 60% of the county's manufacturing work force. The village is the retail and wholesale hub of the county, accounting for nearly 70% of wholesale sales. In addition, the village accounts for approximately one-third of selected service receipts in Allegany County.

Other economic centers of note include: Cuba, Friendship, and the Village/Town of Alfred. In addition to serving as a "bedroom community" to Olean (Cattaraugus County), Cuba has traditionally served as a major agricultural trading center in the Southern Tier. Cuba Cheese and Trading Company, Inc. employing some 130 persons, is one of the foremost food processors in the region. Cuba is also the location of Acme Electric Corp.-employing approximately 1,200 persons. The Hamlet of Friendship (Town of Friendship) is the location of Friendship Dairies - a major producer of cottage cheese. Friendship Dairies employees approximately 140 persons. Finally, the Village and Town of Alfred is the location of two institutions of higher learning having a combined enrollment of approximately 7,000.

Allegany County's economy is best characterized by its rural agricultural base. It is not likely that significant changes in this orientation will occur in the foreseeable future.

1980 Employment/unemployment data for Allegany County is shown on the following page.

EMPLOYMENT - UNEMPLOYMENT STATISTICS

1980

JAN. FEB. MARCH APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

ALLEGANY COUNTY

Total Employment	18,800	19,400	19,200	19,300	19,071	19,079	19,200	19,100	19,400	19,900	20,100	20,062
Total Unemployment	2,000	1,900	1,700	1,811	1,712	1,725	1,600	1,500	1,400	1,700	1,800	1,876
Unemployment Rate	9.7	9.0	8.1	8.6	8.2	8.3	7.7	7.4	6.5	7.7	8.0	8.6

CATTARAUGUS COUNTY

Total Employment	34,400	34,500	34,100	33,400	34,000	33,900	35,000	35,200	34,300	34,500	34,500	34,100
Total Unemployment	4,100	4,000	3,500	3,800	3,200	3,600	3,800	3,600	3,200	3,800	3,900	3,700
Unemployment Rate	10.6	10.3	9.2	10.1	8.7	9.6	9.7	9.2	8.5	9.9	10.3	9.8

CHAUTAUQUA COUNTY

Total Employment	64,500	63,900	64,100	62,700	64,500	65,600	66,400	66,900	65,000	65,300	64,900	63,800
Total Unemployment	6,200	5,500	4,600	5,000	5,900	5,300	5,500	5,200	4,400	5,300	5,400	5,500
Unemployment Rate	8.8	7.9	6.8	7.4	8.4	7.5	7.7	7.2	6.4	7.6	7.7	7.9

SOUTHERN TIER WEST

Total Employment	117,700	117,800	117,400	115,400	117,571	118,579	120,600	121,200	118,700	119,700	119,500	117,962
Total Unemployment	12,300	11,400	9,800	10,611	10,812	10,625	10,900	10,300	9,000	10,800	11,100	11,076
Unemployment Rate	9.7	9.1	8.0	8.7	8.4	8.5	8.4	7.9	7.1	8.4	8.7	8.8

B. Sociological Factors

COUNTY Allegany

MUNICIPALITY Friendship Town (Inc. Former Village)

DATE May, 1981

1980 Population 2164 SOURCE Final 1980 Census, 4/01/81

1970 Population 2106 SOURCE 1970 Census - 4th Count

Number of Housing Units 727 SOURCE 1970 Census - 4th Count
(1970)

	<u>Number</u>	<u>Percent</u>
OWNER OCCUPIED HOUSING UNITS	494	68
RENTAL OCCUPIED HOUSING UNITS	131	18
VACANT HOUSING UNITS	69	10
VACANT OWNER UNITS	14	20
VACANT RENTAL UNITS	23	33
OTHER VACANT UNITS	32	46
SUB-STANDARD HOUSING UNITS	31	4
SUB-STANDARD UNITS - OWNER	7	23
SUB-STANDARD UNITS - RENTAL	9	29
FEMALE HEAD OF HOUSEHOLDS	46	6.9
ELDERLY HEAD OF HOUSEHOLDS	85	12.9
MINORITY HEAD OF HOUSEHOLDS	13	2

Population Projection (1980) 2,300

Household Size Projection (1980) 3.22

Source: Southern Tier West, Areawide Housing Opportunity Plan, 1981

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
BUREAU OF MINERAL RESOURCES

NOTICE OF INTENTION OR APPLICATION FOR PERMIT TO
DRILL, DEEPEN, PLUG BACK OR CONVERT

CHECK ONE:

- ☐ Notice of Intention
☐ Application for Permit

PLANNED OPERATION: (Check One)

- ☐ Drill ☐ Plug back
☐ Deepening ☐ Conversion

NAME OF OWNER OR OPERATOR (Full Name of Company, Organization or Individual)			
ADDRESS (P.O. Box or Street Address, City, State, Zip Code)			
NAME AND TITLE (Local representative who can be contacted while operations are in progress)			
ADDRESS - Business (P.O. Box or Street Address, City, State, Zip Code)			TELEPHONE NO. (Include Area Code)
ADDRESS - Night, Weekend and Holiday (P.O. Box or Street Address, City, State, Zip Code)			TELEPHONE NO. (Include Area Code)
LOCATION DATA			
COUNTY		TOWN	
FIELD/POOL NAME (or "wildcat")			
LEASE OR UNIT NAME		NO. OF ACRES IN LEASE OR UNIT	WELL NO.
LOCATION DESCRIPTION 7 1/2" Quad. Name		Ft. S of _____ Latitude	Ft. W of _____ Longitude
GENERAL DESCRIPTION			
PROPOSED WELL DATA			
TYPE OF WELL (Check One) ☐ Gas Producer ☐ Oil Producer ☐ Input ☐ Storage ☐ Brine ☐ Other _____		Planned total depth ft.	Planned date of commencement of operations
SURFACE ELEVATION _____ ft. (Check One) ☐ Surveyed ☐ Altimeter ☐ Topo Map		TYPE TOOLS ☐ Cable ☐ Rotary	SURFACE (WATER) CASING Depth _____ ft. Size _____ in.
NAME OF PLANNED CONTRACTOR (If Known)			TELEPHONE NO. (Include Area Code)
ADDRESS (P.O. Box or Street Address, City, State, Zip Code)			
REMARKS:			
I hereby affirm under penalty of perjury that information provided on this form is true to the best of my knowledge and belief. False statements made herein are punishable as a Class A misdemeanor pursuant to Section 210.45 of the Penal Law.			
TYPEWRITTEN NAME AND TITLE			
SIGNATURE			DATE
OFFICE USE ONLY			
BOND NO.	PERMIT NO.		DATE ISSUED
REMARKS:			

INSTRUCTIONS

1. Form 85-12-5 shall be filed in **triplicate** with the Bureau of Mineral Resources, New York State Department of Environmental Conservation, 128 South Street, Olean, N. Y. 14760 by any owner or operator planning to drill a well for production, input, storage, brine or other related use.
2. Filing is **not required**, however, for deepening or plug back operations to be conducted exclusively within the producing horizon of the pool in which the well presently is completed.
3. Each Application for Permit must be accompanied by a neat, legible **plat** which has been certified as to correctness by a licensed land surveyor or licensed engineer. The plat must be drawn to scale and show the boundaries of the lease (farm) or unit containing the well, the distance in feet from the well to the two nearest boundaries, the distance in feet from the well to the nearest well completed in the objective pool (if same is within one mile) and the distance in feet from the well to the nearest producing well (if same is within one mile). Both of the latter two distances may be obtained by scaling from a map, stadia measurements, pacing, odometer or other reasonably accurate means. However, if the distance between the well and the nearest well completed in the objective pool is such that there is a possibility of violation of the State-wide spacing requirements (Section 403.1 of the Rules and Regulations of the Bureau of Mineral Resources) or superseding spacing requirements promulgated by spacing order, the distance between the well and the nearest well completed in the objective pool shall be measured accurately on the ground. The plat also must have indicated thereon the latitude and longitude of the well and the scaled distances in feet in east-west and north-south directions from the nearest corner of the United States Geological Survey topographical map upon which the well location is situated, with the topographical map being identified by title, date and as to whether seven and one-half minute or 15-minute coverage.
4. Each Application for Permit must be accompanied by a twenty dollar (\$20.00) fee in the form of a check or money order payable to the New York State Department of Environmental Conservation.
5. This form shall be completed by **typewriter** and be signed by a responsible individual who has full and correct knowledge of the facts stated and the authority to make such statements.

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
BUREAU OF MINERALS

WELL DRILLING PERMIT
(Oil, Gas, and Solution Salt Mining)

No. _____

Well Identification No. _____ Fee \$20.00 Expiration Date _____

Pursuant to Section 23-1501 of the Environmental Conservation Law,

_____ of _____
(Owner or Operator) (Address)

is hereby authorized to drill the _____ No. _____
(Well Name)

in the Town of _____, County of _____,

as described in that Owner or Operator's Application for Permit, dated _____.

This Permit, or a copy certified by the department, must be publicly displayed by the operator at the well site and must at all times be visible, legible, and protected from the elements.

NOTIFY THE BUREAU OF MINERALS PRIOR TO SPUDDING THE WELL. PHONE (716) 372-5636

SPECIAL INSTRUCTIONS OR CONDITIONS

1. Issuance of this permit is conditioned upon the following:

(If blank, permit is unconditioned)

2. Washed and bagged drill cutting samples are required for the State as follows:

(If blank, samples are not required)

Issued by: _____
Department Representative Title Date

ORGANIZATIONAL REPORT

1. Two (2) copies of Form 85-15-1 shall be filed with the New York State Department of Environmental Conservation by every person acting as a principal or agent for another or independently engaged in mining or in the drilling for, production of, or underground storage of oil, gas or brine in the State of New York.
2. An updated copy of Form 85-15-1 shall be filed as specified above within ten (10) days of any change to the facts stated in the most recent report filed with the Department.
3. The form shall be completed by typewriter, or printed in black ink, and be signed by a responsible individual who has full and correct knowledge of the facts stated.

I hereby affirm under penalty of perjury that information provided on this form is true to the best of my knowledge and belief. False statements made herein are punishable as a Class A misdemeanor pursuant to Section 210.45 of the Penal Law.

NAME AND TITLE OF APPLICANT OR AUTHORIZED REPRESENTATIVE (Print or Type)

FOR DEPARTMENT USE ONLY

X

INDIVIDUAL WELL PLUGGING AND SURFACE RESTORATION BOND

INSTRUCTIONS

1. Form 85-02-1 shall be filed with the Bureau of Mineral Resources, New York State Department of Environmental Conservation, Albany, N. Y. 12233 by the owner or operator of each well existing or to be drilled for oil, gas or brine, input or storage unless a blanket bond (utilizing Form 85-02-2) has been secured.

2. The form shall be completed by typewriter and be signed by responsible individuals who have full and correct knowledge of the facts stated and the authority to make such bindings.

SURETY BOND NO. _____

KNOW ALL MEN BY THESE PRESENTS:

That we _____ of permanent address
(Principal)

(P.O. Box or Street Address, City, State, Zip Code)

as Principal, and _____ of
(Surety)

(Mailing Address of Responsible District Office)

as Surety, a corporation organized and existing under the laws of the State of _____, and authorized to transact the business of suretyship in the State of New York, are held and firmly bound unto the State of New York, in the penal sum of _____ dollars (\$ _____), lawful money of the United States of America, for which payment, well and truly to be made, we bind ourselves, our heirs, executors, administrators, successors and assigns, jointly and severally, firmly by these presents.

The condition of this obligation is that whereas the said Principal has extant or plans to drill a well for oil, gas or brine, input or storage in and upon the following described land within New York State, to wit:

County: _____ Town: _____

Pool (or "wildcat"): _____

Lease or farm name: _____ Well number: _____

Location description: _____

and whereas it shall have been required by the Department of Environmental Conservation of the State of New York that a bond to guarantee proper plugging of said well and adequate restoration of the adjacent surface terrain on a bond form approved by said Department be in force.

NOW, THEREFORE, if said Principal shall comply with all applicable provisions of the laws of the State of New York and the rules, regulations, orders and amendments thereof of the Department of Environmental Conservation with reference to the proper plugging of said well and shall file with the Department of Environmental Conservation of the State of New York all notices and reports required by said Department in the event said well does not produce oil, gas or brine on a commercial basis, or is no longer to be used for whatever other purposes it shall have been utilized, and the well has been properly plugged and abandoned, then this obligation shall be void; otherwise to remain in full force and effect.

This bond shall be further subject to the following conditions:

1. The bond shall be continuous and shall remain in force until the Surety is released from liability by the Department of Environmental Conservation of the State of New York, or until the bond is canceled by the Surety as herein provided. Without prejudice to any liability accrued prior to such cancellation, the Surety may cancel this bond upon thirty (30) days advance notice in writing sent by mail to the Principal and to the Department of Environmental Conservation of the State of New York;

2. In no event shall the total liability of the Surety for any one or more recoveries under this bond exceed in the aggregate the penal sum hereof;

3. Any suit brought upon this bond must be instituted before the expiration of two years after the release, cancellation or termination hereof.

IN WITNESS HEREOF, said Principal and said Surety have caused these presents to be duly signed and sealed this _____ day of _____, 19 _____.

(Principal)

(Surety)

By: _____
(Title)

By: _____
(Title)

OFFICE USE ONLY

Approved	SIGNATURE AND TITLE	DATE	FILE NO.
Disapproved			