TRW NO. 97248.000

MASTER

DOE/ET/27039--T2

USE OF GEOTHERMAL HEAT FOR SUGAR REFINING IN IMPERIAL COUNTY

FINAL REPORT - PHASE I

DECEMBER, 1980

DOE Contract No. DE-AC-03-79ET-27039

Prepared for:

U. S. DEPARTMENT OF ENERGY

TRW SYSTEMS, INC. / HOLLYWOOD, CALIF. 91601

FINAL REPORT
PHASE 1
HOLLY SUGAR GEOTHERMAL PROJECT

Prepared By:
TRW SYSTEMS AND ENERGY, INC.
Redondo Beach, CA 90278

DISCLAIMER

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

Prepared For:
The U.S. Department of Energy
San Francisco Operations Office
Oakland, CA 94612

Under Contract
No. DE-AC03-79ET27039

31 December, 1980

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. BACKGROUND	2
3. RESULTS	4
3.1 Reports	4
3.1.1 Phase I Environmental Report	4
3.1.2 The Drilling and Resource Development Plan	7
3.1.2.1 General Site Activities	8
3.1.2.2 Occupational Health and Safety	9
3.1.2.3 Drilling Operations	9
3.1.2.4 Permits	15
3.1.2.5 Environmental Report	16
3.1.2.6 Schedule	16
3.1.2.7 Injection Well	16
3.1.3 Final Environmental Report for the Imperial County Planning Department	18
3.1.4 Drill Site Selection and Justification Report	18
3.1.4.1 Geology	19
3.1.4.2 Reservoir Description	19
3.1.4.3 Geophysical Measurements	20
3.1.5 The Environmental Assessment and Monitoring Plan	20
3.1.6 Geothermal Test Plan	20
3.2 Preliminary System Design	22
3.3 Preliminary Economic Analyses	22
3.4 Dissemination of Project Related Information	25
3.5 Preparation of Follow-on Proposal.	25
4. CONCLUSIONS	

ABSTRACT

The objective of the three-phase Holly Sugar Geothermal Project was to replace fossil fuels with geothermal energy for sugar beet processing at the Holly Sugar plant located in Brawley, California, in a technically straightforward, economically sound and environmentally acceptable manner. The first phase of the project, discussed in this final report, encompassed the design and analysis of a geothermal industrial heat system for Holly Sugar and addresses: (1) assessment of the geothermal resource; (2) development of a preliminary system design; (3) analysis and publication of an environmental analysis and monitoring report; (4) preliminary economic analyses; (5) dissemination of project related information, and; (6) the development of a proposal for the follow-on phases.

In preparation for Phase II of the program (Resource Verification and Pilot Plant Operation), a series of reports necessary for the initiation of that Phase were prepared and published. These included: (1) Environmental Report for the U.S. Department of Energy (Brown^{*}); (2) Drilling and Resource Development Plan (Red); (3) Final Environmental Report for the Imperial County Planning Department (Orange); (4) Drill Site Selection and Justification Report (Yellow); (5) Environmental Assessment and Monitoring Plan (Green); and (6) Geothermal Test Plan (Blue). A discussion of Phase I activities can be found in these, and the contract Monthly Status reports. The contents of the six reports are summarized in this Final Report.

*Colors refer to each report cover

1. INTRODUCTION

TRW and its industrial partner, the Holly Sugar Corporation, proposed to implement a three-phase program to replace fossil fuels with geothermal energy for sugar beet processing at the Holly Sugar plant at Brawley, California. The project would, if carried to completion, replace over 225,000 barrels of fuel oil per year used by the Holly plant, equivalent to more than two-thirds of the current plant consumption.

Meeting the objectives of the project would completely satisfy DOE's goal of near-term commercialization of direct utilization of hydrothermal resources by the private sector through:

- o demonstration of the technical, economic and environmental attributes of geothermal energy in replacing fossil fuels for commercial applications of industrial process heat;
- o demonstration that geothermal systems could provide reliable, cost effective operations continuously for periods of several months;
- o determination of the economic, conservation, and environmental attributes of geothermal systems for various process heat applications both individually and in cascaded systems;
- o identification of a specific set of commercial users and demonstration of how their processes could be integrated into the Brawley complex to the economic advantage of all participants with significant savings in the use of fossil energy;
- o dissemination of data which would demonstrate that geothermal systems are practical and profitable in the Brawley area and other KGRA's, and;
- o promotion of public and industrial awareness of the beneficial attributes of geothermal systems.

These objectives were to be met through a three-phase program consisting of (1) design and analysis, (2) pilot plant implementation, and (3) retrofit system installation. This report addresses the first phase of the program.

2. BACKGROUND

In 1976 TRW completed a study to develop information about the potential of geothermal energy and the technology required for its use by utilities.⁽¹⁾ This work was followed by a study for ERDA,⁽²⁾ on the application of geothermal energy to sugar refining. From these programs TRW and Holly Sugar, under DOE sponsorship embarked upon Phase I of a multi-phased program to use geothermal energy in the processing of sugar beets.

This report covers the Phase I program which was initiated February 5, 1979 and completed December 31, 1980.

The Holly Sugar factory currently uses a system of oil-fired steam boilers to supply non-condensing turbines to produce electricity and mechanical power. Turbine exhaust steam is used for some of the process steam needed for sugar refining. The remainder of plant steam requirements is produced by a separate oil-fired boiler. Beet pulp dryers are heated directly with oil burners.

The entire factory is adaptable to eventual conversion exclusively to geothermal energy. The Phase I program addressed the design of a pilot plant to demonstrate the feasibility of converting the makeup steam supply and the pulp dryers from fuel oil to geothermal heat. Makeup steam and pulp dryers are responsible for 71.7% of the plant's fuel oil demand and could be converted to geothermal energy without affecting the rest of

(1) "Utilization of U.S. Geothermal Resources", EPRI ER-382, TPS 76-638, TRW Systems and Energy Group, Inc., December, 1976.

(2) "Use of Geothermal Heat for Sugar Refining", ERDA, Division of Geothermal Energy, Contract E(04-3)-1317, SAN/1317-3, TRW Systems and Energy, May 1977.

the plant's energy processes. The energy demands of the potentially retrofitted parts of the Holly plant are approximately 75,000 lb/hr of process steam at 268°F (25 psig) and 250 MM Btu/hr in the flow of air heated to 275°F for pulp drying. It was found that the demands could be satisfied by a cascaded system using a series of heat exchangers which would drop the temperature of 3600 GPM of geothermal fluid from 350°F to 140°F. The geothermal fluid could be supplied from four productions wells and returned to three injection wells on Holly property.

3. RESULTS

3.1 REPORTS

3.1.1 Phase I Environmental Report

The Phase I Environmental Report, dated July 1979, included all baseline data, descriptions, and evaluations for each of the three phases of the project. Geophysical and geological surveys of the Holly property were conducted to estimate the extent of the geothermal reservoir and to determine specific environmental impacts that might be associated with; drilling of the well, drill site preparation, and installation of required piping. No long term environmental impacts were identified. The only land entry was for 3 seismic lines (5 miles, (8km)), 5 boreholes for temperature surveys (125 feet, 38 m), and 3 electrical resistivity measurement lines (4 miles, 6.4 km in total). These surveys, as well as an archaeological examination, were completed early in the project. No mitigation measures were identified as being necessary during Phase I activities.

The report examined potential long term environmental impacts that might occur in Phase II. During this second Phase, operations would include construction of; additional access roads, drill site, and drilling and production pad area; a drilling mud sump with a containment berm; areas for equipment storage and staging; and a pipeline right-of-way. Mitigation of some of these construction environmental impacts would be achieved through the use of existing roads, railroad right-of-ways, and using the area designated as unsuitable for agriculture for the location of the site specific drilling areas. In addition, methods of mitigating any environmental impacts associated with the drilling of the wells, the testing of the wells, and accidents that might occur during the testing were addressed. Although drilling operations would take place on a 24-hour basis, procedures were identified to minimize noise and dust; for example, it was planned to run tests during daylight hours whenever possible. Emergency fluid containment, by berm and channel diversion to existing waste water ponds used by Holly Sugar and then into the mud sump, was discussed so that minimum damage might occur to croplands.

Fugitive dust emissions resulting from equipment movement during Phase II would be minimized by water spraying to minimize dust. Noise generated by equipment movement would be minimized at night. Although it was anticipated that there would be low H₂S emissions, the levels would be measured and necessary mitigation measures would be taken if these levels became substantial.

The noise levels during well drilling operations identified in the environmental report were generally in the range of 90 dBA at 50 feet (15.2 m). Noise levels that might occur during well testing were estimated at 96 dBA at 100 feet (30.5m). Noise resulting from well testing would be maintained within local noise regulation requirements. It was also found that noise levels generated during drill stem testing, if these tests were carried out, might have an adverse environmental impact depending on the quantities and pressures of the fluid released to the surface.

The water required for drilling mud was estimated to be 180,000 gallons (681,300 l). It was anticipated that water, especially in the early drilling stages, would be made available from the Imperial Irrigation District through their Newhouse lateral. Later, when the chemical composition of the water becomes important, it would be made available from East Mesa. No impact on the overall water supply or quality of the water in the area was anticipated.

The report identified Phase III as an expansion of Phase II with an additional requirement for a sufficient number of boilers and beet pulp dryers to retrofit the entire Holly plant. Geothermal energy would be used to supply all makeup steam and dry all beet pulp accumulated during the annual sugar campaign. In Phase III, 3 production and 2 injection wells (depending on the quality and quantity of the geothermal resource) would be required. The necessary piping, valving and transport systems would be from the Phase III platform area.

Based on the results of the Phase II experience, H₂S abatement systems, noise mufflers and fluid containment system would be installed, as required, to protect the environment.

Six potential alternatives to the project were investigated as part of the Environmental Report. These were:

- no project;
- different location
- revised exploratory techniques
- use an alternative energy source
- alternate use for the energy produced
- use the existing Mercer I-28 well

No Project: Since the objectives of the project were to demonstrate the economic and technical feasibility of using liquid-dominated geothermal resources in an industrial process, delay or cancellation of the project would negate the realization of these objectives and effectively inhibit the development of an energy source alternative to fossil fuel.

Different Location: The selected site for the project was close to a known geothermal resource area, showed promise of containing a geothermal resource, was close to a newly developed geothermal well, would exist close to an industrial user (thus minimizing pipe costs and pipeline environmental impacts), and as a full scale geothermal system was developed, would be applied to a variety of other non-sugar beet industrial processes.

Revised Exploratory Techniques: Standard exploratory techniques applicable to the Imperial Valley were followed to determine optimum well locations. It was planned to use mud-drilling rather than air drilling since mud-drilling was more suitable for liquid-dominated resources and generated less noise.

Alternate Energy Resource: The main objective of the project was to replace fossil fuels which were currently being used. Solar, although potentially suitable for use in the Imperial Valley, would require significant quantities of agricultural land and appeared to be un-economic at this stage of its development.

Alternate Use for the Energy Produced: The energy could be used in the generation of electricity and other industrial, agricultural or space heating applications. Its use in the highly energy intensive sugar beet process is an efficient use relative to alternate applications. And, to a degree, the amount of energy available would influence its end use.

Use the Existing Mercer I-28 Well: Although this would probably be possible, extensive piping would be required to and from the well to the Holly plant. The possibility of extending the discovered reservoir or testing a potential new resource would not occur if the Mercer well were used. There is a possibility that the Holly well is near the junction of the Imperial Fault and a northwest trending transverse fault which implies the likelihood of fracture permeability at shallower depths, which would improve production economics. Laying the pipe would disturb an archaeological area, would cross or be buried under agricultural land, but in general, would result in environmental impacts. Finally, although operationally the use of the geothermal fluid from the Mercer well would result in very little difference to the Holly plant, the fact that the source would be further removed from the plant would probably increase maintenance, increase scale removal problems, and probably increase overall lifetime costs.

3.1.2 The Drilling and Resource Development Plan

The Drilling and Resource Development Plan, issued June, 1979, discussed general site activities, occupational health and safety considerations, drilling operations, permits, required reports, schedules and production and injection well activities.

3.1.2.1 General Site Activities

General site activities include site preparation and maintenance. These consist of: preparation of the access road; preparation of the drill pad; excavation of a mud reserve pit; excavation of a mud reserve pit; excavation for a concrete-lined cellar; spudding, drilling and installation of a 20 inch conductor pipe; arranging for site watering and dust control; drilling the "rat" and "mouse" holes; and providing for site maintenance.

General site activities also include site specific housing, communications, power, fuel, vehicles and transportation, operational and logistics support, and site cleanup and restoration.

Site specific housing, such as trailers and mobile homes, were to be furnished by the drilling contractor and, as required, by the various sub-contractors associated with the drilling activities. The cities of El Centro, Brawley and Imperial provide adequate housing for visitors.

No specific communications systems were planned for the site. Radio communications will be maintained by the drilling contractor. Telephone communications are available through the nearby Holly Sugar facility.

All electrical power for site operation will be provided by the drilling contractor during the time the drill rig is in operation. All fuel to operate the drill rig, trailers and all other site specific equipment will be provided by the drilling contractor.

All vehicles and transportation will be provided on an individual basis. The drilling contractor will furnish all transportation associated with rig operations. All service companies will be required to provide their own transportation.

Except for drilling and logistics associated with drilling, TRW will provide craft, clerical and office support.

Site cleanup and restoration includes disposition of all drilling and test related fluids, removal of the rig and rig-associated equipment, backfilling the mud reserve pit and restoration of the pad. Wellhead equipment and equipment for the cellar will be installed in accordance with State of California regulations.

3.1.2.2 Occupational Health and Safety

All drilling operations and other site activities will be conducted in accordance with the standards of the Occupational Safety and Health Act of 1970. All participants, contractors and service companies will be responsible for the health and safety of their own personnel. These responsibilities include: a safe and healthful environment for the employees; control and minimization of hazards to the public and to personnel of other participants; minimization of accidental damage or loss of equipment, materials and property.

First aid supplies and trained personnel will be available at the nearby Holly Sugar plant. The location of the local medical facilities and physicians will be posted at the project site.

Hand-operated fire extinguishers for the drill rig and associated equipment will be provided by the drilling contractor. Extinguishers suitable for class A, B and/or C fires will be on location at all times.

Chemical toilets will be supplied and serviced by the drilling contractor.

3.1.2.3 Drilling Operations

The site will be prepared prior to moving the rig on location. Site preparation includes emplacement of the concrete cellar, and setting and cementing of the 20-inch conductor pipe to a depth of approximately 75 feet. The overall plan for the well is shown in Figure 1. From 2400 feet the deviation is 3° per 100 feet to 17° with a drop off toward vertical at 8,500 feet (Figure 2). The planned, overall schedule for drilling the production well is shown in Figure 3.

Figure 1

Figure 2

Figure 3

Although a detailed set of drilling plans were prepared as part of the Drilling and Resource Development Plan, these plans were amended several times before the actual drilling. It was expected that small revisions might occur on site as daily activities indicated deviations were advisable to the preset plans. However, the general drilling sequence was:

1. Prior to moving in drilling rig, weld, run and cement to the the surface 20" conductor in a 32" hole from 75 feet. Install concrete lined cellar in preparation for rig move-in.
2. Move in drilling rig, rig up, drill 17-1/2" hole to 1400 feet.
 - A. If prior to cementing 13-3/8" casing, abnormally high temperatures are recorded in mud return line, TRW well site manager, drilling superintendent are to be notified.
 - B. Take single shot survey every 250' while drilling 17-1/2" hole.
3. Run open hole logs from bottom hole to surface as follows:
 - A. Dual induction laterolog
 - B. Four arm caliperLogs to be recorded on magnetic tape. Condition hole as necessary prior to logging.
4. Run and cement to surface 13-3/8" casing.
5. If a poor cement job is suspected, run cased hole logs from bottom hole to surface as follows:
 - A. CBL/variable density/Gamma Ray
 - B. High resolution temperature log
6. Prior to drilling out shoe of 13-3/8" casing, install and test Class III BOPE. DOG to witness test.
7. Drill out cement, shoe, etc., of 13-3/8" casing and drill ahead 12-1/4" hole to 2400'.
8. Directional survey representative to be on-site after drilling out shoe.
9. At 2400' begin deviation as directed by TRW well site manager/directional survey representative (details provided later). Run subs, etc., as appropriate for operation.

10. Drill ahead to 6300' M.D. maintaining deviation angle or change as directed by TRW well site manager/directional survey representative under direction of TRW.
11. Run open hole logs as follows:
 - A. Dual induction laterolog
 - B. Formation density compensated/Gamma Ray
 - C. Compensated neutron log
 - D. Borehole compensated sonic log
 - E. High resolution temperature log
 - F. High resolution digital dipmeter
 - G. Sidewall sampler (optional, as directed, 20 samples estimated)
 - H. Repeat formation tester (optional, as directed by TRW)Salinity Coraband log to be based on combinations of several of the logs. Run logs on magnetic tape.
12. Run 9-5/8" casing from 6300 M.D. to surface. Wellhead service representative to direct and perform installation of geothermal wellhead as necessary.
13. Cement 9-5/8" casing to surface.
14. Drill out cement/shoe, etc., of 9-5/8" casing with 8-1/2" bit.
15. Drill ahead to 8500' V.D. or as directed by TRW well site manager.
16. Run open hole logs as follows:
 - A. Dual induction laterolog
 - B. Formation density compensated/Gamma Ray
 - C. Compensated neutron log
 - D. Borehole compensated sonic log
 - E. High resolution temperature log
 - F. High resolution digital dipmeter
 - G. Sidewall sampler (optional, as directed, 20 samples estimated)
 - H. Repeat formation tester (optional, as directed by TRW)Record logs on magnetic tape. Salinity Coraband log to be made.
17. Run cased hole logs as follows:
 - A. Cement bond log--variable density 0 - 6300'
 - B. High resolution temperature log, 0 - T.D.

18. Conduct DST (optional). Nitrogen lift necessary if DST is conducted. DST not to exceed 24 hours--estimate eight hour test.
19. If formation evaluation warrants completion of well, proceed to step 21, if not, proceed to step 20.
20. TRW well site manager to determine whether to drill deeper, **plug plus sidetrack or abandon**. If abandoned proceed with DOG regulations. If not abandoned complete drilling operation and log. (Conduct DST if directed by TRW well site manager).
21. Hang 7" liner/slotted liner combination. Cement in liner hanger and portion of liner as directed.
22. Run cased hole logs as follows:
 - A. Cement bond log/variable density/Gamma Ray
 - B. High resolution temperature log
23. Finish assembling wellhead. Skid rig and move in between or tear down as directed by TRW well site manager.
24. Restore site to original condition.

In addition to the drilling sequence, the Drilling and Resource Development Plan described the surface equipment and services (wellhead, Blowout Preventer, Drilling Recorder, mud logging, mud pit level monitoring), cement, drilling fluid, drill cuttings (lithology samples), to be taken, sidewell coring to be done, a drill stem test option, directional surveys to be taken and identified an abandonment procedure.

3.1.2.4 Permits

The Drilling and Resource Development Plan identified the permits that would be required. During Phase I permits were obtained for the temporary discharge of geothermal "pre-test" fluids (from the California Regional Water Quality Control Board - Order No. 81-17) and for the discharge of waste (California Regional Water Quality Control Board - Order No. 79-101). Other permits and licenses included: an Individual Geothermal Resources Well Indemnity Bond (unto the State of California - Bond No. 215 33 71 for the injection well and 215 33 72 for the production well); an "Authority to Construct" (from the Imperial County Air Pollution Control District - Permit No. 1417); a Geothermal Exploration

Permit (County of Imperial, Permit No. 104-80); approval from the Department of Conservation, Division of Oil and Gas, Resources Agency of California to drill a production and an injection well (No. PG279-44 for the production well and No. PG279-43 for the injection well); a Notice of Intention to Drill a Geothermal Resources Well to the Division of Oil and Gas, State of California; and an Application Environmental Information Form to the Imperial County Planning Commission. A Bond (No. BND-327391) was posted with Imperial County.

3.1.2.5 Environmental Report

Two Environmental Reports were planned, essentially identical. One was for the Department of Energy, the other for the Imperial County Planning Department. These reports are discussed in Section 3.1.1.

3.1.2.6 Schedule

Initiation of the drilling activity was dependant upon the availability of a drilling rig, after the decision to proceed with the second phase of the program was agreed to by DOE. The schedule (Figure 3) identified only the production well activity, although the overall program schedule (Figure 4) assumed a start in September of 1980. In every case, however, a major decision point was identified prior to the initiation of the drilling for the injection well. This decision point emphasized that the production well had to meet minimum requirements before a decision to drill the injection well could be made.

3.1.2.7 Injection Well

Although the injection well was discussed in the Plan, the activities associated with it were patterned after the production well. Basically the only major changes identified were in the hole dimensions, depths, final completion, BOP equipment, and changes to be identified as a result of the on-site experience of the production well.

NOTE:
P - PRODUCTION
I - INJECTION
D - DRAFT
F - FINAL

Figure 4 Milestone Schedule

3.1.3 Final Environmental Report for the Imperial County Planning Department

This document was required by the Imperial County Planning Department before we could receive permission to drill the production well. To all intents and purposes, this document was identical to that submitted to DOE as the Environmental Report, the details of which are discussed in Section 3.1.1.

3.1.4 Drill Site Selection and Justification Report

This document, issued November 1979, received significant comments in February 1980 as a result of its review by the DOE. Although tempered by the realization that the well was a "wildcat", there was a lot of justifiable concern on the specific site selection. The comments generally addressed the following areas:

- Consider the economics of (a) drilling a deeper hole, (b) handling high TDS and CO₂ fluids, and (c) utilizing a lower temperature resource
- Assess the relationship of faults to the production-injection scheme
- Consider the possibility for a well bore to be damaged by fault movement
- Should a well be drilled, retain an expert consultant to oversee any well drilling and completion work
- Submit both a production-test program and an injection-test program for review
- Thoroughly address each SOW topic
- Identify the reliability of data, for example, using an index scale of 0 to 10.

The comments also included a series of specific questions relating to various sections of the report and represented a thorough review. A detailed response to these comments was forwarded to DOE on 27 February (TRW document No. 80.1455.JJS.2277). (In retrospect, some of the comments from both DOE and TRW were correct, some were proven to be optimistic, and some were proven to be needlessly pessimistic.)

The Report addressed the geology (of the selected area), described the anticipated reservoir, discussed the various geophysical measurements that had been taken, and identified the proposed field development program. It based its recommendation for the well location on the tectonic activity of the area, the location of the proposed well in the middle of a large regional area of low resistivity, the fact that the proposed well site was in a highly fractured area adjacent to the Imperial Fault and its branches allowing for potential hydrothermal convection cells to exist, the location of the site near three known wells with high geothermal potential and the fact that the location of the drill site was closer to a basin-margin source of clastics than the wells with high temperature geothermal resources, potentially allowing more permeable sand lithologies to occur.

3.1.4.1 Geology

The Report presented a tutorial exposition of the geological history of the Imperial Valley, with direct identification of the general area where it was proposed to drill the well. The geologic structure of the Imperial Valley was discussed and the location of the well site in relation to the Imperial Fault System and the Brawley Fault was identified.

3.1.4.2 Reservoir Description

Although it was recognized that the cut and fill lithology of the Imperial Valley made extrapolations into exploratory areas somewhat risky, an attempt was made to identify the potential of the anticipated reservoir. Published data and unconfirmed reports on the thermal gradient of the nearby Mercer 1-28 indicated it was reasonable to expect a temperature of 350°F (160°C) at around 8,000. With the large number of fractures in the vicinity of the well, it also seemed reasonable to anticipate fracture permeability. If the production zone was of any appreciable thickness, satisfactory flow could be expected.

The potential chemistry of the reservoir was extrapolated from the data for the Brawley field to the north, and the Heber field to the east,

recognizing that the salinity of the geothermal fluids is known to decrease to the south (to Cerro Prieto) and with decreasing depth. An engineering extrapolation for the production well at a vertical depth of about 8,000' and with a bottom hole temperature of 350°F, suggested that the resource would have 30,000 to 50,000 ppm dissolved solids.

3.1.4.3 Geophysical Measurements

Geophysical surveys (Figure 5) consisted of; a five hole temperature gradient survey; approximately five miles of resistivity profiles; and approximately 4 miles of seismic refraction surveys. The surveys were used to select a drill site that would have high probabilities of penetrating the central part of any upwelling thermal convection cell, and encountering permeable sands and fracture permeability associated with the intersection of multiple faults. Site selection was based on an integration of all the information obtained; from surveys, experience of other near-by wells, and geologic data.

3.1.5 The Environmental Assessment and Monitoring Plan

This Plan, published December 1979 as Topical Report No. 3, was based on the requirements set by the State of California, Water Quality Control Board, and the Division of Oil and Gas as well as special requirements by the County of Imperial, Air Pollution Control Board and other county offices. The Plan addressed all of the applicable environmental impacts identified in the Final Environmental Reports discussed in Sections 3.1.1 and 3.1.3. Each environmental monitoring and reporting requirement was addressed in terms of impact, mitigation measures and/or engineering practices, and monitoring and reporting requirements. These reporting and monitoring requirements are shown in Table 1.

3.1.6 Geothermal Test Plan

This Plan, issued February 1980, identified a series of tests of the geothermal resource predicated on obtaining progressively more information.

GEOPHYSICAL SURVEYS

Figure 5

Initially, the information would be obtained from the tests and data gathered while the production well was being drilled. When the production well was tested, more information would be obtained and two separate independent resource analyses would be made. After production testing, the injection well would be drilled and additional data gathered from the drilling and tests conducted during the drilling. Finally, tests would be run for full scale evaluation using both the production and injection wells.

Details as to the type of tests and data that would be gathered during the drilling of the production well have been discussed in Section 3.1.2.3.

3.2 PRELIMINARY SYSTEM DESIGN

Since the system design was so strongly dependent on the characteristics of the brine (temperature, flow, chemical composition) the iterations made of the design attempted to develop a general model. The final configuration, (Figure 6) assumed a temperature of around 350°F, a flow rate of 500 gpm and total dissolved solids less than 50,000 ppm.

3.3 PRELIMINARY ECONOMIC ANALYSES

With an unknown temperature, at an unknown flow rate, with an unknown maintenance and chemical treatment cost, preliminary economic analyses of the system had to be of a most general nature. Since the major cost item, other than the well system, was the dryer, an analysis was made of its cost as a function of the well temperature (Figure 7).

Using Holly Sugar's known energy costs, estimates were made of the length of time for the investment in the total geothermal system to pay for itself, assuming a four month sugar campaign. Other estimates assumed the use of the energy produced by the well for the period of time when it would not be needed for Holly Sugar, which spread the capital investment costs over a variety of un-committed uses.

PILOT PLANT PRELIMINARY PIPING AND INSTRUMENTATION DIAGRAM

Figure 6

Cost of Dryers (1979 prices) as a
Function of Brine Temperature

Figure 7

With Holly Sugar having a utility bill of about \$500,000 per month, and assuming that another user could be identified for the period of time that Holly would not require the geothermal energy, it appeared that the geothermal system would result in energy savings of about \$6,000,000 per year, with a return on the capital investment of less than 3 years.

3.4 DISSEMINATION OF PROJECT RELATED INFORMATION

Technical papers were prepared, presented and/or published in the following conferences and their proceedings:

- Presentation to Geothermal Resources Council Meeting, Reno, Nevada, September 1979
- "Geothermal Energy for Sugar Beet Processing," ASHRAE, Los Angeles, California, February 1980
- Presentation at the Long Beach State College course on Alternative Energy Systems, Long Beach, California, March 1980
- Presentation at the Geothermal Direct Heat Applications Meeting El Centro, California, May 1980
- Presentation to the Mexican American Engineering Society National Symposium on Engineering, Anaheim, California, May 1980
- Presentation at DOE Program Review of Geothermal Programs Las Vegas, Nevada, November 1980

3.5 PREPARATION OF FOLLOW-ON PROPOSAL

The proposal for Phase II, Resource Verification and Pilot Plant Operation, was submitted by TRW to Holly Sugar late in September, 1980 and Holly submitted their final proposal to DOE which included TRW as their major sub-contractor, early in November 1980.

4. CONCLUSIONS

All of the analyses and investigations indicated that even with a probability of success between 0.1 and 0.3 the Holly geothermal well would result in an economically sound and environmentally acceptable new resource that could successfully replace the consumption of an appreciable quantity of fossil fuel. The drilling of the geothermal well could be accomplished in a technically straightforward manner and the application of the resultant energy would not only encourage the further use of this type of energy by the industrial community, but would verify the existence of a broad KGRA with resultant further exploitation potential.

Although solutions to all of the identified problems were not given, their recognition and awareness that they were being addressed yielded confidence that the successful development of the Holly Sugar geothermal resource was possible within the fiscal and time constraints of the program.

Table 1

STATE OF CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
COLORADO RIVER BASIN REGION

SUBJECT MONITORED	FREQUENCIES OF REPORTING/NOTIFICATION		
	MONTHLY	ONE TIME	PERIODICALLY WHERE NECESSARY
1. Technical Report detailing sump construction		One time prior to waste discharge	
2. Certificate stating that sump and attendant facilities meet requirements		"	
3. Volume of geothermal wastes discharged to the mud sump	On 15th of month following report month		
3a Volume contained in the mud sump	"		
3b TDS content of waste fluid contained in mud sump	"		
4. Report on complete disposal of all geothermal wastes from mud sumps - reported within one week following completion of work.		One Time	
5. At least 10 days prior to re-habilitation of any mud sump area the discharger shall request a Regional Board Staff inspection and approval of the cleanup procedure.			
6. Within 10 days after the initial discharge of any geothermal fluids from a well, the discharger shall report said initial discharge to the Board.		One Time	
7. Estimate of total amount (tons) of saline drilling muds and salt and brine waste hauled to Class I or Class II-1 solid waste disposal site upon completion of haul.			*
8. Estimate of total amounts (tons) of non-saline drilling muds hauled to a Class II-2 solid waste disposal site upon completion of operations reported in final monitoring report.			*
9. Immediate reporting of any accidental spillage or release of waste material and plan for immediate measures being taken to correct same and to limit detrimental effects.			*

Table 1 Continued

CALIFORNIA DIVISION OF OIL AND GAS

SUBJECT MONITORED	FREQUENCIES OF REPORTING/NOTIFICATION		
	MONTHLY	ONE TIME	Periodically where necessary
10. Witness field testing and inspection of blowout prevention equipment, cementing and plugging operators, water shutoff.			24-hour prior to test
11. Well Testing and Logging Data Well Summary Report Well Log and Core Record Well History		Within 60 days after well completion, abandonment or suspension of operation	
12. Geothermal Resources Report and Inspection Report	On or before the 30th day of the month following the report month		
COLORADO RIVER BASIN REGION			
13. Volume directly reinjected to subsurface strata from the production well.	On the 15th day of month following month		
13a TDS concentration of waste fluid injected into injection well.			
14. TDS concentration of ground water contained in strata receiving waste fluids		10 days prior to commencement of injection	
14a Depth of the injection well			
COUNTY OF IMPERIAL AIR POLLUTION CONTROL BOARD			
15. Well testing			24-hours prior to testing
16. Non-condensable gas analysis			Report submitted after testing and drilling operations
OTHER			
17. Archeologic sensitive site flagged and staked		One Time (Inspection only)	
18. Mud Sump Berm			(Visual only)