HEBER-79-002

Volume II
Proposal Abstract

Heber Geothermal Project

Binary-Cycle Demonstration Plant

Proposal By

San Diego Gas & Electric

December 1979

Unsolicited Proposal Submitted To:
Director, Division of Geothermal Energy
U.S. Department of Energy
20 Massachusetts Avenue, N.W.
Mail Stop 3122-C
Washington, D.C. 20845

Copy 5

DISCLAIMER

DISCLAIMER

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

San Diego Gas & Electric

R. E. MORRIS
PRESIDENT
AND CHIEF EXECUTIVE OFFICER

December 3, 1979

FILE NO
PMA 100

Mr. Bennie G. DiBona
Director, Division of Geothermal Energy
U. S. Department of Energy
20 Massachusetts Avenue, N.W.
Mail Stop 3122-C
Washington, D. C. 20845

Mr. Thomas Heenan
Director, Division of Geothermal Energy
U. S. Department of Energy
1333 Broadway
Oakland, California 94612

Re: Unsolicited Proposal to Construct and Operate a Binary-Cycle Geothermal Power Plant at Heber, California

Gentlemen:

San Diego Gas & Electric (SDG&E) is pleased to submit this unsolicited proposal to obtain financial assistance from the Department of Energy (DOE) for the design, construction, and operation of the world's first large-scale binary-cycle geothermal power plant. We are also submitting this proposal to the Electric Power Research Institute (EPRI) for co-funding as well. The project, known as the "Heber Binary-Cycle Geothermal Project", will support development of this Country's geothermal resources.

Though the binary-cycle is widely accepted as the most economical means of generating power from moderate temperature resources common to a majority of the nation's hydrothermal fields, its technology has not as yet been demonstrated on a commercial scale. The Heber Project will provide that critical demonstration.

Through an intensive data acquisition and dissemination program, the project will transfer power plant technology and reservoir experience to electric utilities, resource developers, equipment manufacturers, and the financial community, thus providing the necessary confidence for these groups to make commitments to accelerate binary-cycle development.

POST OFFICE BOX 1831 · SAN DIEGO, CALIFORNIA 92112 · TELEPHONE: 714/232-4252

San Diego Gas & Electric

Unsolicited Proposal to Construct and Operate a Binary-Cycle Geothermal Power Plant at Heber, California

SDG&E has assembled a highly qualified management team for the project. We have already secured many of the key permits and licenses necessary to construct and operate the plant. The Southern California Edison Company, the Imperial Irrigation District, and the State of California Department of Water Resources have expressed an interest in funding and owning a portion of the power plant. In addition, the project has received broad industry endorsement. EPRI, whose member utilities represent more than 80% of the nation's electric generating capacity, has indicated strong support for the project. We are encouraged by such widespread utility interest; nonetheless, we are continuing to solicit additional participation from the geothermal industry to assure the broadest industry involvement.

Any questions regarding this proposal or the project should be addressed to:

R. G. Lacy
Manager, Heber Geothermal Project
San Diego Gas & Electric Company
P. O. Box 1831
San Diego, California 92112
Telephone: (714) 235-7730

Sincerely,

R. E. Morris
President and
Chief Executive Officer

REM:GA:pjh
Attachment

cc: R. E. Balzhiser
Vice-President of Research Development
Electric Power Research Institute

San Diego Gas & Electric

December 3, 1979

Mr. Bennie G. DiBona
Director, Division of Geothermal Energy
U. S. Department of Energy
20 Massachusetts Avenue, N.W.
Mail Stop 3122-C
Washington, D.C. 20845

Dear Mr. DiBona:

The estimates of the cost for plant design and construction, plant demonstration, and data acquisition and dissemination for the Heber Geothermal Project have been prepared by San Diego Gas and Electric Company using established estimating practices. We believe they are reasonable given the research and development nature of the project and the extent of design work which has taken place. However, we recognize these costs could be adjusted when contractual arrangements between SDG&E,Chevron, participants and contributors are finalized.

In order to bound the DOE cost exposure for the project we are willing to negotiate a ceiling on potential DOE expenditures prior to signing an agreement.

Sincerely,

R G Lacy

Robert G. Lacy, Manager
Heber Geothermal Project

RGL:rm

Volume II
Proposal Abstract

Heber Geothermal Project

Binary-Cycle Demonstration Plant

Proposal By

SDGE

San Diego Gas & Electric

December 1979

Unsolicited Proposal Submitted To:
Director, Division of Geothermal Energy
U.S. Department of Energy
20 Massachusetts Avenue, N.W.
Mail Stop 3122-C
Washington, D.C. 20845

Reference No.: PMA 100 Heber Binary

ACKNOWLEDGEMENT

SDG&E would like to acknowledge the extremely valuable contributions in the fields of binary-cycle technology and geothermal technology made by the Electric Power Research Institute and the federal government, the Department of Energy and its predecessor, the Energy Research and Development Administration. The pioneering work sponsored by these organizations, along with our activities, have made it possible for us to prepare this proposal. EPRI sponsored numerous studies which are relied upon in this proposal. The federal government not only sponsored a comprehensive environmental baseline study of the Imperial Valley, but co-funded with SDG&E the operation of the Geothermal Loop Experimental Facility at the Niland Reservoir. The development of binary-cycle energy conversion, and geothermal energy in general, exhibits the cooperative effort between the private sector and the federal government that will result in the development of binary-cycle technology for the benefit of the United States.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION 1
INTRODUCTION

SECTION I
INTRODUCTION

BINARY CONVERSION PROCESS

San Diego Gas & Electric (SDG&E) believes that the binary-cycle offers an improved method of converting moderate temperature geothermal resources into electric power. The process, shown schematically in Figure 1-1, has significant advantages over existing methods of geothermal power generation. The advantages of the binary process are that greater amounts of power can be generated from a given resource, fewer wells are needed to support a given power output, and the binary-cycle is expected to be more economical than the flash process for this type of resource. Another advantage is that the binary-cycle is a closed process and thus enhances environmental acceptability.

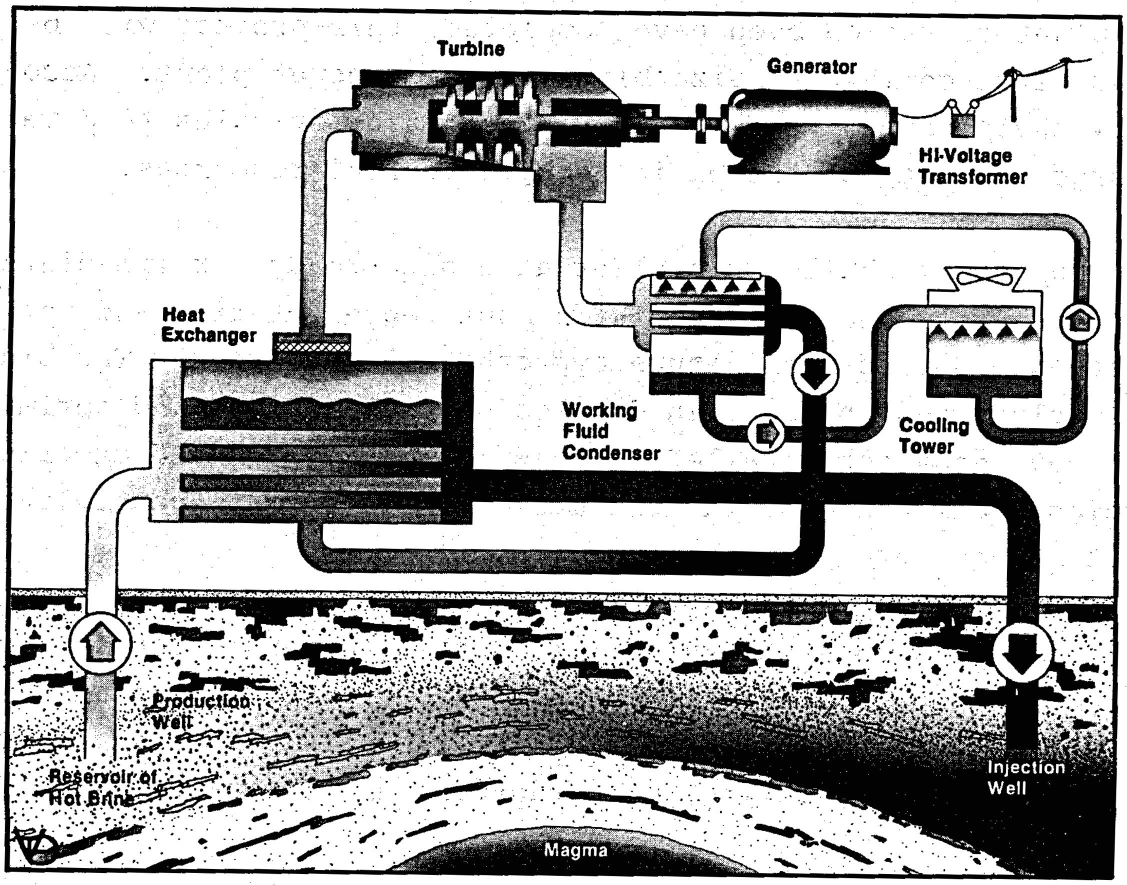

Figure 1—1. Binary-Cycle Conversion Process for a Geothermal Reservoir.

In addition, this process is applicable to a larger range of the nations geothermal reservoirs. It is estimated that 80 percent of the nation's hydrothermal resources can be classified as moderate temperature (300 to 410°F) resources. The flash process, commonly used to convert high temperature geothermal resources to electric power, is technically feasible for moderate temperature resources. However, when compared to the binary process for moderate temperature applications, the flash process conversion efficiency is lower, environmental impacts may require abatement, and power production costs may not be commercially competitive.

HEBER BINARY PROJECT

The objectives of the Heber Binary Project are to demonstrate the reliability, technical and economic feasibility, and environmental acceptability of a commercial-size, binary process geothermal power plant at a representative moderate temperature resource. Although successful feasibility studies, laboratory and field testing, and pilot plant operation been have completed, this project will be the world's first commercial size binary process power plant. Accomplishment of these objectives will serve as a major stimulus to develop the large majority of the nation's hydrothermal resources.

SDG&E proposes to build this plant at a site ready for immediate construction and located on one of the most representative and well understood moderate temperature hydrothermal resources. The binary process plant design has been developed, field tested and optimized, and is now ready for detailed engineering. A proven and experienced management team will combine executive direction with centralized project management.

SDG&E has assembled a highly qualified team to manage, design, and construct the power plant and the associated reservoir facilities. SDG&E will manage the project. In this capacity, SDG&E will implement the engineering, permitting, construction, and operation of the plant by drawing upon its own expertise and that of Fluor Power Services, Inc. as the architect-engineer and plant constructor, and Chevron Resources Company as the resource operator and developer. We have developed a statement of work for the project, a detailed work plan and work breakdown structure, and detailed schedules for the work. We believe that our proposal for the Heber Binary Project establishes a firm basis for realizing the objectives of the project.

This volume presents a discussion of the salient features of our proposal. The titles and location of these features are as follows:

SUMMARY

This project will lead to the accelerated commercial use of moderate temperature geothermal resources by proving the binary process on a commercial scale. Our proposal offers an equitable basis for sharing the costs of demonstrating this binary-cycle process. We are also convinced that every reasonable effort has been made to assure realization of the project objectives. We are highly confident that the project will successfully provide the data necessary to prove the economic viability of the binary-cycle and accelerate the commercial development of these currently unused resources. These data together with our planned information dissemination and technology transfer will result in a significant step forward in meeting our nation's electrical energy needs.

This proposal offers the following unique benefits to the government and to the geothermal industry.

Immediate Results

- Prior design and licensing accomplished.
- Site purchased, approved and ready for construction.
- Plant architect-engineer selected.

Excellent Probability of Success

- Site specific studies, laboratory and site field testing, and related pilot plant activities.
- One of the most well understood reservoirs.
- Selection of a simple, single cycle, binary process, proven and available components.
- Acceptable environmental impacts with assured sources of cooling water.

Potential for Large Regional Commercial Expansion and Use

- SDG&E's long range commitment to geothermal development.
- Imperial Valley's potential of 6760 megawatts of geothermal power.
- Direct participation of four utilities.

National Applicability for Commercial Development

- The most representative moderate temperature hydrothermal resource.
- Commercial basis for project agreements.
- Broad community, regulatory and industry support.

SECTION 2
THE SITE

SECTION 2
THE SITE

The site we have selected for the power plant is located near the center of the Heber Geothermal Reservoir in California's Imperial Valley, as shown in Figure 2-1. It is approximately 120 miles east of San Diego and about one mile south of the town of Heber. The site has been purchased by SDG&E, is readily accessible, and a Conditional Use Permit for the power plant obtained. Adequate supplies of cooling water for plant operation, and transmission lines for the distribution of the electrical power are located within or adjacent to the site.

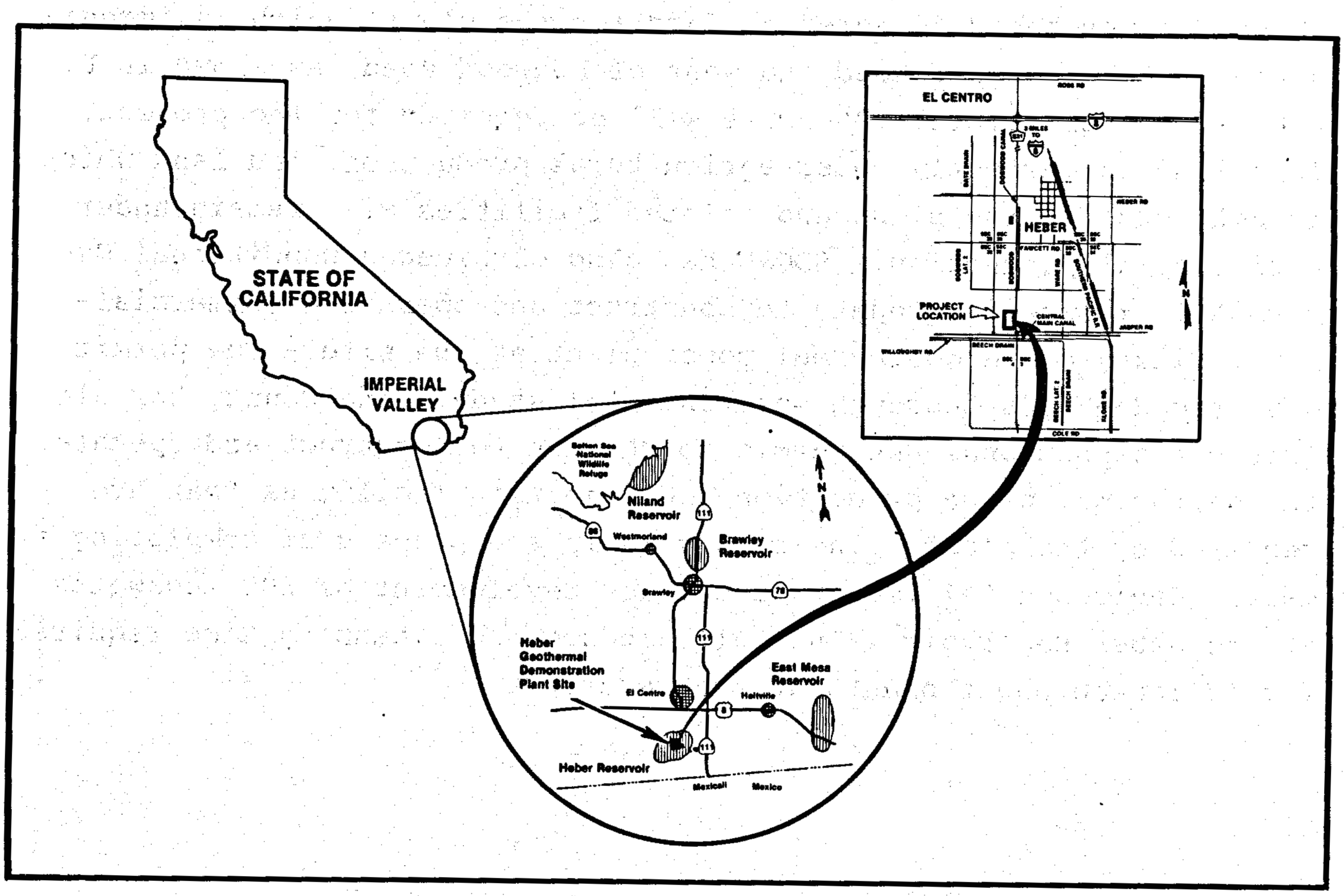

Figure 2—1. Heber Demonstration Plant Site.

Collectively, the geothermal reservoirs in the Imperial Valley have an estimated 6760 megawatts of electrical generating capacity. Imperial County has recognized this potential and has added a Geothermal Element to its General Development Plan. The element is consistent with state policies to accelerate geothermal development. The County has actively encouraged geothermal development. Extensive reservoir exploration, testing and environmental studies have already taken place.

Accessibility to the site by highway is shown by the index map in Figure 2-2. Paved county roads allow easy access from Interstate 8, which passes four miles north of the site. Rail access for freight is provided by a branch line of the Southern Pacific Railroad, which passes within a mile of the plant site, as shown in Figure 2-3. Scheduled air service is provided to the Imperial Valley airport, located about eight miles north of the site.

SDG&E has purchased 40 acres of land for the plant, which is immediately north of Jasper Road and west of Dogwood Road, as shown in Figure 2-3. Approximately 20 acres will be required for the project. This land is currently under agricultural production, and land which is not used for the plant and related facilities will remain under agricultural production. SDG&E has also obtained a Conditional Use Permit from Imperial County to construct and operate a commercial-size, binary-cycle geothermal power plant at the site. The permit was preceded by a thorough environmental study. The County has also issued a Conditional Use Permit to Chevron to construct and operate the geothermal brine production and injection facilities that are required by the plant. The county is in the process of completing a master Environmental Impact Report for development of 500 megawatts at the Heber Reservoir. This will reduce the licensing time required for follow-on power plants at the reservoir.

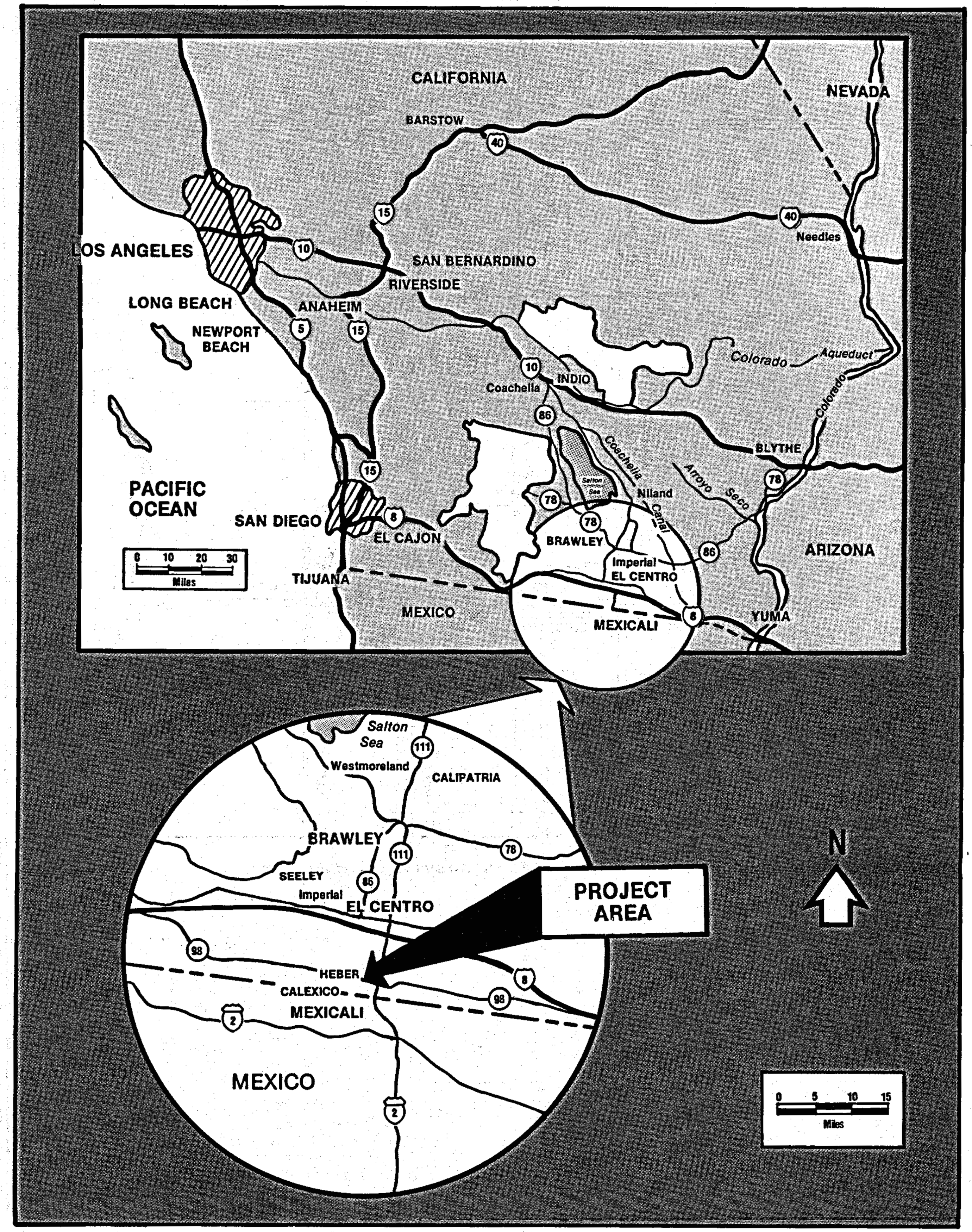

Figure 2—2. Index Map of Imperial Valley and the Project Area.

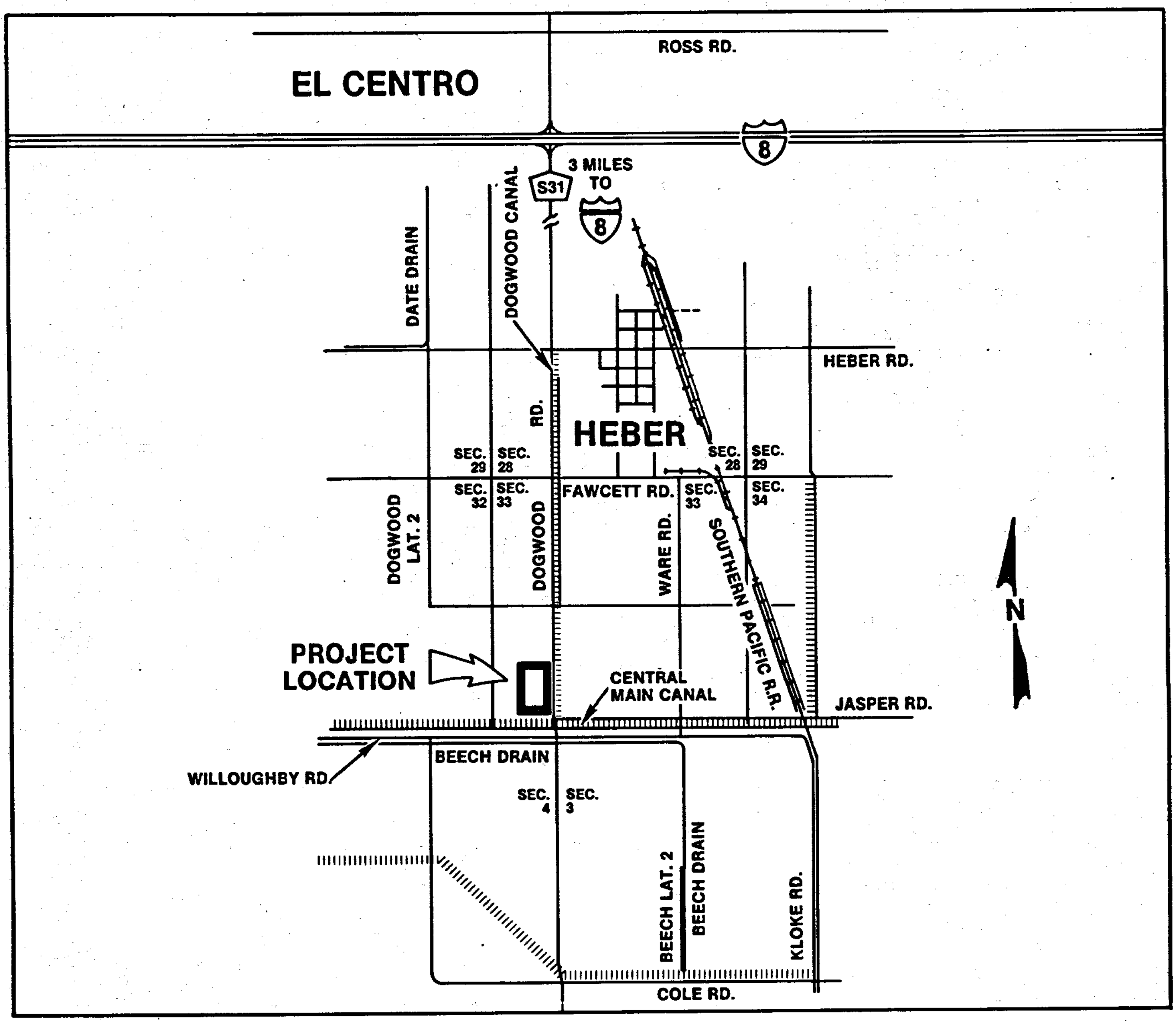

Figure 2—3. Roads and Highways in the Heber Area.

SECTION 3
THE HEBER RESERVOIR

SECTION 3
THE HEBER RESERVOIR

The Heber Geothermal Reservoir has been subjected to an extensive evaluation. Geophysical surveys, well drilling, well testing, and reservoir evaluations have been completed. Fifteen exploratory wells have been drilled in the area, the average depth being 5500 feet and the deepest 9700 feet. A northwest by southeast cross-section of the reservoir is provided in Figure 3-1. This figure shows some of the wells and includes the reservoir temperature profile to a depth of 6000 feet. As a result of this testing and evaluation, the Heber Geothermal Reservoir is one of the best understood reservoirs in the United States.

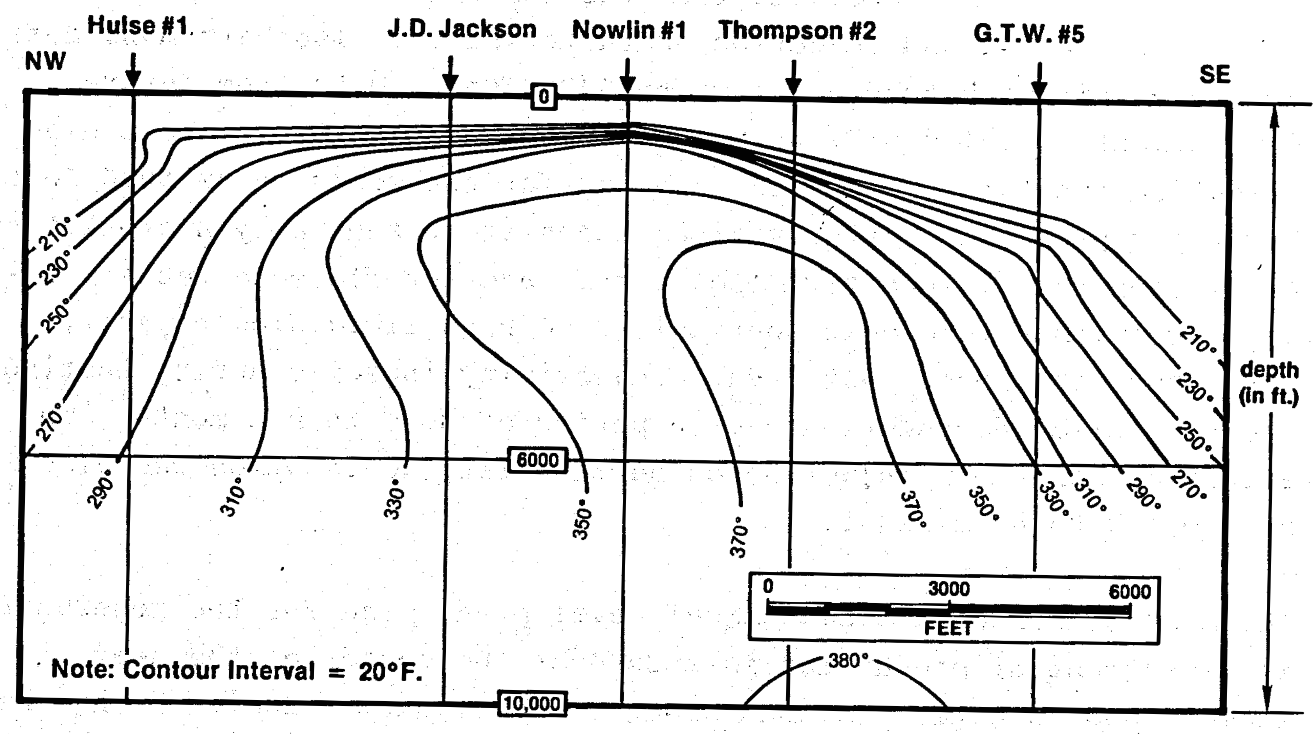

Figure 3—1. NW-SE Temperature Cross-Section of the Unit Area.

The Heber Reservoir lies within the Salton Trough. This trough is a broad depression that extends from the Gulf of California to the Salton Sea. The Salton Trough is filled with mainly non-marine upper tertiary and quaternary sediments that reach a thickness in excess of 20,000 feet. High heat flows are generally observed in this area. In several local areas the sediments are charged with hot geothermal brine.

The reservoir was defined by geophysical surveys, a shallow temperature drilling program, deep drilling, and well testing. It covers an area of approximately 7400 acres, with temperatures up to 375°F as shown in Figure 3-1. The reservoir is sharply defined with an asymmetrically skewed plume of high temperature. The brine is contained within porous and permeable sediments and has a total dissolved solids content of 14,000 ppm. There is continuity of gross sand content across the field, and no impediments to flow have been observed in detailed reservoir testing.

Analyses of log and core data from the wells indicate acceptable reservoir production and injection characteristics. Isotherm maps define the reservoir with good accuracy to 6000 feet. Data from future development drilling will be used to confirm estimates of heat distribution and total reservoir capacity for the zones below 6000 feet. Reservoir pressures in the various sands are essentially hydrostatic. Drill stem tests, long term flow tests, and interference tests indicate acceptable reservoir continuity and high fluid flow capacity throughout the Heber Unit Area. Injectivity indicies during testing showed minimal degradation over a period of more than a month. The effect of long-term injection on permeability degradation was also determined to be minimal.

The most efficient and economical development plan for the reservoir involves central production islands over the center of the heat anomaly and injection islands along its periphery. Cooled brine that is returned to the reservoir would sweep hot brine to the central producing wells to maintain reservoir pressure. The reservoir has about 75 percent of its heat contained in the rock grains and about 25 percent of its heat is contained in the geothermal brine. A central production and peripheral injection well-pattern allows the injected brine to contact the hot rock grains, thereby extracting and sweeping a larger fraction of the reservoir heat. The distance between the injecting and producing wells also minimizes the risk of cold brine break-though into the producing wells during the 30 year life of the power plant.

Directional drilling from well-islands is a technique that has been applied by the petroleum industry for many years on off-shore rigs and on urban sites, and recently for geothermal steam at the Geysers. Moreover, Magma has used directional drilling at East Mesa. The technique is firmly established.

The use of production and injection islands for geothermal plants offer a number of significant advantages over older techniques. Common well-pads require less land, and the number and length of surface production and injection pipelines are reduced, thereby minimizing environmental impacts. Equipment for production or injection well-drilling, completions, and operations can be concentrated and put to common use. The use of concentrated areas of production and injection is expected to assist in data collection and verification of total field capability. All of these advantages reduce the cost of field development.

Down-hole pumps will be developed for the production wells of the Heber Project, and the cost of this development paid for by Chevron. Since down-hole pumps are expected to be required by nearly all low and moderate temperature reservoirs, the Heber Project will again be representative. The pump design is expected to be an adaptation of the proven concept of the shaft-driven pump. This type of pump has already been proven at several geothermal reservoirs. However, other pump designs are currently undergoing test and development and will be reviewed before the type to be used in the Heber Project is finally specified.

SUMMARY

It has been independently estimated that the Heber Reservoir has enough heat-in-place to support more than 500 megawatts of power generating capacity for 30 years. Although actual operating experience is required to confirm the field's total capacity, our assessment indicates that there is a high probability that the total capacity is in the range of 500 megawatts.

SECTION 4
CONVERSION SYSTEM

SECTION 4
CONVERSION SYSTEM

BINARY-CYCLE CONVERSION PROCESS

The binary-cycle conversion process is one in which heat is transferred from the geothermal brine to a secondary working fluid. The working fluid is then vaporized and used to drive a turbine-generator. Upon leaving the turbine, the working fluid is condensed and re-used in a closed loop. A cross-sectional diagram of the process at a geothermal reservoir is provided in Figure 4-1. This process is in contrast to a direct flash cycle, associated with higher temperature resources. In the direct flash cycle a portion of the geothermal brine is flashed into steam in flash vessels and the flashed steam is used to drive a turbine-generator.

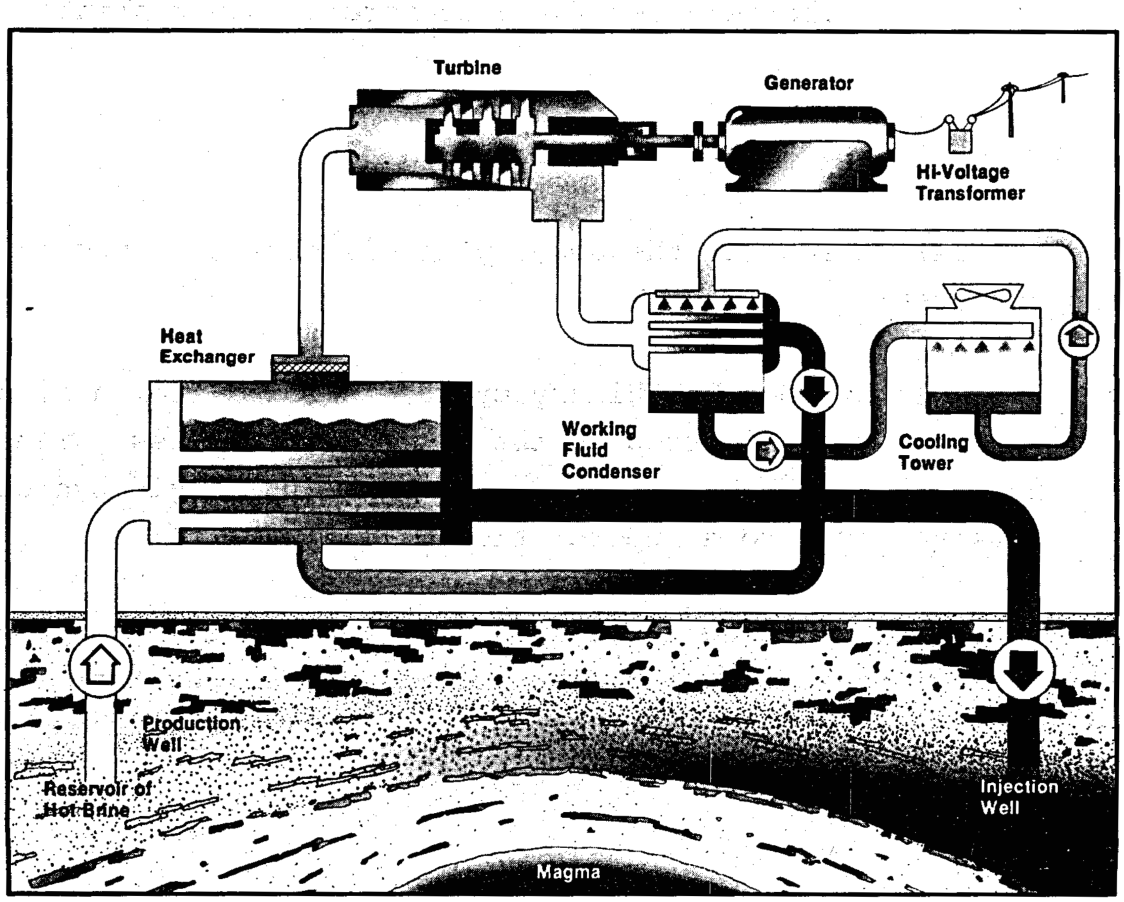

Figure 4—1. Binary-Cycle Conversion Process for a Geothermal Reservoir.

Selection of the binary-cycle conversion process resulted from studies, many of which were funded by the Electric Power Research Institute, that evaluated the importance of moderate temperature geothermal resources, and the comparative economics of the process with other technologies, such as direct flash cycle. These studies were completed in 1976 and subsequently verified. They supported the conclusion that the binary-cycle, using a saturated hydrocarbon as the working fluid, has significant potential for generating reliable electric power at a cost that is lower than a direct flash cycle when operated on reservoirs in the low to moderate temperature range. Other significant advantages include greater use of a given resource per unit of electrical output, flexibility to adapt to changing reservoir conditions, and elimination of non-condensable gas emissions to the atmosphere.

The binary process is based on a technology that is well established in the process industry, and it requires little modification for geothermal power generation. However, some of the components are not available in the size required for a commercial power plant.

HEBER GEOTHERMAL POWER PLANT

The conceptual design for the power plant is characterized by the following features:

- A single hydrocarbon binary cycle, tailored from a simple Rankine Cycle, is used in the conversion process. Sensible heat from the brine is used to change the liquid hydrocarbon working fluid to a supercritical fluid.

- The binary working fluid is a saturated hydrocarbon mixture of 90 percent isobutane and 10 percent isopentane that will be used over the life of the plant. This fluid is then expanded to drive the turbine-generator.

- The geothermal brine enters a conventional, shell and tube, heat exchanger where the temperature is reduced to about 160°F. This reduction is a result of counter-flow heat exchange with the binary working fluid. The brine is then pumped to the injection island and returned to the reservoir. The geothermal brine is never exposed to the ambient air or hydrocarbon working fluid.

- The hydrocarbon turbine is an efficient, compact, and clean unit.

- Plant accessories and cooling water systems are typical of inland power plants of this size.

The Heber Geothermal Power Plant is an outdoor-type facility with a net power output of approximately 45 megawatts. The gross capacity of the plant is 65 megawatts, which includes the power for auxiliary systems and the reservoir facilities. The net cycle efficiency for the power plant is estimated to be 11.2 percent. Reservoir temperature decline over the plant life will cause a slight reduction in efficiency. Geothermal brine flow will increase from about 7 to 9 million pounds per hour at end of life conditions. These brine flows are about 38 percent less than an equivalent dual-stage flash plant.

The outdoor concept provides for all major plant equipment to be installed outside to reduce capital cost and to simplify handling of the hydrocarbon working fluid. The plant is designed for operation from a central control room, and it will include complete support facilities.

The brine production wells are located adjacent to the power plant to minimize heat and pressure losses during the transport of the brine. The power plant and production island occupy approximately 20 acres. Figure 4-2 shows the relative location of the power plant, production island, injection island, and the brine return pipeline to the township of Heber.

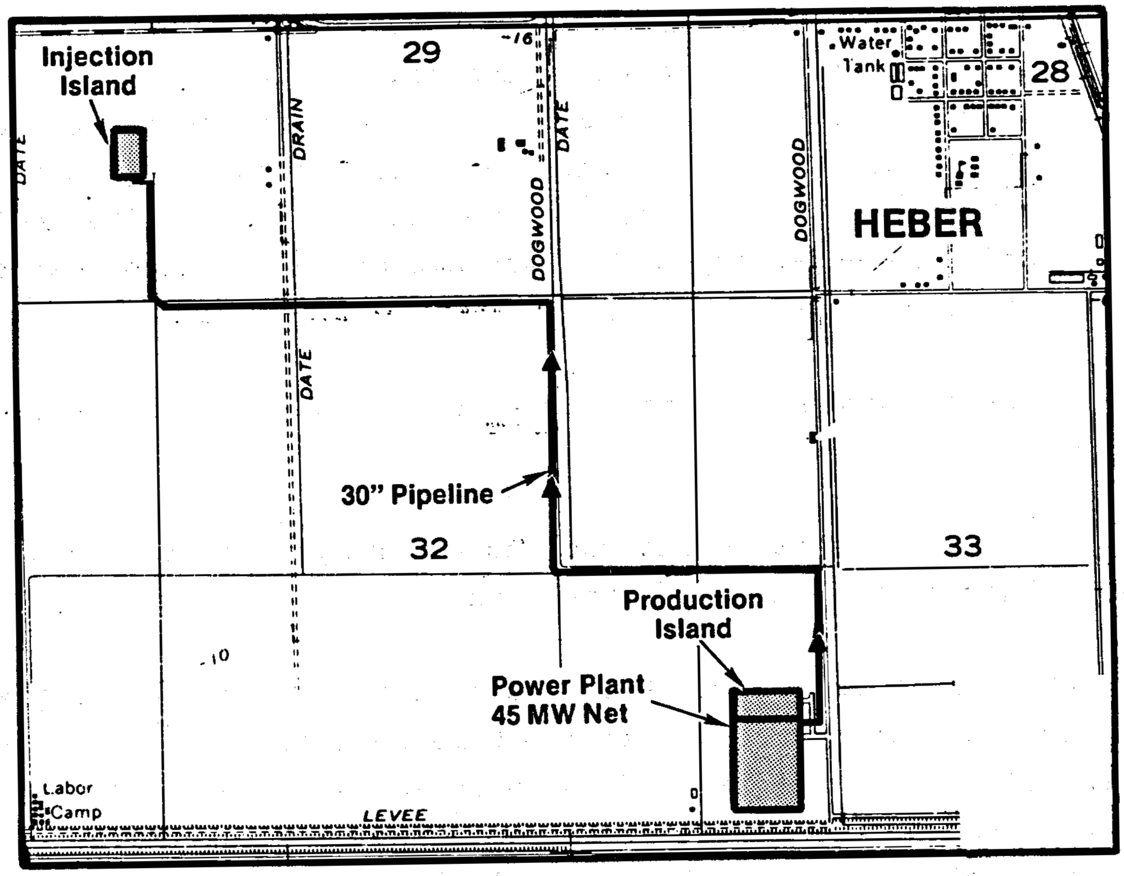

Figure 4—2. Brine Return Pipeline Route from Power Plant to Injection Island.

A preliminary arrangement of the power plant is provided in Figure 4-3. The energy conversion equipment is strategically positioned around the turbine-generator to allow direct runs of hydrocarbon piping, thereby decreasing pressures losses. Clearance and accessibility for maintenance and safety were also a primary consideration in the plant layout. The control room will be located in the main building near the major equipment. This location avoids excessive lengths of control loops and provides the operators with easy access to the equipment. The flare stack is located in the settling pond area. This location provides a safety circle radius of 170 feet to ensure personnel protection during upset conditions.

The binary-cycle conversion process consists of three fluid loops: a geothermal fluid (brine) loop, a hydrocarbon working fluid loop, and a cooling water loop. The brine loop is a closed loop, returning the brine to the reservoir without direct exposure to the atmosphere or to the working fluid. The purpose of this loop is to provide an ef-

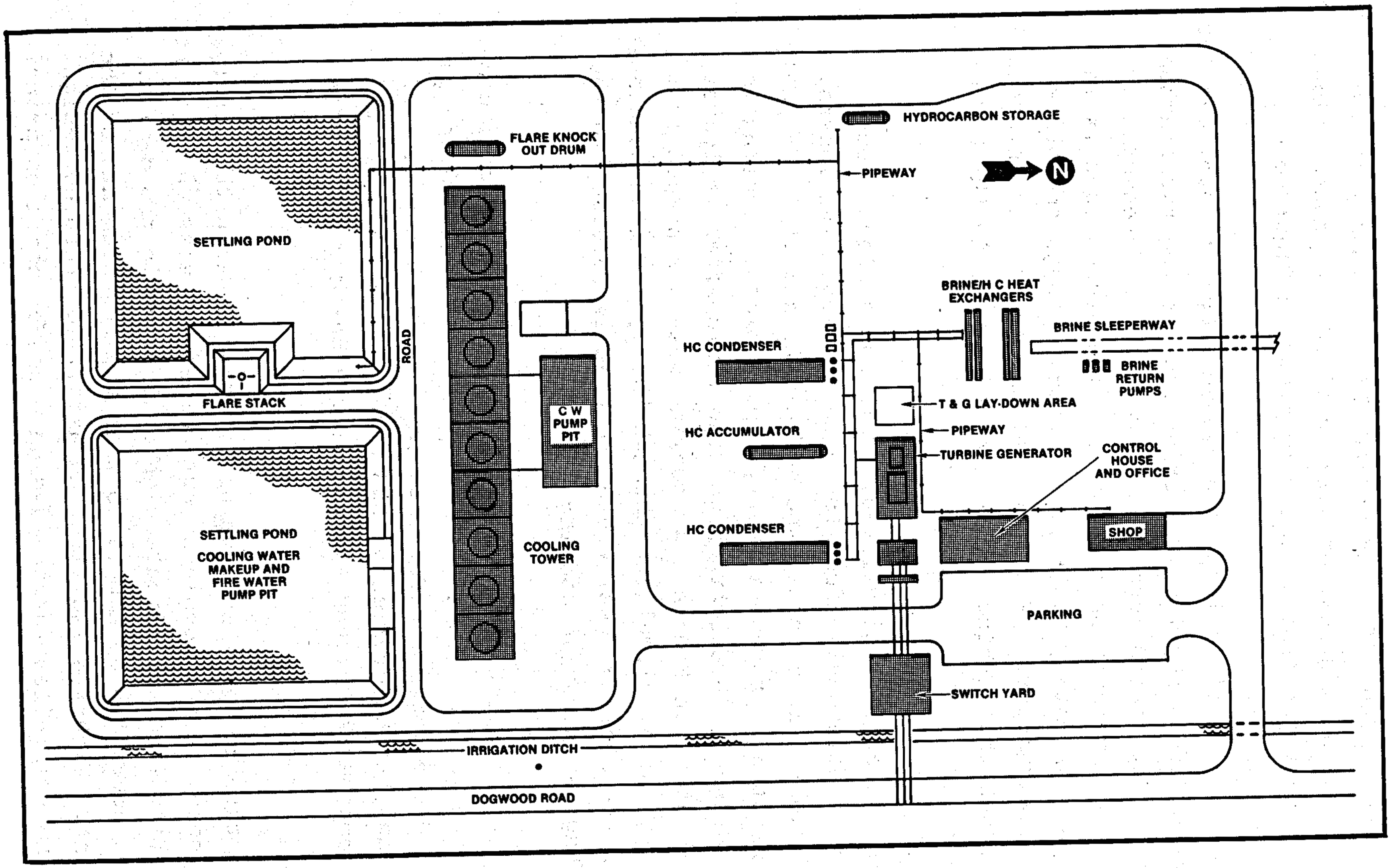

Figure 4—3. Power Plant—Layout.

ficient and economic means of transferring the heat energy in the geothermal fluid to the hydrocarbon working fluid. A process flow diagram of the binary conversion system is shown in Figure 4-4.

The hydrocarbon working fluid loop is a closed loop. It provides for efficient transfer of energy from the brine loop to the hydrocarbon turbine. In the hydrocarbon loop, the hydrocarbon is pressurized after it leaves the hydrocarbon condensers. The hydrocarbon is in turn heated to approximately 305°F as it passes through the brine-hydrocarbon heat exchangers. From the heat exchangers, the hydrocarbon expands through the turbine and is then condensed in the hydrocarbon condensers.

Although cooling water is recirculated, it is not a closed loop. Make-up water is continuously added to balance evaporative losses. This method of cooling is economic and efficient, and it is commonly used in power plant and process industry applications. Cooling is provided to condense the hydrocarbon working fluid after it leaves the turbine. As shown in Figure 4-4, cooling water is pumped from the cooling tower basin, circulated through the hydrocarbon condenser and returned to the cooling tower where the heat is released to the atmosphere through evaporative cooling.

An objective of the project is to use as many proven commercial components, developed for the process industry, as possible. Although many research and development efforts to improve the components of this process appear to be promising, SDG&E has chosen to limit the number of new components through the use of the basic single cycle concept.

The hydrocarbon turbine is a key development component in the binary power plant. There are many designs, but commercial size units do not exist. Feasibility studies indicate high confidence in the design, manufacture, and operation of a unit to meet the requirements of the Heber Power Plant. Either a radial or an axial-flow turbine design is feasible. The axial-flow turbine design would be based on princi-

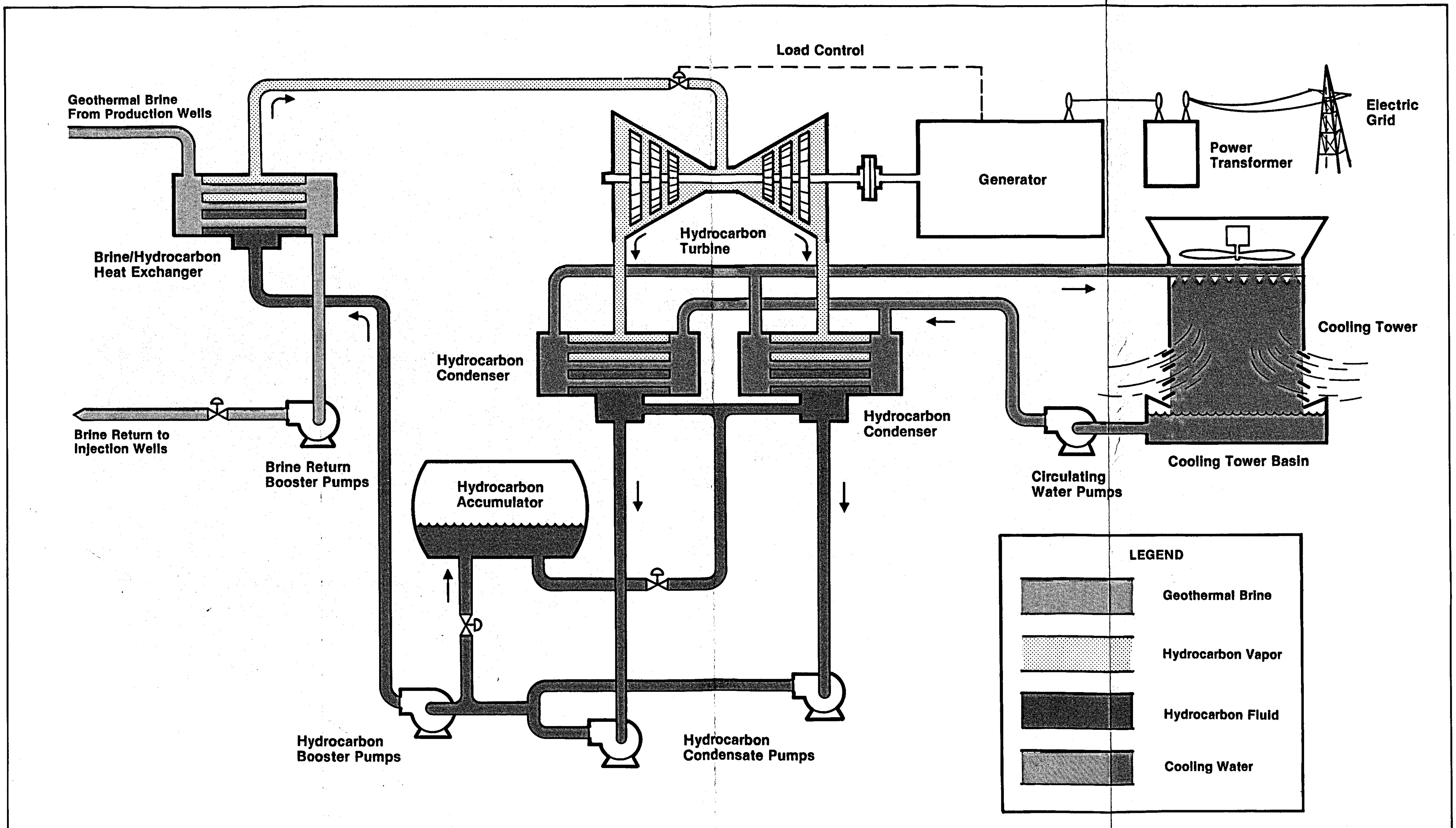

Figure 4—4. Simplified Process—Flow Diagram of the Binary Conversion System to be used in the Heber Plant.

ples used in the design of existing steam turbine and centrifugal and axial hydrocarbon compressors. The radial in-flow hydrocarbon expander design would be based on existing commercial gaseous fluid turbo-expanders used in the process industry.

The hydrocarbon turbine has several advantages over a flash cycle steam turbine. Turbine expansion efficiency is expected to be significantly improved. The problems associated with brine carry-over, sealing, corrosion, or non-condensable gases do not apply to the hydrocarbon turbine. The significantly reduced size of the hydrocarbon turbine, due primarily to fluid density differences, is expected to lead to substantial cost reductions.

Turbine specifications will include development milestones and design reviews. However, responsibility for the development of the turbine will be placed on the manufacturer, and performance guarantees will be the primary means to assure its successful development. This approach reduces the costs and risks of major component development, assures data transfer, and allows the remainder of the project team to concentrate on system performance. Several U.S. manufacturers have expressed a willingness to supply a turbine under these conditions.

SUMMARY

Based upon an extensive background of technical studies, it is apparent that the combination of binary-cycle technology and the moderate temperature geothermal reservoir at Heber is the most efficient means to use this type of resource to produce electricity. The single binary-cycle, will achieve a major performance using many components and technology proven in the process industry, and efficiency gain over the flash process at comparable conditions. Previous laboratory and heat exchanger field testing at this resource has confirmed the applicability of the plant design.

SECTION 5
POWER DISTRIBUTION

SECTION 5
POWER DISTRIBUTION

The major portion of the electrical power generated by the Heber Power Plant will be transmitted and distributed using circuits owned and operated by the Imperial Irrigation District (IID) and SDG&E, which are shown in Figure 5-1. A major SDG&E transmission line project, the 500-kV Eastern Interconnection, is expected to be in service before the Heber Binary Project. This will provide needed transmission capacity for many sources of power, including future geothermal power generated in the Imperial Valley, to the metropolitan areas of Southern California. However, the Eastern Interconnection is not part of this proposal.

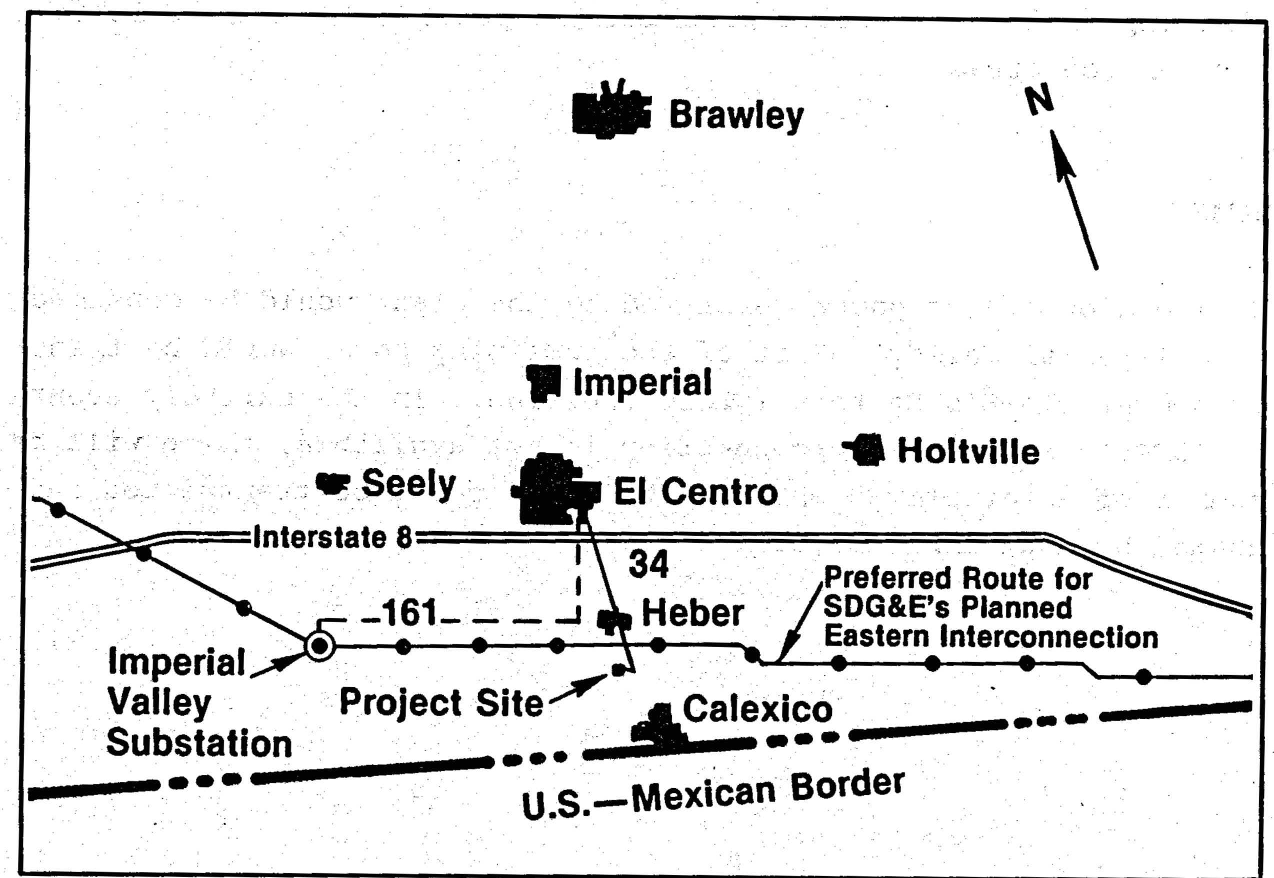

Figure 5-1. Electrical Distribution Diagram Showing Routes from the Plant to the El Centro and Imperial Valley Substations.

IID's 34.5-kV circuit which passes near the Heber Plant site will be connected with the plant's 34.5-kV switchyard. The output from the power plant would be delivered over IID's transmission system to the point of interconnection with SDG&E's Eastern Interconnection. That portion of the output of the plant not consumed in the Imperial Valley will be transmitted over the Eastern Interconnection to SDG&E's service territory. If required, existing interconnections with the Los Angeles area network will allow consumption in broad areas of Southern California in accordance with power sales agreements. The route of this interconnection is shown in Figure 5-2.

If the Eastern Interconnection is not completed when the Heber Power Plant becomes operational, there are several alternate means of delivering power to the metropolitan areas of Southern California. In the unlikely event that transmission capability from the Heber Power Plant to San Diego is not possible, utilities with interconnections in the Imperial Valley could purchase the power and transmit it to their service areas.

SUMMARY

IID's portion of the power generated by the plant would be consumed in the Imperial Valley. Most of the remaining power would be transmitted over SDG&E's Eastern Interconnection. In the unlikely event that SDG&E's Eastern Interconnection is not available, there will be a number of alternatives whereby the power could be transmitted and consumed by Southern California.

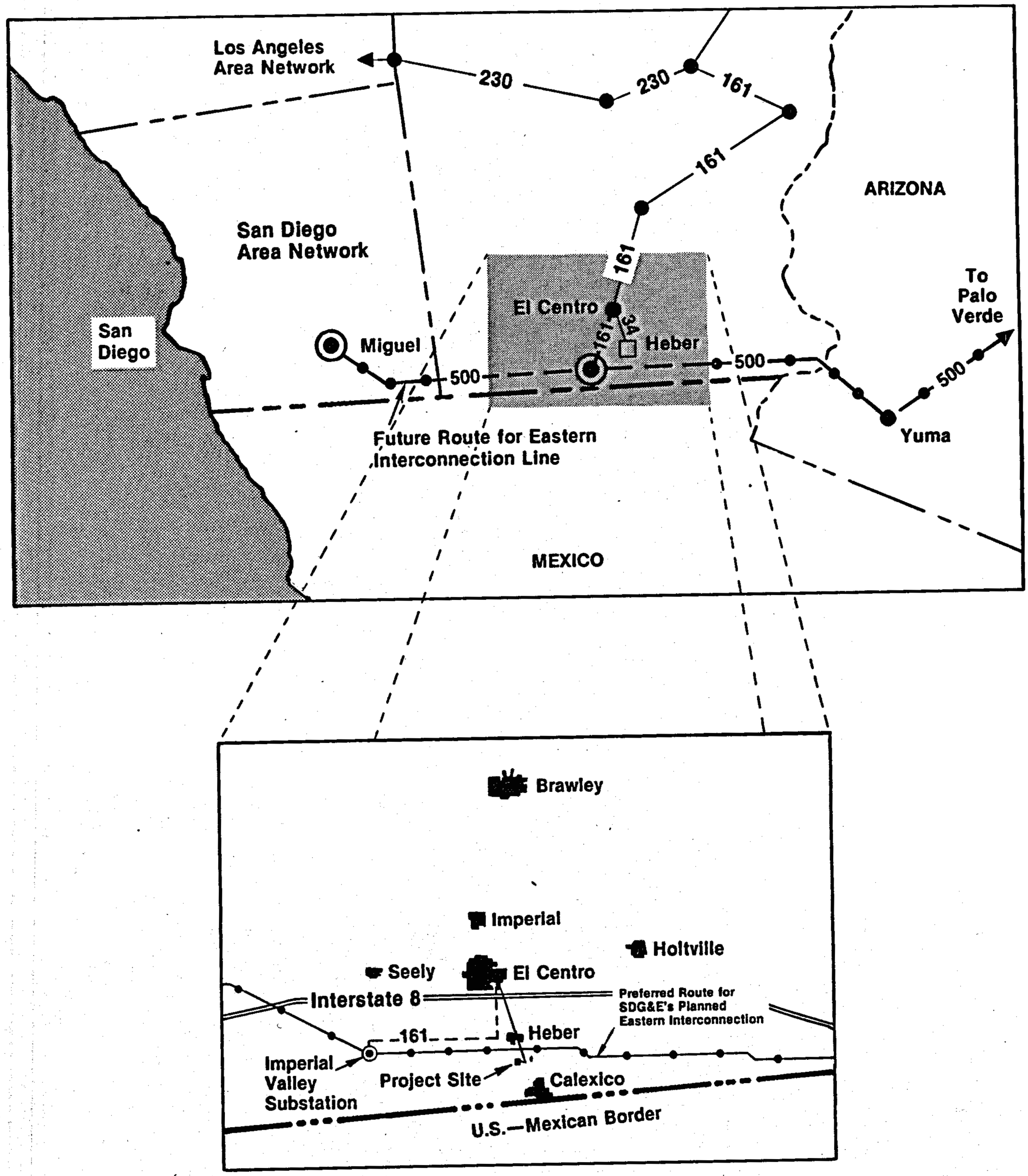

Figure 5—2. Electric Transmission Corridors in Southern California. The beaded, 500 KV line is SDG&E's planned "Eastern Connection."

SECTION 6
COST OF ELECTRICITY

SECTION 6
COST OF ELECTRICITY

The busbar cost of electricity produced from any new source of power must be competitive with the alternative sources of power. The binary-cycle process offers the potential of competitive busbar costs using moderate temperature geothermal resources. Our estimate of the cost of electricity for the first year from a commercial, binary-cycle, geothermal, power plant operating at an 80 percent capacity factor is 89 mills/kWh. This estimate is for a plant that is operational in mid-1984. The estimate was developed using a revenue-requirements method of computation. The components representing the total cost of electricity are listed in Figure 6-1.

• Plant Capital Investment	35 mills/kWh or	39 percent
• Operation and Maintenance	12 mills/kWh or	13 percent
• Energy (Geothermal Heat)	42 mills/kWh or	48 percent
Total	89 mills/kWh or	100 percent

Figure 6—1. Cost Elements for First-Year Operation of a Commercial, Binary-Cycle, Power Plant.

Derivation of the commercial economics for a binary-cycle power plant is a primary objective of the Heber Binary Project. Although a firm estimate of the commercial cost of power is not possible, we have conducted an analysis of these costs and established a preliminary estimate. Our analysis indicates that the cost of power from follow-on binary-cycle plants should be in the range of our alternative sources of power.

The utility capital investment represents a portion of the commercial busbar cost of power. The capital investment must provide a rate of return for the investor or lender. Direct capital costs involve expenditures for licensing and environmental, engineering design and procurement of power plant facilities and brine pipelines, construction and start-up. However, similar to any other construction project, additional capital investment is required to provide for escalation and allowance for funds used during construction accumulated before plant operation.

The cost of operating and maintaining the power plant and brine pipelines is directly connected with the production of electricity and is also included in the busbar cost of power. The annual operation and maintenance costs include the expenses for operation and maintenance to keep the plant in efficient operating condition along with the cost of cooling water, operating supplies, and property taxes.

The Heber Binary Project will purchase geothermal heat from the reservoir developers. The exact terms and conditions of the heat purchase agreements have not been completed however, an understanding has been reached as to the pricing method that will be used. The energy charge will be separated into "fixed" and "variable" portions. The fixed portion will be represents a minimum heat charge and it is independent of the capacity factor achieved by the plant. The variable portion depends on the amount of heat used by the plant.

Power production costs are normalized to allow comparison of plants with different generating capacity. A unit cost of power (in mills/

kWh) is simply the total revenue requirements (costs plus a return on investment and depreciation) for a year divided by the electrical energy generated in that year.

As stated above, the first year (mid-1984) busbar cost of power is 89 mills/kWh at a constant 80 percent capacity factor. The three major cost elements which constitute this estimate are energy, plant capital, and operation and maintenance. Their percentages of busbar cost of power are shown in Figure 6-1. This estimate does not represent the cost of the proposed project, but the commercial cost of power from a plant of identical design, assuming the project demonstration is successful. These costs appear to be in the range of estimated costs for some of our alternate commercial sources of power initiated in this time frame. Other advantages of geothermal power generation are:

- Energy costs (geothermal heat) are anticipated to escalate at a rate that is lower than the fuel cost escalation for alternative power sources.

- The short licensing and construction time required for small geothermal plants minimizes the plant capital interest charges during construction.

SUMMARY

Follow-on binary power plants will benefit from the engineering, procedures, and testing accomplished by the Heber Binary Project. The cost reduction associated with equipment manufacturing and testing are difficult to quantify, but significant reductions are not unreasonable to expect. In addition, there are several other factors which are expected to cause the power production cost from commercial, geothermal, binary, power plants to be lower than our present estimate. These factors are: binary cycle efficiency allows increasing the generating capacity to obtain economies of scale; common site and reservoir facilities for multiple binary plants at the same resource;

concurrent improvements associated with production wells and pumps. Each of these factors, singly or in some combination, tend to make follow-on binary, geothermal, power plants even more competitive with available conventional generating alternatives.

SECTION 7
WORK PLAN & MASTER SCHEDULE

SECTION 7
WORK PLAN AND MASTER SCHEDULE

WORK PLAN

The scope of this project is to design, construct, and operate a commercial-size, binary-cycle, geothermal, power plant at the Heber Reservoir for a two year demonstration period. The goal of the project is to demonstrate the technical and economic feasibility, as well as the environmental acceptability of geothermal power generation using the binary process. Our work plan for the project consists of four major tasks, which are shown in Figure 7-1. The tasks are to be performed by SDG&E, the Chevron Resources Company, Fluor Power Services, Inc., and a Data Subcontractor.

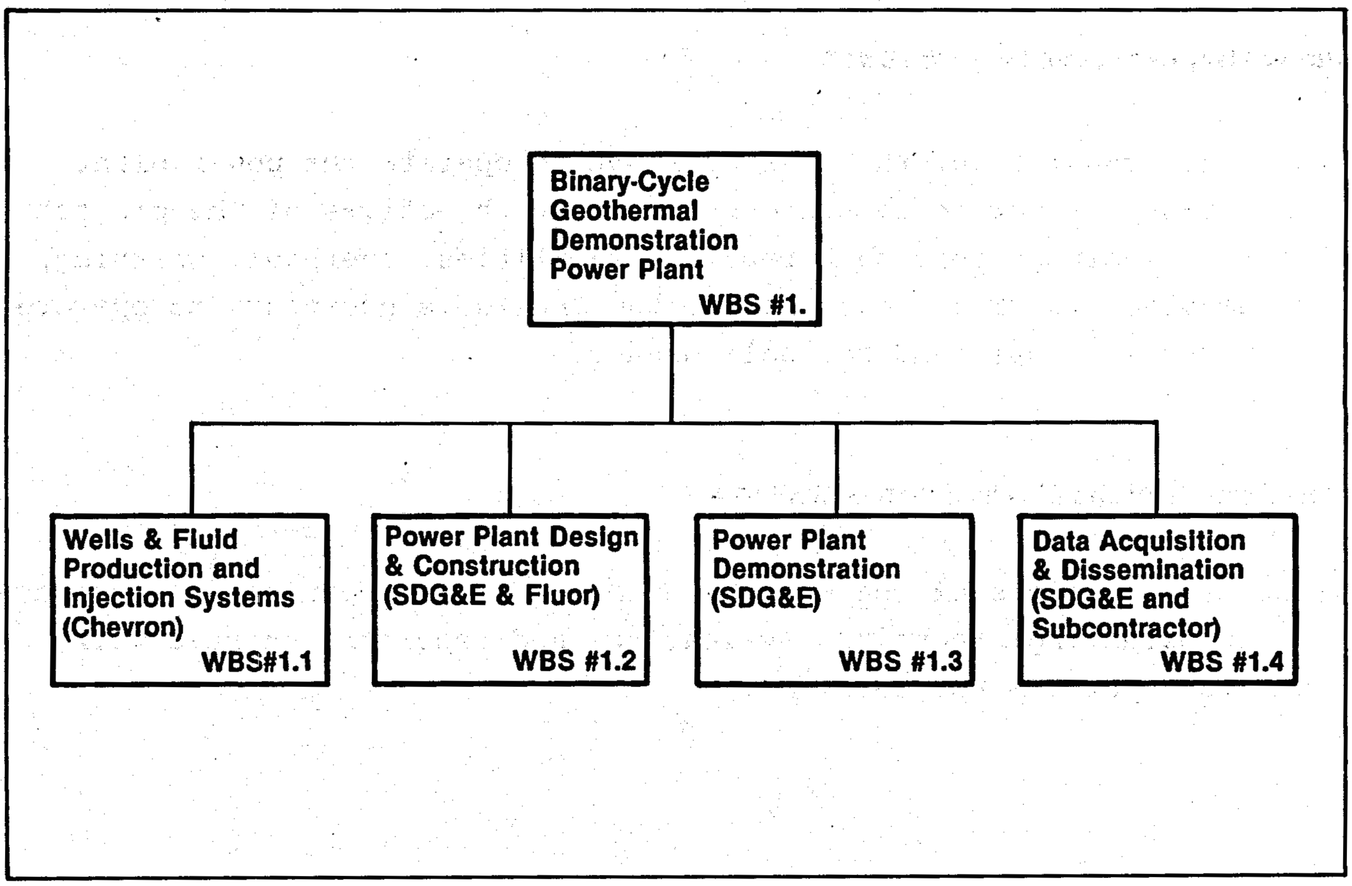

Figure 7—1. First and Second Levels of the Work Breakdown Structure for the Heber Binary Project.

Wells and Fluid Production and Injection Systems — WBS #1.1

Primary responsibility for this task has been assigned to Chevron Resources Company. The task consists of well drilling, the construction of surface facilities for geothermal fluid production and injection, and operation of the field facilities to support plant operation.

Power Plant Design and Construction — WBS #1.2

This task consists of the work by SDG&E and Fluor to manage the design, procurement, construction, and start-up of the power plant systems and the associated switchyard, distribution system, and the brine return pipeline. The task includes obtaining necessary permits, associated monitoring, design, procurement, construction, start-up, and project management activities.

Power Plant Demonstration — WBS #1.3

This task consists of the work by SDG&E to operate the power plant for a two-year period to achieve the basic objectives of the project The task includes services, repairs, facilities, overhaul, cleaning, consumables, testing, spare parts, and the tools necessary to operate the plant in a safe and reliable manner.

Data Acquisition and Dissemination — WBS #1.4

This task consists of the work by SDG&E and an independent subcontractor in gathering, reducing, evaluating, and reporting on reservoir and plant performance data.

MASTER SCHEDULE

The Master Schedule for the project is shown in Figure 7-2. The project term is 82 months. It will begin with the Cooperative Agreement between the DOE and SDG&E and will end four months after a two-year power plant demonstration. At the conclusion of the project, SDG&E will submit a final project report to the DOE and the Electric Power Research Institute. The report will document the results of the project and contain SDG&E's assessment of the economic vitality of the plant. This report will form the basis for the DOE's planned withdrawal from the project.

Because of the progress previously accomplished in design and licensing for the project, engineering will begin immediately with the Cooperative Agreement. Equipment procurement will begin in the third month and the purchase order for the turbine-generator will be issued in the eleventh month. Construction of the power plant starts in the twenty-fifth month, subsequent to approval of the Federal Environmental Impact Statement. Power plant start-up is scheduled to begin in the thirty-seventh month and conclude nine months after mechanical completion of the plant. The power plant demonstration period commences at the end of plant start-up and continues for twenty-four months. The project is concluded four months later with a final report to the DOE and the Electric Power Research Institute.

Major milestones for the project are also identified in Figure 7-2. In addition to these milestones, we have scheduled the following formal design review meetings over the first two-years of the project.

- The first review is a Conceptual Design Review, which will cover the design criteria for the power plant, the conceptual design documentation, and it will establish the basis for initiating the detailed design and engineering effort.

- The second review is a Preliminary Design Review which will result in releasing the preliminary design to begin the final

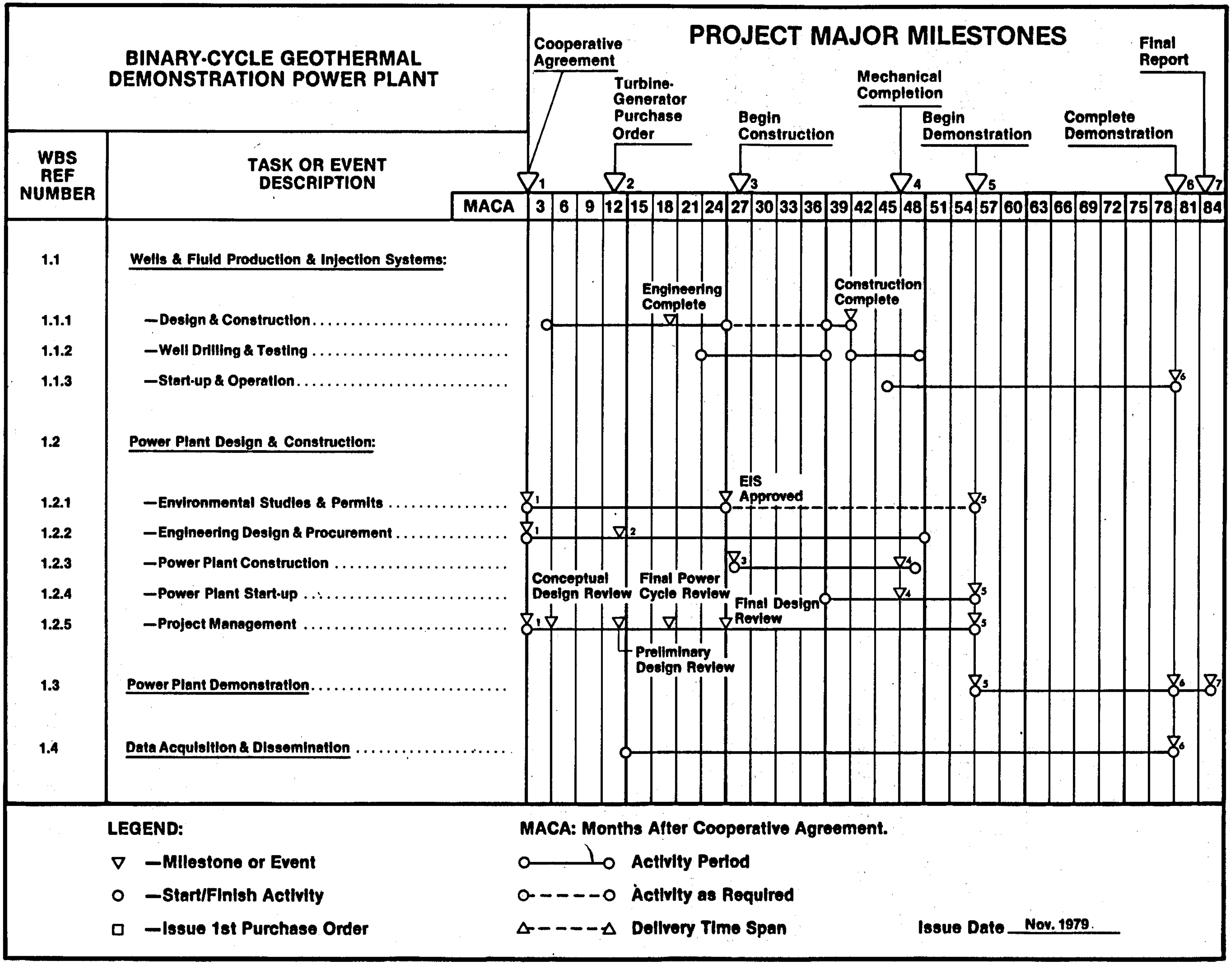

Figure 7—2. Master Schedule for the Heber Binary Project.

systems design effort. This review will concentrate on the piping and instrumentation diagrams and system descriptions of the primary power cycle components; hydrocarbon, brine, and water systems. The review will also include a review of the procurement package for the turbine-generator.

- The third review is a Final Power Cycle Design Review, which will concentrate on the final design of the primary power cycle components.

- The fourth review is a final Design Review, which will include all systems and subsystems of the power plant which are ready for release to the construction effort.

SECTION 8
PROJECT MANAGEMENT

SECTION 8
PROJECT MANAGEMENT

PROJECT ORGANIZATION

Executive control of the project rests with an Executive Committee, which is composed of five members of SDG&E's management, one member from each of the participating organizations, namely, the Imperial Irrigation District, the Southern California Edison Company, and the California Department of Water and Power, and one member from the Electric Power Research Institute. The chairman of this committee will be SDG&E's Vice President of Engineering. The interaction of the major management elements and project responsibilities of the participating companies are shown in Figure 8-1.

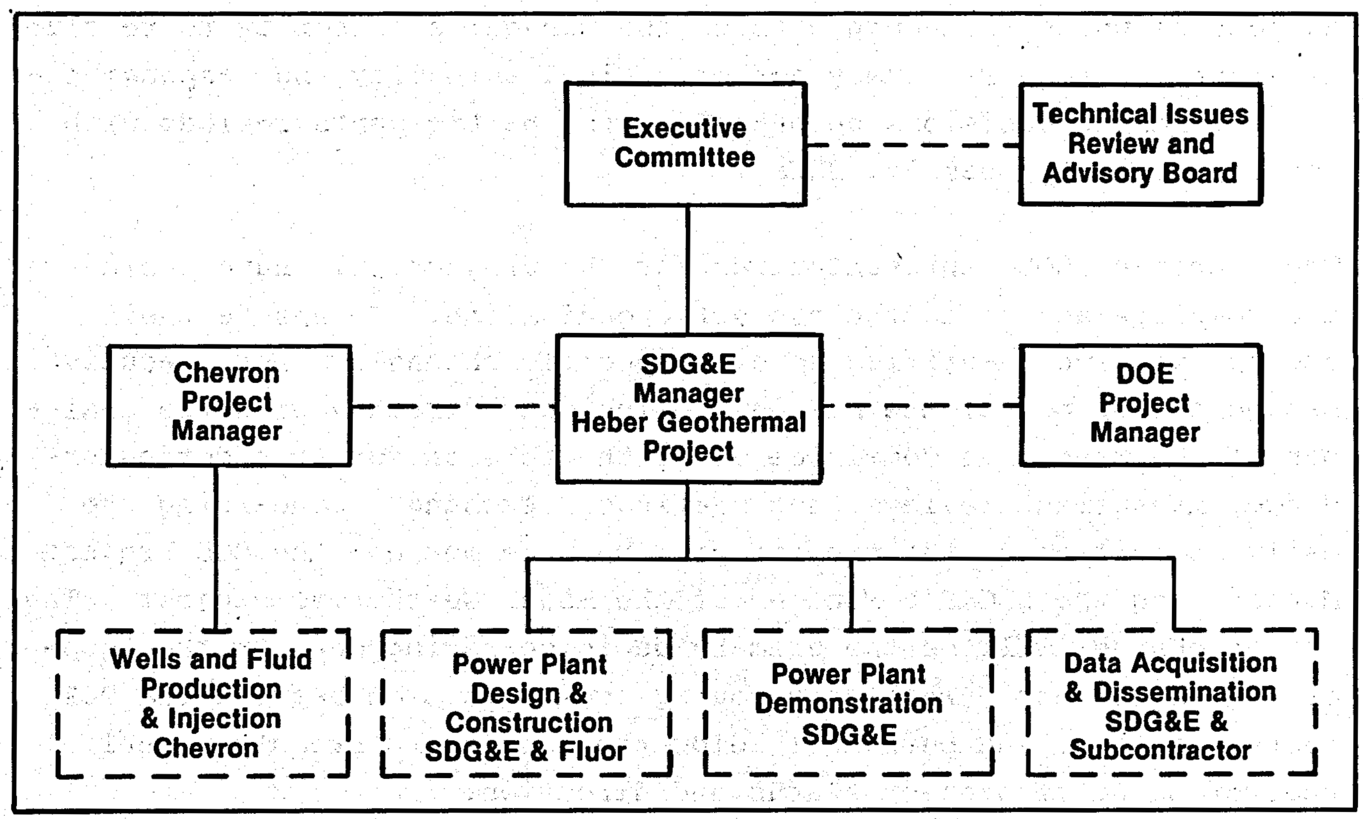

Figure 8—1. Operating Relationships and Project Responsibilities.

EXECUTIVE COMMITTEE

This committee has as its charter the successful execution of the project in accordance with the agreement between the participating companies. In brief, the committee oversees the Heber Binary Project on a business endeavor and provides management-by-exception resolution of technical and business problems outside of the scope of the Cooperative Agreement with the DOE, or referred to it by the Manager of the Heber Geothermal Project.

Regarding matters of procedure, the committee will act as an evaluation forum for problems or issues which do not have gross financial or operating implications on the participating companies. The committee will deliberate on the possible courses of action open to it and on the consequences of those actions. If the committee is unable to approach a unanimity of decision within the time alloted by the problem, the committee chairman will exercise authority to render such decision. This procedure will ensure a definitive response to program exigencies which, although outside the Manager's authority to resolve, nevertheless require timely action. Final authority and responsibility for making decisions on behalf of the participants resides with the lead utility, namely, SDG&E.

The cognizant DOE representatives for the project will have unhindered and complete access to the project organization. To ensure their access, we have identified several specific channels. For executive management purposes, the DOE may communicate directly with the chairman of the Executive Committee using the telecon, written correspondence, management reviews, and meetings. Exchanges concerning the daily activities of the project will be made between the DOE Project Manager and the SDG&E's Manager of the Heber Geothermal Project. The latter channel will be the primary decision-making one for the Cooperative Agreement. We also encourage communication between the DOE representatives and personnel below the Manager to promote mutual understanding of project status and direction.

TECHNICAL ISSUES REVIEW AND ADVISORY BOARD

Supporting the project is a Technical Issues Review and Advisory Board, chaired by a member of SDG&E's Engineering Department. The role of this board will be one of support to the Executive Committee and to the Manager of the Heber Geothermal Project for the resolution of technical issues that may be required. Membership will consist of one representative from each participating company, the Electric Power Research Institute, the California Energy Commission, and other contributing companies. Technical consultants in the geothermal field will be called upon as necessary to assist the board. This board will provide a strong technical foundation for the decisions of the Executive Committee.

MANAGER OF THE HEBER GEOTHERMAL PROJECT

Mr. Robert G. Lacy has been selected as the Manager of the Heber Geothermal Project. In this position he will report directly to the Executive Committee, and he will be responsible for the daily activities of the project. His time is committed 100 percent to the project, and he has total responsibility and commensurate authority for all technical, cost, and schedule aspects of the project. His current administrative position within SDG&E is Manager of Generation Engineering.

The functional organization selected to carry out the Heber Binary Project is shown in Figure 8-2. Because it is project-oriented, the organization features strong, central lines of communication and authority between the Executive Committee and the Manager of the Heber Project, and between the Manager and the principal individuals for carrying out task assignments. At the same time, the task individuals retain access to the supporting line departments of SDG&E and the various subcontractors. As shown on Figure 8-2, Chevron's Project Manager is Mr. A. M. Cooper and the Project Manager for Fluor Power Services, Inc., is Mr. S. G. Unitt.

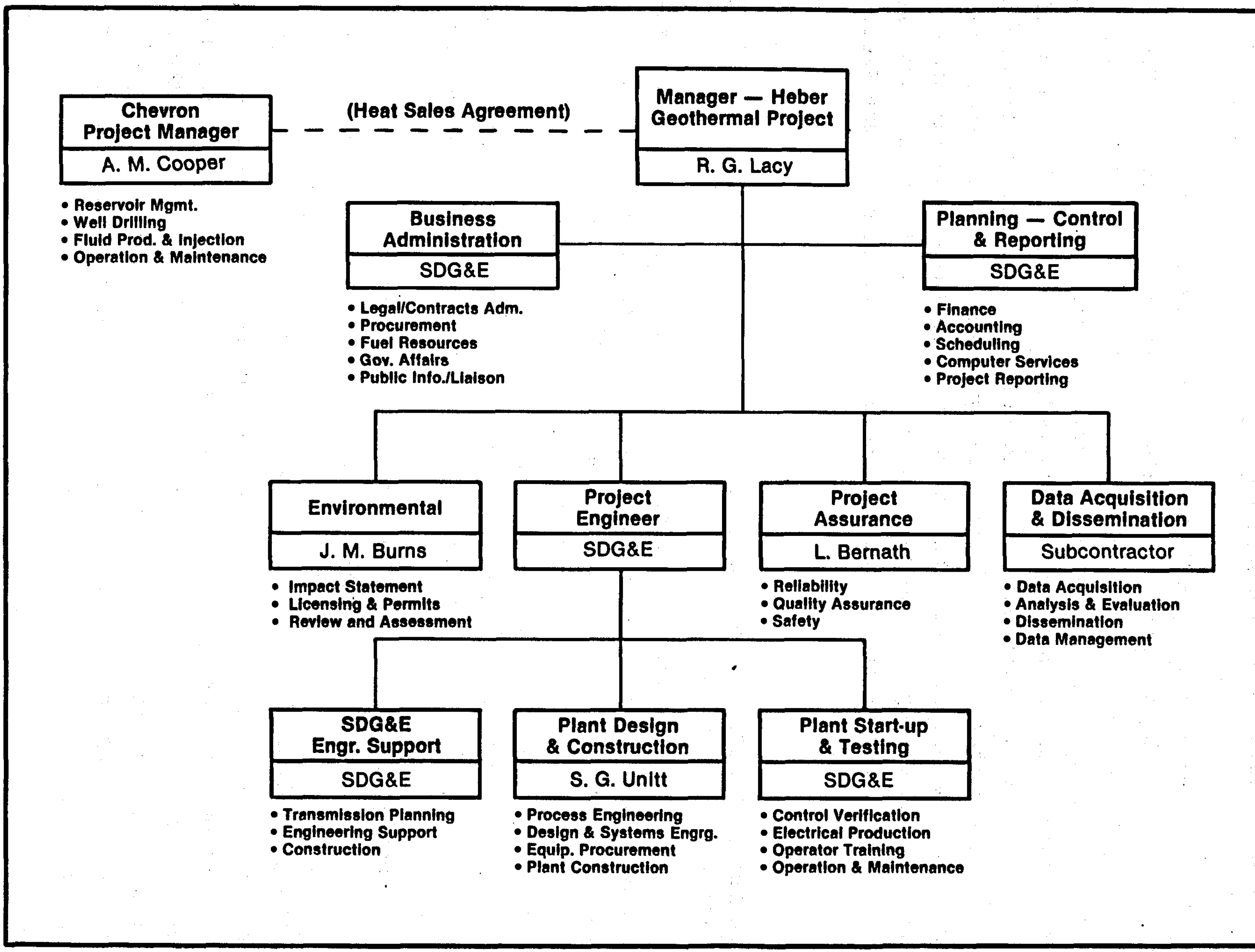

Figure 8—2. Functional Organization for the Heber Binary Project.

This project organization allows immediate response to changing project needs while drawing upon the full technical experience and judgemental capabilities residing with the participating companies. The SDG&E positions shown on the project organization chart will be filled by following SDG&E's standard administrative practices after the Cooperative Agreement with the DOE has been signed. The Manager has complete freedom to allocate his resources to meet project exigencies, and he may take any other actions he deems appropriate to fulfill project goals, so long as those actions are consistent with the operating policies and procedures of the participating companies and the Cooperative Agreement with the DOE.

QUALIFICATIONS

Over the past 40 years, SDG&E has developed project management capabilities by supervising the design, construction, and operation of fossil steam power plants, liquid natural gas storage and handling facilities, and gas and electrical transmission systems. We have also acquired geothermal experience through such activities as exploration, research, field development, and test demonstration.

Chevron is the major leaseholder on the Heber Reservoir and has been designated the Unit Operator for evaluation and development of the reservoir. Chevron is a subsidiary of Standard Oil Company of California. The company is engaged in a world-wide, integrated petroleum operation to explore for and develop crude oil and natural gas reserves, to transport crude oil, natural gas, and petroleum products by pipeline, tank ships, and trucks, to operate large refinery complexes, and to market a complete line of petroleum products. The company maintains extensive research facilities for studies of petroleum resources, processes, and products. The company is also investigating alternate energy sources, such as geothermal. Because of the similarity between geothermal and oil or gas field development, Chevron has a large base of expertise to draw upon for well drilling and the activities associated with resource extraction and injection.

The Fluor office that will be responsible for the design and construction of Heber Power Plant is located in Irvine, California, about 90 miles north of San Diego. Fluor's qualifications as engineers and constructors extend from major experience in refining, chemical processing, and power generation to many years of government contract work in the energy field. Fluor provided the conceptual design for the proposed binary-cycle plant and conducted design optimization studies under an earlier project sponsored by SDG&E, the Electric Power Research Institute, and several other utilities and state government agencies. Their experience includes the application of hydrocarbon turbo-expanders to natural gas processing. This experience will be directly applied to the binary-cycle power plant at Heber.

SECTION 9
FINANCIAL ARRANGEMENTS

SECTION 9
FINANCIAL ARRANGEMENTS

PARTICIPANTS AND CONTRIBUTORS

The parties that have expressed their interest in being co-owners with SDG&E are the Imperial Irrigation District, the Southern California Edison Company and the California Department of Water Resources. The Electric Power Research Institute and the Department of Energy are expected to provide financial assistance to the project without ownership interest. Other utilities and California state agencies are also expected to provide contributions to the project. Based upon letters of interest from the prospective co-owners and EPRI, we have developed the cost sharing plan shown in Figure 9-1.

Source of Funding		Project Cost Sharing (Percent)		
		Capital	Demonstration	Total
Government:	DOE	50	50	50
Participants:	SDG&E	30	32	31
	IID	4	10	6
	SCE	2	5	6
	CDWR	1	3	1
Contributors:	EPRI	10	—	7
	Others	3	—	2
TOTAL		100%	100%	100%

Figure 9—1. Anticipated Financial Arrangements for the Heber Geothermal Project.

II

A Participation Agreement will be required for the project. It will contain provisions for the owners to share any obligations and revenues that are derived from the plant. Such sharing will be in proportion to the financial investment in the project by each owner. Some of the other provisions that will be included in this agreement are:

- Management of the project by SDG&E.
- Participant membership on the project's Executive Committee and Technical Issues Review and Advisory Board.
- Participant ownership and project obligations.
- Operating arrangements, such as geothermal heat sales, water supply, power sales, land ownership, plant operation, termination, etc.

Following execution of this agreement, SDG&E will act on behalf of the owners to negotiate a Cooperative Agreement with the DOE.

OPERATING AGREEMENTS

Major agreements required to operate the plant are heat sales, water supply and power sales, and transmission agreements. Long term heat sales agreements are being negotiated with Chevron and the other reservoir developers. These agreements will provide the reservoir developers with a reasonable commercial return on their investment, but are expected to limit escalation, limit liability in the event of reservoir failure, and specify interfaces on a commercial basis. Transmittal of all non proprietary reservoir data will also be included in the agreements.

SDG&E has entered into an agreement with Imperial Irrigation District for an assured plant cooling water supply.

Power sales agreements will be the responsibility of each participant. The power generated will be allocated based on ownership interest. Transmission to the metropolitan area of San Diego is expected to use SDG&E's Eastern Interconnection Line.

COST SHARING

The total capital cost of the project will be shared by the DOE, participants, and contributors. SDG&E is requesting that the DOE provide fifty percent of the operating costs for the two-year demonstration period. We are also requesting that the DOE pay 100 percent of the data acquisition and dissemination costs. These costs are subject to the agreement between SDG&E and the DOE on the scope of work for this task. SDG&E also expects to receive additional funding for the project from contributors such as the Electric Power Research Institute and others.

REVENUE SHARING

Net revenues resulting from the sale of power from the Binary-Cycle Geothermal Demonstration Power Plant will accrue solely to the participants (plant owners) in proportion to their respective ownership interests in the plant. In view of the contributions to the project by the DOE, the participants would be willing to negotiate a provision whereby any net revenues earned from the electric power sales could be shared with DOE. It is proposed that such revenue sharing would commence at the beginning of demonstration period and extend into the commercial operation period.

LONG TERM COMMITMENT

San Diego's load growth and long-term commitment to geothermal development should easily allow integration of the power from this plant, if successful and competitive in cost, into SDG&E's resource base. SDG&E's 1979 resource plan shows up to 800 megawatts of geothermal electric energy capacity through 1995. In addition to the Heber Project, other SDG&E geothermal activities include a contract with Magma for purchase of power and data from their 10 megawatt binary pilot plant at East Mesa, letters of intent for two commercial, 50 megawatt power plants with Magma and Republic Geothermal, reservoir development and related activities. These plans and activities, plus the significant capital and other resources committed to this project, assure maximum long range usefulness of this project and subsequent geothermal expansion.

SECTION 10
DATA GENERATION & TECHNOLOGY TRANSFER

SECTION 10
DATA GENERATION AND TECHNOLOGY TRANSFER

DATA GENERATION

Our plan for the generation and management of data on system performance, reliability, commercial potential, and environmental acceptability of the power plant and reservoir operations is summarized in Figure 10-1. We have established a Data Acquisition and Dissemination task for the project. We are proposing that this task will be the joint responsibility of SDG&E and an independent subcontractor. Dissemination of power plant and reservoir operational data will be the Data Subcontractor's responsibility. The technology transfer, which will involve access to the plant by the geothermal industry and the release of plant design information that is developed during the project, will be a joint responsibility.

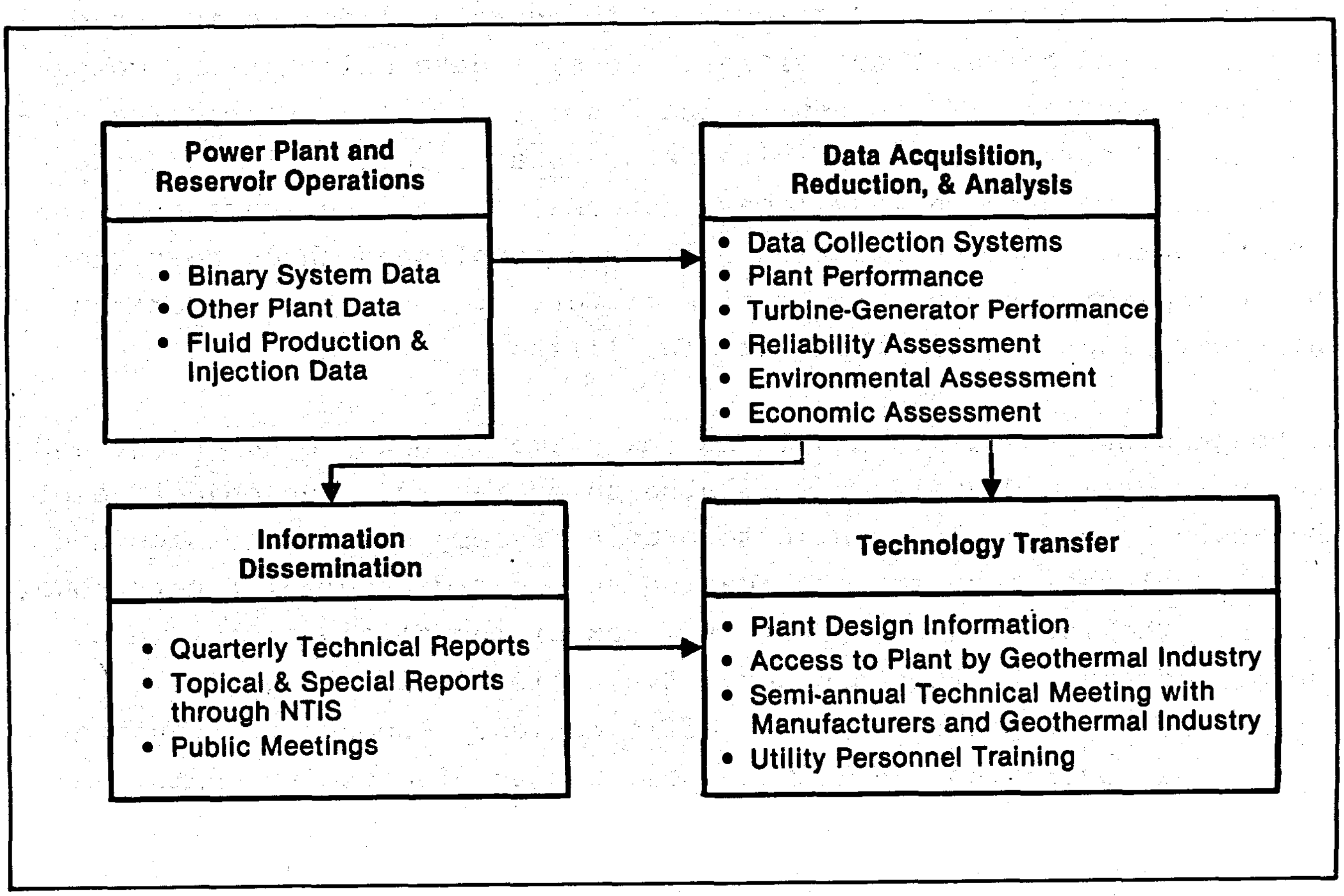

Figure 10—1. Key Elements of SDG&E's Data Generation and Technology Transfer Plan.

Broad applications of the binary-cycle technology are expected to result from this project. The objective of the data acquisition and dissemination task will be to collect and disseminate useful power plant and performance information on this technology to a broad spectrum of potential users to accelerate commercial development of moderate temperature hydrothermal resources.

DATA COLLECTION

An on-site data collection system will be designed and constructed. Binary-cycle data and information will receive first priority. The design of this system will be reviewed by the Data Subcontractor and integrated into this subcontractor's data handling requirements and procedures. This phase of the effort will be accomplished concurrently with the design and construction of the plant. Data such as design criteria, specifications, drawing, and "as-built" configurations will be acquired during this phase.

Management, storage, and retrieval of the data will be accomplished by both on and off-site activities. On-site data calibration, computer and cassette tape processing and display will allow immediate validation and correction. Off-site data storage, retrieval, and reduction will also provide easy access for analysis and evaluation by the subcontractor. Data collection will be accomplished throughout the entire project, ranging from design criteria to operational data on the power plant and the reservoir facilities.

Although binary-cycle data will be the primary focus, other plant and reservoir data and analysis will also be addressed. The objective of the analysis and evaluation is to provide a comprehensive design and operational data base for application to other geothermal binary power plants. The intent is to identify areas of insufficient data which can be addressed by this project. Evaluation will include design parameters, system and component efficiencies, response to transient conditions, operation and maintenance, busbar electricity costs, and plant reliability.

INFORMATION DISSEMINATION

The dissemination of information will be accomplished by several methods. Technical reports will be distributed through the National Technical Information Service as well as direct mailings to interested parties. Semi-annual meetings with representatives of the geothermal industry will be held to discuss technology status and problems and to receive industry inputs to the project.

TECHNOLOGY TRANSFER

A staff training program will allow participating and non-participating utility staff personnel to obtain first hand geothermal plant experience and training. The spectrum of project participants, contributors such as EPRI, and the use of an independent subcontractor assures a wide audience within the project. Experience gained in the project can be directly applied to other binary geothermal projects.

SUMMARY

Our plan presents an imaginative and comprehensive method to generate and effectively transfer technical data from this project. We will concentrate on those portions of the binary-cycle technology that can be directly used by industry for other geothermal applications. This will conserve funds and focus attention on required areas. The selection of an independently qualified subcontractor will result in direct two way communication with the geothermal industry, provide the detailed information required for effectively transfering the technology, and promote commercial geothermal development.