PART II

GEOTHERMAL ENERGY

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CHAPTER 1

INTRODUCTION

1.1 Legislative Background

Section 3001 (b)(2)(A) of the 1980 amendments to the Resource Conservation and Recovery Act temporarily exempted from regulation as hazardous wastes several types of solid wastes associated with geothermal energy. Specifically, drilling fluids, produced waters, and other wastes generated during the exploration, development, or production of geothermal energy were excluded from regulation until the Environmental Protection Agency reported to Congress on these wastes. In Section 8002(m) of the amendments, Congress directed EPA to report on the following elements:

1. The sources and volumes of discarded material generated per year from such wastes;
2. Present disposal practices;
3. Potential danger to human health and the environment from the surface runoff or leachate;
4. Documented cases that prove or have caused danger to human health and the environment from surface runoff or leachate;
5. Alternatives to current disposal methods;
6. The cost of such alternatives; and
7. The impact of those alternatives on the exploration for, and development and production of, crude oil and natural gas or geothermal energy.

1.2 Scope Of Report

The types of wastes to be examined for this study include those wastes originally exempted under Section 3001 (b)(2) of the 1980 amendments. Using selection criteria derived from RCRA's language and the accompanying legislative history, EPA has determined that the following geothermal energy wastes are considered exempt under Section 3001(b)(2) and are therefore within the scope of this study:

- Drilling media and cuttings;
- Reinjection well fluid wastes;
- Piping scale and flash tank solids (except for those associated with electrical power generation);
- Precipitated solids from brine effluent; and
- Settling pond wastes.

Geothermal wastes that are not exempt and are not within the scope of this study include the following:

- Wastes resulting from the generation of electricity; such as
  - hydrogen sulfide wastes
  - cooling tower drift
  - cooling tower blowdown
- Waste lubricants;
- Waste hydraulic fluids;
- Waste solvents;
- Waste paints; and

- Sanitary wastes.

1.3 Report Organization

This report begins in Chapter 2 with a basic discussion of the various types of geothermal resource systems. Included within this discussion are brief descriptions of hot igneous systems, geopressured resources, and hydrothermal systems.

Chapter 3 profiles the geothermal industry by presenting a complete listing by type of operation and geographical location for all known geothermal commercial activities. The types of geothermal activities that are profiled include surface exploration and geothermal well drilling operations, electric power generation from both vapor-dominated and liquid-dominated systems, and several direct-use applications that are currently being practiced.

Waste sources and volumes that are generated from the industries described in Chapter 3 are then discussed in Chapter 4. The most significant wastes described in this Chapter include drilling mud and cuttings from geothermal exploration and development operations and reinjection fluids and settling pond precipitated solids from electrical power generation operations.

In Chapter 5, a limited number of chemical analyses the solid and liquid wastes described in Chapter 4 are given for a range of constituents. The constituent concentrations of the liquid wastes and liquid extractions from the solid wastes are then compared to regulatory limits. Since data characterizing geothermal wastes are lacking in most cases, Chapter 5 concludes by presenting a status of current data availablity and by outlining suggestions for further data gathering programs.

A presentation of current waste disposal practices and alternatives to current practices is provided in Chapter 6. Along with this presentation, geothermal regulations that have been implemented by the states are reviewed. Finally, this chapter also discusses the types of environmental damages or threats to human health that have occurred, from the perspective of geothermal waste management practices that are in compliance with regulatory requirements as well as waste management practices that are improper and not in compliance with established regulatory requirements.

A methodology for determining the costs of current and alternative geothermal waste disposal practices is provided in Chapter 7. Chapter 8 describes a methodology where waste disposal costs generated in Chapter 7 are used to forecast probable impacts on the geothermal industry resulting from the use of the alternative waste disposal practices.

Finally, in Chapter 9 conclusions and recommendations are made.

CHAPTER 2

OVERVIEW OF THE NATURE AND OCCURRENCE OF GEOTHERMAL ENERGY RESOURCES

The purpose of this section is to provide background information on the nature of geothermal energy resources by briefly describing geothermal energy systems, where geothermal energy systems are found, and how usable geothermal energy pockets are naturally formed.

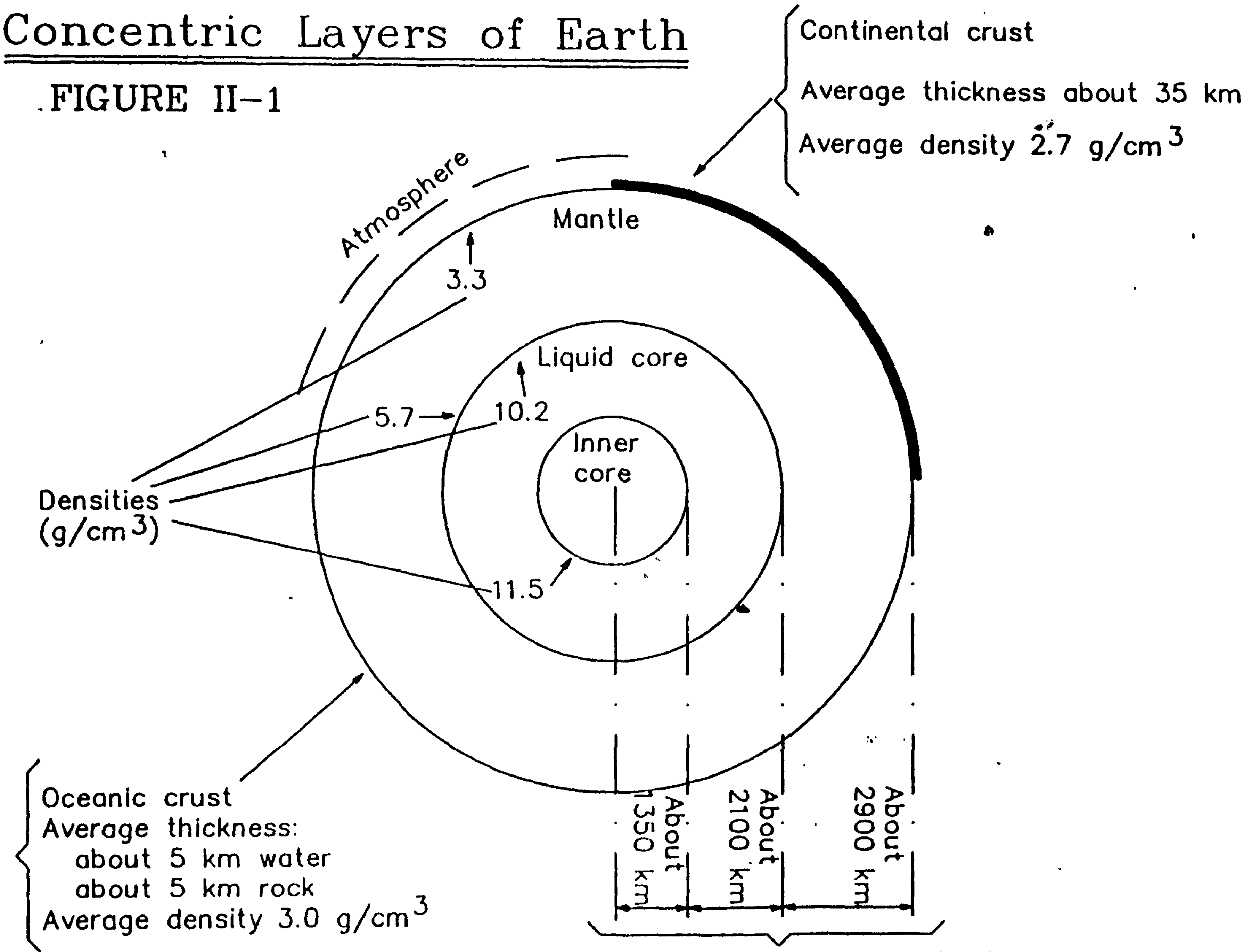
2.1 Background

The crust and the atmosphere of the earth account for less than one-half of a percent of the total mass of the earth. The remaining 99.5 percent lies beneath the crust, and scientific knowledge of the nature of the material beneath the crust is largely a result of the study of earthquake waves and lavas, and measurements of the flow of heat from the interior towards the earth's surface. Nevertheless, this indirect knowledge has allowed geophysicists to construct a fairly clear and consistent model of the internal structure of the earth.

The currently accepted model of the earth's internal structure consists of four concentric spheres; from the outermost to the innermost they are the crust, the mantle, the liquid core, and the innermost core, which

Concentric Layers of Earth

FIGURE II–1



SOURCE: ARMSTEAD, 1983

is believed to be solid. This model is presented in Figure II-1.

Temperatures and densities rise rapidly as the center of the earth is approached.

The term "geothermal energy" is often defined to include all of the heat contained in these four concentric spheres (approximately 260 billion cubic miles that constitute the entire volume of the earth) (Chilinger, et al, 1982). The exploitable part of this enormous energy supply, however, is represented by that small fraction of the earth's volume in which crustal rocks, sediments, volcanic deposits, water, steam, and other gases occur at usefully high temperatures and accessible depths from the earth's surface and from which useful heat can be economically extracted. Even this small portion of the total is an enormous reservoir of thermal energy. It is estimated that up to 1.2 million quads (a quad is one thousand trillion British Thermal Units) are available from geothermal energy resources. The classification, location, and recovery of this portion of the available thermal energy are the subjects of this section.

Geologists and engineers classify geothermal energy systems into three major categories:

- Hot igneous systems;
  - Hot dry rock
  - Magma
- Geopressured systems; and
- Hydrothermal systems
  - Vapor-dominated reservoirs
  - Liquid-dominated reservoirs.

The first two categories may contain the largest amount of useful heat energy, but are not economically and/or technologically exploitable at this time. Advancements in current technology would be required in order to economically use these potential heat sources on a commercial basis.

The third category, hydrothermal energy systems, is commercially viable and has received the most attention because extraction technology exists for the economic recovery of heat from these resources.

2.2 Hot Igneous Systems (Hot Dry Rock and Magma)

Hot igneous systems are created by the buoyant rise of molten rock (magma) from deep in the crust. There are two major types of hot igneous systems: hot dry rock systems, where the rock is no longer molten (less than 650° C or 1200° F) and magmatic systems, where the rock is still molten or partly molten (greater than 650° C).

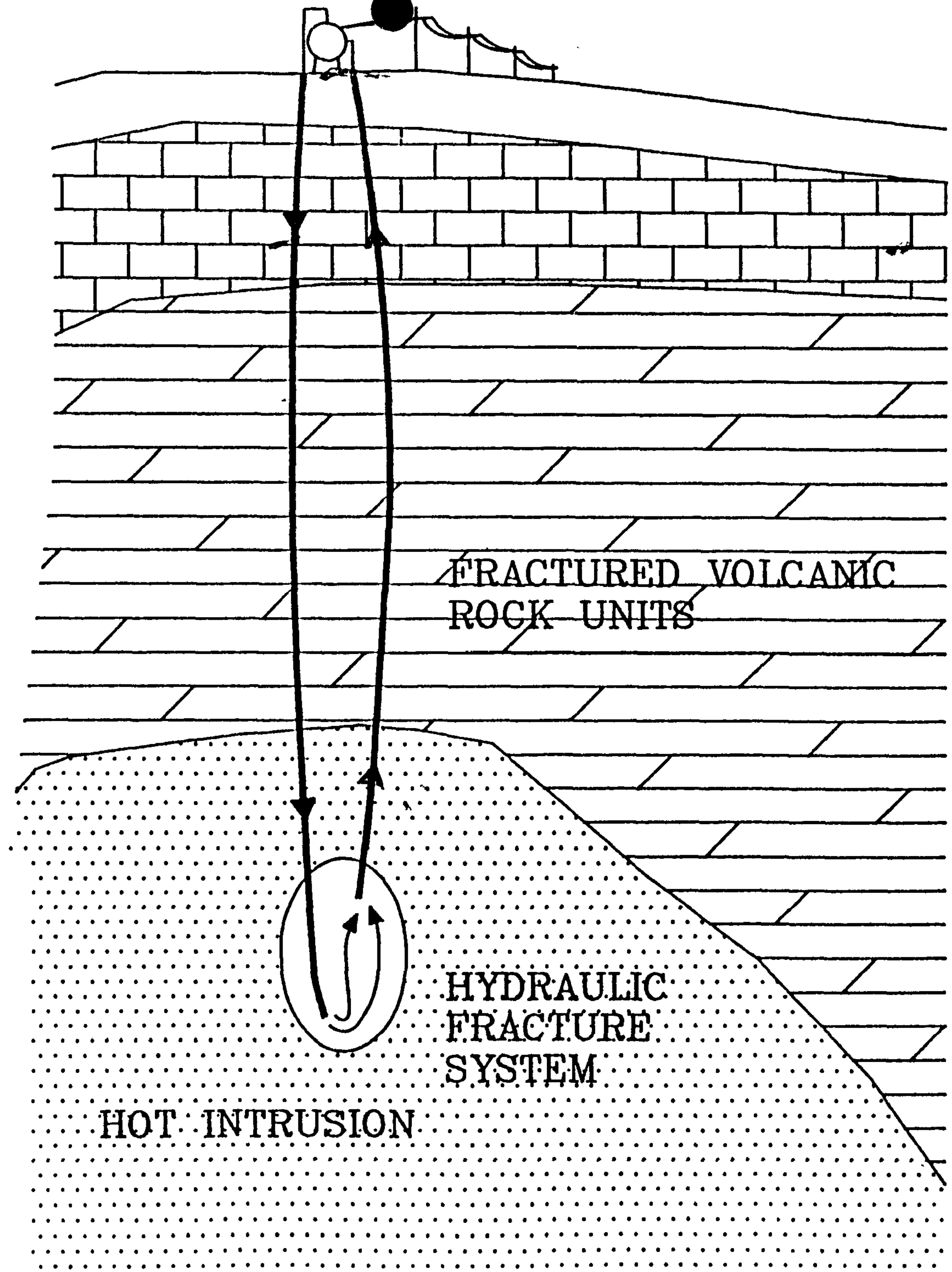

FRACTURED VOLCANIC
ROCK UNITS
HYDRAULIC
FRACTURE
SYSTEM
HOT INTRUSION

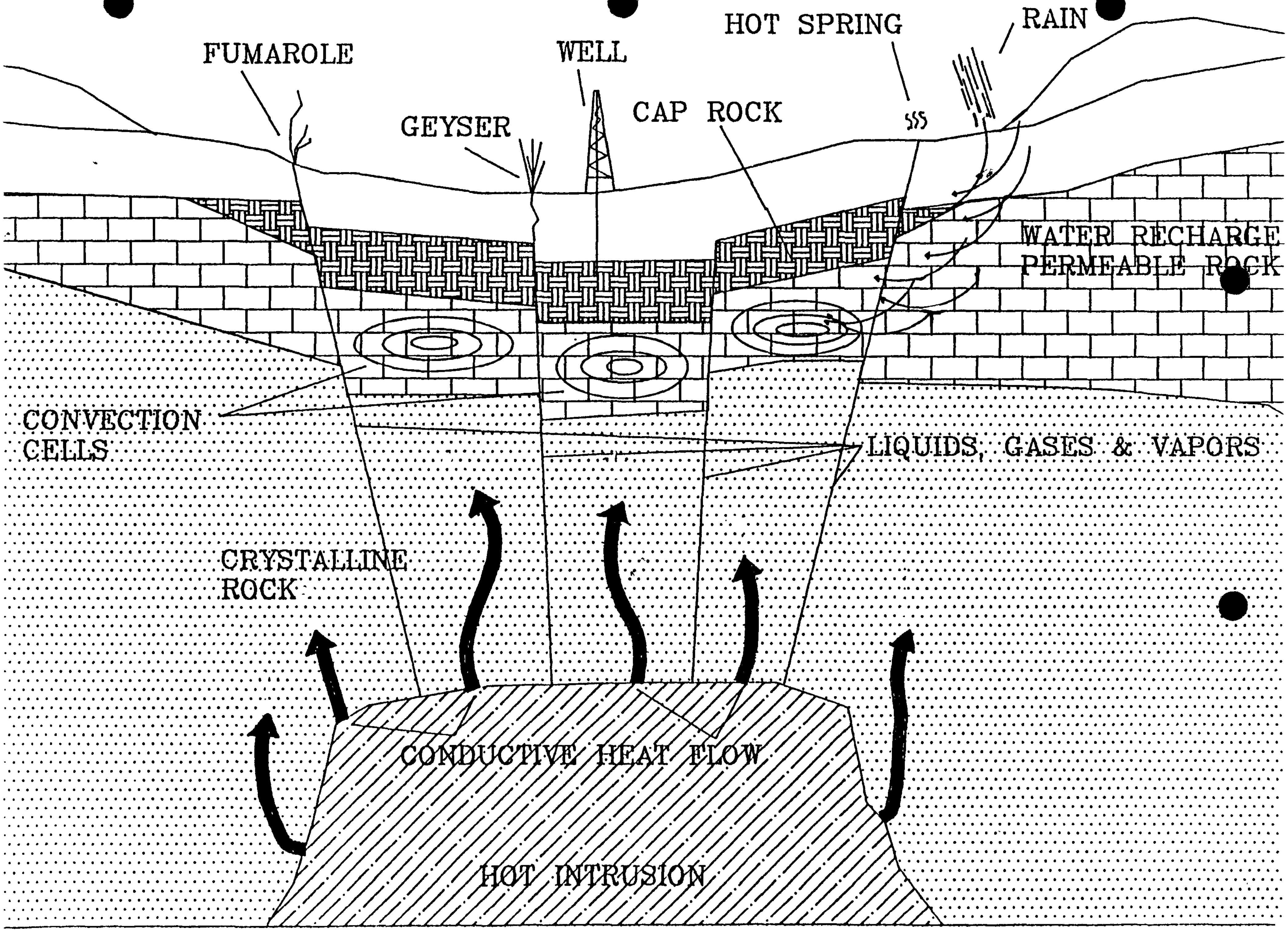
Figure II-2 presents a schematic diagram of a representative hot dry rock system.

Because of the great depth (3 km) and high temperatures (650-1200° C or 1200-2200° F) associated with magmatic systems, the heat is not recoverable with current technology. However, the scientific feasibility of heat extraction has been demonstrated in the laboratory and on a small scale basis by near-surface field experiments at an encrusted lava lake in Hawaii. The engineering and economic feasibility of using magma resources has not yet been determined.

The hot dry rock systems, located on the margins of magma chambers, are favorable candidates for heat energy extraction. In order to accomplish heat extraction efficiently, it will be necessary, in some cases, to create a system of hydraulic fractures between special, directionally-drilled wells to improve rock permeability and provide circulation loops. This technology was originally developed for the oil and gas industry, but a research program at Los Alamos Scientific Laboratory in New Mexico is underway to develop this technology for geothermal applications. Heat has been extracted and electricity produced from hot dry rock resources at Fenton Hill, New Mexico on a small scale. A heat extraction system has now been completed which is of sufficient size and longevity to attract commercial interest. The economics of using hot dry rock systems remain uncertain, but use of these systems appears to be an attractive mid- to long-term national energy option.

2.3 Geopressured Systems

Geopressured systems are characterized by the presence of hot fluids under high pressure, usually found in deep sedimentary basins where a low level of sediment compaction has taken place over geologic time and where an effective caprock exists. For example, wellhead pressures in excess of 11,000 pounds per square inch (psi) and temperatures up to 237° C (459° F) have been recorded in some geopressured zones in Texas and Louisiana (Chilinger, et al, 1982). Since there is no deep circulation of the water, it only reaches moderately elevated temperatures. Because geopressured reservoirs are usually associated with petroleum, the water is generally saturated with methane and other hydrocarbon gases. Therefore, these reservoirs could represent an important natural gas supply. There is still no direct evidence that heat, natural gas, or both can be extracted economically from geopressured reservoirs, but large-scale field experiments are now underway in Texas and Louisiana to investigate this possibility.



FUMAROLE
WELL
HOT SPRING
RAIN
GEYSER
CAP ROCK
WATER RECHARGE
PERMEABLE ROCK
CONVECTION
CELLS
LIQUIDS, GASES & VAPORS
CRYSTALLINE
ROCK
CONDUCTIVE HEAT FLOW
HOT INTRUSION

2.4 Hydrothermal Systems

Hydrothermal systems are the geothermal resources of current economic importance. These systems consist of high-temperature water and/or steam trapped in porous and permeable reservoir rocks. Because of the convective circulation of water and steam through faults and fractures, the heat is transported near the earth's surface. The density difference between cool and heated fluid causes cool water or steam to move downward and the heated water or steam to move upward.

The heat that is available in the geothermal reservoir rock is produced by bringing hot water and/or steam to the surface. Figure II-3 presents a schematic diagram of a simplified hydrothermal system.

There are two classes of hydrothermal systems: vapor-dominated systems, which liberate mostly steam, and liquid-dominated systems. Liquid-dominated sytems are much more abundant than vapor-dominated systems. They are usually found in permeable sedimentary rock or in competent rock systems, such as volcanic formations, if open channels along faults or fractures exist. A brief discussion of both systems is presented below.

2.4.1 Vapor-Dominated Systems

If the caprock in a hydrothermal reservoir is not able to sustain the pressure level to prevent boiling, then pockets of steam will form. When the pressure is relieved (for example, by drilling a well into the pocket), most of the dissolved minerals are left behind in the formation, and relatively pure steam is recovered. Except for a variable content of noncondensible gases (which could be methane, carbon dioxide, radon, and hydrogen sulfide), the evolved steam can be an economical energy source. Frequently, it is used to drive turbines and generate electricity.

The existence of a large, bounded volume of rock within which temperatures are high enough and pressures are low enough to permit boiling within the cavity is rare; this is why vapor-dominated systems are far less common than liquid-dominated systems. Nevertheless, the technology for utilizing energy from vapor-dominated systems is well developed; the largest geothermal power plant development in the world (at The Geysers in California) uses steam from a vapor-dominated system (Chilinger, et al, 1982).

Power generation from vapor-dominated resources produces relatively small quantities of solid wastes. This is primarily due to the nature of the vapor transport mechanism that carries the volatile components to the surface. Some secondary waste components, however, are generated from use of the vapor or off-gas hydrogen sulfide (H_2S) abatement systems employed at some power plants. These solid wastes could include measurable levels of hydrogen sulfide treatment by-products such as used Stretford solution (Stretford solution is a component of H_2S abatement systems; it breaks the H_2S into elemental sulfur and water using a vanadium catalyst), elemental sulfur and cooling tower sludge along with boric acid, arsenic, and mercury (US EPA, 1978).

2.4.2 Liquid-Dominated Systems

In liquid-dominated systems, water percolates through permeable rocks, encounters high-temperature crystalline rock and, becoming less dense as it is heated, rises toward the surface. If some geologic barrier prevents the water from actually reaching the surface, an undergound reservoir may form, within which the water will circulate convectively. This slow circulation allows the water to continuously extract enough heat from the lower part of the reservoir to compensate for the heat that escapes upward through the formation. Thus, an equilibrium may eventually be reached in which the water temperature throughout the reservoir is approximately uniform (this temperature may range anywhere from slightly above ambient temperature to 350° C/662° F or higher).

Hydrostatic pressure on the water is usually high enough to keep it from boiling. Because of high temperature and residence time in the reservoir, the water can become saline or saturated with the dissolved constitutents of the minerals with which it comes in contact. Since the solubilities of a number of minerals increase with temperature, the hotter geothermal waters generally contain greater amounts of dissolved solids than water at ambient temperatures. This condition is, however, strongly site-dependent because the mineralogical composition of rock formations in geothermal reservoirs varies widely from site to site (US EPA, 1978).

Geothermal liquids range rather widely in hydrogen ion concentration, with pH values generally between 2.0 and 8.5 (US EPA, 1978). Most geothermal liquids have a pH value above 7.0. Liquids of higher salinity generally have very low pH values and can be highly corrosive to man-made materials.

Noncondensible gases - those that do not condense at normal operating temperatures - are environmentally important constitutents of geothermal liquids. These may be free gases, dissolved or entrained in the liquid phase. Hydrogen sulfide traditionally has been the component of greatest concern because of its toxicity. Noncondensible gases usually comprise between about 0.3 percent and 5 percent of flashed steam from geothermal liquids (US EPA, 1978).

Radioactive elements are also occasionally found in geothermal liquids in very low concentrations. Thse include uranium and thorium isotopes, radium, and radon. Radon, a radioactive gas and one of the products of radium decay, is the most significant radioactive components in geothermal liquids. EPA data covering 136 geothermal sites showed a range of 13 to 14,000 pCi/L (picoCuries per liter), with a median of about 510 pCi/L (US EPA, 1978).

Chemicals such as acids, bases, and various flocculants and coagulants may be added to geothermal liquids to minimize scaling and corrosion or to remove certain constituents. Although these chemicals may not in themselves be of great consequence as pollutants, consideration must be given to interactions that might alter the geothermal liquid composition. This is particularly true of any metal compounds which may be added during this process. Most such chemicals will be acids and/or bases used for pH adjustments.

2.5 The Geographic Distribution of Geothermal Energy Systems

The locations of hydrothermal and geopressured resource areas are shown in Figure II-4. Identified hydrothermal systems with temperatures greater than or equal to 90° C (194° F) are located primarily in the western United States, while low-temperature geothermal waters are found in the central and eastern United States.

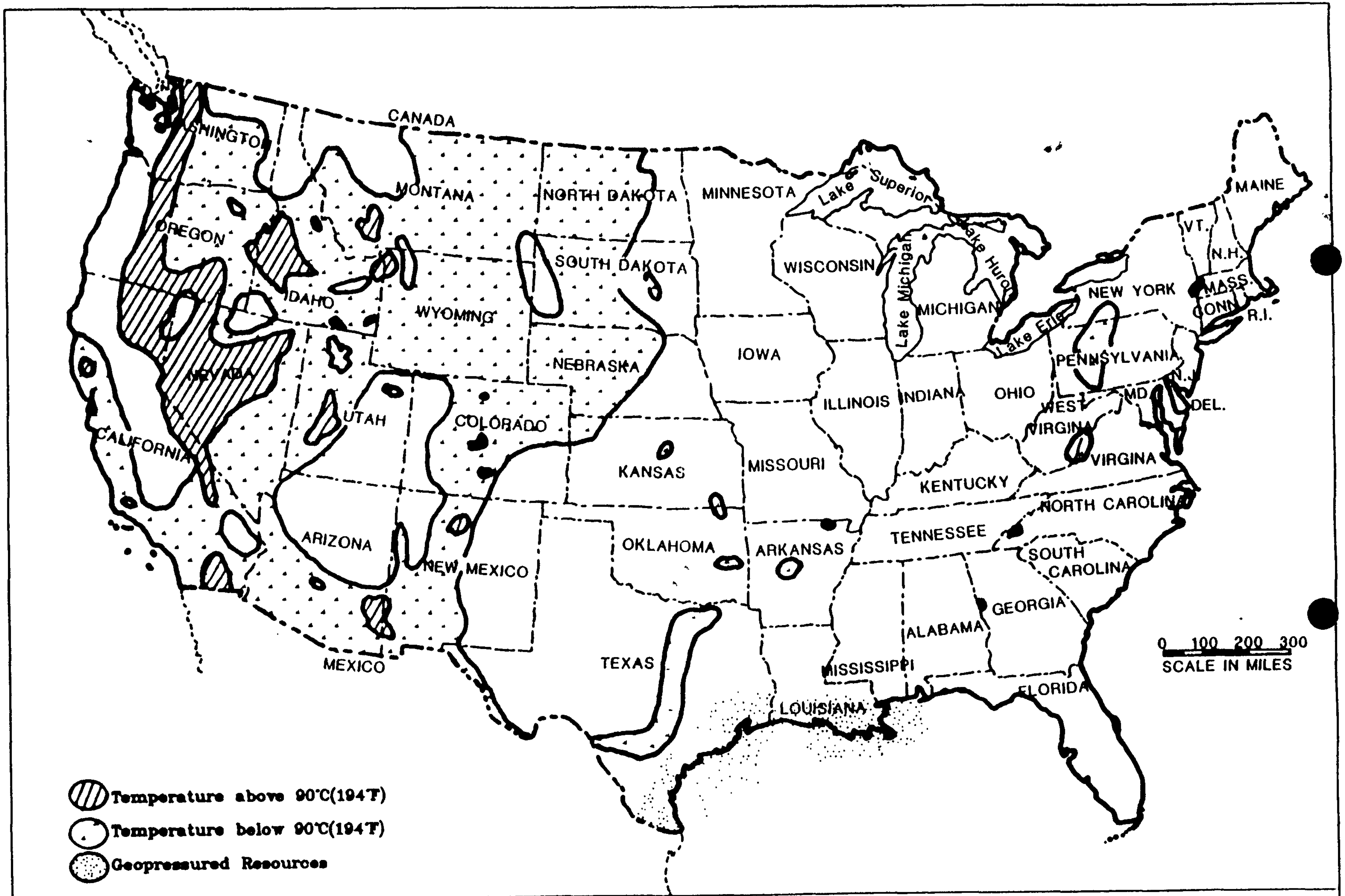


FIGURE II-4 KNOWN AND POTENTIAL GEOTHERMAL RESOURCES

CHAPTER 3

INDUSTRY PROFILE

Prior to discussing the types and volume of wastes generated during geothermal energy activities, it is first necessary to accurately describe and characterize, by location and type of operation, the geothermal industry. The following sections present analyses of geothermal exploration activities for the past five years, current electrical power generation operation for both vapor-dominated and liquid-dominated systems, and current direct-user applications.

3.1 Methodology

A review of information from pre-selected databases indicates that available literature is limited in areas of identifying and quantifying current operations, production, operational characteristics, and management techniques for specific wastes derived from geothermal activities. Nevertheless, there appears to be enough data to formulate fairly accurate conclusions regarding the types and characteristics of current operations.

Abstracts and other data sources that have been searched include:

- Chemical Abstracts;
- Enviroline;

- U.S. Geological Survey Library;
- U.S. Department of Energy, Geothermal Division Reports;
- Cambridge Scientific Abstracts;
- Sandia National Laboratories Technical Publications;
- Los Alamos Scientific Laboratory Publications;
- Proceedings of the Geothermal Resource Council;
- U.S. Bureau of Land Management;
- Oregon Institute of Technology, Geo-Heat Center; and
- Numerous State Regulatory Agencies

3.2 Exploration and Development Operations

3.2.1 Surface Exploration

The overall objective of any geothermal exploration program is to locate geothermal resource systems from which energy can be profitably extracted. Rapid, low-cost surface reconnaissance techniques are employed in the early stage of exploration to screen large land areas for commercial potential. Surface reconnaissance may include geophysical, geological and/or remote sensing surveys.

A wide variety of geophysical methods are used for surface geothermal exploration. The objectives are to identify certain geophysical characteristics, such as electromagnetic or gravitational anomalies, or attenuation of seismic waves, which arises from contrasts in rock characteristics inside and outside of the geothermal systems (Hochstein, 1982). The selected geophysical methods depend primarily on the type of geothermal system being explored. For example, the U.S. Geological Survey's interpretation of a seismic refraction survey in the Imperial Valley showed that most of the geothermal areas are along axes of apparent seismic rifting (Reed, 1981).

Surface geological methods apply where leakage of liquids through impermeable caps occur in natural geothermal systems. These leaks and/or seeps may produce such features as fumaroles, hot springs, warm springs, geysers, mud volcanoes, or mud pots, and are the most direct and obvious indicators of the presence of a geothermal reservoir or system. Seeps can provide quantitative information on the nature of the reservoir and the liquids contained within.

Remote sensing technology, such as infra-red imagery, is used on a broad scale to identify potential geothermal resources. On a smaller scale, in areas of known geothermal potential, remote sensing helps to identify surface features such as faults and joints, and thus aids in the design of more efficient drilling programs.

3.2.2 Geothermal Well Drilling

Well drilling operations are conducted after a potential geothermal resource is identified. Initial exploratory drilling is undertaken to confirm the existence of a geothermal resource and to determine the extent and physical/chemical characteristics of the resource. When a commercially producible resource if confirmed, further drilling may be required to develop and utilize the resource.

Methods and equipment used for geothermal well drilling are similar to those used in petroleum and gas drilling. Major differences between geothermal and oil and gas wells have been described in the literature (Armstead, 1986) as follows:

- o Nearly all geothermal well drilling is performed at relatively low pressures, except for the geopressured geothermal testing now underway in the Gulf Coast area;
- o The majority of the geothermal wells are relatively deep (about 2,700 mi.), with high formation temperatures;
- o The rocks being drilled are mostly igneous and metamorphic;
- o Geothermal wells are usually 50-100° C (122-212° F) hotter than oil and gas wells of comparable depths (Armstead, 1983);
- o Cooling towers are sometimes required to lower the temperature of the geothermal drilling fluids; and
- o Gas/drilling fluid separation is sometimes required for geopressurized field drilling.

Figure III-1 shows a typical drilling rig. In this instance a concrete cellar is shown housing the wellhead valving. Beneath the valving system a steel casing or

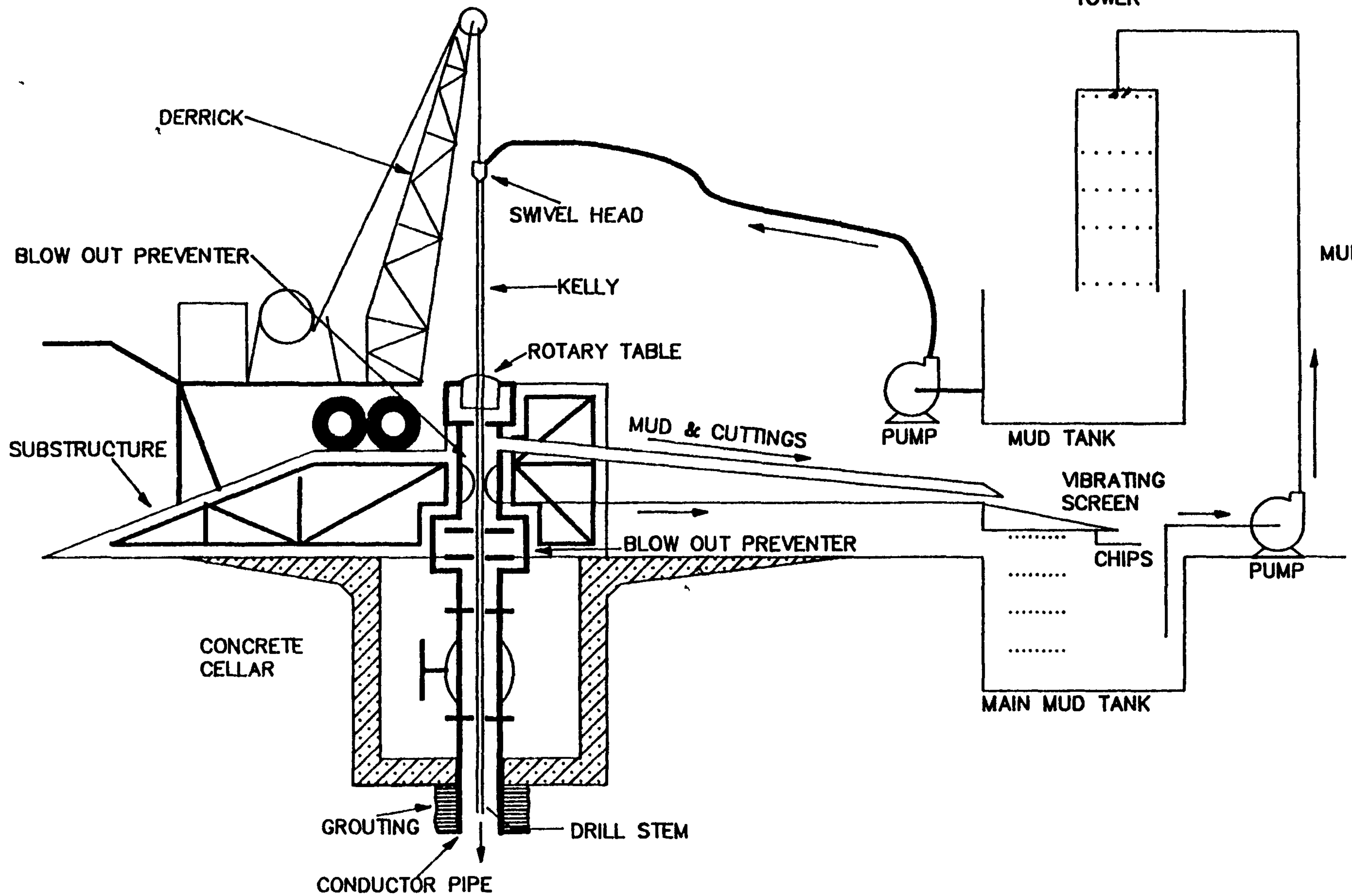


FIGURE III–1 TYPICAL ROTARY DRILLING RIG AND MUD CIRCULATION ARRANGEMENT
(ADAPTED FROM: ARMSTEAD 1986)

TYPDRILL

"conductor pipe" extends into the ground. A portion of this casing is grouted to prevent blowouts from the accidental ascension of gas or steam between the borehole wall and the casing.

Rotary drilling, as depicted in Figure III-1, uses a swivel head, kelly, rotary table and drill string (or "stem"). The swivel head allows free rotation of the kelly and drill string. The kelly is an hexagonal steel pipe which passes through and is turned by the rotary table to transmit rotary motion to the drill string. As drilling advances, additional sections of drill pipe, 20 or 30 feet long, are added to the top of the drill string.

The terminus of the drill string is a drill bit. A wide variety of drill bits are available and selection depends on the nature of the rock being drilled. It is not uncommon to change drill bits as different rock types are encountered.

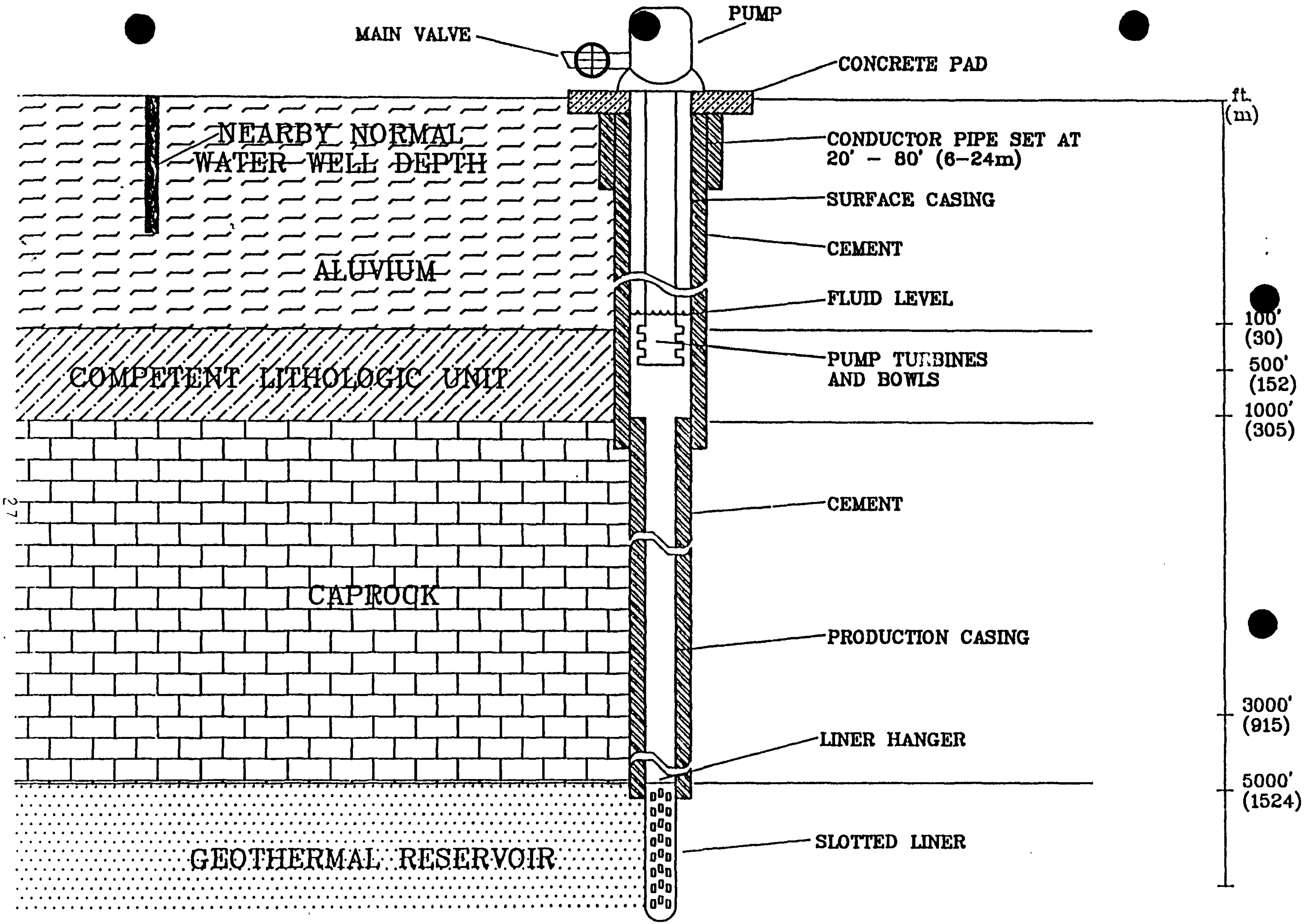
Drilling difficulties, such as low penetration rates and short bit lives, result from elevated temperatures and hard rocks encountered in typical geothermal reservoirs (Varnado, et al, 1981). Federal research programs such as the Geothermal Drilling and Completion Technology Development Program and the Salton Sea Scientific Drilling Program have contributed to the development of improved hardware which is better able to withstand the harsh subsurface environment (Varnado, 1981; Wallace, et al, 1986). Such technological advances encourage deeper drilling for better quality hydrothermal resources (Wallace, 1986).

A variety of ancillary equipment is necessary for drill rig operation. The derrick is a still framework tower that supports a pulley system. The pulley system hoists and lowers equipment used in drilling and completing the well. Diesel generators provide power to electric motors that drive the rotary table, winch, and mud pumps. Sections of casing and drill pipes are stocked on racks.

One of the most important factors in the installation of a production well is the provision of adequate, high quality steel casings. The functional purpose of the casing is to lend support to the borehole wall and to help prevent ground-water contamination. Figure III-2 is a diagram of a completed liquid-dominated hydrothermal well with installed casing. As many as four concentric casings may be installed in a single well. Each casing is rigidly fixed with cement to the surrounding rock matrix.

3.2.3 Drilling Mud

The drilling fluid or mud is a formulation of clay and chemical additives, such as caustic soda or other materials, in a water or oil base. This fluid is pumped



MAIN VALVE
PUMP
CONCRETE PAD
NEARBY NORMAL
WATER WELL DEPTH
ALUVIUM
COMPETENT LITHOLOGIC UNIT
CAPROCK
GEOTHERMAL RESERVOIR
CONDUCTOR PIPE SET AT
20' – 80' (6–24m)
SURFACE CASING
CEMENT
FLUID LEVEL
PUMP TURBINES
AND BOWLS
CEMENT
PRODUCTION CASING
LINER HANGER
SLOTTED LINER
ft.
(m)
100'
(30)
500'
(152)
1000'
(305)
3000'
(915)
5000'
(1524)

from a reservoir, pit, or tank down through the drill string and circulated up through the annulus (between the drill stem and the wall of the bore). After removal of drill cuttings, the mud may be directed to a cooling tower if excessive heating has occured downhole. After cooling, the mud returns to the reservoir (see Figure III-1).

Drilling mud serves multiple purposes. It cools and lubricates the drill bit and flushes rock chippings out of the borehole. Weighted drilling mud, with high specific gravity additives such as barite, prevents blowouts by maintaining hydrostatic pressure in the borehole to offset excessive geologic formation pressures. The proper selection and management of drilling fluid is essential in geothermal drilling operations. The drilling fluid used for both the vapor-dominated and liquid-dominated systems may be similar. However, drilling into vapor-dominated systems generally utilizes compressed air as a circulating medium instead of mud so as not to kill the production zone with a hydrostatic column of fluid. Liquid-dominated systems are normally drilled with conventional drilling muds. 90 percent of muds are composed of bentonite-water and bentonite-lignite (Robinson, 1987). Various types of drilling muds may be used and the type and composition of the mud depends upon the drill site conditions. Some of the more common drilling fluid systems are listed in Table III-1.

TABLE III-1

Common Drilling Fluid Systems Prevalent in Geothermal Drilling

Bentonite-Water	Bentonite provides viscosity and fluid loss control.
Bentonite-Lignite	Lignite is incorporated in the fluid to provide greater thermal stability and better viscosity/ fluid loss cntrol than a simple bentonite-water system.
Polymer System	Predominantly composed of polymers. This results in bentonite extension and flocculation of drill solids, thus creating a low-solids mud system.
Sepiolite System	Sepiolite clay is substituted for bentonite because it does not flocculate at high temperatures and provides better viscosity control. Modified polymers are added for fluid loss reduction and caustic soda for pH adjustment.

Research is continuing to develop new muds for drilling geothermal systems. McDonald, et al, (1978) state that improved geothermal drilling fluids will reduce well drilling costs by ten percent and reduce the costs of power on-line three to five percent. Bufe (1982) reports that in 1981, drill-pipe corrosion was greatly reduced in tests using nitrogen drilling fluids at Valles Caldera, New Mexico.

When drilling operations are completed, the used drilling fluids constitute the major waste source, and thus, are of primary environmental importance. The waste aspects of drilling fluids are covered in detail in Chapters 4 and 5 of this report.

3.2.4 Distribution of Geothermal Drilling Activity

Table III-2 presents data on the locations of geothermal drilling activity in the United States during the years 1981 through 1985 (Williams, 1986). Thermal gradient holes, which are inexpensive holes drilled to locate high-temperature zones, are not included in this tabulation. California has, by far, the greatest amount of activity; The Geysers and Imperial Valley are the primary development sites.

TABLE III-2

Summary of Geothermal Drilling Activity by State
Geothermal Production, Injection and Wildcat Wells
(1981-1985)

	NUMBER OF WELLS					
	1981	1982	1983	1984	1985	Total
Alaska	-	4	-	-	-	4
California	55	67	47	88	64	321
Colorado	1	-	-	-	-	1
Hawaii	2	1	-	-	-	3
Idaho	6	-	3	-	-	9
Louisiana	1	-	-	-	-	1
Montana	-	1	1	-	-	2
New Mexico	6	3	3	-	-	12
Nevada	14	2	4	3	3	26
New York	-	1	-	-	-	1
Oregon	3	-	1	-	1	5
Texas	-	1	1	-	-	2
Utah	-	2	1	2	-	5
Washington	2	1	-	-	-	3
TOTAL EACH YEAR	90	83	61	93	68	395

Source: Williams 1986

In 1986 development and scientific research continued at identified geothermal fields. Two important research projects are the Salton Sea Scientific Drilling Program and the Cascades Thermal Gradient Program (Wallace, et al, 1986). The Salton Sea Program, which is jointly sponsored by the Department of Energy, the U.S. Geological Survey and the National Science Foundation, completed a 3221-meter (10,564 foot) well on March 17, 1986. Core holes drilled by DOE/Industry Cascades Thermal Gradient Program went to depths of 1372 meters (4500 feet) at Newberry Caldera and 1524 meters (5000 feet) at Breitenbush Hot Springs (Wallace, et al, 1986).

3.3. Electrical Power Production Operations

There are economically viable methods for producing electrical power using the two types of hydrothermal systems. Vapor-dominated hydrothermal systems consist of high-temperature steam which can be used directly to generate electricity. Liquid-dominated systems contain hot saline waters which can be converted to steam by a flashing process. The following sections describe electrical energy production using these two hydrothermal systems.

3.3.1 Vapor-Dominated Systems

Electrical power is generated in a vapor-dominated system using the conventional steam cycle (see Figure III-3).

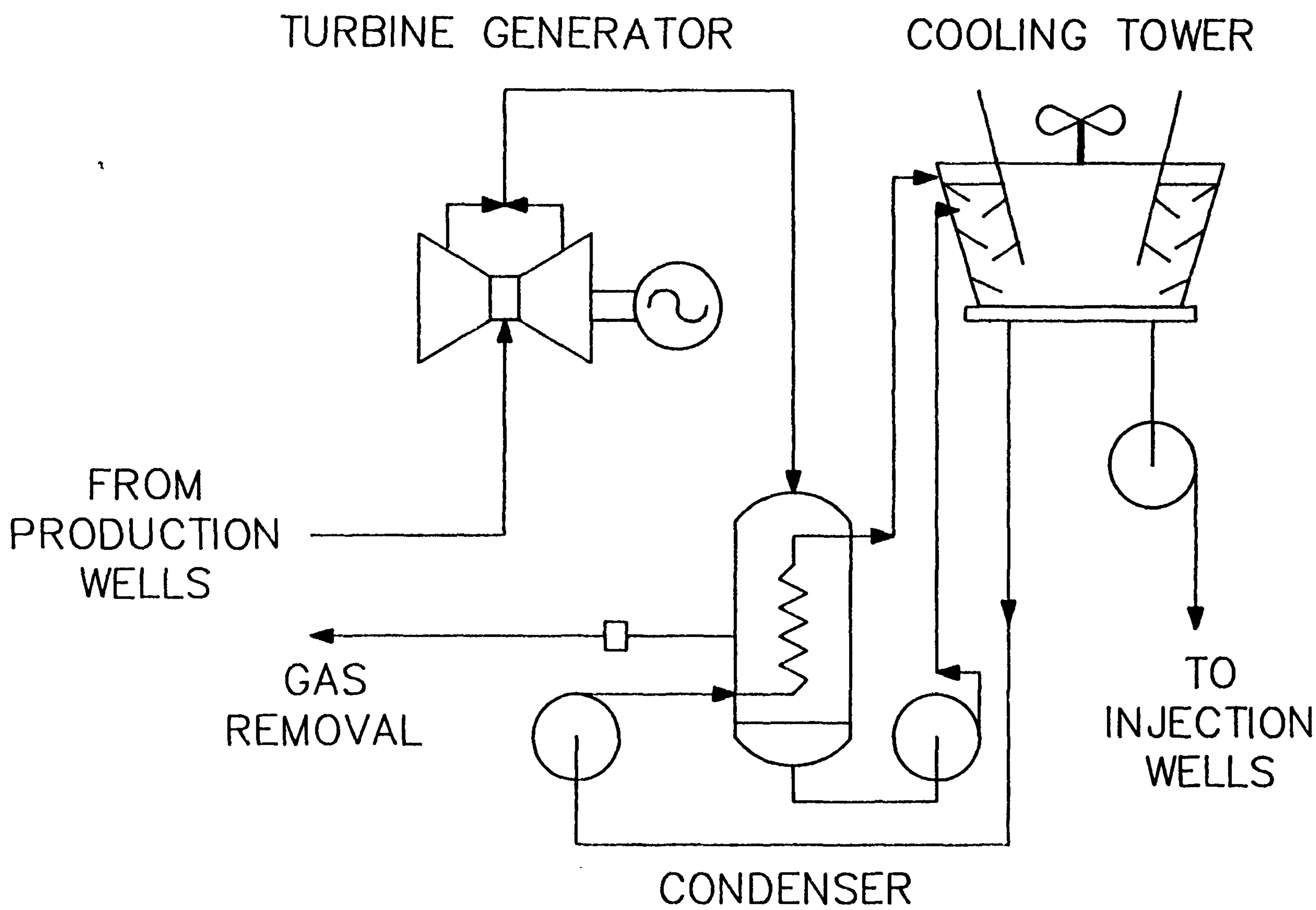


FIGURE III–3 DRY–STEAM SCHEMATIC

(SOURCE: DOE 1986)

Vapor-dominated systems generally maintain downhole temperatures of around 240° F and vent steam at a pressure 498 psi (EPA, 1977); the steam is piped from the production well to a manifold where it provides direct power to drive the turbine generator.

Production wells are connected to a gathering system composed of carbon steel pipes. A centrifugal axial separator is located on the steam line, at the wellhead of each well, to remove solids from the steam and prevent fouling of the pipelines. Typically, seven wells are connected to a gathering system, delivering one million pounds of steam per hour. This amount is sufficient to power one 55 megawatt plant (US DOE, 1980a).

The exhaust steam from the turbine is condensed in a surface or direct contact condenser. The condensate is then pumped to a cooling tower where it is cooled and reused as a cooling medium. The cooling tower acts as a concentrating unit for dissolved solids in the condensate. The condensate is then transported to a settling pit so that dissolved solids will settle out. The purified condensate is reinjected into the geothermal reservoir and the sludge from the pit is dewatered. The disposal method for the filter cake from the dewatered sludge is determined by the applicable state regulations. Using The Geysers as an example, California law requires that the concentrations of listed chemical constituents be determined for a given waste sample by an extraction procedure. If the concentration of any of the listed constituents exceeds the established threshold value, the waste must be disposed of in a Class I waste management unit (landfill, surface impoundment, or waste pile) for hazardous wastes. If the concentrations in the extracts do not exceed threshold values, the waste can be disposed of in a Class II or III waste management unit. (See Appendix, California State Regulations Summary).

Noncondensible gases are removed from the condenser through an off-gas ejector system. Before the gas mixture is vented into the atmosphere, hydrogen sulfide is removed using one of the following processes: incineration of the hydrogen sulfide followed by sulfur dioxide scrubbing; precipitation of hydrogen sulfide by an iron catalyst (Ferifloc process); or the Stretford-Peroxide-Surface Condenser (SPSC) System (California Division of Oil & Gas, 1985).

The Geysers in California is the largest geothermal electrical generating complex in the world. It is also the only known vapor-dominated hydrothermal reservoir under commercial development and operation in the United States. The electrical generating capacity exceeded 1000 megawatts late in 1982 when Pacific Gas & Electric Company (PG&E)

Unit 17 began operation (California Division of Oil & Gas, 1983). In 1985, four power plants were brought on-line at The Geysers geothermal field:

- PG&E Units 16 and 20 (each generating 113 megawatts, net);
- The California Department of Water Resources Bottle Rock Power Plant (generating 52 megawatts, net); and
- The Northern California Power Agency (NCPA) 2 (Unit 3, generating 55 megawatts, net).

The four power plants raise the total electrical generating capacity at The Geysers to 1718 megawatts, net, as of December 31, 1985 (California Division of Oil & Gas, 1986). Unocal, one of PG&E's suppliers, is responsible for the extraction of steam from The Geysers geothermal reservoir and reinjection of any returned condensate (Morton, 1987).

Table III-3 presents production statistics from 1960 through 1986 for The Geysers geothermal field.

3.3.2 Liquid-Dominated Systems

Two processes are commonly used to produce electricity from liquid-dominated geothermal reservoirs: the flash process and the binary process. Figures III-4 and III-5 present flow diagrams of these two processes.

The Flash Process

The flash process utilizes the conventional steam cycle in

Table III-3

Production Statistics, The Geysers Geothermal Field

				Steam			
		Net Capacity		Prod	Inject[1]	Avg. No.	
Year	Plants	Unit	MWe	CUM MWe	10^9 kg	10^9 kg	Prod. Wells
1960	PG&E	1	11	11			
1963		2	13	24			
1967		3	27	51			
1968		4	27	78	3.5		16
1969					6.8		20
1970					6.4	0.5	20
1971		5	53				
		6	53	184	7.8	1	22
1972		7	53			2	37
		8	53	290	15.8		
1973		9	53				
		10	53	396	21.5	3	53
1974					26.3	6	65
1975		11	106	502	30.5	7	81
1976					32.0	8	91
1977					32.5	7	94
1978					27.7	6	94
1979		12	110			9	
		15	59	671	36.2	10	118
1980		13	134				
		14	110	915	47.0	12.5	151
1981					52.8	13.7	
1982		17	110	1025	49.4	13.8	163
1983		18	110	1135			
	Smudged	1	72	1207			
	NCPA	1	110	1317	65.9	19.5	175
1984	Oxy	1	80	1397	80.0	24.6	224
1985	Bottle Rock		55	1452			
	PG&E	16	113	1565			
		20	113	1678			
	NCPA	2	55	1733	95.9	26.7	252
1986	NCPA	3	55	1788	54.4	N.A	N.A

1 Injection amounts prior to 1981 are estimated from graphs.

Sources: Calif. Div. of Oil and Gas 1983, 1984a, 1986
Williams 1986

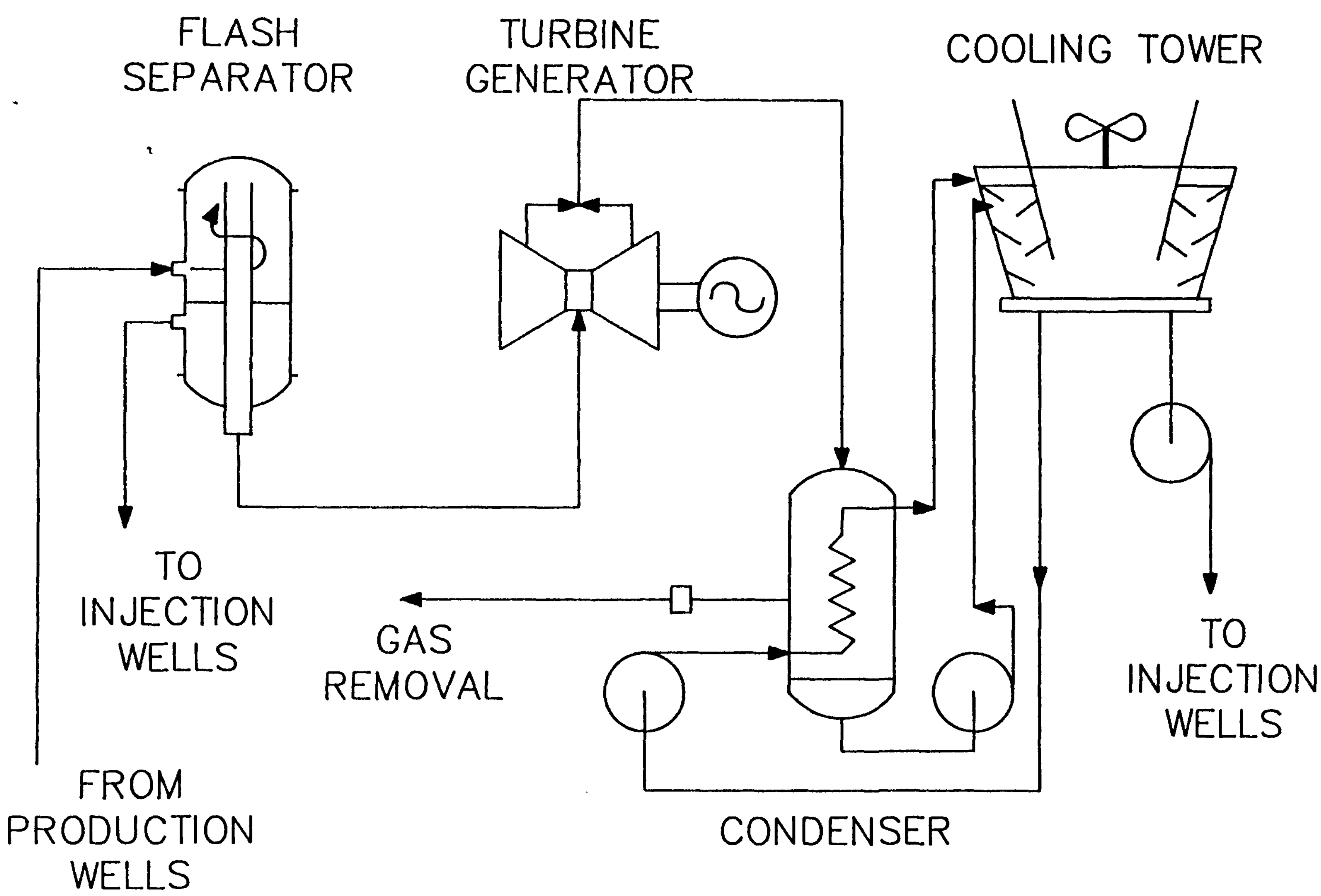


FIGURE III–4 FLASHED–STEAM SCHEMATIC

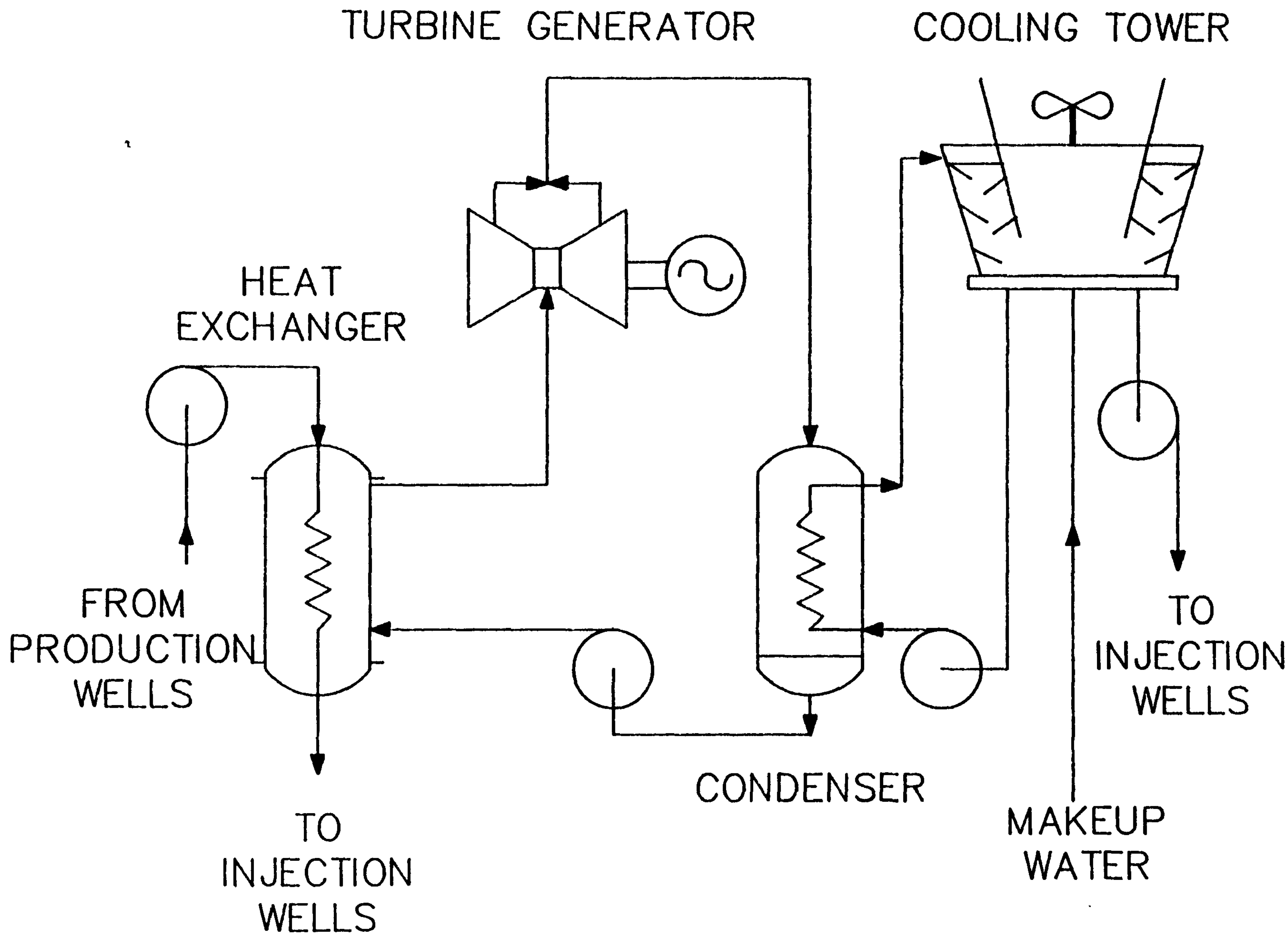


FIGURE III-5 BINARY SCHEMATIC

(SOURCE: DOE 1986)

which geothermal brine is "flashed" to produce the steam. The flash process is the partial evaporation to steam of the hot liquid brine by sudden reduction of pressure in the system. The steam from the flash step is fed directly to the turbine, with subsequent usage and disposal as described in the subsection on vapor-dominated systems.

The Vulcan Power Plant in California's Imperial Valley, owned by the Magma Power Plant, is an example of a liquid-dominated system which uses a flashing process to generate electricity. The Vulcan Power Plant is designed to produce 35 megawatts, net, of electricity from the high temperature, highly saline geothermal fluid in the Salton Sea area. A crystallizer-clarifier process, patented by Magma, is used to produce the steam needed to drive the turbine generator.

The brine supply to the Vulcan Power Plant comes from 12 production wells and is transmitted to the plant via four brine headers. (A brine header is a pipe which distributes fluid from a smaller series of pipes.) The two-phase geothermal fluid mixture is combined at the plant and split into two trains. The brine first goes through a high-pressure crystallizer where the silica is seeded (caused to crystallize) to prevent scaling of the pipe and tank walls. The pressure in the containment vessel is reduced to flash sufficient steam to drive the 29.4 megawatt turbine-generator. The remaining heavily seeded, unflashed brine flows to a low-pressure crystallizer where the second flashing step is undertaken to generate more steam to drive the 9.4 megawatt turbine generator.

The unflashed brine from the low-pressure crystallizer flows to a reactor-clarifier where the fully developed crystals begin to settle. The crystals are pushed to the center of the vessel by a rake mechanism to agglomerate and thicken. Clarified brine flowing out of the top of the clarifier is filtered to remove any remaining solid prior to injection. The solids are drawn off the bottom of the clarifier to a thickener. A portion of the sludge is retained to seed the incoming brine. The rest is mixed with the filtered solids and disposed of in a Class I waste management unit if it is a designated hazardous waste, or a Class II or III waste management unit if it is a non-hazardous waste.

The steam exhaust from both turbines is stripped of the non-condensible gases at the condensers. The condensate is cooled in a counterflow cooling tower where heat is rejected to the atmosphere. The condensate is used as make-up to the cooling tower.

The non-condensible gases are brought into contact with the brine to allow the hydrogen sulfide to react with the heavy metals in the brine. The remaining gas mixture, composed mostly of carbon dioxide, is vented out of the low-pressure crystallizer.

The Binary Process

The 45 megawatt Heber Demonstration Plant, also in California's Imperial Valley, is the largest binary power plant in the world (California Division of Oil & Gas, 1985). The Heber Plant uses a simple binary-cycle conversion process which consists of three fluid loops: a geothermal fluid loop, a hydrocarbon working fluid loop, and a cooling water loop. The single-phase geothermal fluid is withdrawn from the reservoir into the production well. Production lines from thirteen production wells connect to a common header. The combined geothermal stream then flows to a desanding vessel and a metering station. Next, the geothermal brine passes through two parallel brine/hydrocarbon heat exchanger trains at the rate of about 8 million lbs/hour. The temperature of the brine at Heber is approximately 182° C (359° F); the binary process utilizes brines in the 150° C to 210° C (320-410° F) range. The brine and the hydrocarbon are contained in separate closed loops, allowing no direct contact with the atmosphere. The saturated hydrocarbon mixture of 90 mole percent isobutane and 10 mole percent isopentane is heated from a liquid state at 38° C to a supercritical vaporous state at 152° C (305° F) by the heat transferred from the brine. The vaporous hydrocarbon expands through the turbine which drives the 70 megawatt electric generator. Spent brine is reinjected into the geothermal reservoir at about 72^{o} C (162^{o} F). The brine temperature must be kept above 65^{o} C (149^{o} F) to prevent precipitation of dissolved solids prior to reinjection.

The owners of the Heber Binary Facility (SDG&E) purchase hot brine from Chevron (Morton, 1986). The hot brine is pumped to Heber, the heat is extracted, and the spent brine is returned to Chevron for reinjection.

3.3.3 Annual Production

Table III-4 lists geothermal power facility sites that are either operating or are under construction in the United States. This table lists a total of 25 sites. A site is defined as a single power plant or multiple operating units. For example, power generating facilities at The Geysers are shown as four different sites, although these four sites contain 25 operating units, owned by four different power companies. Table III-4 also lists information on capacity, location, ownership, and process type. Figure III-6 graphically shows capacity distributions of geothermal power plants by process type and by state. 96 percent of geothermal power plant

TABLE III - 4
SITE LISTING - POWER PLANTS

NAME	OWNER	ST	COUNTY	PROCESS TYPE	ELECTRICAL CAPACITY (MW)
NILAND GEOTHERMAL	PARSONS CO.	CA	IMPERIAL	LPF	38.60 OP
EAST MESA	ORMAT	CA	IMPERIAL	LPB	20.00 OP
EAST MESA (B.C. MCCABE NO.1)	MAGMA POWER CO.	CA	IMPERIAL	LPB	12.50 OP
HEBER	HEBER GEOTHERMAL CO.	CA	IMPERIAL	LPF	49.00 OP
HEBER	SDG&E BINARY DEMO	CA	IMPERIAL	LPB	45.00 OP
SALTON SEA	UNOCAL (SCE/SPLC/MPC)	CA	IMPERIAL	LPF	10.00 OP
SALTON SEA (VULCAN)	MAGMA POWER CO.	CA	IMPERIAL	LPF	34.50 OP
COSO	CALIFORNIA ENERGY CO.	CA	INYO	LPF	25.00 UC
WENDELL-AMEDEE(HONEY LAKE)	GEOPRODUCTS	CA	LASSEN	LPH	20.00 UC
WENDELL-AMEDEE (WENDELL HOT SPRINGS)	WINEAGLE DEVELOPER	CA	LASSEN	LPB	0.60 OP
MONO-LONG VALLEY (CAS DIABLO)	MAMMOTH PACIFIC	CA	MONO	LPB	7.00 OP
THE GEYSERS	PACIFIC GAS & ELECTRIC CO.	CA	SONOMA	VPS	1441.00 OP
THE GEYSERS	SACREMENTO MUNICIPAL UTILITY DISTRICT	CA	SONOMA	VPS	72.00 OP
THE GEYSERS	NORTHERN CALIFORNIA POWER AGENCY	CA	SONOMA	VPS	220.00 OP
THE GEYSERS(BOTTLE ROCK)	CALIFORNIA DEPT. OF WATER RESOURCES	CA	SONOMA	VPS	55.00 OP
PUNA NO. 1	HELCO	HI	HAWAII ISLAND	LPF	3.00 OP
LIGHTING DOCK	BURGETT FLORAL	NM	HIDALGO	LPB	0.90 OP
BRADY HAZEN	CHEVRON	NV	CHURCHILL	LPB	8.30 OP
FISH LAKE	STEAM RESERVE COPR.	NV	ESMERALDA	LPB	15.00 UC
BEOWAWE	CRESCENT VALLEY GEOTHERMAL (SUBSID. OF SCE)	NV	LANDER/EUREKA	LPF	17.00 OP
WABUSKA HOT SPRINGS	TAD'S ENTERPRISES	NV	LYON	LPB	0.60 OP
DESERT PEAK	PHILLIPS PETROLEUM/SIERRA PACIFIC POWER CO.	NV	RENO	LPF	9.00 OP
STEAMBOAT SPRINGS	GEOTHERMAL DEVELOPMENT ASSOCIATES	NV	WASHOE	LPB	5.40 OP
COVE	MOTHER EARTH	UT	BEAVER	LPB	4.70 OP
FORT-SULPHURDALE	INDUSTRIES, CITY OF PROVO				
ROOSEVELT HOT SPRINGS - MILFORD	UP&L	UT	BEAVER	LPF	20.00 OP

KEY

Process Type

First Letter	Second Letter	Third Letter	Electrical Capacity
V-Vapor	P-Power Generation	F-Flash Process	MW-Megawatts
L-Liquid		B-Binary Process	OP-Operating
		S-Conventional Steam	UC-Under Construction
		H-Hybrid	

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HEBER	HEBER GEOTHERMAL CO.	CA	IMPERIAL	LPF	49.00 OP
HEBER	SDG&E BINARY DEMO	CA	IMPERIAL	LPB	45.00 OP
SALTON SEA	UNOCAL (SCE/SPLC/MPC)	CA	IMPERIAL	LPF	10.00 OP
SALTON SEA (VULCAN)	MAGMA POWER CO.	CA	IMPERIAL	LPF	34.50 OP
COSO	CALIFORNIA ENERGY CO.	CA	INYO	LPF	25.00 UC
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WENDELL-AMEDEE (WENDELL HOT SPRINGS)	WINEAGLE DEVELOPER	CA	LASSEN	LPB	0.60 OP
MONO-LONG VALLEY (CAS DIABLO)	MAMMOTH PACIFIC	CA	MONO	LPB	7.00 OP
THE GEYSERS	PACIFIC GAS & ELECTRIC CO.	CA	SONOMA	VPS	1441.00 OP
THE GEYSERS	SACREMENTO MUNICIPAL UTILITY DISTRICT	CA	SONOMA	VPS	72.00 OP
THE GEYSERS	NORTHERN CALIFORNIA POWER AGENCY	CA	SONOMA	VPS	220.00 OP
THE GEYSERS(BOTTLE ROCK)	CALIFORNIA DEPT. OF WATER RESOURCES	CA	SONOMA	VPS	55.00 OP
PUNA NO. 1	HELCO	HI	HAWAII ISLAND	LPF	3.00 OP
LIGHTING DOCK	BURGETT FLORAL	NM	HIDALGO	LPB	0.90 OP
BRADY HAZEN	CHEVRON	NV	CHURCHILL	LPB	8.30 OP
FISH LAKE	STEAM RESERVE COPR.	NV	ESMERALDA	LPB	15.00 UC
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WABUSKA HOT SPRINGS	TAD'S ENTERPRISES	NV	LYON	LPB	0.60 OP
DESERT PEAK	PHILLIPS PETROLEUM/SIERRA PACIFIC POWER CO.	NV	RENO	LPF	9.00 OP
STEAMBOAT SPRINGS	GEOTHERMAL DEVELOPMENT ASSOCIATES	NV	WASHOE	LPB	5.40 OP
COVE FORT-SULPHURDALE	MOTHER EARTH INDUSTRIES, CITY OF PROVO	UT	BEAVER	LPB	4.70 OP
ROOSEVELT HOT SPRINGS - MILFORD	UP&L	UT	BEAVER	LPF	20.00 OP

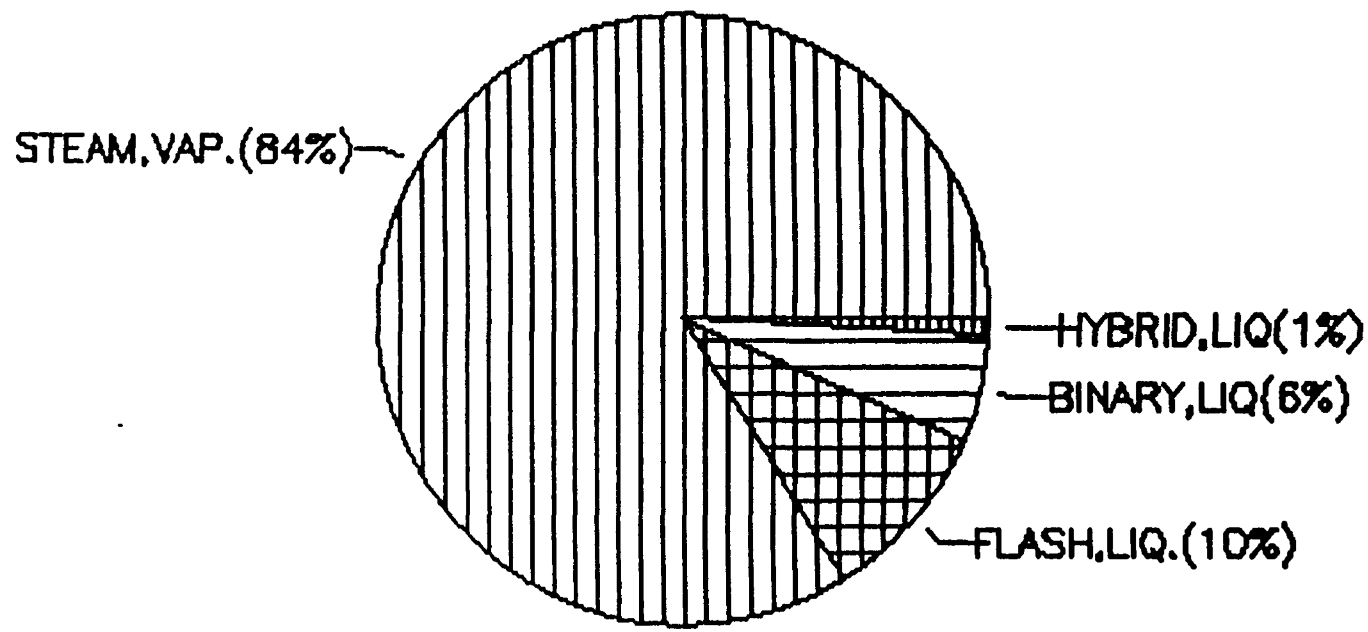
KEY

Process Type

First Letter	Second Letter	Third Letter	Electrical Capacity
V-Vapor	P-Power Generation	F-Flash Process	MW-Megawatts
L-Liquid		B-Binary Process	OP-Operating
		S-Conventional Steam	UC-Under Construction
		H-Hybrid	

FIG. III—6: GEOTHERMAL POWER PLANTS

CAPACITY DISTRIBUTION BY PROCESS TYPE



electrical capacity if in California alone; the other four percent is distributed throughout other states.

3.4 Direct-Use Applications

In some areas of the country, it is often efficient and economical to use geothermal energy as a direct source of heat. This heat can be extracted from the condensate from an electrical generating facility or directly from a geothermal production well. Geothermal resources with low to moderate temperatures, suitable for direct application, are more widespread than electric generation sites. This is because direct-use applications are less capital-intensive and can be developed on a relatively small scale. The high cost of transporting the available heat from hydrothermal resources has limited the development of multi-user direct heat systems to areas close to the geothermal source. As a result, for hydrothermal direct heat use to be economical, prospective users must be within close proximity to the geothemal production well.

Direct-use systems consist of two basic types: those that conduct the hydrothermal fluid directly through the entire system, and those that utilize heat exchangers to transfer hydrothermal heat to a secondary working fluid. Examples of the various types of geothermal systems are discussed in the following sections.

Table III-5 shows the various direct-use applications of geothermal fluid corresponding to fluid temperature. Many processes require fluid temperatures of 150° C (320° F). However, power generation is expected to dominate those resources.

3.4.1 <u>Downhole Heat Exchangers (Klamath Falls, Oregon)</u>

Some 400-500 shallow wells are used for space heating in the Klamath Falls and Klamath Hills geothermal areas (<u>Geonomic</u> 1978; Lienau, 1986). Of these, only a few pump geothermal fluid to the surface. The rest utilize downhole heat exchangers consisting of one or two tube loops suspended down the well in direct contact with the hydrothermal fluid. Downhole exchangers have the lowest investment cost of all types of heat exchangers.

In most cases, the water inside the heat exchanger cycles thermally (thermo-syphon); therefore, pumps are not required to move the water and the need for fluid disposal is eliminated (Zimmerman, et al., 1984).

Downhole exchangers are feasible only where reservoir depths are typically less than 500 feet (Zimmerman, et al, 1984). Wells in the Klamath Falls area are commonly less than 700 feet deep; most are less than 250 feet deep. Presently, about 500 homes, offices, commercial buildings,

TABLE III-5

Fluid Temperatures Required for Various Direct-Use Applications

C°		Application
190+	--	
180	--	Evaporation of highly concentrated solutions Refrigeration by ammonia absorption Digestion in paper pulp, kraft
170	--	Heavy water via hydrogen sulfide process Drying diatomaceous earth
160	--	Drying fish meal Drying timber
150	--	Alumina via Bayer's process
140	--	Drying farm products at high rates Food canning
130	--	Evaporation in sugar refining Extraction of salts by evaporation and crystallization
120	--	Fresh water by distillation Most multiple-effect evaporation, concentrations of saline solution
110	--	Drying and curing light aggregate cement slabs
100	--	Drying organic materials, seaweeds, grass, vegetables, etc. Washing and drying wool
90	--	Drying stock fish Intense de-icing operations
80	--	Space heating Greenhouses by space heating
70	--	Refrigeration (lower temperature limit)
60	--	Animal husbandry Greenhouses by combined space and hot bed heating

50	--	Mushroom growing Balneological bath
40	--	Soil warming
30	--	Swimming pools, biodegradation, fermentations Warm water for year-round mining in cold climates De-icing
20	--	Fish hatching and farming

Source: Lienau, et al., 1979

schools, churches, and greenhouses are heated by geothermal water from the shallow wells (Lienau, 1986). Typically, well temperatures range from 38° C to 110° C (100-230° F).

3.4.2. Surface Heat Exchangers

Unlike downhole exchangers, all types of surface exchange systems require extraction of geothermal fluid from the reservoir and subsequently some means of fluid or brine disposal. Of the various types of surface exchangers available, the plate type seems to be the most suitable for hydrothermal systems (O'Banion, et al, 1981).

Applications of this type of energy system are numerous, ranging from heating of private residences to various commercial uses. One such application is the Pagosa Springs Geothermal District space heating system, which has successfully demonstrated the feasibility of utilizing moderate temperature (60° C) geothermal fluid for direct-use application (Goering, et al, 1984). This system provides space heating to public buildings, school facilities, residences, and commercial establishments at significantly lower cost than conventional fuels.

At Pagosa Springs, geothermal fluid is withdrawn from the production well at about 60° C (140° F) and is directed through a plate heat exchanger where heat is extracted to produce hot, recirculated city water. This city water exits the heat exchanger at about 58° C (136° F) and is distributed via a closed loop system to individual users who extract heat for space heating at the point of use. Cooled water is recirculated back to the heat exchanger where it is reheated by the geothermal fluid. The flow of geothermal fluid from the well is controlled by the discharge temperature of the circulating fluids. The spent geothermal fluid is discharged from the heat exchanger at about 40° C (104° F) directly to the San Juan River.

Space Conditioning

Hydrothermal fluid is a suitable heat source for conventional forced air, hydronic space heat systems, gas heat pumps, and refrigeration units (O'Banion, et al, 1981). In a forced air system, air is blown from a heat source and distributed by ducts to outlets. In a hydronic system, hot water is used directly as a heat source in radiant panels, convectors, and radiators. Heat pumps operate by transferring energy from a low-temperature heat reservoir such as a hydrothermal fluid to a warmer medium such as indoor air. A gaseous working or energy transfer medium such as freon is exposed to the hydrothermal fluid; the cool gas absorbs heat and expands and then moves to a heat sink where the gas condenses, driving off heat into the sink or the air to be heated. The freon then evaporates and is pumped back to the heat source for recirculation. Hydrothermal temperatures as low as 10° C

(50° F) can be utilized for heat pumps; however, the feasibility of using low-temperature resources is dependent upon cost-effectiveness, taking into account the price of a pump and associated power.

No documented usage of geothermal energy for refrigeration was found in the literature that has been reviewed, however, several technologies exist. These technologies include the ammonia-water and water-lithium- bromide cycles which operate in the 110° C - 150° C (230° F-302° F) geothermal fluid temperature range (O'Banion, et al, 1981).

Agricultural and Industrial Uses

Lower geothermal temperatures are applicable to agricultural uses (O'Banion, et al, 1981) which can consist of any of the following:

- Greenhousing - This application involves the raising of plants in a controlled environment to improve yields and enable harvesting of off-season crops. The basic concept is to trap solar heat by enclosing the growing area and to offset heat losses with a secondary source, such as geothermal energy. Hydrothermal fluid can be utilized as a secondary heat source via a forced air or hydronic space heating system. The fluid temperature can be as low as 32° C (90° F) (Lienau, et al, 1979).
- Mushroom Culturing - Direct heat applications in mushroom culturing temperature requirements include: 54-60° C (129-140° F) for compost preparation; 22-24° C (72-75° F) for fertilization; and 26° C (79° F) for production. Heat is distributed by exposed hot pipes along the mushroom-house walls. Cooling may also be hydrothermally driven if the fluid temperature is adequate (Lienau, et al, 1979).

- Livestock Raising - For this application, geothermal heat is used to maintain an optimum temperature environment. Good environmental control results in lower mortality, faster growth, lower animal fat levels, and easier disease control in livestock raising. The mechanisms for environmental control range from floor heating in open feed lots to a completely enclosed system of raising hogs and chickens. The enclosed system employs both radiant panel and forced air heating and requires a minimum intake temperature of 32° C (90° F) (Lienau, et al, 1979).

- Aquaculture - One location in Coachella Valley (O'Banion, et al, 1981) uses water from three (3) geothermal wells and five (5) irrigation wells to supply sixty-one (61) aquaculture ponds. The supplied water first flows to a series of prawn production ponds before cascading through irrigation pipes to ponds growing other species of fish. These aquaculture projects have the advantage of year-round production. For these applications, the fluid temperature ranges from 30° C to 40° C (86-140° F).

3.4.3 Annual Utilization

Table III-6 presents a site listing of direct-use commercial and community applications that are currently operating in the United States. This table includes process type, owner, location, and daily flowrate.

Table III-6 is constructed from a database containing numerous references. The primary reference (Lienau, 1986) provided much of the flowrate and operational data. All database references are listed in Section 11.2.

Table III-6 contains a total of 122 sites that have been identified from the literature. Figure III-7 shows the

TABLE III - 6
SITE LISTING - DIRECT USERS

NAME	OWNER	ST	COUNTY	PROCESS TYPE	BRINE (MGD)
CHENA HOT SPRINGS	PRIVATE OWNERSHIP	AK	DOYON	LDP	0.30
CIRCLE HOT SPRINGS	PRIVATE OWNERSHIP	AK	DOYON	LDS	0.19
MANLEY HOT SPRINGS	PRIVATE OWNERSHIP	AK	DOYON	LDS	0.21
MELOZI HOT SPRINGS	PRIVATE OWNERSHIP	AK	DOYON	LDS	0.19
HOT SPRINGS NATIONAL PARK	US GOVT	AR	GARLAND	LD	0.00
NILAND	ENGLER FISH FARMS	CA	IMPERIAL	LDF	0.00
SALTON CITY	CROCKER ENTERPRISES	CA	IMPERIAL	LD	0.00
CRABTREE HOT SPRINGS	US GOVT	CA	LAKE	LD	0.01
SUSANVILLE	CITY OF SUSANVILLE	CA	LASSEN	LDD	0.73
SUSANVILLE	LITCHFIELD CORRECTIONAL INSTITUTE	CA	LASSEN	LDS	1.37
SUSANVILLE - NURSERY	PRIVATE OWNERSHIP	CA	LASSEN	LDG	0.43
WENDELL-AMEDEE	RAMCO RESOURCES	CA	LASSEN	LDG	0.86
CEDARVILLE HIGH SCHOOL & ELEMENTARY SCHOOL	MODOC COUNTY	CA	MODOC	LDS	0.18
FORT BIDWELL	INDIAN RESERVATION	CA	MODOC	LDF	0.43
FORT BIDWELL-DISTRICT HEATING	INDIAN RESERVATION	CA	MODOC	LDD	0.04
FORT BIDWELL - FISH	INDIAN RESERVATION	CA	MODOC	LDF	0.43
MAMMOTH LAKES	NOT FOUND	CA	MONO	LD	0.00
MAMMOTH LAKES-DISTRICT HEATING		CA	MONO	LDD	2.48
MAMMOTH LAKES-FISH		CA	MONO	LDF	0.10
INDIAN VALLEY HOT SPRINGS (GREENVILLE)	INDIAN VALLEY HOSPITAL	CA	PLUMAS	LDS	0.41
COACHELLA	TAKASHIMA NURSERIES	CA	RIVERSIDE	LDS	2.88
ELSINORE HOT SPRINGS	LAKE ELSINORE COMMUNITY	CA	RIVERSIDE	LDS	0.72
MECCA	AQUAFARMS INTERNATIONAL	CA	RIVERSIDE	LDF	3.60
SAN BERNADINO-DISTRICT HEATING	CITY OF SAN BERNARDINO	CA	SAN BERNADINO	LDD	1.80
SAN BERNADINO-INDUSTRIAL	CITY OF SAN BERNARDINO	CA	SAN BERNADINO	LDI	0.25
PASO ROBLES	CALAQUA INC.	CA	SAN L. OBISPO	LDF	0.24
HUNTS HOT SPRINGS	INDIAN SPRINGS SCHOOL	CA	SHASTA	LDS	0.01
BOULDER-GREENHOUSE	NOT FOUND	CO		LDS	0.45
SALIDA	NOT FOUND	CO		LDP	0.11
ALAMOSA	ALAMOSA SHOPPING CENTER	CO	ALAMOSA	LDS	1.44
PAGOSA SPRINGS	THE SPA MOTEL	CO	ARCHULETA	LDD	1.73
GLENWOOD SPRINGS	REDSTONE CORP.	CO	GARFIELD	LDS	1.73
OURAY HOT SPRINGS	NOT FOUND	CO	OURAY	LDS	0.07
BOISE CITY	BOISE CITY GEOTHERMAL SYSTEM DISTRICT HEATING	ID	ADA	LDD	2.88

Key for Process Type

First Letter	Second Letter		Third Letter
L-Liquid	D-Direct Use	S-Space Heating	F-Fish Farm
		D-District Heating	G-Greenhouse
		P-Pool	I-Industrial

Source: See Appendix A for Development of Data

TABLE III - 6 (continued)
SITE LISTING - DIRECT USERS

NAME	OWNER	ST	COUNTY	PROCESS TYPE	BRINE (MGD)
BOISE WARM SPRINGS	BOISE WARM SPRINGS WATER DISTRICT	ID	ADA	LDD	1.19
HUNT	MILSTEAD FLORAL GREENHOUSE	ID	ADA	LDG	0.35
IDAHO STATE CAPITAL MALL	STATE OF IDAHO	ID	ADA	LDD	1.44
THE EDWARD'S GREENHOUSE	THE EDWARD'S GREENHOUSE	ID	ADA	LD	0.58
VETERANS ADMINISTRATION MEDICAL CENTER	US GOVT	ID	ADA	LDS	0.43
DONLAY RANCH HOT SPRINGS	DONLAY RANCH	ID	BOISE	LDG	0.10
GARDEN VALLEY	WARM SPRINGS GREENHOUSE	ID	BOISE	LDG	0.43
HOT SPRINGS	CORRAL	ID	CAMAS	LDS	0.04
CALDWELL	CALDWELL MUNICIPALITY	ID	CANYON	LDS	1.14
NAMPA	NAMPA CITY	ID	CANYON	LDS	1.04
HOOPER SPRINGS	HOOPER ELEMENTARY	ID	CARIBOU	LDS	0.35
ALMO	LDS CHURCH	ID	CASSIA	LDS	0.29
BURLEY	PRIVATE OWNERSHIP	ID	CASSIA	LDS	0.13
CROOK'S GREENHOUSE	CROOK'S GREENHOUSE	ID	CASSIA	LDG	0.01
MALAD CITY	MALAD HIGH SCHOOL	ID	ONEIDA	LDD	5.48
BANKS	PRIVATE OWNERSHIP	ID	OWYHEE	LDG	0.19
BRUNEAU	PRIVATE OWNERSHIP	ID	OWYHEE	LDG	0.38
HOT SPRINGS	PRIVATE OWNERSHIP	ID	OWYHEE	LDG	0.49
MARSING	PRIVATE OWNERSHIP	ID	OWYHEE	LDG	0.09
BUHL	ROBERT LUNTY	ID	TWIN FALLS	LDG	0.03
BUHL	ROBERT LUNTY	ID	TWIN FALLS	LDF	0.58
BUHL-CAL FLINT	CAL FLINT FLORAL	ID	TWIN FALLS	LDG	0.43
BUHL-FLINT	FLINT GREENHOUSES	ID	TWIN FALLS	LDG	0.86
BUHL-M&L	M&L GREENHOUSES	ID	TWIN FALLS	LDG	1.01
BUHL-RAY	FISH BREEDERS OF IDAHO	ID	TWIN FALLS	LDF	11.50
TWIN FALLS	COLLEGE OF SOUTHERN ID	ID	TWIN FALLS	LDS	1.73
WARM SPRINGS STATE HOSPITAL	WARM SPRINGS HOSPITAL	MT	DEER LODGE	LDS	0.09
ENNIS	MONTANA LUMBER CO.	MT	MADISON	LDS	0.04
ENNIS	MONTANA LUMBER CO.	MT	MADISON	LDS	0.03
WHITE SULFUR SPRINGS	FIRST NATIONAL BANK	MT	MEAGHER	LDS	0.09
WHITE SULFUR SPRINGS	WHITE SULFUR SPRINGS MOTEL	MT	MEAGHER	LDS	0.58
AVON	EARTH ENERGY INSTITUTE	MT	MISSOULA	LDG	0.02
LOLO	PRIVATE OWNERSHIP	MT	MISSOULA	LDS	0.12
JAMES SPRINGS	NOT FOUND	NM		LDD	0.04
LAS ALTURAS	LAS ALTURAS ESTATES	NM	DONA ANA	LDS	0.00
LAS CRUCES SPACE HTG& GREENHOUSE	NEW MEXICO STATE UNIVERSITY	NM	DONA ANA	LDS	0.60

Key Process Type

First Letter	Second Letter	Third Letter	
L-Liquid	D-Direct Use	S-Space Heating	F-Fish Farm
		D-District Heating	G-Greenhouse
		P-Pool	I-Industrial

Source: See Appendix A for Development of Data.

TABLE III - 6 (continued)
SITE LISTING - DIRECT USERS

NAME	OWNER	ST	COUNTY	PROCESS TYPE	BRINE (MGD)
APPACHE TEJO & KENNECOTT WARM SPRINGS	KENNECOTT CORP.	NM	GRANT	LDI	1.09
GILA HOT SPRINGS-SPACE HTG & POOL	NOT FOUND	NM	GRANTS	LDS	0.20
ANIMAS	BURGETT FLORAL	NM	HIDALGO	LDG	0.94
ANIMAS	BEALL COMPANY GREENHOUSE	NM	HIDALGO	LDG	0.10
ANIMAS	MCCANT GREENHOUSE	NM	HIDALGO	LDG	0.03
TRUTH OR CONSEQUENCES	CITY OF T. OR C.	NM	SIERRA	LDS	0.05
RENO	CITY OF RENO	NV		LDS	0.72
RENO - POOL	PRIVATE OWNERSHIP	NV		LDP	0.16
BRADY HOT SPRINGS	GEOTHERMAL FOOD PROCESSORS, INC.	NV	CHURCHILL	LDI	1.03
CARLIN (H.P.)	CARLING HIGH SCHOOL	NV	ELKO	LDS	0.29
ELKO HOT SPRINGS	ELKO HEAT COMPANY	NV	ELKO	LDD	1.01
ELKO JUNIOR HIGH SCHOOL	ELKO COUNTY	NV	ELKO	LDS	0.43
CALIENTE - SPACE HEATING	NOT FOUND	NV	LINCOLN	LDS	0.07
CALIENTE - SPACE HTG & POOL	NOT FOUND	NV	LINCOLN	LDS	0.22
WABUSKA	ALEXANDER DAWSON CO.	NV	LYON	LDF	0.00
FIRST CHURCH OF RELIGIOUS SCIENCE	FIRST CHURCH OF RELIGIOUS SCIENCE	NV	RENO	LD	0.09
VETERAN ADMINISTRATION MEDICAL CENTER	VETERANS ADMINISTRATION MEDICAL CENTER	NV	RENO	LD	0.43
MOANA GEOTHERMAL AREA	WARREN ESTATES	NV	WASHOE	LDD	0.43
MOANA GEOTHERMAL AREA	SIERRA GEOTHERMAL INC.	NV	WASHOE	LD	0.22
WELLS (H.P.)	WELLS RURAL ELECTRIC CO.	NV	WELLS	LDS	0.07
AUBURN	CAYUGA COMMUNITY COLLEGE & EAST MIDDLE SCHOOL	NY	CAYUGA	LDS	0.22
MERRILL	PRIVATE OWNERSHIP	OR		LDG	0.14
KLAMATH FALLS-DISTRICT HTG	CITY OF KLAMATH FALLS	OR	KLAMATH	LDD	0.40
KLAMATH FALLS-DISTRICT HTG	OREGON INST OF TECH	OR	KLAMATH	LDS	1.04
KLAMATH FALLS - POOL	PRIVATE OWNERSHIP	OR	KLAMATH	LDP	0.04
KLAMATH FALLS-SPACE HTG	PRIVATE OWNERSHIP	OR	KLAMATH	LDS	0.50
KLAMATH FALLS-SPACE HTG	PRIVATE OWNERSHIP	OR	KLAMATH	LDS	2.08
HUNTERS HOT SPRINGS	COMMERCIAL RESORT	OR	LAKE	LDS	0.10
LAKEVIEW - GREENHOUSE	PARKERS GREENHOUSES	OR	LAKE	LDG	0.14
LAKEVIEW - POOL HEATING	PRIVATE OWNERSHIP	OR	LAKE	LDP	0.03
LAKEVIEW - SPACE HEATING	PRIVATE OWNERSHIP	OR	LAKE	LDS	0.10
SUMMER LAKE	COMMERCIAL RESORT	OR	LAKE	LDP	0.03

Key Process Type

First Letter	Second Letter	Third Letter	
L-Liquid	D-Direct Use	S-Space Heating	F-Fish Farm
		D-District Heating	G-Greenhouse
		P-Pool	I-Industrial

Source: See Appendix A for Development of Data.

TABLE III - 6 (continued)
SITE LISTING - DIRECT USERS

NAME	OWNER	ST	COUNTY	PROCESS TYPE	BRINE (MGD)
VALE	INDUSTRIAL	OR	MALHEUR	LDI	0.43
VALE	SUNDECO OREGON TRAIL MUSHROOM CO.	OR	MALHEUR	LDG	0.12
COVE HOT SPRINGS	COMMERCIAL POOL	OR	UNION	LDP	0.43
HOT SPRINGS	PRIVATE OWNERSHIP	SD		LDP	7.20
PHILIP-GREENHOUSE	PRIVATE OWNERSHIP	SD	HAAKON	LDG	0.36
PHILIP DISTRICT HEATING	CITY OF PHILIP	SD	HAAKON	LDD	0.49
ST. MARY'S HOSPITAL	ST. MARY'S HOSPITAL	SD	HUGHES	LDS	0.53
MARLIN	MARLIN CHAMBER OF COMMERCE BUILDING	TX	FALLS	LD	0.00
T-H-S MEMORIAL HOSPITAL	NOT FOUND	TX	FALLS	LD	0.00
CORSICANA	NAVARRO COLLEGE	TX	NAVARRO	LD	0.00
NEWCASTLE	CHRISTENSON BROS	UT	IRON	LDG	0.36
BLUFFDALE	UTAH ROSES	UT	SALT LAKE	LDG	0.58
SANDY	UTAH ROSES	UT	SALT LAKE	LDG	1.73
UTAH STATE PRISON	STATE OF UTAH	UT	SALT LAKE	LDS	0.72
SOL DUC HOT SPRINGS SPACE HTG & POOL	PRIVATE OWNERSHIP	WA	CLALLAM	LDS	0.11
EPHRATA	CITY OF EPHRATA	WA	GRANT	LDD	0.00
YAKIMA	CITY OF YAKIMA	WA	YAKIMA	LDS	1.01
LANDER	NOT FOUND	WY	FREMONT	LDF	0.07
THERMOPOLIS	NOT FOUND	WY	HOT SPRINGS	LDG	1.44
JACKSON	JACKSON NATIONAL FISH HATCHERY	WY	TETON	LDF	0.19

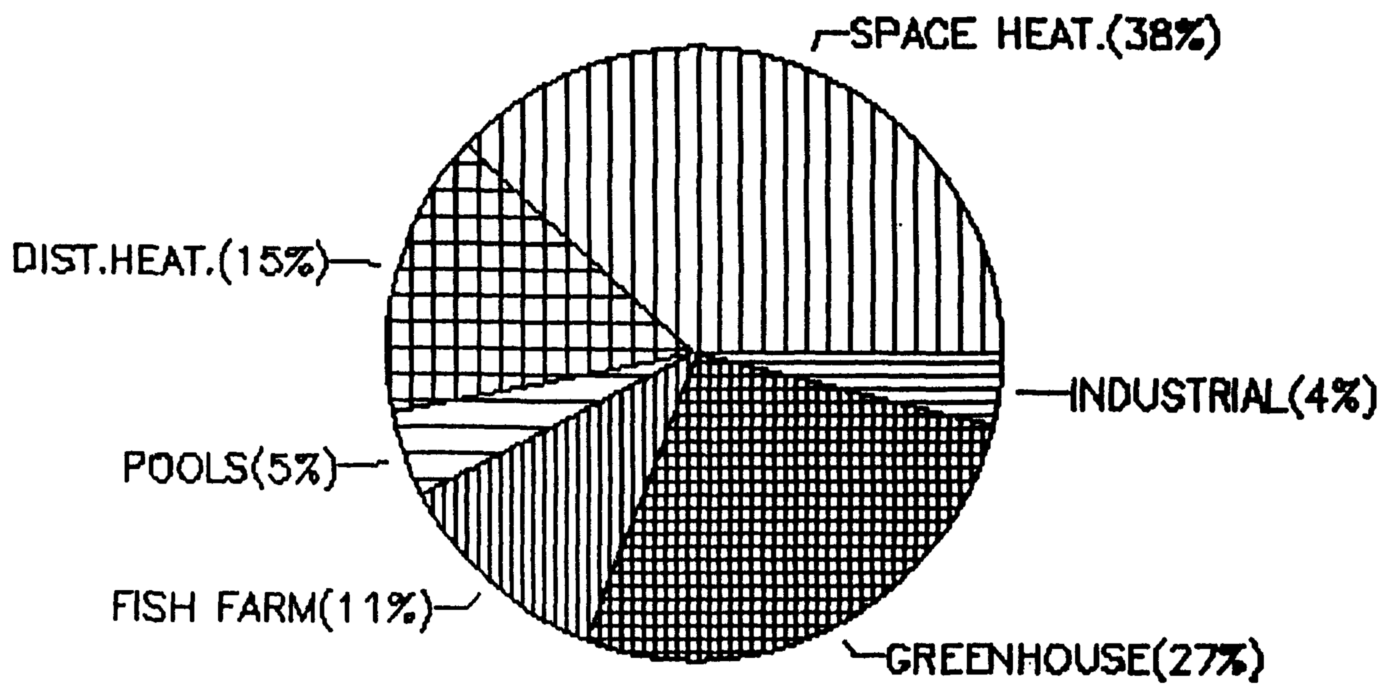
Key Process Type

First Letter	Second Letter	Third Letter	
L-Liquid	D-Direct	S-Space Heating	F-Fish Farm
		D-District Heating	G-Greenhouse
		P-Pool	I-Industrial

Source: See Appendix A for Development of Data.

FIG.III-7: GEOTHERMAL DIRECT USERS

SITE DISTRIBUTION BY UTILIZATION



breakdown of types of direct-user for 107 of the 122 sites. Sufficient information to determine the exact application of the other 15 sites is not currently available, but these sites are believed to be space heating applications.

Table III-7 shows a distribution of direct-users per state. The geographical location of direct-users is shown to be much more widespread than that of electric power generation facilities. This is due, in part, to the fact that direct-use applications can use a wider range of temperatures (see Table III-5) than electric power generation facilities.

Table III-7

Geothermal Direct Users
Site Distribution by State

State	Percent of Total Number of Users
Alaska	3
Arizona	1
California	19
Colorado	5
Idaho	23
Montana	6
New Mexico	7
Nevada	12
New York	1
Oregon	11
South Dakota	3
Texas	2
Utah	3
Washington	2
Wyoming	2
Total	100

CHAPTER 4

SOURCES AND VOLUMES OF WASTE

The previous chapter described the geothermal industry in terms of three categories; (i.e., exploration and development operations, electrical power production, and direct use applications). This chapter continues the characterization of these geothermal activities with a description of the geothermal operations or processes that generate waste and a discussion of the waste volumes. Where quantitative data are missing, a methodology for estimating waste volumes is also presented.

4.1 Methodology

The geothermal industry profiles, described in the previous chapter, were prepared from an extensive literature search and a subsequent data compilation project. The data base established by these activities provided a pool of information from which a methodology for identifying waste sources and estimating waste volumes was formulated. The applications of this methodology are discussed in detail in the following sections.

In developing the data base, raw data from the literature search was loaded into a computerized data management program that flagged areas where information was deficient. To correct these deficiencies, personal contacts with state and federal agencies, universities and selected authors were made to obtain the required information.

During the data gathering process, certain limitations in data availability became evident. These limitations are summarized as follows:

- Very little site-specific information on waste generation is available directly from the literature;
- Many of the references are old and the information outdated; and
- Among the various references, there are many discrepancies regarding names of geothermal sites, owners, waste quantities, etc.

4.2 Exploration and Development Wastes

Well drilling activities generate the bulk of wastes from geothermal exploration and development operations. In general, wastes from well drilling fall within one of the following two categories:

- Drilling fluid/mud and drill cuttings; and
- Small quantities of miscellaneous wastes.

4.2.1 Drilling Mud and Cuttings

During well drilling operations, large quantities of wastes are generated that consist of discarded drilling muds and residues from drilling mud cleaning processes. Used drilling muds are cleaned by circulating the fluid through solids removal equipment such as shale shakers, sand traps, hydrocyclones, and centrifuges. After the cleaning process, the solids which consist of drill cuttings are discharged as a waste residue, and the mud is recycled to the drilling operations. Further treatment of the recycled muds, in the form of additives, is required to control mud characteristics such as pH and viscosity (loss of viscosity reduces the usefulness of the mud). Drilling muds are discharged to reserve pits for storage, disposal, or when the drilling mud system must be purged due to a change in drilling conditions.

Documentation of drilling mud and cuttings waste volumes is very sparse. One study (US DOE, 1982), based on experience of drilling 50 wells in the Imperial Valley, indicated that about 600 metric tons of mud and cuttings resulted from the drilling of a typical 1,500-meter well. Because of the scarcity of actual waste generation data, a methodology was developed to estimate waste volumes of drilling muds and cuttings. For the annual drilling activity, shown in Table III-2, average values for well depth and diameter have been determined by geothermal resource area. These average dimensions were calculated from site-specific well data contained in the data base. For states where no information on well dimensions were available, a determination of average well dimensions was made based on fluid flowrate, temperature, and intended application of the well.

Cuttings volumes for specific geothermal areas were calculated from the number of wells in the area and the average depths and diameters. From the calculated cuttings volumes, an associated mud volume was computed based upon a cuttings/drilling mud conversion or correlation factor derived from site-specific drilling information (Morton, 1986). In the preparation of Table IV-1, cuttings and drilling mud waste volumes were combined, converted to thousands of barrels, and summarized for the years 1981 through 1985.

4.2.2 Miscellaneous Wastes

Miscellaneous waste quantities are relatively small compared to the volumes of mud and cuttings generated. Miscellaneous wastes are generally categorized as follows:

- o Deck drainings;
- o Cooling tower wastes; and
- o Maintenance and trash.

Typically, drilling operations generate deck drainings. These wastes are composed of rig washdown, rinses, drilling fluids, and other miscellaneous waste materials generated on or around the drill derrick.

Depending on the type of drilling operations, these volumes can be substantial.

Some operations may necessitate that the drilling fluid be cooled before being recycled into the well bore. Under such circumstances, the drilling fluid is circulated through a cooling tower. The tower requires occasional cleaning of scale and other deposits that build up in the tower.

Table IV - 1

Estimated Waste Volumes for Drilling Activities
Associated with Exploration and Development
of Geothermal Resources

Total Mud and Cutting Volume

State	1981	1982	1983	1984	1985
California	97.3	103.7	51.2	199.0	109.4
The Geysers	49.8	59.5	46.2	52.2	53.4
Imp. Valley	47.2	43.3	3.9	145.6	55.1
Other	0.3	1.0	1.1	1.1	0.8
Nevada	7.2	1.0	2.0	1.0	1.5
Idaho	0.6	NA	0.3	NA	NA
Montana	NA	0.1	0.1	NA	NA
Wyoming	NA	NA	NA	NA	NA
New Mexico	2.8	1.4	NA	NA	NA
Oregon	0.3	0.1	0.1	NA	0.1
Washington	0.2	0.1	NA	NA	NA
Utah	NA	2.3	1.2	2.3	NA
South Dakota	NA	NA	NA	NA	NA
North Dakota	NA	NA	NA	NA	NA
Hawaii	5.1	2.5	NA	NA	NA
Total U.S.	210.8	215.0	107.5	401.2	220.3

NA - No Activity

Source: See Appendix A.

Other wastes produced in drilling operations consist of empty containers, bags, broken tools, paint wastes, minor spills and leaks of diesel fuel, hydraulic fluid, wood pallets, solvents, and miscellaneous trash.

4.3 Geothermal Power Plant Wastes

Wastes generated from geothermal power operations include spent brine, flash tank scale and separated solids from pre-injection treatment of spent brines (Royce, 1985). Depending on the nature of the geothermal fluid, scale formed in process lines, valves, and turbines, must also be removed and disposed. These wastes generally consist of heavy metal salts. The amount and composition of these wastes are highly dependent on site mineralogy and the type of power production process used. Very little information describing and quantifying these wastes was discovered from the literature review. Most of the available information was from areas such as The Geysers and Imperial Valley.

For estimating waste volumes from geothermal power plants, different approaches were developed depending on the amount of detail available per geothermal site.

Steam flows for all vapor-dominated electric power generation facilities were estimated using operating data (California Div. of Oil & Gas 1986) from 1985 for PG&E, from which a "pounds of steam per MW" conversion factor was calculated. Also, ratios of steam usage to condensate reinjection for vapor-dominated facilities were calculated from historical operating data for The Geysers over the past five years (Calif. Div. of Oil & Gas 1987). From the ratios, steam condensate for these flows were calculated, but values are not reported as fluid wastes since these flows are likely to be considered non-exempt wastes. Verification was received from PG&E that <u>all</u> condensate is cycled through cooling towers prior to reinjection, making these reinjection fluids part of the intrinsic power generation cycle. By excluding these flows as waste streams, it is assumed that the other vapor-dominated power producers are operating in the same manner as all geothermal power operations at The Geysers are non-exempt and thus outside the scope of this report.

Brine flows for both binary and flash power production processes were calculated from equations derived from a plot of hydrothermal fluid requirements versus fluid temperature (Zimmerman, 1984). The following equations were generated from extrapolation of data points taken from the above referenced plot.

Binary Process:
$$\text{KG Brine/KWH} = 583{,}903 - 4.141T + 0.007611T^2$$

Flash Process:
$$\text{KG Brine/KWH} = 456.78 - 2.576T + 0.003855T^2$$
where T = temperature in degrees Celsius.

KWH = kilowatt hour

KG = kilograms

Hydrothermal temperatures were obtained from four separate sources (DiPippo 1985, U.S.Geological Circular 790 1978, and California Div. of Oil & Gas 1984 and 1985) and were coupled with site-specific power ratings (See Appendix A for Development of Data) to calculate daily volumes of brine throughput. From this daily flow throughput and by applying an annual operating factor of between 90 to 95 percent, (depending on type of process, plant age, etc.) brine volume was obtained for a particular facility in millions of gallons per year. (See Table IV-2.) This value is considered conservative since no loss due to solids formation or evaporation prior to disposal is taken into account.

The types of wastes generated from geothermal power production are discussed briefly in the following sections.

4.3.1 Spent Brine for Injection

Spent brine from The Geysers is generated from steam condensate which is used in the cooling tower before reinjection. The condensate from the cooling tower is sent to a sump where some solids or sludge settles prior to reinjection.

Spent brines from operations in the Imperial Valley are also reinjected (Morton, 1986) to the producing zone, but in much larger quantities. Brines from binary systems are maintained under set temperatures and pressure to prevent precipitation of dissolved solids. This allows reinjection of almost 100 percent of the geothermal fluid. Brine produced at the flash plants requires treatment prior to reinjection due to a very high TDS content (Morton, 1986). This treatment process consists of a series of crystallization, clarification, and filtration steps resulting in a solid precipitate that is hauled offsite. 80 to 90 percent of the brine is reinjected after this treatment.

Table IV - 2

Estimated Liquid Waste Volumes from both Binary and Flash Process Plants*

State	Number of Sites	Billions of Gallons per Year
California	9	43.70
Nevada	5	9.26
New Mexico	1	.24
Hawaii	1	.06
Utah	2	3.17
Total	18	56.43

*Plants that are currently operational; does not include the estimated volume for the three facilities under construction.

Source: See Appendix A for Development of Data.

4.3.2 Sludges from Brine Precipitation

One method of treating brine is via precipitation in spent brine holding ponds. A holding pond is used at the East Mesa site for treatment of spent brine. This holding pond has sufficient residence time so that liquid withdrawn from the end opposite the inlet is sufficiently clear to be reinjected into the producing reservoir. Solids that accumulate in the pond are dredged and then dried by evaporation; the solids are disposed of at the type of landfill prescribed by state regulations, based on the characteristics of the waste. This method has been successful in those cases where the salinity of the brine is low. At the East Mesa site, the salinity of the brine is low compared to other areas in the Imperial Valley. (US DOE, 1982).

4.3.3 Estimate of Waste Volumes

Table IV-2 shows estimated liquid waste volumes for the 18 operational power generation facilities that utilize a "liquid" type process. Of the estimated 56 billion gallons per year (BGY), 62 percent are generated at "flash" process facilities, and 38 percent at "binary" process facilities. If the estimated production rates for the three facilities under construction are included, the total waste volume increases to 71.63 BGY.

(See Appendix A for Development of Data.)

Due to the lack of data, no attempt was made to quantify the solid waste generated from power generation facilities. Several facilities in California (Morton, 1986) generate solids using a patent clarification/thickening process. Based on the literature review, these facilities are the sole source of significant solids generation.

4.4 Waste Generation from Direct Users

The primary waste generated from direct-use applications consists of the spent geothermal fluid remaining after usable heat has been extracted. In most cases, this fluid is of adequate quality to allow surface water discharge to nearby water bodies. There are some cases where spent geothermal fluids meets the drinking water standards, and it may be discharged to the community water supply.

Waste generated by direct-use applications was calculated in a similar manner to waste quantities for power generation facilities. Time of operation factors for industrial direct-users were estimated to be 80 percent (292 days per year). It was estimated that all other types of direct-users operate 25 percent of the time (91 days per year), or less, depending on geographical location. By multiplying daily flowrates by operating days per year, annual rates in millions of gallons per year were obtained.

No mention of significant solid waste generation is contained in the literature for direct users. At this site, barium sulfate is added to the cooled geothermal fluid to precipitate radium prior to discharge into a river. The quantity of this solid is unknown; however, it is presumed to be small in quantity and handled as a hazardous waste under state requirements.

Table IV-3 shows estimated liquid waste volumes for 104 direct users in 12 different states. This represents over 85 percent of the sites on Table III-5. These volumes are calculated as described in Section 4.1.

Table VI - 3

Estimated Liquid Waste Volumes
Estimated for Direct Users

State	Number of Sites	Billions of Gallons per Year
California	18	1.41
Oregon	14	.60
Idaho	27	3.02
Montana	7	.09
South Dakota	4	.78
Utah	4	.31
Wyoming	3	.15
New Mexico	8	.50
Nevada	10	.61
Colorado	6	.50
New York	1	.01
Washington	2	.10
Totals	104	8.09

Source: See Appendix A for Development of Data

CHAPTER 5

WASTE CHARACTERIZATION

To assess the potential environmental impacts due to wastes generated from the geothermal industry, it is necessary to characterize various waste streams resulting from exploration, development, and production operations. The following discussions contain a summary of the analytical data found in the literature for both liquid and solid wastes. These data are summarized in tables and are compared to current RCRA characteristic thresholds, (ignitability, corrosivity, reactivity, and extraction procedure toxicity) for both solid and liquid wastes.

5.1 Liquid Wastes

Tables V-1 and V-2 contain temperature, pH, and chemical constituent analysis summaries for selected power generation and direct use application waste streams. These tables were constructed from several references listed in Section 11.2.

Table V-1 contains analyses of seven different power generation facilities. Five of the seven facilities produce power via the binary process. For these facilities, the analysis parameters are shown for the incoming brine, with the exception of the temperature, which is the actual discharge value. Since there is no change of physical state

TABLE V-1

POWER PLANT
LIQUID ANALYSIS SUMMARY

NAME	ST COUNTY	TYPE	TEMP °C	pH	TDS mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cl mg/L	F mg/L	ALK mg/L	SO_4 mg/L	B mg/L	SIO_2 mg/L	H_2S mg/L
EAST MESA	CA IMPERIAL	LPB	71.0	9.00	1978	623	39.00	3.2	0.1	514	4.0	530	169	3.2	489.0	0.00
EAST MESA (B.C. MCCABE NO. 1)	CA IMPERIAL	LPB	71.0	7.40	16330	4720	231.00	1062.0	23.0	8242	1.5	202	148	8.0	187.0	0.00
HEBER	CA IMPERIAL	LPF	72.0	7.10	14100	3600	360.00	880.0	2.4	9000	1.6	20	1000	5.0	120.0	2.00
HEBER	CA IMPERIAL	LPB	72.0	7.10	14100	3600	360.00	880.0	2.4	9000	1.6	20	1000	5.0	120.0	2.00
SALTON SEA (VULCAN)	CA IMPERIAL	LPF	105	5.30	183700	36340	7820.00	14550.0	780.0	93650	0.0	60	58	210.0	350.0	0.00
WENDELL-AMEDEE (WENDELL HOT SPRINGS)	CA LASSEN	LPB	92.2	8.50	827	227	6.80	16.0	0.0	160	4.5	27	288	4.0	96.0	0.00
STEAMBOAT SPRINGS	NV WASHOE	LPB	89.2	7.90	2169	653	71.0	5.0	0.0	865	1.8	305	100	49.0	293.0	4.70

KEY FOR POWER PLANT TYPE

First Letter	Second Letter	Third Letter
L - Liquid	P - Power Generating	F - Flash Process
		B - Binary Process

Source: See Appendix A for Development of Data

TABLE V - 2
DIRECT-USERS
LIQUID ANALYSIS SUMMARY
(BY SITE)

NAME	ST	COUNTY	TYPE	TEMP °C	pH	TDS mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	Cl mg/L	F mg/L	ALK mg/L	SO_4 mg/L	B mg/L	SIO_2 mg/L	H_2S mg/L
CHENA HOT SPRINGS	AK	DOYON	LD	57.0	9.10	380	110	3.30	1.3	0.1	29	18.6	131	68	0.2	8.5	1.59
MANLEY HOT SPRINGS	AK	DOYON	LD	56.0	7.70	446	130	4.50	4.0	1.0	134	8.5	90	54	1.3	6.5	1.61
HOT SPRINGS NATIONAL PARK	AR	GARLAND	LD	60.0	7.30	189	4	1.50	45.0	4.7	2	0.2	165	9	0.0	42.0	0.00
CRABTREE HOT SPRINGS	CA	LAKE	LD	40.6	7.80	5350	1650	34.00	50.0	188.0	1120	0.4	3680	29	277.0	154.0	0.00
SUSANVILLE	CA	LASSEN	LDD	51.7	7.10	825	215	5.00	26.0	2.0	0	0.0	0	320	2.0	0.0	0.00
COACHELLA	CA	RIVERSIDE	LDG	32.2	9.00	171	55	1.00	5.0	1.0	17	0.8	97	31	0.0	13.0	0.00
SAN BERNARDINO - DISTRICT HEATING	CA	SAN BERNARDINO	LDD	35.5	8.40	730	215	3.00	14.0	0.6	60	17.0	52	341	0.5	54.0	0.00
PASO ROBLES	CA	SAN LUIS OBISPO	LDF	32.2	8.30	995	465	5.10	5.0	0.6	184	2.7	596	252	2.0	79.0	0.00
HUNTS HOT SPRINGS	CA	SHASTA	LDS	57.6	8.80	1130	300	4.30	52.0	0.1	140	3.6	55	520	13.0	47.0	0.00
PAGOSA SPRINGS	CO	ARCHULETA	LDD	40.0	6.60	3310	800	87.00	240.0	2.6	190	5.0	862	1500	2.0	58.0	0.00
GLENWOOD SPRINGS	CO	GARFIELD	LDS	40.0	6.40	20500	7000	380.00	500.0	82.0	11000	27.0	773	1100	0.9	30.0	0.00
DURAY HOT SPRINGS	CO	DURAY	LDS	24.0	6.50	1660	120	8.80	360.0	8.5	44	3.6	131	1000	0.2	49.0	0.00
BOISE CITY	ID	ADA	LDD	80.0	9.00	290	90	1.60	1.7	0.0	10	14.0	70	23	0.0	160.0	0.00
CALDWELL	ID	CANYON	LDS	27.0	7.70	203	53	2.00	11.0	0.1	5	1.5	160	3	0.1	49.0	0.00
ALMO	ID	CASSIA	LDS	32.0	6.80	855	240	13.00	58.0	9.0	380	4.4	138	44	0.1	37.0	2.90
MALDA CITY	ID	ONEIDA	LDD	25.0	6.80	1220	280	29.00	110.0	33.0	470	0.7	331	110	0.0	21.0	0.00
BANKS	ID	OWYHEE	LDG	41.0	9.10	232	70	1.30	1.9	0.1	4	16.0	88	39	0.0	67.0	0.00
BRUNEAU	ID	OWYHEE	LDG	35.0	8.70	227	52	7.20	6.7	0.1	9	9.4	98	18	0.1	77.0	0.00
WARM SPRINGS STATE HOSPITAL	MT	DEER LODGE	LDS	60.0	6.46	1310	120	26.00	220.0	22.0	5	3.9	258	670	0.1	56.0	0.70
WHITE SULFUR SPRINGS	MT	MEAGHER	LDS	43.0	6.80	1950	480	20.00	44.0	12.0	180	7.4	835	310	9.1	51.0	0.70
WHITE SULFUR SPRINGS	MT	MEAGHER	LDS	43.0	6.80	1950	480	20.00	44.0	12.0	180	7.4	835	310	9.1	51.0	0.70
LOLO	MT	MISSOULA	LDS	32.0	9.30	224	52	1.20	1.8	0.1	6	6.4	86	18	0.1	72.0	0.50
LAS ALTURAS	NM	DONA ANA	LDS	45.1	8.07	2160	488	55.00	142.0	32.0	980	1.6	348	223	0.6	68.0	0.00
APACHE TEJO AND KENNECOTT WARM SPRINGS	NM	GRANT	LDI	27.0	8.43	370	48	4.60	34.0	17.0	19	2.7	222	70	0.8	0.0	0.00
GILA HOT SPRINGS - SPACE HTG & POOL	NM	GRANT	LDS	41.0	8.13	468	13	3.00	9.9	0.1	105	9.1	101	45	0.1	74.0	0.00
TRUTH OR CONSEQUENCES	NM	SIERRA	LDS	54.0	6.70	2620	742	17.50	57.0	18.8	1340	3.5	250	120	0.2	41.0	0.00
CALIENTE - SPACE HTG & POOL	NV	LINCOLN	LDS	58.0	7.20	335	39	14.00	34.0	4.8	8	1.4	200	30	0.0	106.0	0.00
CALIENTE - SPACE HTG & POOL	NV	LINCOLN	LDS	54.0	7.20	335	39	14.00	34.0	4.8	8	1.4	200	30	0.0	106.0	0.00
MOANA GEOTHERMAL	NV	WASHOE	LDD	96.0	8.00	856	199	3.70	21.0	4.1	32	1.5	211	325	0.7	79.0	0.00
MOANA GEOTHERMAL	NV	WASHOE	LD	96.0	8.00	856	199	3.70	21.0	4.1	32	1.5	211	325	0.7	79.0	0.00
KLAMATH FALLS DISTRICT HEATING (INJECT)	OR	KLAMATH	LDD	60.0	8.20	736	195	3.90	24.0	0.1	58	1.5	44	400	1.0	31.0	0.00

TABLE V - 2 (continued)
DIRECT USERS
LIQUID ANALYSIS SUMMARY
(BY SITE)

NAME	ST COUNTY	TYPE	TEMP °C	pH	TDS mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	C1 mg/L	F mg/L	ALK mg/L	SO_4 mg/L	B mg/L	SIO_2 mg/L	H_2S mg/L
KLAMATH FALLS - DISTRICT HEATING (SURF)	OR KLAMATH	LDD	60.0	8.20	736	195	3.90	24.0	0.1	58	1.5	44	400	1.0	31.0	0.00
KLAMATH FALLS - POOL	OR KLAMATH	LDP	60.0	8.20	736	195	3.90	24.0	0.1	58	1.5	44	400	1.0	31.0	0.00
KLAMATH FALLS - SPACE HEATING (INJECT)	OR KLAMATH	LDS	60.0	8.20	736	195	3.90	24.0	0.1	58	1.5	44	400	1.0	31.0	0.00
KLAMATH FALLS - SPACE HEATING (SURF)	OR KLAMATH	LDS	60.0	8.20	736	195	3.90	24.0	0.1	58	1.5	44	400	1.0	31.0	0.00
VALE	OR MALHEUR	LDI	66.0	8.00	476	134	2.20	3.0	0.5	4	1.6	192	121	0.3	40.0	0.00
VALE	OR MALHEUR	LDG	77.0	8.00	476	134	2.20	3.0	0.5	4	16.0	192	121	0.3	40.0	0.00
COVE HOT SPRINGS	OR UNION	LDG	24.0	8.57	196	32	0.80	2.0	0.1	6	0.3	114	7	1.0	36.0	0.00
ST MARY'S HOSPITAL	SD HUGHES	LDS	37.0	6.80	2084	50	21.00	402.0	86.0	75	0.0	124	1445	1.6	27.0	0.70
NEWCASTLE	UT IRON	LDG	41.0	7.60	1120	270	21.00	58.0	0.4	52	7.3	53	580	0.7	99.0	0.00
UTAH STATE PRISON	UT SALT LAKE	LDS	66.0	7.50	891	191	16.00	76.0	25.0	226	0.8	264	191	0.4	35.0	0.00
SOL DUC HOT SPRINGS-SPACE HTG & POOL	WA CLALLAM	LDS	24.0	9.46	262	80	1.00	0.8	0.0	21	1.7	181	7	1.4	60.0	10.00
THERMOPOLIS	WY HOT SPRINGS	LDG	43.0	6.90	2190	250	37.00	310.0	71.0	300	6.8	710	730	0.5	37.0	0.00

KEY FOR DIRECT USER TYPE

First Letter	Second Letter	Third Letter
L - Liquid	D - Direct User	F - Fish Farm
V - Vapor		S - Space Heating
		G - Greenhouse
		D - District Heating
		I - Industrial
		P - Pool heating

Source: See Appendix A for Development of Data

of the geothermal liquid in the binary process, it is expected that these results are representative of the discharged brine.

This assumption is not necessarily valid, however, for power plants utilizing the flash process. In these situations, the various chemical constituents can be concentrated in the liquid that remains after the progressive series of steam generation steps.

Only one set of analyses (Salton Sea - Vulcan) is representative of a fluid that remains after a flashing process. The analysis for the other flash processes, at Heber, CA, applies only to the incoming fluid. Comparison of these two results provides an estimate of the increase in concentration of constituents that can occur from the flashing process. Table V-1 indicates that there is about one order of magnitude increase in concentration.

Table V-2 reports analyses of geothermal fluids for 43 direct users in 13 states. In general, the levels of chemical constituents are much lower than for power plant reinjection brines.

Table V-3 contains analyses of three brine samples tested for both major and trace constituents. These samples were collected in Imperial Valley, CA, at three test well sites in 1980 (Accurex, 1980). This test data can only be considered as preliminary since the chemical analyses have not been verified through further testing. The first eight elements reported under the trace element analyses column are contaminants from the RCRA extraction procedure (EP) toxicity test for determining whether a waste is hazardous.

Table V-4 (Morris, 1981) also contains analyses of three sites, two of which are from the same sites as Table V-3. All three are test well samples were taken from on-site fluid pits or tanks. Again, the first eight elements shown are the eight RCRA EP toxicity contaminants.

5.2 Solid Wastes

Very little site-specific data relating to the composition of solid wastes from geothermal operations have been found in the literature. Two references (Accurex 1980, 1983) discuss the analyses of 33 samples of various solid and liquid samples collected in 1980. As stated before, these data can only be considered as preliminary at this time since the results have not been verified or been subjected to a quality assurance procedure. These samples were analyzed in considerable detail, including leachate analyses

Table V-3

Liquid Waste - Test Well Brine Analyses

Location: Imperial Valley

Site:	East Mesa	Niland	Westmoreland
Owner:	Republic Geothermal	Republic Geothermal	MAPCO
Bulk Composition (mg/l)			
Al	1.6	<1	1.2
Ca	30.0	51,000	14,800
Fe	0.97	3,200	2,100
Mg	1.7	313	440
K	91	38,000	10,000
Na	1,500	55,000	60,000
Cl	1,700	295,000	158,700
F	10	19	10
SiO2	13	300	18
SO4	65	<0.01	<1
S	<0.1	<0.1	<0.1
Trace Analysis (µg/l)			
As	310	<250	14,000
Ba	<300	363,000	22,000
Cd	<5	70	4,000
Cr	<20	980	<60
Pb	<20	NR	83,000
Hg	<1	Int.	<1
Se	<20	<500	5,100
Ag	<20	NR	<20
Sb	<100	<200	<1,000
Be	<20	<20	<20
B	<200	660,000	230,000
Cu	<70	7,400	<100
Li	2,800	NR	240
Ni	<200	300	<200
Sr	<500	1,295,000	1,400,000
Zn	30	NR	6,000,000
pH	8.7	1.6	3.8
TSS (mg/l)	56	5,600	220
Radium 226 (pCi/s)	0.0	0.4	1,320

NR - Not Reported (proprietary data restriction)
Int - Interference (reporting of results not possible)

Table V-4

Metals Detected in the Extracts of Geothermal Brines[a]

	Imperial Magmamax	Republic Fee	MAPCO Courier
Ag	.1	.5	.1
As[b]	25	<5	20
Ba	250	400	1300
Cd	<5	<4	<3
Cr	<1	<1	<1
Hg[b]	<.1	<.2	<.2
Pb	50	200	130
Se	NA	NA	NA
B	600	400	130
Be	<.2	<.4	<.3
Cu	5	10	<.7
Li	130	2000	1000
Ni	<1	5	<3
Sb	<5	<10	<7
Sr	400	800	1750
Zn	200	1000	400
Al	<1	10	70
Ca	MC	MC	MC
Co	<1	<1	<1
Fe	250	1000	650
K	MC	MC	MC
Mg	100	400	250
Mn	400	800	250
Mo	<2	<4	<3
Na	MC	MC	MC
Rb	10	25	17
Si	300	30	20
Sn	<4	<4	<4
Ti	<.5	<10	<10
V	<4	<4	<4

Units - milligrams of constituent per liter of extract.
MC - Major constituent, ranging from approximately 2000 mg/l to higher levels.
NA - Not applicable.

a Determinations by opticla emission spectroscopy.
b Preconcentration using CuS carrier prior to spectographic analysis.

for EP toxicity. Tables V-5 through V-9 list results of the analyses for 11 of these samples which are applicable to this study.

Table V-5, V-6 and V-7 lists concentrations for major constituents contained in the 11 samples. These constituents provide an indication of the mineralogy of the sample. Results are reported for total constituent content, neutral and acid extractable values, along with pH, percent moisture, and radium concentrations.

Table V-8 and V-9 lists concentrations for 16 trace constituents for the same 11 samples. Eight of these constituents are EP toxicity contaminants.

In addition to the analyses for the eight EP toxicity contaminants, tests were also conducted for eight other metals. These metals (Sb, Be, B, Cu, Li, Ni, Sr, Zn) were included because of being listed in the water quality standards of several western states. Analytical results for these metals are summarized in Table V-10. In general, the measured concentrations of these metals are fairly low, except for the levels of boron and zinc.

TABLE V-5
SOLID WASTE - BULK COMPOSITION

SITE	OWNER	SAMPLE TYPE	TOTAL	TOTAL % AL	TOTAL % CA	TOTAL % FE	TOTAL % MG	TOTAL % K	TOTAL % NA	TOTAL % CL	TOTAL % F	TOTAL % SIO2	TOTAL % SO4 % S	pH	% MOISTURE	RADIUM 226 pCI/G
DESERT PEAK - NEVADA	PHILLIPS PETR.	MUD	1.98	0.87	2.95	0.92	0.59	0.77	0.98	0.024	27.40	0.08	<0.0002	9.10	9.90	1.50
HUMBOLT - NEVADA	PHILLIPS	MUD	2.02	1.90	2.35	0.73	0.54	0.40	0.10	0.034	20.20	0.22	<.02	9.80	36.00	1.60
IMPERIAL VALLEY - WESTMORELAND	MAPCO	MUD	2.10	2.20	1.60	0.69	0.97	2.00	5.30	0.029	42.40	0.01	<.2	8.80	31.00	5.90
IMPERIAL VALLEY - NILAND	REPUBLIC GEO.	MUD	2.57	2.20	1.70	1.15	1.10	1.25	2.00	0.042	29.20	0.15	<.02	8.40	62.00	2.10
IMPERIAL VALLEY - EAST MESA	REPUBLIC GEO.	MUD	1.20	1.65	0.66	0.43	0.36	0.24	0.10	0.023	24.40	0.05	<.1	12.00	60.00	1.00
THE GEYSERS	AMINOIL USA	MUD	2.45	0.93	3.90	1.78	0.51	0.09	0.01	0.018	45.60	0.01	<.0002	9.60	23.00	0.40
THE GEYSERS	UNION OIL OF CA	MUD	1.58	0.59	3.03	1.65	0.27	0.11	0.01	0.024	19.40	0.02	<.02	10.00	53.00	0.50
STEAMBOAT - NEVADA	PHILLIPS	MUD	1.63	1.80	1.85	0.67	0.46	0.19	0.04	0.015	21.60	0.05	<.0002	9.30	34.00	1.00
IMPERIAL VALLEY - EAST MESA	DOE/WESTECT	BRINE	0.22	0.73	0.32	0.15	0.09	0.09	0.09	0.010	9.80	0.01	<.0002	8.80	34.00	3.80
IMPERIAL VALLEY - EAST MESA	DOE/WESTEC	SCALE	0.29	11.40	5.10	0.13	0.04	0.11	0.08	0.040	9.90	0.01	<.01	8.80	61.00	3.00
IMPERIAL VALLEY -	DOE/MAGMA	BRINE	0.01	1.50	2.45	0.02	1.10	4.30	9.30	0.340	12.40	0.01	<.01	6.10	46.00	78.00

KEY FOR SAMPLE TYPE

MUD - Sample taken from drilling mud disposal pit.

BRINE - Brine solution sample taken form test well.

SCALE - Sample taken form inside brine containment vessel.

Source: See Appendix A for Development of Data.

TABLE V-6

SOLID WASTE ACID EXTRACT - BULK COMPOSITION

SITE	OWNER	SAMPLE TYPE	ACID	ACID EXT mg/L Al	ACID EXT mg/L Ca	ACID EXT mg/L Fe	ACID EXT mg/L Mg	ACID EXT mg/L K	ACID EXT mg/L Na	ACID EXT mg/L Cl	ACID EXT mg/L F	ACID EXT mg/L Si02	ACID EXT mg/L S04	EXT mg/L S
DESERT PEAK - NEVADA	PHILLIPS PETR.	MUD	<1	790	2.6	18	28	350	487	.33	<4	16	<0.1	
HUMBOLT - NEVADA	PHILLIPS	MUD	<1	1300	4.6	27	13	140	53	.64	9	82	<.1	
IMPERIAL VALLEY - WESTMORELAND	MAPCO	MUD	<1	1200	0.8	18	170	975	2260	.32	11	6.5	<.1	
IMPERIAL VALLEY - NILAND	REPUBLIC GEO.	MUD	<1	360	1.2	32	130	580	1280	.95	4	80	<.1	
IMPERIAL VALLEY - EAST MESA	REPUBLIC GEO.	MUD	1.2	1100	5.8	38	24	115	54	.60	32	64	.1	
THE GEYSERS	AMINOIL USA	MUD	<1	690	14	6	2.5	28	3	.13	5	<1	<.1	
THE GEYSERS	UNION OIL OF CA	MUD	<1	280	32	9.6	6.3	24	2	.34	<4	32	<.1	
STEAMBOAT - NEVADA	PHILLIPS	MUD	<1	700	1.6	15	21	53	23	.54	14	39	<.1	
IMPERIAL VALLEY - EAST MESA	DOE/WESTECT	BRINE	<1	680	1.8	7.5	17	63	49	1.8	8	7.0	<.1	
IMPERIAL VALLEY - EAST MESA	DOE/WESTEC	SCALE	<1	1800	<.2	4.4	9.4	55	57	6.3	4.0	4.5	<.1	
IMPERIAL VALLEY -	DOE/MAGMA	BRINE	<1	800	1.0	3.5	400	1900	5000	1.7	4	1.0	<.1	

Source: See Appendix A for Development of Data.

TABLE V-7

SOLID WASTE NEUTRAL EXTRACT - BULK COMPOSITION

SITE	OWNER	SAMPLE TYPE	NEUT	NEUT EXT mg/L Al	NEUT EXT mg/L Ca	NEUT EXT mg/L Fe	NEUT EXT mg/L Mg	NEUT EXT mg/L K	NEUT EXT mg/L Na	NEUT EXT mg/L Cl	NEUT EXT mg/L F	NEUT EXT mg/L SiO2	NEUT EXT mg/L SO4	EXT mg/L S
DESERT PEAK - NEVADA	PHILLIPS PETR.	MUD	<1	8.1	1	.55	20	170	492	.31	<4	40	<0.1	
HUMBOLT - NEVADA	PHILLIPS	MUD	4.5	25	9.2	4	4.7	120	53	.61	9	78	<.1	
IMPERIAL VALLEY - WESTMORELAND	MAPCO	MUD	<1	330	<.02	5	160	950	2220	.24	4	5.7	<.1	
IMPERIAL VALLEY - NILAND	REPUBLIC GEO.	MUD	<1	120	<.2	5	120	550	1150	.55	<4	170	<.1	
IMPERIAL VALLEY - EAST MESA	REPUBLIC GEO.	MUD	1.2	28	.2	.04	18	105	55	.32	4	30	.1	
THE GEYSERS	AMINOIL USA	MUD	<1	.81	.8	.40	.83	25	1	.14	4	14	<.1	
THE GEYSERS	UNION OIL OF CA	MUD	<1	34	<.2	<.04	2.5	48	<1	.28	16	62	<.1	
STEAMBOAT - NEVADA	PHILLIPS	MUD	<1	8.1	<.2	.08	12	48	22	.46	13	22	<.1	
IMPERIAL VALLEY - EAST MESA	DOE/WESTECT	BRINE	<1	6.4	<.2	.48	11	50	58	.74	5	5.5	<.1	
IMPERIAL VALLEY - EAST MESA	DOE/WESTEC	SCALE	<1	3.2	<.2	.08	6.3	50	59	.42	4.0	6.2	<.1	
IMPERIAL VALLEY -	DOE/MAGMA	BRINE	<1	840	<.2	3.7	400	1900	5370	1.8	2	6.5	<.1	

Source: See Appendix A for Development of Data.

TABLE V-8

SOLID WASTE ACID EXTRACT - TRACE ANALYSIS

SITE	OWNER	SAMPLE TYPE	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Sb	Be	B	Cu	Li	Ni	Sr	Zn	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DESERT PEAK - NEVADA	PHILLIPS PETR.	MUD	<20	500	<5	<20	<20	<1	30	<20	<50	<20	230	200	300	<300	2600	140	
HUMBOLT - NEVADA	PHILLIPS	MUD	<20	600	6	<20	400	<1	<20	<20	<50	<20	<200	<70	50	<300	3000	420	
IMPERIAL VALLEY - WESTMORELAND	MAPCO	MUD	49	13000	20	<20	60	<1	100	<20	<50	<20	250	<70	3300	<200	23000	7000	
IMPERIAL VALLEY - NILAND	REPUBLIC GEO.	MUD	63	1800	6	<20	<20	<1	30	<20	<50	<20	<2000	<70	1300	<200	5400	1300	
IMPERIAL VALLEY - EAST MESA	REPUBLIC GEO.	MUD	<20	1400	<5	<20	30	<1	<20	<20	<50	<20	<2000	<70	<50	<200	2200	150	
THE GEYSERS	AMINOIL USA	MUD	<20	1400	<5	70	20	<1	<20	<20	<50	<20	<200	<70	<50	<500	3500	80	
THE GEYSERS	UNION OIL OF CA	MUD	<20	<300	<5	<20	<20	<1	<20	<20	<50	<20	870	<70	<50	300	600	300	
STEAMBOAT - NEVADA	PHILLIPS	MUD	60	600	<5	<20	<20	<1	<20	<20	<50	<20	300	<70	500	<300	1000	120	
IMPERIAL VALLEY - EAST MESA	DOE/WESTECT	BRINE	45	3800	<5	<20	<20	<1	<20	<20	<50	<20	<2000	<70	170	<200	8300	110	
IMPERIAL VALLEY - EAST MESA	DOE/WESTEC	SCALE	36	10500	<5	<20	<20	<1	<20	<20	180	<20	<200	150	220	<200	<500	70	
IMPERIAL VALLEY -	DOE/MAGMA POWER	BRINE	230	5000	60	<20	200	<1	180	<20	<50	<20	12000	150	5800	500	12000	6400	

Source: See Appendix A for Development of Data.

TABLE V-9

SOLID WASTE NEUTRAL EXTRACT - TRACE ANALYSIS

SITE	OWNER	SAMPLE TYPE	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Sb	Be	B	Cu	Li	Ni	Sr	Zn	
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DESERT PEAK - NEVADA	PHILLIPS PETR.	MUD	<20	<300	<5	39	<20	<1	<20	<20	<50	<20	470	100	200	<300	<500	50	
HUMBOLT - NEVADA	PHILLIPS	MUD	140	500	5	27	400	<1	<20	<20	<50	<20	<200	100	<50	<300	<500	280	
IMPERIAL VALLEY - WESTMORELAND	MAPCO	MUD	41	6800	<5	<20	<20	<1	120	<20	50	20	1100	70	3100	<200	20000	<20	
IMPERIAL VALLEY - NILAND	REPUBLIC GEO.	MUD	<20	<300	<5	<20	<20	<1	20	<20	<50	<20	200	<70	1100	<200	1500	<20	
IMPERIAL VALLEY - EAST MESA	REPUBLIC GEO.	MUD	<20	<300	<5	<20	<20	<1	<20	<20	<50	<20	<200	<70	<50	<200	<500	<20	
THE GEYSERS	AMINOIL USA	MUD	20	<300	<5	<20	<20	<1	<20	<20	<50	<20	<200	<70	<50	<500	<500	<20	
THE GEYSERS	UNION OIL OF CA	MUD	32	<300	<5	<20	<20	<1	<20	<20	<50	<20	15000	<70	<50	500	<500	<20	
STEAMBOAT - NEVADA	PHILLIPS	MUD	260	<300	<5	<20	<20	<1	<20	<20	70	<20	570	<70	400	<300	<500	<20	
IMPERIAL VALLEY - EAST MESA	DOE/WESTECT	BRINE	65	600	<5	<20	<20	<1	<20	<20	<50	<20	<200	<70	130	<200	<500	<20	
IMPERIAL VALLEY - EAST MESA	DOE/WESTEC	SCALE	33	300	<5	<20	<20	<1	<20	<20	180	<20	<200	70	140	<200	<500	<20	
IMPERIAL VALLEY -	DOE/MAGMA POWER	BRINE	230	5400	60	<20	<20	<1	220	<20	<50	<20	13000	<70	7900	<200	15000	4000	

Source: See Appendix A for Development of Data.

Table V-10

Metals Detected in the Extracts of Geothermal Solid Wastes from the Imperial Valley Area[a]

	Well drilling Mud and Cuttings				Scale	Brine
	Occidental Fed. Lease[b]	Occidental Neasham	Republic Fee	MAPCO Courier	(GLEF)[d]	Prec. (GLEF)
Ag	<.01	<.01	<.01	<.01	.01	.02
As[c]	<.5	<.5	<1	<1	<.5	<.5
Ba	.3	.5	3	25	3.5	7
Cd	<.1	<.1	<.1	<.1	<.1	<.2
Cr	<.02	<.01	<.03	<.03	<.02	<.04
Hg[c]	<1	<1	<1	<1	<1	<1
Pb	<.1	<.1	.06	.1	7	.07
Se[c]	<.5	<.5	<.5	<.5	Int.	Int.
B	.02	.1	2	6	4	7
Bd	<.003	<.003	<.01	<.01	<.007	<.01
Cu	<.02	.02	.01	.03	.7	1
Li	.02	.04	3	10	15	30
Ni	.5	.1	.1	.2	.07	<.02
Sb	<.1	<.1	<.2	<.3	<.2	<.4
Sr	1	2	10	25	5	13
Zn	<.1	<.1	.5	15	.5	.7
Al	.05	.6	.2	.1	.07	.1
Ca	MC	MC	MC	MC	MC	MC
Co	<.03	<.03	<.03	<.03	<.02	<.04
Fe	2	2	1	1	.2	<.4
K	5	40	MC	MC	MC	MC
Mg	10	10	10	15	2	3
Mn	.4	1.3	4	10	5	10
Mo	<.03	<.03	.1	<.1	<.1	<.1
Na	MC	MC	MC	MC	MC	MC
Rb	<.1	.15	1	2	1	1
Si	5	30	10	3	2	4
Sn	<.1	<.1	<.1	<.1	<.1	<.1
Ti	<.1	<.1	<.3	<.3	<.1	<.1
V	<.1	<.1	<.1	<.1	<.2	<.4

Units - Milligrams of constituent per liter of extract.
Int - Interference.
MC - Major constituent, ranging from approximately 5000 mg/L to higher levels.
a Determinations by optical emission spectroscopy except as noted.
b Values represent mean of 5 samples analyzed.
c As, Hg, and Se were determined by atomic absorption spectrophotometry. Interference on Hg precludes lower detection level of Hg.
d GLEF - Geothermal Loop Experimental Facility.
Source: Morris 1981

One other study (Morris 1981) provided analyses of a similar group of samples with both major and trace elements. The results are presented in Table V-8 and V-9 and are based on the acid extract from the six solid samples. Four of the samples are from various drilling mud pits. The other two are from the GLEF test facility. Two of the drilling samples are the same as those shown in Tables V-5, V-6 and V-7.

5.3 Analysis of Waste Constituents

A few of the geothermal wastes that were characterized in the previous sections could be classified as hazardous under RCRA because they exhibit hazardous characteristics. The hazardous characteristics that are present include corrosivity and EP toxicity for certain metals.

The corrosive characteristic applies to wastes with pH values equal to or less than 2.0, or greater than or equal to 12.5. Maximum concentration levels for EP toxicity metal contaminants are as follows:

Metal Contaminant	Maximum Concentration (mg/L)
Arsenic	5.0
Barium	100.0
Cadmium	1.0
Chromium	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0
Silver	5.0

Two of the three brine samples, characterized in Table V-3, exceed allowable levels of RCRA hazardous characteristics. The sample from the Niland site exhibits the corrosivity characteristic with a pH of 1.6 and also exceeds the EP toxicity concentration for barium. At the Westmoreland site, the brine sample exceeds the EP toxicity limits for metals; i.e., arsenic, cadmium, lead, and selenium. Similarly, the three geothermal brine samples characterized in Table V-4 also exceed allowable contaminant concentrations for arsenic, barium, and lead.

Sufficient constituent data are not available to further evaluate the other waste streams with respect to the EP toxicity contaminant concentrations.

5.4 Data Needs

Sufficient data are not presently available to accurately characterize or quantify wastes generated from power production and drilling activities related to geothermal operations. Waste information available in the literature applies to only a few site-specific cases. Since characteristics of geothermal wastes relate directly to the geology and mineralogy of a resource area, additional site-specific data are required to more fully characterize wastes from the geothermal industry.

Presently, available historical data are insufficient for making future projections of total volumes of drilling mud and cuttings generated by the geothermal industry. To predict future waste disposal requirements and associated potential problems, it is important to establish an accurate historical record from which to extrapolate. The type of data needed is not generally published in the literature and industry cooperation is essential. Information must be obtained concerning volume, characteristics and chemical constituents of mud pit solids, drill cuttings and reinjection fluids. Waste treatment, handling and disposal practices need to be established for each facility (or, at the very least, for each geothermal region).

CHAPTER 6

WASTE MANAGEMENT PRACTICES

This chapter describes current waste disposal practices for wastes generated from geothermal exploration, development and operations. Also explored are alternatives to current disposal practices that may be required if geothermal wastes were to be regulated under RCRA. Finally, a summary of state regulatory requirements for geothermal operations requirements is presented. Accompanying this summary is a discussion of the availability of information documenting the potential danger to human health and environment resulting from geothermal operations or waste disposal practices.

6.1 Current Practices

The following discussions pertain to waste management techniques that are practiced during geothermal drilling, power production, and direct-use applications.

6.1.1 Disposal Practices for Drilling Wastes

A review of the literature indicated that only two references addressed handling and disposal of wastes from geothermal drilling activities. At Heber, Imperial Valley, California, drilling wastes are discharged to a reserve pit, and from there the wastes are collected for off-site disposal (US DOE, 1980).

One reference (Royce, 1985) describes the waste handling and disposal methods employed at The Geysers. These waste management methods reflect current regulatory policies in California. At The Geysers, an on-site reserve pit is constructed with a two-foot thick clay liner with a permeability of less than 10^{-6}cm/s. If wastes within the pit are tested and shown to be non-hazardous, according to the RCRA characteristic test, then these wastes will remain in the pit. Wastes that are determined to be hazardous are transported to approved hazardous waste disposal sites (For more details on waste toxicity testing and approved waste disposal facilities, see California Geothermal Regulations Summary in Appendix B). After the solids settle and the liquid is pumped off for reinjection into the well, the pit is capped. Pit dewatering consists merely of allowing liquids to evaporate from the surface of the reserve pit prior to back filling. A more complex technology involves the use of alum and polymers as flocculants. After separation, the water is discharged and thickened solids are covered with backfill (Hansen, et al, undated). Problems associated with this method involve potential future liabilities that could result from waste sludge remaining buried at the site (Hansen, et al, undated).

Land farming, another reserve pit disposal option, involves the mechanical distribution and mixing of reserve pit waste into soils in the vicinity of the drilling site (Fairchild 1980, Hansen, et al undated). In the petroleum industry this method of disposal is controversial because of the high chloride content of drilling wastes in some geographical locations (Tucker 1985, Hansen, et al, undated).

In California, off-site waste disposal is used for disposition of hazardous wastes from geothermal drilling. However, instead of vacuum truck removal, the reserve pit contents are allowed to desiccate and the solids are transported to an approved disposal site.

Stringent permitting requirements and state prohibitions limit the general application of annular disposal of drilling wastes in the United States (Hansen, et al, undated). When applied to geothermal drilling, this method is not particularly applicable if it will have an adverse effect on the development of the geothermal well.

Solidification of reserve pit wastes may be economically attractive and is more environmentally acceptable than backfilling of the wastes (Hansen, et al, undated). Solidification methods typically involve mixing fly ash or kiln dust with the drilling fluids to decrease the overall moisture content of the mixture (Hansen, et al undated). One reference (Hansen, et al undated) states that problems associated with this waste management method include the potential for leaching toxic metals, organics and non-metallicions (particularly chlorides) into groundwater, or possible bioaccumulation of these constituents in plants and the food chain.

The primary wastes from either geothermal or petroleum drilling activities are drilling muds and drill cuttings. Methods currently practiced by the geothermal industry for handling and disposal of these materials have generally been developed by the petroleum industry.

After completion or abandonment of a well, drilling mud and cuttings remain within the reserve mud pit. The following quote from Raferty (1985) is offered to provide some perspective on the nature of the reserve pit.

> "In the early days of drilling, the reserve pit was used to remove drilled solids and store the active mud system. As more advanced solids control and drilling fluid technology became available to the oil and gas industry, mud tanks began replacing the reserve pit as the storage and processing area for the active mud system. Today's reserve pit is little more than oversized collection point for drill site waste, well bore cuttings, and rainwater."

Fairchild (1985a) lists the following five methods for handling of reserve pit contents:

- o dewatering of pit wastes with subsequent backfilling;
- o land farming the wastes into surrounding soils;

- vacuum truck removal and hauling to an off-site pit;
- pumping the waste down the well annulus; and
- chemical solidification of the wastes.

6.1.2 Waste Management Practices- Power Generation Facilities

Seven types of liquid waste disposal have been described in the literature for power generation facilities. These seven include:

1) Direct release to surface waters;
2) Treatment and release to surface waters;
3) Closed cycle ponding and evaporation;
4) Injection into a producing horizon;
5) Injection into a non-producing horizon;
6) Treatment and injection; and
7) Consumptive secondary use.

An international review of waste disposal methods showed potential applications for each of these methods depending on the legal, technical, and environmental aspects of the different power generation sites (US DOE, 1980). At least one of the above mentioned disposal methods is being practiced or will be implemented at the 25 power generation facilities that are currently opeational or under construction. These data are summarized in Table VI-1. For the seven methods, a brief description follows, with discussion of sites where each type is practiced.

Direct release to surface waters is the most simple method of disposal and consists of discharging the spent fluid to a local drainage system. In the past, this method has been practiced at some time at all power generation facilities (US DOE, 1980). Current environmental constraints have made this practice almost non-existent for facilities in the United States. One small binary facility (Wendell-Amedee, Wendell Hot Springs) has been identified as performing surface discharge. (California Div. of Oil and Gas 1985). This situation is justified due to the good high quality of the brine, as is indicated in Table V-1. Treatment and release to surface waters can also be a relatively simple process; however, it can become cost intensive, depending on the type of treatment required. Treatment can vary from simple settling and flocculation to sophisticated physical/chemical processes (US DOE, 1980). Currently, no power facilities have been identified as using this type of brine treatment.

Closed cycle ponding and evaporation consists of cycling the spent brine through one or a series of ponds where salts can settle out and the liquid is able to evaporate. Ponds can be either natural or man-made. Currently, there are no power generation facilities utilizing this method, but this method could be applicable in areas where the

TABLE VI - 1

WASTE DISPOSAL PRACTICES
FOR POWER GENERATION FACILITIES

NAME	ST	COUNTY	DIRECT RELEASE SURFACE WATER	INJECTION INTO PRODUCING HORIZON	TREATMENT AND INJECTION	CONSUMPTIVE SECONDARY USE
NILAND	CA	IMPERIAL		X		
EAST MESA	CA	IMPERIAL		X		
EAST MESA (B.C. MCCABE NO.1)	CA	IMPERIAL		X		
HEBER	CA	IMPERIAL		X	X	X
HEBER	CA	IMPERIAL			X	
SALTON SEA	CA	IMPERIAL		X		
SALTON SEA (VULCAN)	CA	IMPERIAL		X		X
COSO	CA	INYO		X		
WENDELL-AMEDEE (HONEY LAKE)	CA	LASSEN		X		
WENDELL-AMEDEE (WENDELL HOT SPRINGS)	CA	LESSEN	X			
MONO-LONG VALLEY (CAS DIABLO)	CA	MONO		X		
THE GEYSERS	CA	SONOMA		X		X
THE GEYSERS(BOTTLE ROCK)	CA	SONOMA		X		X
PUNA NO. 1	HI	HAWAII		X		
LIGHTING DOCK	NM	HIDALGO		X		
BRADY HAZEN	NV	CHURCHILL		X		
FISH LAKE	NV	ESMERALDA		X		
BEOWAWE	NV	LANDER/EUREKA		X		
WABUSKA HOT SPRINGS	NV	LYON				X
DESERT PEAK	NV	RENO		X		
STEAMBOAT SPRINGS	NV	WASHOE		X		
COVE FORT-SULFERDALE	UT	BEAVER		X		
ROOSEVELT HOT SPRINGS - MILFORD	UT	BEAVER		X		

Source: See Appendix A for Development of Data

climate is arid and land is relatively inexpensive (US DOE, 1980).

Injection of liquid wastes into the producing horizon consists of recycling the spent brine back into a different location of the geothermal reservoir. This process has to be carefully planned to ensure injection into an area that is permeable enough to handle large volumes of liquid. Also, the injection well should be far enough away from the production well to keep from cooling the production brine. Even with such constraints, 22 of the power generation facilities practice this method of disposal (Source: See Appendix A for Development of Data). This is the most often used liquid waste management practice for power generation facilities located in the United States.

Injection into a non-producing horizon is identical to the management practice previously mentioned, except the reinjection well is drilled to a zone that is vertically separated or laterally located from the production well (US DOE, 1980). This is primarily done in regions where the production zone is fractured and can be easily contaminated by the cooler injection fluid. Reinjection to a non-producing zone has only been tested at one location. Tests of injection into a non-producing horizon at the Roosevelt Hot Springs flash facility in Utah proved successful in 1980 (US DOE, 1980).

Treatment and injection is utilized in instances where either the brine quality is so poor that potential plugging is high, or in the case where a usable byproduct could be recovered from the brine prior to reinjection. Several examples of pretreatment to prevent plugging are currently operational in the United States. The Heber flash facility in Imperial Valley operates a crystallizer/clarifier processing arrangement for silica removal prior to reinjection. (Royce, 1985). The Salton Sea-Vulcan plant uses this same process and is investigating turning the silica solids product into a commercial product (Morton, 1986).

Consumptive secondary use of liquid wastes is utilized as a waste disposal method when the spent fluid can be re-used as part of the power generation process or by some adjacent facility. Six of the facilities shown in Table VI-1 re-use condensate or clarified brine as make-up water to the cooling towers (Source: See Appendix A for Development of Data). The Wabasha Hot Spring facility in Nevada discharges warm water to a neighboring fish farm, where the water passes through a series of fish ponds and is then surface discharged (Lienau, 1986).

The solid wastes described in Section 4.3 can be managed by either of two methods: on-site, or off-site disposal. In some instances, a combination of both alternatives is used. Some facilities use brine holding ponds to accumulate solids. Once these ponds are full, the material is excavated and hauled to a landfill, much the same as desiccated drilling mud. Facilities using the EIMCO process (Vulcan-Magma Power) produce a solid material that is filtered and then hauled to a California Class I, II, or III landfill depending on how the waste tests with regard to RCRA characteristics. (Morton, 1986). Small quantities of waste generated, such as scale, are collected in 35-gallon drums on site and then similarly hauled away (Morton, 1986).

As previously indicated, all solid wastes generated from geothermal power plants in California are handled as hazardous wastes - if tests are positive for the RCRA characteristics - and are disposed of in state-specified waste management units. Solids disposal practices implemented in each state are addressed in Appendix B, State Geothermal Regulations Summaries.

6.1.3 Current Waste Management Practices - Direct Users

The seven methods of liquid waste disposal for power generation facilities are applicable to, but not necessarily required by the direct users. Table VI-2 presents the waste disposal status for 104 direct users in

TABLE - VI - 2
WASTE DISPOSAL PRACTICES
FOR DIRECT USERS

NAME	ST	COUNTY	BRINE (MGY)	DIRECT RELEASE SURFACE WATER	TREATMENT RELEASE SURFACE WATER	INJECTION INTO PRODUCING HORIZON	INJECTION NON PRODUCING HORIZON	TREAT AND INJECT	CONSUMP SECOND USE
SUSANVILLE	CA	LASSEN	66	.X.					
SUSANVILLE	CA	LASSEN	125	.X.					
SUSANVILLE - NURSEY	CA	LASSEN	39	.X.					
WENDELL-AMEDEE	CA	LASSEN	78	.X.					
CEDARVILLE HIGH SCHOOL ELEMENTARY SCHOOL	CA	MODOC	16	.X.					
FORT BIDWELL	CA	MODOC	31	.X.					
FORT BIDWELL - DISTRICT HEATING	CA	MODOC	4	.X.					
FORT BIDWELL - FISH	CA	MODOC	39	.X.					
MAMMOTH LAKES - DISTRICT HEATING	CA	MONO	226			.X.			
MAMMOTH LAKES - FISH	CA	MONO	9			.X.			
INDIAN VALLEY HOT SPRINGS (GREENVILLE)	CA	PLUMAS	37	.X.					
COACHELLA	CA	RIVERSIDE	262	.X.					
ELSINORE HOT SPRINGS	CA	RIVERSIDE	8	.X.					
MECCA	CA	RIVERSIDE	328	.X.					
SAN BERNADINO - DISTRICT HEATING	CA	SAN BERNADINO	67	.X.					
SAN BERNADINO - INDUSTRIAL	CA	SAN BERNADINO	73	.X.					
PASO ROBLES	CA	SAN LUIS OBISPO	9			.X.			
BOULDER - GREENHOUSE	CO		41	.X.					
SALIDA	CO		10	.X.					
ALAMOSA	CO	ALAMOSA	131	.X.					
PAGOSA SPRINGS	CO	ARCHULETA	157	.X.					
GLENWOOD SPRINGS	CO	GARFIELD	157	.X.					
OURAY HOT SPRINGS	CO	OURAY	6	.X.					
BOISE CITY	ID	ADA	262				.X.		
BOISE WARM SPRINGS	ID	ADA	188	.X.					
HUNT	ID	ADA	32	.X.					
IDAHO STATE CAPITAL MALL	ID	ADA	131			.X.			
THE EDWARD'S GREENHOUSE	ID	ADA	53	.X.					
VETERANS ADMINISTRATION MEDICAL CENTER	ID	ADA	39	.X.					
DONLAY RANCH HOT SPRINGS	ID	BOISE	9	.X.					
GARDEN VALLEY	ID	BOISE	39	.X.					
HOT SPRINGS	ID	CAMAS	4	.X.					
CALDWELL	ID	CANYON	184			.X.			
NAMPA	ID	CANYON	95			.X.			
HOOPER SPRINGS	ID	CARIBOU	32	.X.					
ALMO	ID	CASSIA	26	.X.					
BURLEY	ID	CASSIA	12	.X.					

TABLE - VI - 2 (Con't.)
WASTE DISPOSAL PRACTICES
FOR DIRECT USERS

NAME	ST	COUNTY	BRINE (MGY)	DIRECT RELEASE SURFACE WATER	TREATMENT RELEASE SURFACE WATER	INJECTION INTO PRODUCING HORIZON	INJECTION NON PRODUCING HORIZON	TREAT AND INJECT	CONSUMP SECOND USE
CROOK'S GREENHOUSE	ID	CASSIA	1	.X.					
MALAD CITY	ID	ONEIDA	499			.X.			
BANKS	ID	OWYHEE	17	.X.					
SUMMER LAKE	OR	LAKE	3	.X.					
VALE	OR	MALHEUR	126	.X.					
VALE	OR	MALHEUR	11	.X.					
COVE HOT SPRINGS	OR	UNION	39	.X.					
HOT SPRINGS	SD		655	.X.					
PHILIP - GREENHOUSE	SD	HAAKON	33	.X.					
PHILIP DISTRICT HEATING SYSTEM	SD	HAAKON	45		.X.				
ST. MARY'S HOSPITAL	SD	HUGHES	48	.X.					
NEWCASTLE	UT	IRON	33						.X.
BLUFFDALE	UT	SALT LAKE	53	.X.					
SANDY	UT	SALT LAKE	157	.X.					
UTAH STATE PRISON	UT	SALT LAKE	66			.X.			
SOL DUC HOT SPRINGS - SPACE HTG & POOL	WA	CLALLAM	10	.X.					
EPHRATA	WA	GRANT	0	.X.					
YAKIMA	WA	YAKIMA	92	.X.					
LANDER	WY	FREMONT	6	.X.					
THERMOPOLIS	WY	HOT SPRINGS	131	.X.					
JACKSON	WY	TETON	17	.X.					

12 states. Closed cycle ponding, and treatment and injection have been eliminated as waste management options from the table since no facilities that utilize these methods have been identified. For each of the four methods shown, at least one example of the waste disposal practice has been found in the literature.

Direct release to surface waters is by far the most common method of liquid disposal for direct users. (Refer to Figure VI-1). 90 of the 104 direct users listed practice surface discharge. (Source: See Appendix A for Development of Data). This practice is justified due to the low flowrates and high quality of the geothermal fluid being used. Some states (i.e., Oregon) are starting to encourage direct users away from surface discharge and towards reinjection as an alternative since in certain areas serious drops in aquifer levels have been experienced.

Injection into the producing horizon is the next most common method of disposal. 14 sites are currently listed as using this method, with an increase expected in the future.

Consumptive secondary use is used at two facilities (White Sulfur Springs, MT, and Newcastle, UT). Both facilities discharge into holding basins where the water is collected for irrigation.

6.2 Alternative Disposal Methods

Very little information has been discovered for newly developed disposal methods. Several refinements to existing processes have been mentioned in the literature and these are briefly discussed.

With the development of new geothermal resources, the chemical constituents of the brine can vary considerably. This chemical variation could lead to discovery of new constituent recovery operations. As mentioned in Section 6.1.2, Magma Power Company is investigating the marketability of the silica solid residue that is crystallized from the spent brine prior to injection. They are exploring the potential market for "Geocrete", a business decision that could turn what is currently an operating debit for disposal into a credit, or at the least, reduction or elimination of the current waste disposal cost.

Another example of potential resource recovery is currently being considered at The Geysers. Here, it has been found that elemental sulfur can be recovered from the residue generated from the H_2S abatement system. This operation could possibly provide a saleable sulfur product.

One new liquid waste disposal practice is included in the October 31, 1986 Technical Report comments. (Lowes, 1987). However, it is more suited to the Oil and Gas Industry. The process, developed by Aquatech Services, Inc., consists of a proprietary evaporation process for disposal of spent brines. Stated evaporation capacities of 16,800 gallon per day fall far below normal power plant flowrates; however, there are some small direct users for which this flow range is applicable. Since the process is stated as being competitive with reinjection costs, it could have a potential application for some direct-use operation.

6.3 Regulatory Requirements

State statutes and rules and regulations obtained from 35 different states have been examined for their applicability to geothermal energy exploration and development. Fourteen of these states have geothermal acts passed by the state legislature mandating the implementation of geothermal rules and regulations. Typically, these regulations are very comprehensive and, in general, address permitting, solid and liquid waste disposal, well design, well plugging, and restoration of surface.

Of the states that do not have geothermal acts, 11 states have rules and regulations that pertain to some aspects of geothermal exploration and development. Most of these regulations are located in water quality control standards or oil and gas regulations which address some areas of geothermal development, especially drilling and injection well requirements.

6.4 Damage Cases

A total of 42 state and local contacts were made in connection with geothermal energy damage cases. No significant existence of damages associated with the exploration, development, or production of geothermal energy was found. In fact, only three incidents relating to potential damage cases were identified. Two reports of pollution from geothermal waste in The Geysers area of California were obtained from the California Division of Oil and Gas. Also in California, another incident in the Heber area of the Imperial Valley was described by the U.S. Bureau of Land Management.

One of The Geysers incidents occurred in Lake County where a waste sump containing drilling fluids and bentonite muds was pumped and discharged to an adjacent gulley during a period of high rainfall. This discharge caused a temporary increase in the turbidity of a nearby stream resulting in a small fish kill. The incident was written up in a local newspaper, but no official documentation or studies were performed. This incident was exceptional because there are procedures for reinjecting waste drilling fluids during unusual rainfall events. In Sonoma County, a sump pumping truck loaded with drilling fluids and brine illegally dumped its contents along a roadside. This incident was documented by the local Regional Water Quality Board.

At a Chevron well in Heber, a brine blowout occurred, but the salt water migration was confined only to the pad area of the operation. The discharged brine was eventually collected and re-injected. County officials took no actions regarding the blowout, but a report may have been made to the local Regional Water Quality Control Board.
At present, there is a potential damage case evolving at a site in California. This case is currently being researched.

There are three possible reasons why no significant geothermal damage cases were found.

1) There may not be any significant damage to the environment from geothermal waste;

2) The regulations may not be properly enforced and thus some damages may go unnoticed; or

3) The regulations may not be adequate for monitoring potential damages.

An additional study would be required to determine the status of both the enforcement procedures and the adequacy of the regulations now in place. As the status of the regulations and enforcement sector now stands, however, no significant documentation of damage cases from geothermal activity exists.

CHAPTER 7

ECONOMIC ANALYSIS OF WASTE MANAGEMENT PRACTICES

This chapter outlines a methodology for estimating costs of the current and alternative waste disposal practices identified in the previous chapter.

7.1 Cost Estimation Methodology

After a thorough review of the published waste disposal cost data, it was determined that actual producer cost data would be required. The published data were not only out of date (1975-1978), but were primarily rough estimates of waste disposal costs rather than actual costs. Also, most publications dealing with waste disposal cost used one article published in 1979 as the basis for discussions.

When actual waste disposal cost data are available, a cost review and update technique will be applied. Cost estimates can be constructed by reviewing the actual data and then organizing the data into cost categories such as capitalized investment costs and annual operation and maintenance costs.

Each cost estimate will be normalized to account for inflation, geographic location, geothermal production rate, and similar factors that might tend to skew a comparison between existing and alternative practices. Similar cost estimate categories will be used so that the same adjustments can be made in order to determine total economic impacts.

7.2 Costs of Current and Alternative Practices

The geothermal waste disposal practices in current use in California, along with the possible alternatives, are shown in Table VII-1. The majority of geothermal operations use reinjection into the producing horizon primarily to avoid falling pressures and flows, as well as to prevent subsidence. In most liquid geothermal areas, power producers operate at conditions that avoid precipitation of solids in order to eliminate the expense of disposal. Only a small number of locations currently produce solid wastes that require off-site disposal.

Table VII-1

Waste Management Practices

Current Practice	Alternative Practice
Reinjection into a producing horizon	Upgrade injection well to a Class V level.
On-site earthen pit storage and disposal	Use off-site Class I land-waste management unit.
On-site disposal in a Class II or III landfill	Use off-site Class III land-waste management unit.
	Convert solids to a "Geocrete" building material by-product

KEY:

Class V injection well -	Federal Underground Injection Control (UIC) Program classification for geothermal injection well.
Class I waste management unit -	Most secure, double-lined landfill, surface impoundment, or waste pile; RCRA-approved facility.
Class II waste management unit -	Landfill, or surface impoundment class designed for "designated wastes"; commonly used for drilling muds, fluids, cuttings, sump solids.
Class III waste management unit -	on- or off-site landfill for non-hazardous, non-designated wastes.

CHAPTER 8

ECONOMIC IMPACT OF ALTERNATIVE WASTE MANAGEMENT PRACTICES

This chapter addresses the economic impact of the alternative disposal methods, which were described in Chapter 6, concerning the exploration, development, and production of geothermal energy. First, a methodology for determining the economic impacts is described. This presentation is then followed by a discussion of how these impacts may affect the future profitability of the geothermal industry.

8.1 Methodology

An economic impact assessment analysis will be conducted in future work on a facility-by-facility basis. This assessment will encompass evaluation of impacts on production costs and profitability due to requirements for more stringent waste disposal practices. The impact on plant profitability and the likelihood of plant closure will be made using computerized discounted cash flow techniques.

The cost of disposal practices evolving from the cost analysis will provide both capital investment and operations/maintenance costs for both existing and alternative waste treatment/disposal systems. The impacts of the existing treatment/disposal systems will be subtracted from the baseline financial data, and the cost of installing and operating the new system will be added. The impact of this change will be reflected in a mills/kwh or similar measure that can be compared to the estimated cost of alternative energy. The impact on profitability is the final step of determining the economic impacts. A closure analysis will be conducted wherein the current liquidation value of the facility will be compared to the present values of cash flow over the remaining life of the facility. From this closure analysis, the impact on employment, small business, and the community can be estimated.

In order to account for uncertainty, sensitivity studies will be conducted wherein major cost items and assumptions will be varied to determine the impact. Ideally, these financial comparisons will be conducted at the facility level so that the economic impact on the geothermal facility can be isolated and quantified.

8.2 Forecast of Future Profitability for the Geothermal Industry

The recent drop in energy prices, with the reduced growth in demand for electrical power and cutbacks in government support and incentives has initiated a consolidation phase for the geothermal industry. Development will continue at The Geysers in northern California due to the favorable economics of this area. Exploration for new resources has dropped significantly with most new drilling occurring at

currently operating fields. (Wallace 1986).
Geothermal energy production increased during 1986 primarily due to increases in direct use projects and small scale modular binary units for reduced cost electrical power generation. Electrical power generation capacity for 1986 remained basically unchanged from 1985. Under the current energy market conditions, future developments will be restricted to expanding existing economic fields (Wallace et al, 1986). As existing older plants reach their economic life and are phased out, it is quite possible that electrical power generation capacity will actually decrease. This would be due to the poor economics and higher economic risk of a brand new facility over an existing one in the current energy market. (Geothermal Resource Council, 1986).

The future profitability of the geothermal industry is tied directly to the price of energy available from other sources, primarily hydrocarbon fuels. When the price of these fuels rise again in the future, the level of new geothermal field development will increase as well. For the majority of current producers, the profit margins have been reduced significantly in the past several years. (Geothermal Resource Council, 1986).

This is a very important consideration in any implementation of more restrictive waste management practices, as any increase in cost could have a very serious impact on the industry.

CHAPTER 10

ABBREVIATION OF UNITS AND SCIENTIFIC TERMS USED IN THE FIGURES AND TABLES

10.1

BGY	Billions of gallons per year
G/cm	Grams per cubic centimeter
Kg	Kilogram
Km	Kilometer
MGD	Millions of gallons per day
Mg/L	Milligrams per liter
MW	Megawatts
μg/L	Micrograms per liter
pCi/g	PicoCuries per gram
pCi/s	PicoCuries per second

Al	Aluminum
Alk	Alkalinity
As	Arsenic
B	Boron
Ba	Barium
BaSO	Barium sulfate
Be	Berylluim
Ca	Calcium
Cd	Cadmium
Cl	Chlorine
Cr	Chromium
Co	Cobalt
Cu	Copper
CuS	Copper sulfide
F	Fluorine
Fe	Iron
H_2S	Hydrogen sulfide
Hg	Mercury
Zn	Zinc
Li	Lithium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
Ni	Nickel
Pb	Lead
Rb	Rubidium
S	Sulfur
Sb	Antimony
Se	Selenium
Si	Silicon
SiO	Silicon dioxide
Sn	Tin
SO	Sulfate
Sr	Strontium
Ti	Titanium
V	Vanadium

TDS - Total Dissolved Solids

TSS - Total Suspended Solids

10.2 GLOSSARY

ANNULUS	The space between the casing and wall of a hole or between a drill pipe and casing.
BALNEOLOGICAL BATH	A therapeutic bath, usually associated with hot mineral springs.
BAYER'S PROCESS	A process developed by the Austrian chemist, Karl Josef Bayer, used almost universally to extract alumina from bauxite.
BINARY PROCESS	A geothermal conversion process that utilizes a secondary working fluid that has a boiling point less than that of water. The heat from the geothermal brine is transferred to the working fluid via a heat exchanger; the working fluid is vaporized, then used to power the turbine generator. The brine and the working fluid are in separate closed loops. The geothermal fluid is maintained in the liquid state by high pressure, and it is reinjected into the reservoir after use.
BRINE	An aqueous solution containing a higher concentration of dissolved salt than ordinary sea water (about 35,000mg/l, or 35%).
CASING	A steel pipe placed in an oil, gas, or geothermal well as drilling progresses to prevent the wall of the hole from caving in during drilling and to provide a means of extracting petroleum or brine if the well is productive.

CENTRIFUGAL FORCE	The force exerted as a material moving along a curve reacts to the body that constrains the motion and is impelled by inertia to move away from the center of curvature; the force directed outwardly along the radius of curvature.
CENTRIFUGE	A rotating device for separating liquids of different specific gravities or for separating suspended colloidal particles by centrifugal force.
CONDENSATE	The liquid obtained by the condensation of a gas, vapor or liquid.
CONDENSIBLE GAS	Gas that can be reduced to a denser form, as from steam to water.
CONDUCTOR PIPE	A relatively short length of steel pipe, with slightly greater diameter than that of the first string of casing, inserted into the drill hole to guide installation of the casing.
COOLING TOWER BLOWDOWN	The removal of liquids or solids from a process vessel or line by the use of pressure.
COOLING TOWER DRIFT	A fine mist of water droplets that escape from the top or sides of the tower during normal operation. Any compound normally present in the circulating water will be carried out with the drift.
DERRICK	A large apparatus for lifting and moving heavy objects, and for supporting drilling machinery on a drilling rig.
DIRECT-USE GEOTHERMAL SYSTEM	The utilization of geothermal energy as heat without converting it to another form of energy.
DRILL BIT	The cutting or boring element used in drilling oil, gas, or geothermal wells.

DRILL CUTTINGS — Fragments of rocks dislodged by the drill bit and brought to the surface in the drilling mud.

DRILL STEM — The element that rotates the drill bit and provides a passageway through which the drilling fluid is circulated.

DRILL STRING — A term used in rotary drilling for the assemblage in a borehole of drill pipes, drill bit and either core barrel or drill collars, connected to and rotated by the drill machine.

EFFLUENT — An outflow of treated or untreated liquid waste from an industrial facility or from a holding structure, such as a pit or pond.

EXTRACTION PROCEDURE (EP) TOXICITY — A solid waste exhibits EP toxicity if, using the test methods as described in 40 CFR or equivalent methods approved by the Administrator, the extract from a representative sample contains any of the contaminants listed in 40 CFR 261.24, Table I, at a concentration equal to or greater than the value given for that waste in the table. If the waste contains less than 0.5 percent filterable solids, the waste, after filtering, is considered to be the extract.

If a solid waste exhibits EP toxicity, but is not listed as a hazardous waste in 40 CFR, Subpart D, an EPA hazardous waste number, that corresponds to the toxic contaminant causing it to be hazardous, is specified by statute.

FERIFLOC PROCESS (IRON CATALYST PROCESS)
A process of hydrogen sulfide emissions control developed by Pacific Gas and Electric Co. as a downstream system for retrofit to existing geothermal plants that use direct contact condensers. The process has been modified significantly since its introduction. The improved system is known as the Iron-Catalyst-Peroxide-Caustic (ICPC) system.

FILTER CAKE
The compacted solid or semisolid material separated from a liquid and remaining on a filter after pressure filtration; the layer of concentrated solids from the drilling and left behind on the walls of the borehole.

FLASH PROCESS
Partial evaporation of hot condensed liquid by a stepwise reduction in system pressure; vaporization of volatile liquids by either heat or vacuum.

FLOCCULATION
Aggregation or coalescence of fine particles to form a settled, filterable mass.

FLY ASH
Fine solid particulate, essentially non-combustible refuse. Fly ash is carried by draft out of a bed of solid fuel and deposited in isolated spots within a furnace or flue, or carried out through a chimney.

FORCED AIR SYSTEM
A space heat system where hot air is blown from a heat source and is then distributed by ducts to outlets.

FREON
A trade name used for any of various nonflammable gaseous and liquid fluorinated hydrocarbons used as refrigerants and as aerosol propellants.

FUMAROLE	A volcanic vent from which gases and vapors are emitted.
GEOPHYSICAL SURVEY	The use of one or more of the following geophysical techniques in geophysical exploration: electrical resistivity surveys, infra-red surveys, heat flow monitoring, magneto-telluric surveys, and seismic monitoring.
GEOPRESSURED SYSTEM	Hot, high-pressure brines containing dissolved natural gases.
GEOTHERMAL GRADIENT	The rate of increase of the earth's temperature with increasing depth. The average gradient is approximately 1 deg C/30 meters (2 deg F/100 feet).
GEYSER	A type of hot spring from which columns of hot water and steam gush into the air at more or less regular intervals.
HOT DRY ROCK	Non-molten hot rocks where the geothermal gradient is above normal, but neither steam nor hot water can be produced economically.
HOT SPRING	A spring whose temperature is above that of 98 °F.
HYDROCYCLONE	A device which separates a pulp into coarse, heavy product and fine, light product. The pulp takes a circular path in a conical vortex where centrifugal forces act to separate the pulp into a coarse fraction, which is discharged at the apex, and a fine fraction, which is removed by the vortex finder.
HYDROGEN SULFIDE (H_2S)	A flammable, toxic, colorless gas with offensive odor, commonly found in petroleum fractions.

HYDRONIC SYSTEM	A space heat system that uses hot water directly in radiant panels, convectors or radiators, either singly or in combination with one another.
HYDROSTATIC PRESSURE	The pressure at a point in a fluid at rest due to the weight of the fluid above it. Also known as gravitational pressure.
IGNEOUS ROCK	Rock solidified from molten or partly molten materials. Examples are granite, andesite and basalt.
KELLY	The heavy square or hexagonal steel pipe which transmits twisting torque from the rotary machinery to the drill string and ultimately to the bit.
KILN	A large furnace for baking, drying, or burning firebrick or refractories, or for calcining ores or other substances.
LAVA	A fluid rock which issues from a volcano or a fissure in the earth's surface; such rock when solidified upon cooling.
LEACHATE	A liquid that percolates through soil, sand, or other media, usually migrating from a pit or landfill.
LIQUID-DOMINATED GEOTHERMAL SYSTEM	A subsurface reservoir of hot water or a mixture of liquid and vapor.
MAGMA	A naturally occurring mobile rock material generated within the earth and capable of intrusion and extrusion. Igneous rocks are thought to have been derived from magma through solidification and related processes.
MOLE	The amount of pure substance containing the same number of elementary units as there are atoms in exactly twelve grams of carbon.

MUD	The natural drilling fluid circulated through the well bore during rotary drilling and workover operations. The mud brings drill cuttings to the surface, cools and lubricates the bit and drill system, protects against blowouts by holding back subsurface pressures, and deposits a coating on the wall of the bore to prevent loss of fluids to the formation.
MUD POT	Type of hot spring containing boiling mud, commonly associated with geysers and other hot springs in volcanic areas.
MUD VOLCANO	An accumulation, usually conical, of mud and rock ejected by volcanic gases; also, a similar accumulation formed by escaping petroliferous gases.
NITROGEN DRILLING	A drilling technique utilizing nitrogen as drilling fluid. It is used in drilling vapor-dominated systems so as not to damage the production zone with hydrostatic columns of water. Nitrogen is preferred over air because the oxygen in air can promote corrosion.
ORDER OF MAGNITUDE	A range of magnitudes of a quantity extending from some value of the quantity to some small multiple of the quantity.
PERMEABILITY	The capacity of a porous rock, sediment or soil to transmit fluid without damage to the structure of the medium; a measure of the relative ease of fluid flow under unequal pressures.
pH	The negative logarithm of the hydrogen ion activity; the degree of acidity or basicity of an aqueous solution. At 25°C, 7 is the neutral value; acidity increases with the decreasing value below 7 and basicity increases with increasing value above 7.

POLYMERIZATION	The joining together of small molecules to form larger molecules.
PORE PRESSURE	The stress transmitted through the fluid that fills the voids between particles of a rock or soil mass; that part of the total normal stress in a saturated soil that is due to the presence of interstitial water.
PRECIPITATION	The chemical process of bringing dissolved and suspended particles out of solution; producing a separable solid phase in a liquid medium.
PRODUCING HORIZON	The rock stratum of an oil or geothermal field that will produce oil or geothermal fluid when penetrated by a well.
REMOTE SENSING	The gathering and recording of information about some property of an object or area by a recording device that is not in actual physical contact with the object or area being studied.
RESERVE PIT	A pit in which muds and other drilling fluids are stored, or an excavated earthen walled pit used for wastes.
ROTARY DRILLING	A drilling method in which a hole is drilled by a rotating bit to which a downward force is applied. The bit is fastened to and rotated by the drill stem.
ROTARY TABLE	The geared rotating table that propels the kelly and drill stem.
SALINITY	The total quantity of dissolved salts in water, expressed by weight in parts per thousand.

SAND TRAP	A device for separating heavy, coarse particles from the cuttings-laden fluid overflowing a drill collar; a trap separating sand and other particles from flowing water and generally including a means of ejecting them.
SCALE	A hard incrustation on the surface of well and plant equipment formed by the precipitation of dissolved and suspended solids.
SCRUBBING	The process of separating soluble gases with extracting liquids.
SEDIMENTARY ROCK	Rock resulting from the accumulation of sediments or organic matter. Examples are shale, sandstone, and limestone.
SENSIBLE HEAT	The heat transferred to or from a body when its temperature changes.
SHALE SHAKER	A series of trays with sieves that vibrate to remove cuttings from the circulating fluid in a rotary drilling operation.
SLUDGE	A residue from air or waste water or other residues from pollution control.
SULFUR DIOXIDE	A toxic, irritating, colorless gas or liquid compound formed by the oxidation of sulfur. It dissolves in water to form sulfurous acid.
SUPERCRITICAL	Property of gas which is above its critical pressure and temperature and which makes it impossible to liquify no matter how much pressure is applied.
SURFACE RUN-OFF	Water that travels over the soil surface to the nearest surface stream; the runoff of a drainage basin that has not passed beneath the surface since precipitation.

SWIVEL HEAD	An assembly at the top of the kelly that allows free rotation of the kelly while not transferring rotation to the mud hose and hoist cables.
TOTAL DISSOLVED SOLIDS (TDS)	The total content of suspended and dissolved solids in a solution.
VAPOR-DOMINATED GEOTHERMAL SYSTEM	A subsurface reservoir of high temperature steam and gases.
VISCOSITY	The resistance of liquids, semi-solids and gases to movement or flow.
VOLCANO	A vent in the earth's crust through which molten rock (lava), rock fragments, gases, ashes, etc., are ejected from the earth's interior.

CHAPTER 11

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APPENDIX A

Data Management

An extensive literature search was conducted to obtain data for this study. Raw data from this literature search was loaded into a computerized data management program that automatically flagged data areas where information was lacking or deficient. To respond to these deficiencies, personal contacts with state and federal agencies, universities and selected authors were made to obtain the required information.

The data base established by the literature search and the follow-up inquiries collectively produced a pool of information that provided the necessary parameters upon which geothermal waste volumes were estimated. Since waste volumes could not be extracted directly form the literature, the information stated in the data base was critical to the calculations leading to the estimation of waste volumes.

The data sources that provided the input to the data base are listed below.

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APPENDIX B

FEDERAL AND STATE GEOTHERMAL REGULATIONS SUMMARIES

APPENDIX

FEDERAL REGULATIONS

REGULATORY AGENCIES

The Geothermal Steam Act, as amended (U.S.C. 1001-1025), gives the U.S. Department of the Interior the authority to issue leases for the development and utilization of geothermal steam and associated geothermal resources. The implementing regulations (43 CFR, Part 3200) are now administered exclusively by the Bureau of Land Management (BLM) except for royalty functions administered by the Minerals Management Service (MMS). BLM may issue leases on federal lands under its jurisdiction and on lands administered by the U.S. Forest Service, with the consent of the latter. In addition to leasing responsibility, BLM evaluates and classifies geothermal resources on federal land and supervises all pre- and post-leasing operations, including exploration, development, and production.

GEOTHERMAL RESOURCES OPERATIONAL ORDERS

Geothermal Resources Operational (GRO) Orders are formal, enforceable orders, originally issued by the U.S. Geological Survey, to supplement the general regulations found in 43 CFR Part 3200. They detail the procedures that lessees, and others in the case of Notice of Intent (NOI) to Conduct Geothermal Resources Exploration Operations permits, must follow in a given area or region. The purpose of this arrangement is to allow consideration of more area-specific operating and environmental conditions.

GRO Order No. 1 outlines the BLM requirements for conducting exploratory operations on federal lands. According to GRO Order No. 1, plans for exploratory operations for geothermal energy must include "provisions for appropriate environmental protection and reclamation of disturbed lands." Before any exploration can begin, a Notice of Intent (NOI) to Conduct Geothermal Resources Exploratory Operations must be submitted by the lessee to the Area Geothermal Supervisor. Any proposed variances from the requirements in GRO Order No. 1 must be submitted with the NOI.

Three categories of actions are considered exploratory operations: casual use, geophysical exporation, and drilling of shallow holes. Casual use, which is the only type of exploratory operation that does not require an NOI permit is "any entrance on the leased lands for geological reconnaissance or surveying purposes." Spring water and well sampling for geochemical analyses would fall into this category. Geophysical exploration includes surface electrical resistivity surveys, seismic ground noise surveys, and all other types of geophysical surveys, including airborne techniques. Airborne operations do not require an NOI. The third types of exploratory operation is the drilling of shallow holes for the purpose of measuring temperature gradients or heat flow. The NOI must include the type of drilling system to be used, approximate depth of hole and casing, type of drilling sump, and proposed method of abandonment of the sump and the hole itself and other itemized information. There are stipulations on depth of the hole and return line temperatures. There are also special provisions for proposed drilling sites in known natural thermal areas, such as special drilling and completion techniques, in order to protect formations containing geothermal or other resources. When drilling holes are abandoned, the Order requires that measures are taken to prevent interzonal migration of fluids and subsurface leakage. For example, the top 3 meters of tubing below the surface must be filled with cement.

Upon cessation of exploratory operations, the lessee must file a Notice of Completion of Geothermal Resources Exploration Operations. The Notice of Completion must include any information on drilling difficulties or unusual circumstances which would be useful in assuring future safe operations or protection of the environment. Some other protective measures set forth in GRO Order No. 1 regarding exploratory operations are: (1) drilling fluids and cuttings cannot be discharged onto the surface where they could contaminate lakes and streams; (2) excavated pits and sumps used in drilling must be backfilled as soon as drilling is completed, and the original topography restored; and (3) unattended sumps must be fenced for the protection of the public, domestic animals, and wildlife.

Other types of liquid wastes, such as toxic drilling fluids, must be disposed of in a manner approved by BLM and in accordance with federal, state, and regional standards.

Solid Waste Disposal

Solid wastes,such as drill cuttings, precipitates, and sand, must be disposed of as directed by the BLM either on location or at approved disposal sites.

Pits and Sumps

The lessee is required to provide and use pits and sumps to retain all wastes generated during drilling, production, and any other operation, unless other specifications are made by the Supervisor. Pits and sumps containing drilling wastes must be lined with impervious material and purged of environmentally harmful chemicals and precipitates before backfilling. 43 CFR 3262.6-3 states that in no event shall the contents of a pit or sump be allowed to contaminate streams, lakes, or groundwater, and that there must be minimal damage to the natural environment and the aesthetic values of the leased land or adjacent properties. Pits and sumps which are unattended must be fenced for the protection of wildlife, domestic animals, and the public. When no longer needed, pits and sumps are to be filled and covered and the premises restored, in a manner prescribed by the BLM.

Pollution Inspection and Reports

Geothermal Resources Operational Order No. 4 requires that the lessee inspect drilling and production facilities daily to safeguard against pollution. Preventive maintenance must be performed as necessary to prevent malfunctions that could lead to pollution. Wells and areas not under production must nevertheless be inspected by the lessee, at intervals prescribed by the Supervisor. All pollution incidents must be reported within 18 hours to the BLM and a written report stating the cause and corrective action taken must follow within 30 days.

UNDERGROUND INJECTION CONTROL PROGRAM

The Bureau of Land Management is in charge of most geothermal waste disposal operations on Federal and Indian lands. However, the Safe Drinking Water Act (P.L. 93-523) of 1974, as amended, requires that the EPA establish a national program to assure that underground injection of wastes would not endanger subsurface drinking water sources. EPA implemented this mandate by enacting the Underground Injection Control (UIC) Program for Federal, Indian, State, and private lands. Under the UIC rules, EPA has jurisdiction over the five categories of injection wells, including Class II injection wells, which are often used to retain drilling wastes from geothermal energy production. In some cases, EPA gives primacy to the States regarding the UIC Program. The Bureau of Land Management defers to EPA or the primacy state the task of determining whether underground fresh water sources are safe, and issues permits for Class II underground injection wells. BLM does, however, retain involvement in approval of wells drilled or converted for Class II injection of Federal and Indian lands, mostly in order to carry out other mandated responsibilities. BLM permits wells for production rather than injection; in this case, BLM is responsible for protection of subsurface water sources in the vicinity of the well.

APPENDIX

STATE REGULATORY AGENCIES

Four state agencies have regulatory authority over the geothermal industry:

- The Department of Natural Resources (DNR)
- The Department of Fish and Game (ADF&G)
- The Alaska Oil and Gas Conservation Commission (AOGCC)
- The Department of Environmental Conservation (DEC)

GEOTHERMAL REGULATIONS

DNR has authority under Alaska Statute 38.05.181, and Chapter 87 of the Alaska Administrative Code (regulations) to oversee most matters affecting exploration and development of geothermal resources.

AOGCC has authority under Alaska Statute 31.05, and Chapter 25, Title 20 of the Alaska Administrative Code to regulate all aspects of well drilling and disposition of drilling related wastes. APGCC also administers requirements for surety bonds.

ADF&G has authority under Alaska Statute 16, of the Alaska istrative Code, to regulate and manage the fish and game s of the state. Due deference is given to this agency by developing stipulations and reviewing development plans.

DEC has the authority under Alaska Statute 46.03-40, and Alaska Administrative Code Title 18, Chapters 20, 40, 50, 60, 70, 72, 75 and 80 to control and regulate all aspects regarding water, air, land and subsurface land pollution.

PERMITS

Department of Natural Resources

Under the Geothermal Regulations and Statutes of May 1983, an operator must file an application for geothermal exploration. An exploration bond may be required. Also, a drilling permit is required before the drilling, redrilling, or deepening of any well and before the re-entry of an abandoned well. 11AAC87.030, 11AAC87.050, and 11AAC87.070.

A well drilled for the purpose of injection of fluids into a reservoir requires a permit. A separate permit must be obtained from the Commissioner before any fluids are injected into any underground reservoir. 11AAC87.230.

Alaska Oil and Gas Conservation Commission

A permit must be approved by the Alaska Oil and Gas Conservation Commission before drilling, redrilling, or deepening an exploratory or development well or before the re-entry of an abandoned well. 20AAC25.005. Approval is also required before the abandonment of an existing well. 20AAC25.105(e).

Department of Environmental Conservation

Wastewater Disposal Regulations are addressed in Title 18, Chapter 72. The department must issue a permit before anyone disposes of nondomestic wastewater into or onto waters or lands. The department also regulates and issues permits for disposal of sludge resulting from a manufacturing or production process or a nondomestic wastewater treatment works. 18AAC72.240. Nondomestic wastewater is defined in 18AAC72.990, in part, as "liquid or water-carried wastes resulting from ... development of natural resources ...."

Water Quality Standards are set by the Department in Title 18, Chapter 70. In general, the water quality standards specify the degree of degradation that may not be exceeded as a result of human actions. 18AAC70.010(b). Short-term variances or re-classifications may be requested in writing. 178AAC70.015 and 70.055.

WELL DESIGN

Department of Natural Resources

Extensive design requirements and testing procedures must be followed as precautions against blow-out. 11AAC87.120 and 11AAC87.130.

Alask Oil and Gas Conservation Commission

AOGCC also regulates well design under 20AAC25.030 through .047. Extensive design requirements for casing and cementing must be followed. Secondary well control and blowout prevention equipment requirements are also stated. In addition, a reserve pit must be constructed or appropriate tankage installed for drilling fluids and cuttings to prevent contamination of groundwater and damage to the surface environment.

DISPOSAL OF SOLID AND LIQUID WASTES

Alaska Oil and Gas Conservation Commission

AOGCC regulates disposal of water and oil field waste fluids under 20AAC25.250. Specifically, underground disposal of freshwater, salt water, brackish water, or other waste fluids are prohibited except as ordered by the commission in response to an application for injection for underground disposal or storage. The operator is required to dispose of or solidify in place all pumpable fluids, and must leave the reserve pit in a condition that does not constitute a hazard to groundwater. 20AAC25.017.

Department of Environmental Conservation

The Solid Waste Management regulations, Title 18, Chapter 60, require anyone owning or operating property where solid waste is accumulated to store the waste in a neat, safe, and sanitary way until it is removed to a permitted solid waste disposal site. Contractual or other arrangements for the removal of accumulated

REFERENCES

State of Alaska, Geothermal Regulations and Statutes, as contained in the Alaska Administrative Code and the Alaska Statutes, includes Title 27, Capter 5, Article 1; Title 38, Chapter 5, Article 1 through 7, 11 and 12; Title 41, Chapter 6, Chapter 20; Title 46, Chapter 15; Title 11, Chapter 82, Article 1 through 8; Chapter 84, Article 1 through 8; Chapter 87, Article 1 through 5; Chapter 88 and Chapter 96, Article 1 through 3.

State of Alaska, Title 20, Chapter 25, Administrative Code for Alaska Oil and Gas Regulations and Title 31, Chapter 5, Alaska Oil and Gas Conservation Act, 1985.

State of Alaska, Title 18, Chapter 60, Solid Waste Management, Department of Environmental Conservation.

State of Alaska, Title 18, Chapter 15, Permit Procedures, Department of Environmental Conservation.

State of Alaska, Title 10, Chapter 70, Water Quality Standards, Department of Environmental Conservation.

State of Alaska, Title 18, Chapter 72, Wastewater Disposal Regulations, Department of Environmental Conservation.

State of Alaska, Title 46, Chapter 3, Water, Air, Energy, and Environmental Conservation, Department of Environmental Conservation.

<u>Personal Communications</u>:

Lynn Cochrane, Permit Information Specialist, Department of Environmental Conservation (907) 274-2533.

Joseph M. Joyner, Chief Legal/Land Status Unit, Department of Natural Resources (907) 465-2400.

APPENDIX

CALIFORNIA

STATE REGULATORY AGENCIES

The following agencies regulate the geothermal industry in California:

- The Geothermal Section of the California Department of Conservation, Division of Oil and Gas

- The California Energy Commission

- The California Public Utilities Commission

- The California Water Resources Control Board, and the nine Regional Water Quality Control Boards

- The California Department of Health Services

- County Government agencies

GEOTHERMAL REGULATIONS

The following California statutes are either applicable to or specific to geothermal energy operations:

1. The California Environmental Quality Act (CEQA). The requirements of CEQA must be fulfilled before drilling and use permits can be issued. Under CEQA, government agencies must consider environmental impacts that may result from the implementation of certain geothermal projects. Since many projects require permits from different agencies, overlapping agency studies could result; to minimize duplication of agency effort and unnecessary time delays, a CEQA procedure has been established. This procedure calls for a lead agency to prepare the environmental documentation, and the remaining permitting agencies to function as responsible agencies.

2. California Administrative Code, Title 14, Chapter 2: Implementation of CEQA. This chapter of the Code defines the scope of the CEQA regulations, designates the lead agency, and sets guidelines for the CEQA process with regard to geothermal exploratory projects.

3. California Administrative Code, Title 14, Chapter 4, Subchapter 4: Division of Oil and Gas Statewide

Regulations. This subchapter provides detailed guidelines for drilling, blowout prevention, production , injection, subsidence, and abandonment.

4. California Administrative Code, Title 23, Chapter 3, Subchapter 15. This subchapter covers discharges of wastes to land from sumps, ponds, landfills, and other waste management units.

5. California Administrative Code, Title 22, Chapter 30. This chapter establishes criteria for determining if a waste is hazardous, designated, or nonhazardous.

6. The Porter-Cologne Water Quality Control Act, California Water Code. This law covers discharges into the waters of the state from many waste sources.

7. California Public Resources Code, Chapter 4, Division 3 (Publication No. PRC02, Jan. 1985): California Laws for the Conservation of Geothermal Resources.

8. California Administrative Code, Title 20, Chapter 2, Subchapters 1, 2, and 5: California Energy Commission, Regulations Pertaining to Rules of Practice and Procedure and Power Plant Site Certification.

9. California Assembly Bill No. 2948, The Tanner Bill. This law requires local jurisdictions to prepare hazardous waste management plans describing types of waste streams, waste management practices and treatment.

The State Oil and Gas Supervisor must supervise the drilling, operation, maintenance and abandonment of geothermal resource wells. The district deputy in each district collects information regarding the wells, which is kept on file in the office of the district deputy of the respective district. Copies are sent to the Director of Water Resources, the State Geologist and the appropriate Regional Water Quality Control Board. The Supervisor must notify the Department of Fish and Game, the Department of Water Resources, and the Regional Water Quality Control Board in the area affected, of the location, operation, maintenance, and abandonment of all wells. (Sections 3714-

3717, California Public Resources Code).

PERMITS

A Notice of Intention must be submitted for approval by the appropriate district office for drilling and exploration, development, injection or temperature observation well, and for reworking, converting to injection, or abandoning an existing well. Well type determines the permitting procedure required for drilling, producing, injecting, and abandoning geothermal wells:

1. Exploratory Wells

The Division of Oil and Gas has been designated by the California State Legislature (Section 3715.5, Public Resources Code) as the lead agency for all geothermal exploratory drilling projects occurring on private and state lands in California. To be considered exploratory, a proposed geothermal well must be at least one-half mile, surface distance, from any existing geothermal well with commercial capability.

High-temperature exploratory wells - after the CEQA process is completed, applications must be filed with the appropriate county planning department. In addition, an operator must apply for permits from state agencies, including the Division of Oil and Gas.

Low-temperature exploratory wells - these wells require the same CEQA documentation as high-temperature wells; the differences between the requirements for the two well types are in bonds, fees, and drilling procedures. Additional differences may exist if the well is classified as noncommercial.

2. Development Wells

When a geothermal resource is discovered through exploratory drilling, resource development may ensue. The city or county is the lead agency for geothermal development projects. A Use Permit must be obtained from the county or city where the project would be implemented before any operations begin.

> <u>High-temperature development wells</u> - development project operators must adhere to county CEQA regulations in the county where the well is drilled. After the CEQA requirements are met, the county permitting processes are the same as those for exploratory wells. County governments issue land use, air, noise, and construction permits.
>
> <u>Low-temperature development wells</u> - same requirements as for low-temperature exploratory wells.

3. Injection wells

Injection wells may be drilled as new wells or converted from existing wells. In either event, a project description must be submitted to the proper division district office and the project must be approved by the division before injection begins.

If a new well is to be drilled, a CEQA document, a county use permit, and all other permits that are needed for high-temperature exploratory wells are required.

If an existing well is to be converted into an injection well, a Rework/Supplementary Notice must be filed with the proper district office. Injection cannot begin until written approval has been received from the Division of Oil and Gas. The Regional Water Quality Control Board has 30 days to review the injection plan and make suggestions to the division before division approval may be issued; generally, the Board only comments on injection wells if underground sources of drinking water might be affected.

4. Temperature Observation Wells

Procedures for permitting temperature-observation wells are the same as those for permitting high- or low-temperature exploratory wells, including the need to designate an agent and secure a bond.

Other Permits:

The California Department of Conservation, Oil and Gas issues Underground Injection Control (U.I.C.) Permits for geothermal injection wells.

The California Resources Control Board issues NPDES permits, and the nine Regional Water Quality Control Boards issue Waste Discharge Permits within their respective regions for discharges of produced waters and drilling wastes.

The local city or county governments issue Land Use Permits for geothermal operations and for disposal facilities.

WELL DESIGN

Extensive design requirements for all types of geothermal wells are given in the California Administrative Code, Title 14, Chapter 4. Design and testing procedures must be followed as precautions against blowout and as prevention of damage to life, health, property, and natural resources.

SOLID AND LIQUID WASTE DISPOSAL

Disposal of nonhazardous solid and liquid wastes from geothermal operations fall primarily under the jurisdiction of the Department of Conservation in the Division of Oil and Gas and the California Regional Water Quality Control Board; hazardous geothermal wastes are regulated by the Department of Health Services.

Liquid Waste Subsurface Injection

The Division of Oil and Gas is in charge of all geothermal injection projects, whether for disposal of spent nonhazardous geothermal fluids from power production or for reservoir pressure maintenance. Geothermal injection wells are Class V under the Federal U.I.C. Program. The Division is mandated by law to ensure that no damage at the surface or subsurface occurs as a result of injection projects. The Division makes decisions whether to approve or disapprove an application for a project based on extensive data from the operator, including such information as: a cross-sectional map with formation depth and age; source and analysis of the injection water; analysis of water in the injection zone; reservoir characteristics; method of injection; precautions to ensure that the injection fluid is confined to the injection zone; and well-drilling and abandonment plans. Operators of proposed projects must give proof to the Division that the reservoir will not suffer damage and freshwater strata will not be infiltrated.

Project approval cannot be granted until an aquifer exemption is granted by the Federal EPA, or until it is known that the total dissolved solids content (TDS) of the injection zone is greated than 10,000 ppm. Exemptions are not required to inject into a formation with water that has TDS content over 10,000 ppm, and/or is proven to be unfit as a source of drinking water. Procedures for obtaining an exemption to inject into an aquifer that does not meet these criteria are outlined in the Division's Geothermal Injection Handbook. If the EPA grants the aquifer exemption and the appropriate agencies give the project a favorable review, the District Engineer will approve the application for the injection project. The Regional Water Quality Control Board is the primary reviewing agency for proposed injection wells. Injection wells must be inspected by the District Engineer every six months to ensure that the well is in good condition and there is no leakage. A Monthly Injection Report must be submitted by the operator to the appropriate district office providing injection data and information on any changes or remedial work.

Surface Disposal - Water

The Porter-Cologne Water Quality Control Act prescribes waste discharge requirements as established by the Water Resources Control Board. Operators must file a report with their Regional Water Quality Control Board on the proposed discharge, providing all information that the Regional Board may require. If protection of water quality and precautions against pollution and contamination appear adequate, the Board wil issue a Waste Discharge Permit (California's NPDES permit) to discharge wastes to the surface waters of the state. The Regional Boards must implement requirements at least as stringent as those of the State Board; some regions have established requirements more stringent than those of the State Board. Surface discharge for beneficial uses, such as agricultural uses, is allowed if water quality meets the Regional Board's standards. Discharge permits will specify the maximum chemical constituent values allowed for beneficial uses.

Surface Disposal - Land

Land disposal of nonhazardous drilling wastes from geothermal operations is under the jurisdiction of the Regional Water Quality Control Board and the county in which the project is being implemented. Land disposal of nonhazardous solid wastes from power production and hazardous wastes from either drilling or power production is under the jurisdiction of the Department of Health Services.

During drilling operations, all drilling wastes are contained in sumps. The counties, which are the lead agencies for geothermal resource development, issue Use Permits for each site, into which county waste disposal requirements have been incorporated. Waste Discharge Requirements issued by the Regional Water Quality Control Board on a site-by-site basis serve as the primary discharge permit.

At the end of drilling operations, state regulations require that the materials in the sump be analyzed for listed chemical constituents using the California Department of Health Service's Waste extraction test. Total threshold level concentrations (TTLC) and soluble threshold level concentrations (STLC), established under California Administrative Code 23.3.15, are the basis for determining whether a waste is hazardous.

Sump contents are generally considered hazardous is any of the following chemical constituent lavels are exceeded:

Constituent	(mg/L) Of Extract
Arsenic	5
Cadmium	1.0
Chromium III	25
Chromium VI	5
Nickel	20
Mercury	0.2
Zinc	250
Boron	100

California Administrative Code 23. 3.15, Appendix III, lists other chemical constituent whose presence in the waste would result in hazardous classification. All hazardous waste must be disposed of in a Class I waste management unit, which has the highest level of containment ability of any class. Sump contents which may contain any of the listed constituent, but in a lower concentration than the hazardous concentration, are called designated wastes. Next drillings wastes are classified as designated wastes. California Administrative Code Title 22, Division 4, Chapter 30, establishes the waste extract concentration differences between hazardous and designated waste categories. Designated wastes can be disposed of either Class II or Class I waste management units.

Solid wastes which do not contain any of the listed chemical constituents are classified as nonhazardous and may be disposed of at a class III, II, or I waste management unit. Drilling wastes which fit the designated or the nonhazardous classification are often dewatered and disposed of on-site. The following table describes the various types of waste management units used in California:

SUMMARY OF WASTE MANAGEMENT STRATEGIES

FOR DISCHARGES TO LAND

Waste Category	Waste Management Unit Class	Waste Management Unit Type	Primary Containment	Siting and Geologic Criteria
Liquid Hazardous	I	Surface Impoundment	Double Liners	(a) Natural features capable of containing waste and leachate as backup to primary containment.
Solid Hazardous	I	Landfill	Double Liners	
Dry Solid Hazardous	I	Waste Pile	Double Liners	(b) Not located in areas of unacceptable risk from geologic or environmental hazards.
Liquid Designated (including underwatered sludge)	II	Surface Impoundment	Double Liners	(a) Natural features capable of containing waste and leachate may satisfy primary containment requirements.
Solid Designated	II	Landfill	Single Liner	
Dry Solid Designated	II	Waste Pile	Single Liner	(b) May be located in most areas except high risk areas.
Nonhazardous Solid Waste (including dewatered sludge and acceptable incinerator ash	III	Landfil	None	(a) Consideration of factors listed in Subsection 2333(b) (b) May be located in most areas except high risk areas.

Source: California Administrative Code, Title 23, Subchapter 15.

Disposal of solid wastes, such as sludges and filter cakes, from power production is regulated by the Department of Health Services. The department requires plant operators to periodically test production wastes at licensed laboratories for the listed chemical constituents in California Administrative Code 23.3.15 (the same list as for drilling wastes). TTLC and STLC are again the criteria for hazardous waste designation; Class I, II, and III designations apply, and each class of waste must be disposed of in the corresponding class of landfill. Some production wastes in California fall into the Class I designation; for example, solid waste from the Geysers Power Plant are generally treated as Class I wastes because of the presence and concentrations of listed trace constituents.

WELL PLUGGING AND ABANDONMENT

S3717 requires the State Oil and Gas Supervisor to notify the Department of Fish and Game, the Department of Water Resources, and the Regional Water Quality Control Board in the area affected, of the abandonment of all wells.

Temperture-observation wells must be abandoned two years from the date of completion.

Requirements for abandonment of an injection well are determined by the District Engineer, based on subsurface conditions and the casing and cementing record of the well.

SURFACE RESTORATION

Title 14, Section 1776 of the Oil and Gas Regulations establishes procedures for surface restoration. Concrete cellars must be removed from the well site or filled with earth. Well locations must be graded and cleaned of equipment, trash, and other wastes, and returned to as near a natural state as possible. Sumps must be filled with earth after removal of harmful materials, and the surface graded and revegetated. Unstable slope conditions created as a result of the project operation must be corrected.

BONDS

An indemnity bond or a cash bond must be on file or accompany a Notice of Intention to Drill a Well. Bond amounts are based on resource types (low- or high-temperature) and well depths:

> High-temperature exploratory and development wells are required to have a $25,000 bond filed for each well, or a $100,000 blanket bond for a group of wells.
>
> Low-temperature exploratory and development wells are required to have a $2,000 bond for each well under 2,000 feet; and $10,000 bond for a well deeper than 2,000 but less than 5,000 feet; a $15,000 bond for a well deeper than 5,000 but less than 10,000 feet; and a $25,000 bond for a well 10,000 feet or deeper.
>
> A $100,000 blanket bond covers a group of low-temperature wells regardless of depth.

REFERENCES

Title 14, California Administrative Code, Chapter 2, Implementation of the California Environmental Quality Act of 1970, Department of Conservation

Title 14, California Administrative Doce, Chapter 3, Section 1776, Well Site Restoration, Department of Conservation, Division of Oil and Gas

Title 14, California Administrative Code, Chapter 4, Oil and Gas, Department of Conservation, Division of Oil and Gas

Title 14, California Administrative Code, Chapter 5, Enforcement of Solid WAste Standards and Administration of Solid Waste Facilities Permits, Solid Waste Management Board

Title 20, California Administrative Code, Chapter 2, Subchapters 1, 2 and 5, California Energy Commission

The Porter-Cologne Water Quality Control Act, 1985, Water Resources Control Board

California Department of Conservation, Division of Oil and Gas, Laws for Conservation of Geothermal Resources, 1985, Publication No. PRCO2

California Department of Conservation, Division of Oil and Gas, Drilling and Operating Geothermal Wells in California, 1986

Personal Communications;

Dan I. Daniels, California Regional Water Quality Control Board, Central Valley Region, (916) 361-5666

Mark Dellinger, Geothermal Coordinator, Lake County, (707) 263-2221

George Eowan, California Solid Waste Management Board, (916) 322-1442

APPENDIX

DELAWARE

STATE REGULATORY AGENCIES

- Department of Natural Resources and Environmental Control.

GEOTHERMAL REGULATIONS

The Department of Natural Resources and Environmental Control, State of Delaware, issued regulations governing underground injection control, effective August 15, 1983, and regulations governing the construction of water wells, effective January 15, 1986.

The definition of a Class V well includes an injection well associated with the recovery of geothermal energy for heating, aquaculture and production of electric power. 122.22.

The Department of Natural Resources and Environmental Control also regulates solid waste disposal.

PERMITS

Any underground injection except as authorized by permit issued under the UIC program or otherwise authorized under these regulations, is prohibited. A temporary emergency permit may be issued if there is an imminent and substantial endangerment to the health of the public. 122.30. When a new injection well is constructed, the permittee must submit a notice of completion of construction to the Secretary. 122.31(2)(i). Permits may be modified, revoked and reissued, or terminated either at the request of any interested person or upon the Secretary's initiative. 124.4. A permit is also required for any well installed for the purpose of obtaining geologic or hydrologic information. (Section 1.02C of Regulations Governing the

Construction of Water Wells).

A permit is required from The Department of Natural Resources and Environmental Control before anyone manages land for the purpose of disposing of solid waste.

WELL DESIGN

Extensive design requirements are specified for UIC injection wells and water wells. 146.08 (Rules and Regulations Governing Underground Injection Control and Section 5, Rules and REgulations Governing Water Well Construction.)

SOLID AND LIQUID WASTE DISPOSAL

Any underground injection is prohibited except as authorized by permit. 122.23.

The Delaware Solid Waste Disposal Regulations address the disposal of all solid waste into or the land. Solid waste is defined, in part, as . . . "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant or water pollution control facility and other discarded material . . . "Certain solid wastes are exempt. These include disposal of dirt, sand, crushed rock, or asphalt debris, and disposal of inert solid wastes. The regulations specify responsible governmental agencies for providing facilities.

WELL PLUGGING

Any applicant for a UIC permit must submit a plan for plugging and abandonment. 122.32(e).

Within 30 days of abandoning a water well, the contractor must submit a well abandonment report to the Department. Section 9.01.D.

RESTORATION OF SURFACE

A UIC permit requires the permittee to maintain financial responsibility and resources to close, plug, and abandon the operation in a manner prescribed by the Secretary. 122.32(f).

SURETY BOND

The permittee must show evidence of financial responsibility by submission of a surety bond or other adequate assurance. 122.32(f).

REFERENCES

State of Delaware, Regulations Governing the Construction of Water Wells, Department of Natural Resources and Environmental Control.

State of Delaware, Regulations Governing Underground Injection Control, Parts 122, 124 and 146, Department of Natural Resources and Environmental Control.

Personal Communications:

Phil Cherry, Supervisor, Water Supply Branch, Division of Water Resources, Department of Natural Resources and Environment Control (302) 736-4793.

Rick Folmsbee, Solid Waste Permits, (302) 736-3688

APPENDIX

GEORGIA

STATE REGULATORY AGENCIES

One agency in Georgia has jurisdiction over Class V underground injection wells, which apply to geothermal energy:

- The Georgia Department of Natural Resources, Environmental Protection Division.

GEOTHERMAL REGULATIONS

Class V wells used for geothermal purposes are defined in the Rules for Underground Injection Control (UIC), Chapter 391-3-.13(3)(e): "An injection well associated with the recovery of geothermal energy for heating, aquaculture, and production of electric power." The UIC Rules include statutes for the drilling of Class V wells for geothermal purposes. The Director of the Department of Natural Resources oversees the regulatory activities of the Department. The Director's duties include: reviewing applications for well construction permits, approving or denying applications for permits, taking enforcement action to stop a violation of the rules, and taking emergency action if there is a direct threat to the public water system as a result of drilling or production activities. UIC 391-3-6-.13(11)(d).

PERMITS

Anyone who wants to operate or construct a Class V well must apply in writing to the Director for an injection well permit. The following information is required on the application: a map of the proposed injection well, the proposed construction plan, injection rate and pressure, and the chemical, physical, and radioactive characteristics of the fluid to be injected. Upon receipt of the application, the Director shall: (1) determine if it is in fact a Class V well, (2) assess potential adverse effects on underground drinking water sources, and (3) determine methods to protect drinking water sources. If the information is sufficient and satisfactory, the Director shall issue a permit. The Director may include conditions for monitoring, testing, and reporting on the well site, if considered necessary. UIC 391-3-6-.13(11) and (12).

WELL DESIGN

Class V wells must be constructed by a water well contractor licensed in Georgia in accordance with the Water Well Standards Act of 1985; Georgia Laws 1977, p.1509, (Georgia Annotated Code, Sec. 84-7506). Casing depth specifications are given, and the annular space around the casing must be grouted and sealed to prevent migration and pollution. Special construction requirements may be issued by the Director to prevent contamination of an underground source of drinking water. A method for evaluating the presence or absence of detectable leaks is required; either monitoring of annulus pressure or pressure tests with liquid or gas is acceptable. UIC 391-3-6-.13(12)(c).

DISPOSAL OF SOLID AND LIQUID WASTES

Although there are provisions in the regulations against allowing well fluids from migrating to and polluting underground drinking water sources, the problem of disposal of wastes resulting from the drilling and operation of the well is not specifically addressed. Well operators must, however, be able to demonstrate that pollution of groundwater will not occur under any circumstances.

WELL PLUGGING AND ABANDONMENT

The Director may order a Class V well plugged and abandoned by the owner when it no longer serves the intended purpose, or when it poses a direct threat to underground drinking water sources. It is the owner's responsibility to have all exploratory, injection, and test wells plugged and abandoned by a water well contractor before any drilling equipment is removed. The entire depth of the well must be completely filled with cement grout or another impervious material. UIC 391-3-6-.13(f).

RESTORATION OF SURFACE

Not addressed in the regulations reviewed.

SURETY BONDS

Not addressed in the regulations reviewed.

REFERENCES

Georgia Department of Natural Resources, Environmental Protection Division. Rules for Underground Injection Control, Chapter 391-3-6. Revised September 17, 1984

Personal Communication

Patricia Franzen, U.I.C. Program, Georgia Department of Natural Resources. (404)656-3214

APPENDIX

HAWAII

STATE REGULATORY AGENCIES

Two state agencies regulate the geothermal industry in Hawaii:

- Board of Land and Natural Resources

- Department of Health

GEOTHERMAL REGULATIONS

The Board of Land and Natural Resources regulates the use of the surface of the land. Geothermal Resource Subzones may be designated within the State's urban, rural, agricultural, and conservation land use districts. The use of a Geothermal Resource Subzone within the State's Conservation District is governed by the Board of Land and Natural Resource's Chapter 2 of Title 13, Administrative Rules on Conservation Districts. The use of a Geothermal Resource Subzone within the State's urban, rural, or agricultural districts is governed by the "appropriate county authority." In each county, the authority is the County Planning Commission. Each County Planning Commission establishes procedures for obtaining Geothermal Resource Permits. The Planning Commission's approval of an application for a geothermal resource permit does not in any way supercede state laws nor abrogate the necessity of obtaining permits from the Board of Land and Natural Resources or other state agencies, as required.

For the subsurface use of land within the Geothermal Resource Subzone, the Board of Land and Natural Resource's Chapter 183 of Title 13, Administrative Rules on Leasing and Drilling of Geothermal Resources is the primary regulation. Some of the State's Department of Health's regulations are also applicable. These include Chapter 23 of Title 11, Administrative Rules for Underground Injection Control; Chapter 55 of Title 11, Administrative Rules for Water Pollution Control; and Chapter 58 of Title 11 Administrative Rules for Solid Waste Management Control.

PERMITS

Board of Land and Natural Resources

State and Reserved Lands

An exploration permit is required to conduct any exploration activity on state or reserved lands for evidence of geothermal resources. All applications are subject to the approval of, and the terms and conditions set by, the Board of Land and Natural Resources. The Board may also grant geothermal mining leases on state and reserved lands. A plan of operations is required before drilling commences. Section 13-183-7 through 13-183-19, and Section 13-183-55.

Other Lands

The Board of Land and Natural Resources must issue a permit before any person drills, modifies, modifies the use of, or abandons a well. A supplementary application must be filed if there is any contemplated change in the original approved application.

The Board of Land and Natural Resources also issues a permit for the modification of any existing well for injection purposes. Section 13-183-65, 13-183-66, and 13-183-77.

Department of Health

Title 11, Department of Health, Chapter 23, Underground Injection Control, states that no injection well shall be constructed until a construction application is made for a UIC permit and the department has approved the start of the construction. Approval of the start of the construction shall not be construed as approval for the operation of that injection well. No injection well shall be operated, modified or otherwise utilized without a UIC permit issued by the department. 11-23-08 and 11-23-11.

The director may issue UIC permits for wells which propose to inject into exempted aquifers on the following basis:

1. Existing or new injection wells that do not or will not endanger the quality of underground sources of drinking water.

2. Existing or new injection wells that are designed and are or will be constructed or modified to operate without causing a violation of these rules or other applicable laws.

3. Proposed injection wells that are designed and built in compliance with the standards and limitations stated in sections 11-23-07 to 11-23-10.

The issuance of a UIC permit for wells which propose to inject into USDW are basd upon the evaluation of the contamination potential of the local water quality by the injection fluids and the water development potential for public or private consumption. 11-23-16.

Title 11, Department of Health, Chapter 55, Water Pollution Control, states that a NPDES permit is required before any person discharges any pollutant, or substantially alters the quality of any discharge, or substantially increases the quantity of any discharge.

County Planning Commissions

A study of each County Planning Commission's regulations was not done. However, for the County of Hawaii, a geothermal resource permit is required from the Planning Comission before any person may conduct geothermal development activities on land that is located within a geothermal resource subzone and located within the Agricultural, Rural, or Urban State Land Use Districts. The Planning Commission determines whether the geothermal development activities would have an unreasonable adverse health, environmental, or socioeconomic effect on residents or surrounding property. 12.3 and 12.6(a).

WELL DESIGN

Board of Land and Natural Resources

Extensive design requirements and testing procedures must be followed as precautions against blowout. Section 13-183-71, Section 13-183-76.

Department of Health

Underground Injection Wells

Section 11-23-10 gives provisions for artesian aquifer protection. A NPDES permit may be issued only if the treatment works are designed, built and equipped in accordance with the best practicable control technology or the best available technology economically achievable, for point sources other than publicly owned treatment works. 11-55-15. The director may issue a permit to an existing facility not in compliance only if the permit includes a schedule of compliance. 11-55-15(d).

County Planning Commissions

In the County of Hawaii, the applicant must submit to the Planning Director final plans for monitoring environmental effects of the project before construction is initiated. 12.8.

DISPOSAL OF SOLID AND LIQUID WASTES

The Board of Land and Natural Resources

Section 13-183-87 requires the operator of any well to comply with all applicable federal, state, and local standards with respect to air, land, water, and noise pollution, and the disposal of liquid, solid, and gaseous effluent. The disposal of well effluents must be done in a manner that does not constitute a hazard to surface or groundwater resources.

Department of Health

Title 11, Department of Health, Chapter 58, Solid Waste Management Control, defines "solid waste" in part as "garbage, refuse, and other discarded solid materials, including solid waste materials resulting from industrial and commercial operations ...." Section 11-58-6 specifies that a person owning or operating a business or industry has the responsibility of removing accumulated solid waste to an approved solid waste disposal facility.

Section 11-23-06 addresses classification of injection wells. Wells in Classes I through IV are prohibited. Only Class V wells are permissible. 11-23-06(b). The Department of Health currently interprets geothermal wells as being "Class V Subclass B," since they are not defined elsewhere. 11-23-06(b)(3)(A). Subclass B is defined as "injection wells which inject non-polluting fluids into any geohydrologic formation, including nonexempted aquifers."

If the operation of the injection wells is aditionally regulated by other pollution control programs, e.g., National Pollution Discharge Elimination System (NPDES), the adherence to their monitoring and reporting requirements will be considered a requirement of this chapter. Section 11-23-18(b).

County Planning Commissions

In the County of Hawaii, the applicant for a geothermal resource permit must include information on existing and the proposed uses and locations of disposal systems and methods for disposing of well effluent and other wastes. 12.3(c) and 12.3(g).

WELL PLUGGING

Board of Land and Natural Resources

Any person proposing to abandon a well must first file an application for a permit to abandon with the Board of Land and Natural Resources. The mehthod of abandonment must be approved by the Board. Section 13-183-81.

Department of Health

Underground Injection Wells

Any owner who wishes to abandon an injection well shall submit an application containing the details of the proposed abandonment. Section 11-23-19(a).

The department may order an injection well to be plugged and abandoned when it no longer performs its intended purpose, or when it is determined to be a threat to the groundwater resource.

Section 11-23-19(b).

Water Pollution Control

A NPDES permittee must report to the director within thirty days after permanent discontinuance of the treatment works or waste outlet for which the NPDES permit had been issued. Section 11-55-18.

County Planning Commissions

In the County of Hawaii, an application for a geothermal permit must include a written description of the proposed well completion program. 12.3(e).

RESTORATION OF SURFACE

Board of Land and Natural Resources

For Leased Lands

Within 90 days of revocation, surrender, or expiration of any mining lease, the lessor or surface owner may require the lessee to restore the land to its original condition insofar as it is reasonable to do so, except for roads, excavations, alterations or other improvements which may be designated for retention by the surface owner. The Board or State agency has the authority to require that cleared sites and roadways be replanted with grass, shrubs or trees by the lessee. Section 13-183-63.

For Other Land

Equipment must be removed and premises at the well site must be restored as near as reasonably possible to its original condition immediately after plugging operations are completed, except as otherwise authorized by the Chairperson of the Board of Land and Natural Resources. Section 13-183-82(b).

Department of Health

Underground Injection Control

Any owner who wishes to abandon an injection well must submit an application containing the details of the proposed abandonment. Section 11-23-19.

County Planning Commissions

In the County of Hawaii, the application for a geothermal resources permit must include a statement addressing how the proposed development would mitigate or reconcile any effects to residents or surrounding properties in the areas of health, environmental and socioeconomic activities. 12.3(k)(i).

SURETY BONDS

Board of Land and Natural Resources

State and Reserved Lands

Exploration permits - Section 13-183-8 requires a $10,000 bond for each exploration permit, or a $150,000 blanket bond.

Other Lands

Section 13-183-68 requires a $50,000 bond for each well to be drilled, re-drilled, deepened, or abandoned, or a $250,000 blanket bond.

REFERENCES

State of Hawaii, Title 11,Chapter 23, Underground Injection Control, Department of Health

State of Hawaii, Title 11, Chapter 55, Water Pollution Control, Department of Health

State of Hawaii, Title 11, Chapter 58, Solid Waste Management Control, Department of Health

State of Hawaii, Title 13, Chapter 2, Administrative Rules, Department of Land and Natural Resources

State of Hawaii, Title 13, Chapter 183, Leasing and Drilling of Geothermal Resources, Department of Land and Natural Resources

Planning Commission, County of Hawaii, Rule 12, Geothermal Resource Permits

Personal Communications:

Albert Lono Lyman, Planning Director, Planning Department, County of Hawaii

Dean Nakano, Board of Land and Natural Resources (808)548-7541

Dennis Lau, Department of Health (808)961-8288

APPENDIX

IDAHO

STATE REGULATORY AGENCIES

In Idaho, two agencies regulate the geothermal industry:

- Department of Water Resources
- Department of Lands

GEOTHERMAL REGULATIONS

The following state rules and regulations are specific to geothermal activities in Idaho:

- The Geothermal Resources Act of 1971 (Idaho Code, Chapter 40, Sec. 42-4001 through 42-4015). This act was passed to encourage development of geothermal resources for the benefit of the people of the state while minimizing damage and costs that could occur.

- Rules and Regulations: Drilling for Geothermal Resources. The state of Idaho adopted these rules and regulations governing geothermal drilling operations in 1972, and revised them in 1975 and 1978. The Geothermal Resources Act gives the Idaho Department of Water Resources regulatory authority for all drilling operations, as well as operation, maintenance, and abandonment of all geothermal wells in the state.

- Rules and Regulations Governing the Issuance of Geothermal Resources Leases. Adopted in 1974 and amended in 1978, these rules cover all aspects of geothermal activities on leased lands. The Idaho State Board of Land Commissioners has the authority to promulgate these rules and regulations.

PERMITS

The Department of Water Resources must issue a permit before the production of or exploration for geothermal resources or the construction of an injection well. The Department must also issue a permit before any person may deepen or modify an existing well. If an owner plans to convert an existing geothermal well into an injection well, approval must be received from the Department. The owner of a proposed injection well must provide the Director with information necessary to evaluate the impact of the injection on the geothermal reservoir and other natural resources. Permits may be amended subject to Department approval. (Rules 4.2 and 7.1)

Leasing - Application to lease state lands must be made to the State Board of Land Commissioners. Prior to drilling for any purpose to 1,000 feet or deeper, the lessee must submit to the Director, for approval, a plan of operations. This plan must include the methods that the operator intends to use to dispose of waste material. Rule 3.

WELL DESIGN

Section 6 sets forth extensive design requirements and testing procedures to be implemented as precautions against blow-out.

DISPOSAL OF SOLID AND LIQUID WASTES

Disposal by Injection

The operation of a proposed injection well must provide all information that the Director deems necessary for evaluating the impact that the well would have on the reservoir, other natural resources, and the environment. Rule 7.2.1 requires that an owner of an injection well must demonstrate to the Director that the well casing has complete integrity, using a test approved by the Director. Rule 7.2.7 requires that the owner make sufficient surveys into a well to prove that all the injected fluid is confined to the intended zone of injection. The Director may order a representative to be present, or if in the Director's opinion such tests are not necessary, a waiver may be granted.

Surface Disposal

Rule 16 of the Idaho State Board of Land Commissioners, states that the lessee must be in compliance with all federal, state, and local waste disposal and pollution control laws. Specific methods for disposal of wastes must be included in the lease agreement, subject to approval by the Director of the Department of Lands.

There are regulations for surface discharges promulgated by the Idaho Water Quality Standards and Wastewater Treatment Standards.

WELL PLUGGING AND ABANDONMENT

For leased lands - Section 16.10 requires the lessee to promptly plug and abandon any nonproductive well in conformance with abandonment procedures promulgated by the Idaho Department of Water Resources.

For all land - The Department requires a notice of intent to abandon geothermal resource wells 5 days prior to beginning abandonment procedures. A history of geothermal resource wells must be filed. The abandoned wells must be monumented to the description included in the history of well report. Injection wells are required to be abandoned in the same manner as other wells.

Specific plugging and abandonment procedures are given in order to block interzonal migration of fluids. Heavy drilling fluid must be used to replace water in the well hole and to fill parts not plugged with cement. Cementing requirements are based on casing and aquifer locations. Casing must be cut off at least 5 feet from the surface. Rules 8.1 - 8.2.

RESTORATION OF SURFACE

For leased lands - Lessee must reclaim all State lands in accordance with applicable reclamation procedures contained in Sections 47-1509 and 47-1510, Idaho Code.

For all land - The Director may correct or stop any person who is operating any well in a manner that causes damage to life or property and to mitigate any injury caused by such practice. Rule 13.1

SURETY BOND

For leased lands - Upon execution of the lease, the lessee must pay the Director a $2,000 bond. Prior to drilling any well to 1,000 feet or deeper, the bond must be increased to $10,000, or the lessee may pay a blanket bond of $50,000. Rule 26.1 and Rule 26.2.

For other lands - A $10,000 bond is required for each individual well. Rule 4.4.1.

REFERENCES

State of Idaho, Geothermal Resources Act of 1971, Chapter 40, Sec. 43-4001 through 42-4015, Department of Water Resources

State of Idaho, Rules and Regulations: Drilling for Geothermal Resources, Department of Water Resources

State of Idaho, Rules and Regulations Governing The Issuance of Geothermal Resources Leases, Idaho State Board of Land Commissioners

State of Idaho, Title I, Chapter 2, Water Quality Standards and Wastewater Treatment Requirements, Department of Health and Welfare

<u>Personal Communications</u>

Leah V. Street, Geologist, Department of Water Resources (208)734-3578

Mr. Koenig, Department of Health and Welfare (208)334-5839

APPENDIX

ILLINOIS

STATE REGULATORY AGENCIES

One agency regulates the oil and gas industry in Illinois:

- Department of Mines and Minerals, Division of Oil and Gas.

GEOTHERMAL REGULATIONS

The Department of Mines and Minerals operates under "An Act in Relation to Oil, Gas, Coal, and Other Surface and Underground Resources". These regulations may be applicable to geothermal energy as an underground resource. Section 3.

Section 3 gives the Mining Board the duty of enforcing the Act and all rules, regulations and orders promulgated in pursuance of this Act.

PERMITS

The Mining Board must issue a permit before any person may drill a geological or structural test hole or water supply well in connection with any operation for the exploration or development of oil or gas. Rule II (4). The Mining Board also requires permits for salt water disposal or for gas, air, water, or other liquid input wells. Rule II(4). Approval must be obtained from the Department of Mines and Minerals before any subsurface injection or disposal project can begin. Rule II A(1). Rule II A(3) sets forth the information required in the application for approval of the disposal operations. Rule II

(4) sets forth the operating requirements for the di
wells. Rule II A(5) sets forth the monitoring and repor
requirements for the disposal wells.

DISPOSAL OF SOLID AND LIQUID WASTES

In addition to the above requirements, Rule IX (2) states that salt water and other waste liquids may be impounded and collected or disposed of by evaporation in excavated earthen pits where the salt water or other waste liquids will not contaminate ground water or pollute surface water. Rule IX gives construction criteria for these pits. Solid waste disposal is not addressed in the regulations.

WELL PLUGGING

Rule XI (1) requires that the Mining Board supervise the plugging and abandonment of wells. Methods and procedures for plugging the wells are outlined in this rule.

RESTORATION OF SURFACE

Rule XI (6) requires that an owner clear the area and leave
e site as nearly as possible in the condition encountered when
ations commenced. Restoration must be accomplished within 6
s of abandoning or plugging a well.

ONDS

III (1) requires every person previous to the
of drilling for oil, gas or any other purpose in

connection therewith to file a 2,5000 individual well bond, or a $25,000 blanket bond to ensure compliance with plugging and abandonment requirements.

REFERENCES

State of Illinois, An Act in Relation to Oil, Gas, Coal and Other Surface and Underground Resources and Rules and Regulations, Department of Mines and Minerals, Division of Oil and Gas, Revised Edition, 1984

Personal Communications:

John Morgan, Illinois Department of Mines and Minerals (217) 782-4970

INDIANA

STATE REGULATORY AGENCIES

The Indiana Department of Natural Resources, Division of Oil and Gas, regulates the oil and gas industry in Indiana.

GEOTHERMAL REGULATIONS

There are no regulations specific to geothermal energy in Indiana. However, some sections of the Oil and Gas Laws are applicable; Section 310 IAC 7-1-1 of the Oil and Gas Rule defines a "well for oil and gas purposes" as "a hole drilled for any purpose for which a permit is required under IC 13-4-7, including a permit for a seismographic test crew or a permit to drill, deepen, or convert an oil, gas, or test well; a geological or structural test well; an enhanced recovery well; a disposal well..." The Oil and Gas Division of the Department of Conservation was created pursuant to IC 13-4-7-1, and thereby charged with the duties of carrying out and enforcing the provisions of the Oil and Gas Laws. The Department of Natural Resources Division of Oil and Gas is authorized under IC 4-22-2 to obtain primary enforcement authority for and implementation of Class II wells under the Underground Injection Control Program, promulgated under part C of the Safe Drinking Water Act. A Natural Resource Commission was created under IC 14-3-3-3, to adopt rules, regulations, and orders necessary for the Oil and Gas Division to administer the Oil and Gas Laws.

PERMITS

An application must be filed for permits to drill, deepen, or convert any type of well. Detailed surveying requirements are required, which include location and spacing of wells. For a disposal or enhanced recovery well, a detailed plan of operation for the proposed well must be included with the application for permit to drill. 310 IAC-7-1-21.

WELL DESIGN

Casing, tubing, and drill pipe must be run and set in conformance with the standards set forth by the American Petroleum Institute. There are specifications for casing string, surface casing, and cementing. The well operator must use more than one string of casing where necessary to protect underground drinking water sources. 310 IAC 7-1-42.

Before commencing to drill, at least one proper and adequate slush pit must be constructed for the reception of mud that can be reused when the hole is plugged. 310 IAC 7-1-40.

DISPOSAL OF SOLID AND LIQUID WASTES

The disposal of solid wastes from drilling activities is not addressed. There are regulations for disposal of salt water and liquid wastes. To prevent surface or underground waste, contamination, or pollution, only those disposal methods approved by the Commission are permitted. Salt water, sulfur-bearing water or other waste liquids from drilling operations may be injected into a subsurface formation if a permit has been issued by the Commission. Evaporation pits are prohibited. Holding pits are permitted for gathering of saltwater for injection and disposal, or for emergency use. If a pit is used for emergency purposes, the liquid in the pit must be purged as soon as the emergency ceases. 310 IAC 7-1-38.

WELL PLUGGING AND ABANDONMENT

A well must be immediately plugged and capped where the well is incomplete one year after issuance of a permit, and is not afforded temporary abandonment status. A cement plug must be placed to 100 feet above the top of a formation. Where insufficient casing has been set or the casing not cemented, the production string of casing must be removed 50 feet below the deepest aquifer containing potable water. 310 IAC 7-1-22(g) and 310 IAC 7-1-33.

SURFACE RESTORATION

Upon completion of a well, pits must be filled and leveled. Within 6 months of plugging and abandoning a well, an operator must clear the area of any refuse and equipment, drain and fill excavations, and restore the surface to as near its condition prior to drilling as possible. 310 IAC 7-1-40(c) and 310 IAC 7-1-33(b).

SURETY BONDS

A surety bond, certificate of deposit, or cash in the amount of $2,000 covers one well. A blanket bond of $30,000 covers a group of wells.

REFERENCES

Indiana Department of Natural Resources, Division of Oil and Gas. Oil and Gas Law, 310 IAC 7-1, Revised 1986.

Personal Communications:

Gary M. Fricke, Division of Gas and Oil. (317)232-4055

IOWA

STATE REGULATORY AGENCIES

- Department of Natural Resources

GEOTHERMAL REGULATIONS

The Department of Natural Resources regulates water quality standards. Chapter 61, Water Quality Standards gives the Commission authority to protect and enhance the quality of the water of the State of Iowa by attempting to prevent and abate pollution to the fullest extent possible consistent with statutory and technological limitations.

The Department of Natural Resources also regulates the production and utilization of oil, gas, and other minerals. Chapter 84 gives the Department the authority to promulgate and enforce rules and orders to effectuate the purposes and intent of the chapter. Section 84.1, declaration of policy, requires that the underground and surface water of the state be protected from pollution.

PERMITS

A permit from the Department of Natural Resources is required for water withdrawals. 455.B.269. Aquifers are considered to be waters of the state. 455.B. A permit from the Department of Natural Resrouces is also required before a discharge may be made into an aquifer. 455.B.186.

SOLID AND LIQUID WASTE DISPOSAL

All wastes discharged to the waters of the state must be of such quality that the discharge will not cause the narrative or numeric criteria limitations to be exceeded. 61.2(3). There are also temperature limitations on water added to streams, lakes, or other bodies of water. 61.3(3).

REFERENCES

State of Iowa, Chapter 93, Energy Development and Conservation.

State of Iowa, Chapter 305, Geological Survey, Department of Natural Resources.

State of Iowa, Chapter 84, Oil, Gas and Other Minerals, Department of Natural Resources.

State of Iowa, Chapter 61, Water Quality Standards, Department of Natural Resources.

Personal Communications:

Keith Bridson, Iowa Department of Natural Resources (515) 281-8868.

Pete Hanlin, Iowa Department of Natural Resources (515) 281-8852.

APPENDIX

LOUISIANA

STATE REGULATORY AGENCIES

The Louisiana Department of Natural Resources, Office of Conservation has jurisdiction over geothermal operations in the State of Louisiana.

GEOTHERMAL REGULATIONS

Louisiana has legislation specific to geothermal energy; Statewide Order No. 29-P adopts rules and regulations governing the drilling for and production of geothermal energy. The Commissioner of Conservation derives authority from Title 30 of the Louisiana Revised Statutes to issue and promulgate rules regarding geothermal operations.

The definition of geothermal resources, given in State Order No. 29-P, includes steam, hot water, hot brines, and geopressured waters, either indigenous to or artificially introduced into geothermal or geopressured water formations. The provisions in State Order No. 29-P apply to all drilling and operational aspects of geothermal exploration, production and injection wells.

PERMITS

All applications for permits to drill or convert an existing well to a geothermal well must be sent to the Department of Conservation District Office for approval by the District Manager. The application must include a location plat, detailing all pertinent lease and property lines and other wells of any kind. A well location certificate must be included with the plat. Rule II.

WELL DESIGN

There are extensive specifications for surface casing and production casing in all geothermal wells, based on the total depth of the contract. Intermediate casing is to be used as required by the District Manager. Casing tests must be conducted before operations proceed. Rule II.

All drilling wells are required to have a master gate and blowout preventer, together with a flow valve of recommended size and working pressure. Rule VI.

SOLID AND LIQUID WASTE DISPOSAL

Any rubbish or debris that might constitute a fire hazard must be removed to a distance of at least 100 feet from any tanks, wells, or pump stations. All wastes and produced fluids must be disposed of in such a manner as to avoid creating a fire hazard or polluting streams and fresh water strata. Salt water and related liquid waste material may be sorted into pits which have been approved by the Commissioner of Conservation. Salt water can be injected into a subsurface formation; a permit is required for this form of disposal. Disposal of all geothermal/geopressure operation waste material into surface waters must be done pursuant to regulations set forth by the Stream Control Commission or other appropriate state or federal regulatory agency. Rules VIII, XIV.

WELL PLUGGING AND ABANDONMENT

If an owner/operator intends to cease production or injection activities, a notification of intention to plug must be given to the District Manager in writing. A schedule of abandonment must be set. There are different plugging requirements for wells with different types of casing and lining, but in general, a cement plug must be placed at least 150 feet immediately above the uppermost perforated reservoir. If freshwater zones are exposed, a cement plug must be placed at least 50 feet from the base of the aquifer. A 30-foot plug at the top of the well is also required. Rule XVI.

RESTORATION OF SURFACE

Not addressed in the regulations reviewed.

SURETY BONDS

A reasonable bond with good and sufficient surety may be required by the Commissioner to ensure proper well plugging. An exact dollar amount is not stated. Rule XVI.

REFERENCES

State of Louisiana, Office of Conservation, Statewide Order No. 29-P. May 4, 1978.

Personal Communication

Jim Welsh, Office of Conservation. (504)342-5540.

MARYLAND

STATE REGULATORY AGENCIES

Two agencies regulate geothermal operations in Maryland:

- The Department of Natural Resources (DNR), which issues permits for oil, gas, and geothermal well drilling, and promulgates rules and regulations for well construction and drilling practices.
- The Department of Health and Mental Hygiene (DHMH), which is responsible for protection of water quality and disposal of solid and liquid drilling and production wastes.

GEOTHERMAL REGULATIONS

The Maryland Geothermal Resources Act, Annotated Code of Maryland, Subtitle 8A, gives authority to the Department of Natural Resources for geothermal energy regulation and defines DNR's powers and duties. Maryland Well Construction Regulations Code of Maryland 10.17.13, establishes standards and procedures applicable to well construction, and integrates DNR's and the Department of Health and Mental Hygiene's programs into a unified regulatory program. The regulations in this chapter apply to well construction activities from initial ground penetration through development, equipment installation, and final approval of the well for production.

The Maryland Health-Environmental Article, Sec. 9-217, regulates pollution of water by industrial wastes. It provides authority for the Secretary of DHMH to issue discharge permits or prohibit discharges. Other sections of the Health-Environmental

Article provide authority for solid waste management (10.17.11) and standards for water quality and water pollution control (10.50.01).

PERMITS

As mentioned before, a permit must be obtained from DNR before any drilling operation commences. A permit to construct a well will only be granted to those persons licensed by the Maryland State Board of Well Drillers. The licensed person to whom a permit is issued is responsible for construction of the well in accordance with DHMH's safety standards.

The DHMH has authority to issue NPDES and Underground Injection Control permits for waste discharges.

Permits must be issued by DHMH for discharge of any pollutant into the waters of the state. Details on the permitting process are included in the section on solid and liquid waste disposal.

WELL DESIGN

Well design requirements in Code of Maryland 10.17.13 are written for groundwater wells, but are applicable to geothermal wells. Specifications are given for types and installation of well casing grouting and grouting materials.

DHMH also specifies construction standards in 10.17.13 for wells installed for the purpose of injecting water, wastewater, and other liquids into a subsurafce formation or aquifer. Standards may include requirements for testing, casing specifications, grouting material, and well-head pressure monitoring devices.

DISPOSAL OF SOLID AND LIQUID WASTES

Any discharge or disposal of waste waters into the surface or underground waters of the state requires the approval of DHMH. If DHMH determines that the proposed activity will not cause a violation of the standards in Code of Maryland 10.50.01, the Department will issue water quality certification. Issuance of water quality certification does not relieve the applicant of responsibility to comply with all federal and state laws. By agreement with either federal or state agencies in order to facilitate the certification process, DHMH may develop a joint application for a federal license or permit and state water quality certification. A separate state discharge permit or NPDES permit is required for discharge of leachate from a landfill, pit, or sump to surface or groundwater. Pits must be lined with impervious material to prevent groundwater contamination. Materials in the pit must be removed and disposed of at a permitted disposal facility, in or out-of-state. Unlined pits must have groundwater discharge permits. Permit approval is granted by DHMH on a site-by-site basis.

An underground injection permit issued under Code of Maryland 10.50.04 constitutes a discharge permit under this regulation. All injection wells must be maintained in a condition to protect groundwater standards.

Liquid wastes and wastes containing free liquids may only be disposed of at a solid waste acceptance facility that has been specifically authorized by DHMH to handle such waste. The presence of free liquids is determined by the free liquid test, FR Vol. 47, 38.

On-site, nonhazardous industrial waste landfills must be permitted and meet the following DHMH requirements (10.17.11.07): the waste must be spread in uniform layers and compacted to the smallest practical volume before covering. The disposal site must be graded and drained to minimize runoff and prevent erosion and ponding. Features and systems to protect groundwater from any leachate are required.

<u>WELL PLUGGING AND ABANDONMENT</u>

A well must be abandoned when it is in a state of disrepair, when use is impracticable, or when it is not productive. Well abandonment procedures are specified in 10.17.13.11.

Before filling the hole, casing and any obstructions to filling must be removed. A well must be filled with clay, silt, sand, gravel, or a mixture of these materials, and sealed with concrete or sodium-base bentonite clay. All wells must be sealed and abandoned in such a way that no interchange of waters of varying quality may occur.

SURFACE RESTORATION

The objective of standards described in 10.17.13.11 is to restore as nearly as possible those surface conditions which existed before the well was constructed.

SURETY BOND

A surety bond in the amount of $2,500 per well is required. General 6-105. In practice, a blanket bond of $1,000 may also be issued. Although bonding procedures are not specified in the regulations, the legal section of the Department of Natural Resources may enter into a contractual arrangement with the owner/operator, (General law 6-105).

REFERENCES

State of Maryland, Title 10, Subtitle 17, Chapter 13, Well Construction, Department of Health and Mental Hygiene.

State of Maryland, Title 10, Subtitle 17, Chapter 11, Installation and Operation of Systems of Refuse Disposal for Public Use, Department of Health and Mental Hygiene.

State of Maryland, Code of Regulations, Subtitle 50, Chapter 1, Water Management, Department of Health and Mental Hygiene.

Personal Communications

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Dept. Health and Mental Hygiene
Solid Waste Division
(301) 225-5659

Ken Schwarz
Dept. of Natural Resources
Environmental Geology and Mineral Resources Division
(301) 554-5525

APPENDIX

MONTANA

STATE REGULATORY AGENCIES

Two state agencies regulate oil and gas activities in Montana:

- The Montana Department of Natural Resources and Conservation, Oil and Gas Conservation Division.
- The Montana Department of Health and Environmental Sciences, Water Quality Bureau.

GEOTHERMAL REGULATIONS

There are no regulations specific to geothermal operations, but sections of the General Rules and Regulations Relating to Oil and Gas Administrative Rules of Montana, Part 36, Ch.22 outlined below may apply. Title 82 of the Montana Annotated Code places certain restrictions on geophysical exploration, but these appear to apply only to geophysical exploration for oil and gas resources.

PERMITS

A notice of intent to drill a stratigraphic test well or core hole must be submitted to the Board of Oil and Gas Conservation before any drilling may commence. If the notice is approved by the Department, a permit will be issued for drilling. The notice of intent to drill must be accompanied by a survey plat, certified by a registered surveyor. Section 36.22.601-602.

A permit for waste discharges must be obtained from the Department of Health and Environmental Sciences. Montana has primacy for the issuance of NPDES permits.

WELL DESIGN

Suitable and safe surface casing is required for all wells. In areas where pressure levels and formation characteristics are unknown, surface casing must be run to reach a depth below all potable fresh water resources that are accessible for domestic or agricultural use. Surface casing must be set and cemented in an impervious formation. Blowout-prevention equipment is required on all drilling wells, and should be used according to established practice in the area. Adequate slush pits for the reception of drilling muds must be constructed before any drilling commences. Section 36.22.1001-1002.

SOLID AND LIQUID WASTE DISPOSAL

All solid wastes that accumulate during drilling operations must be contained and disposed of in an appropriate manner. The waste must either be removed from the well site or buried at the well site to a minimum depth of 3 feet below the restored surface. Section 36.22.1005.

Salt or brackish water may be disposed of by injection into the strata from which it was produced or other salt-water bearing strata. Salt or brackish water may also be disposed of by evaporation in pits that are underlain by tight soil, such as heavy clay or hardpan. Section 36.22.1227-1228.

WELL PLUGGING AND ABANDONMENT

Plugging is required for any well that is no longer used for the purpose for which it was drilled or converted, with limited exceptions. Section 36.22.1303.

RESTORATION OF SURFACE

All operators are required to restore the surface area to its previous grade and productive capability, unless the Board approves a different plan of restoration. Section 36.22.1307.

SURETY BOND

A $10,000 or $25,000 surety bond is required to indemnify owners of property within the state against damages caused by geophysical exploration. The Board requires, from any operator proposing to drill or acquire any oil, gas, or service well on private or state lands, a plugging and restoration bond in the sum of $5,000 for one well, and $10,000 for more than one well. If the Board deems it necessary, they can increase the amount of the bond. The bond remains in force until the well plugging and surface restoration has been approved by the Board. Section 36.22.1308.

REFERENCES

Montana Department of Natural Resources and Conservation, Oil and Gas Division. General Rules and Regulations Relating to Oil and Gas. Administrative Rules of Montana, Part 36, Chapters 22. Revised July 1984.

Personal Communications:

Tom Richmond, Oil and Gas Division. (406)656-0040.

APPENDIX

NEVADA

STATE REGULATORY AGENCIES

Two agencies regulate the geothermal industry in Nevada:

- Department of Minerals,
- Nevada Department of Conservation and Natural Resources, Division of Environmental Protection (for underground injection control).

GEOTHERMAL REGULATIONS

The Nevada Commission on Mineral Resources adopted regulations specific to geothermal activities on August 16, 1985, and filed the regulations with the Secretary of State on November 12, 1985. Authority to make and adopt regulations is derived from Section 534A.090 Nevada Revised Statutes and authority to adopt rules of practice and procedure is derived from Sections 233B.040 to 233B.0617 Nevada Revised Statutes, the Administrative Procedures Act.

New underground injection control regulations have been adopted by the State Environmental Commission. These regulations are administered by the Division of Environmental Protection, but do not replace or in any other way affect the regulations and rules of practice and procedure administered by the Nevada Department of Minerals as they apply to Class II injection wells and Class V geothermal wells. Permits must be obtained from each agency.

PERMITS

The Department of Minerals divides geothermal wells into three categories: (1) domestic wells (used for domestic purposes or by a commercial user who does not produce geothermal heat for sale or the generation of power); (2) commercial wells (used to provide geothermal resources on a commercial basis for purposes other than the generation of power); and (3) industrial wells (used to operate power). Section 16 (NAC 534A.170).

A permit must be obtained from the Department of Minerals before any person drills an observational or thermal gradient well for observational purposes. Authorization is also required from the Department for deepening or plugging any geothermal well. Section 36 (NAC 435A.370).

Unless the director approves an alternative method of disposal, all fluids derived from geothermal resources must be reinjected into the same reservoir from which the fluids were produced. Section 41.1 (NAC 534A.420). The operator must file with the Department an application for a permit to inject geothermal fluids. No re-entry is allowed except for routine clean-out or repair work until an application has been filed with and approved by the Department. Section 22 (NAC 534A.230).

If any water is consumed in the process, a permit to appropriate water must be obtained from the Division of Water Resources. The Division of Water Resources may also recommend conditions for Department of Minerals permits to ensure compliance with the purposes of Chapters 533 and 534 Nevada Revised Statutes.

WELL DESIGN

Section 25. (NAC 534A.260 - NAC 534A.2300) sets forth extensive design requirements as precautions against blowout.

DISPOSAL OF SOLID AND LIQUID WASTE

Effective February 2, 1987, an application must be submitted to and a permit obtained from the Division of Environmental Protection to comply with UIC regulations. As stated in the section on permits, unless the Director approves an alternative method of disposal, all fluids derived from geothermal resources must be reinjected into the same reservoir from which the fluids were produced. There are also reporting and notification requirements for injection. Section 41.1 (NAC 534A. 420), Section 45. (NAC 534A.460), and Section 44.1 (NAC 534A.450).

Currently, Nevada does not require any solid wastes to be transported off-site. Solid waste which may be hazardous must be deposited at a land disposal site only if provisions for such disposal were required by the solid waste management authority. Solid waste management authority is defined as "the officers and agents of the division of environmental protection, any district board of health or any other entity given specific authority by the division." In general, the solid waste management authority must approve a system for the handling, processing, salvage, or disposal of hazardous waste before the system may be placed into operation. However, the method of handling or disposing of solid waste may not be done in a manner which creates a health hazard or impairment to the environment. 444.624-444.646.

Each municipality implements a plan for the management of solid wastes within its jurisdiction. Jurisdictions are contained within the boundary of each county, except where a city develops its own plan or several municipalities develop a combined plan. In general, the storage, collection, or transportation of solid waste is regulated by the city, town, or county where the services are performed. However, the method of storage, collection, or transportation may not be done in a manner that creates a health hazard or impairment to the environment. 444.660-444.658.

WELL PLUGGING

The Department must grant permission before any person abandons a well. Section 46.1 (NAC 534A.470).

RESTORATION OF SURFACE

The surface must be restored as near as practicable to its original condition. Section 47.3 (NAC 534A.480).

SURETY BOND

Section 24.1 (NAC 534A.250) requires a bond not less than $10,000 per individual well, or a $50,000 blanket bond to insure compliance with plugging and abandonment requirements.

REFERENCES

State of Nevada, Chapter 534 A, Geothermal Resources, Department of Minerals

State of Nevada, Regulations and Rules of Practice and Procedure Adopted Pursuant to NRS 534 A, Department of Minerals

Underground Injection Control Regulations, January 1987, Department of Conservation and Natural Resources, Division of Environment Protection

Nevada Annotated Code 444.570 through 444.748, Solid Waste Disposal

Personal Communications:

Richard L. Reyburn, Executive Director, Department of Minerals (702) 885-5050

Dan Gross, Department of Conservation and Natural Resources, Division of Environmnetal Protection (702) 885-4670

APPENDIX

NEW HAMPSHIRE

STATE REGULATORY AGENCIES

The State of New Hampshire Water Supply and Pollution Commission sets regulations for any activities which affect groundwater in the state.

GEOTHERMAL REGULATIONS

There are no regulations specific to geothermal energy; however, some sections of the New Hampshire Codes of Administrative Rules WS 410 may be applicable. The definitions of "well", "injection", and "fluid" given in WS410.04 are written in such a way that geothermal resources could be included. Part WS410 of the New Hampshire Code derives authority from RSA 149:8, III(a); its purpose is to protect groundwaters as potential sources for drinking water.

PERMITS

A groundwater permit issued by the Commission is required for operation of any facility which may significantly and adversely affect groundwater. Applications for a groundwater permit must contain a complete description of the facility, including environmental assessment, groundwater monitoring plan, design plans, and closure plans. Anyone planning to inject fluid must include information on the type of fluid being injected, depth and diameter of the well, and injection rate. (WS 410.06 and .08).

WELL DESIGN

Not addressed in the regulations reviewed.

DISPOSAL OF SOLID AND LIQUID WASTES

Discharge or injection into groundwater of any hazardous waste is prohibited. Injection of a fluid below drinking water aquifers is prohibited. Disposal of solid or liquid waste from drilling or production of any type of well is not addressed in the regulations which were reviewed.

REFERENCES

New Hampshire Water Supply and Pollution Control Commission, Part Ws 410 of Ntl Code of Administration Rules: Protection of Groundwaters of the State.

APPENDIX

NEW JERSEY

STATE REGULATORY AGENCIES

One agency regulates well drilling of all types in New Jersey:

- The New Jersey Department of Environmental Protection. (Division of Water Resources and Division of Solid Waste Management).

GEOTHERMAL REGULATIONS

New Jersey's water quality and water supply regulations, N.J.A.C. 7:9-7.2, set general standards and establish procedures for construction, permits, installation and modification of all types of wells. Specific regulations for geothermal wells are found in N.J.A.C. 7:9-8.6. The Well Drillers and Pump Installers Act, N.J.S.A. 58:4A, provides authority for these rules, and also establishes a Well Drillers and Pump Installers Examining Board to issue licenses and make recommendations to the Commissioner of the Department.

PERMITS

No drilling or any other type of construction on a well is allowed without an approved well permit. Permits are valid for one year. Applications for permits must provide complete, accurate information about the proposed well site and the operation of the well. For geothermal wells, a site plan must be submitted with the permit application, showing location of the proposed well, drawings of distances from the proposed geothermal wells to potable wells, potential sources of contamination and pollution, and all proposed structures.

There are well driller and pump installer licensing and certification procedures and requirements. There are extensive eligibility requirements in order to become licensed. No drilling or construction of a well is allowed by anyone without a license. (7:9-7.2 and 7:9-8.6)

WELL DESIGN

Specific procedures apply for the construction of vertical loop geothermal systems. When installing a vertical loop geothermal system, the borehole must be sealed in order to protect the quality of water present in the geological formations. A geothermal well must be constructed a minimum of 50 feet from any potable well. The geothermal well installation must be sealed from the bottom up under pressure to prevent groundwater contamination, maintain the hydrostatic head of aquifers encountered, and prevent mixing of waters of varying quality. The well casing must be at least 6 inches in diameter, Schedule 40 steel, weighing 19 lbs/foot. Casing installation requirements vary from one environmental Region to another; Regions are established by the New Jersey Department of Environmental Protection.

WELL PLUGGING AND ABANDONMENT

There are specific requirements governing the sealing of all types of wells. Some wells, such as those that present a direct risk of groundwater contamination, may not be sealed without departmental approval. A detailed written description must be filed with the Department after each plugging operation. (9:7-9.1).

DISPOSAL OF SOLID AND LIQUID WASTES

No treatment or discharge of any pollutant may occur without a New Jersey Pollutant Discharge elimination System (NJPDES) permit that has been issued by the Department. The NJPES permit covers discharge of pollutants to all surface and ground waters, and discharges of pollutants into wells (Underground Injection Control). The permitting process is extensive and includes provision for all conceivable wastes types.

New Jersey has primary for its Underground Injection Control Program; its rules are clearly preventative and provide specific regulatory controls for five classes of injection wells. In New Jersey, geothermal wells are Class III if used to produce electric power, and Class V if used for direct heating or aquaculture. No U.I.C. authorization shall be given for injection of any fluid with containants which may cause a violation of any primary drinking water standards. Details are given in N.J.S.A. 7:14 for selecting appropriate formation for injection.

Disposal of solid waste is regulated by the Division of Solid Waste Management in the Department of Environmental Protection. All solid wastes must be disposed of at State-approved facilities in a manner consistent with New Jersey regulations.

RESTORATION OF SURFACE

Not addressed in the regulations reviewed.

SURETY BONDS

A $5,000 bond must be filed with the Department prior to construction, installation, replacement, repair, or modification of any well. New bonds must be submitted to the Department prior to the expiration or cancellation of the bond or insurance policy. (7:9-7.3).

REFERENCES

New Jersey Department of Environmental Protection, Division of Water Resources. N.J.A.C. 7: 9-7, 8, and 9. Water Quality and Water Supply. 1986.

New Jersey Department of Environmental Protection, Division of Water Resources. N.J.A.C. 58.10A, Chapter 14A, the New Jersey Pollutant Discharge Elimination System.

New Jersey Department of Environmental Protection, Division of Solid Waste Management, N.J.A.C. 7: 26-1 through 6, 14, and 15.

APPENDIX

NEW MEXICO

STATE REGULATORY AGENCIES

Two agencies regulate the geothermal industry in New Mexico:

- Oil Conservation Division of the New Mexico Energy and Minerals Department
- Oil Conservation Commission

GEOTHERMAL REGULATIONS

The Geothermal Resources Conservation Act of 1978 gives the Oil Conservation Commission and the Oil Conservation Division of the Energy and Minerals Department authority over matters relating to geothermal resources. Specifically, the division is authorized to enforce the Geothermal Resources Conservation Act and any other laws of the State relating to geothermal resources. The Commission is given concurrent jurisdiction and authority with the Division to the extent necessary for the Commission to perform its duties.

Under the Oil Conservation Division Geothermal Rules and Regulations of 1983, the Division has the duty of enforcing all statutes, rules, and regulations of the State relating to the conservation of geothermal resources. In general, all geothermal operations, exploratory, drilling and producing must be conducted in a manner that will afford maximum reasonable protection to human life and health and to the environment.

PERMITS

Rule G-102(a) requires that the owner or operator of any proposed well to be drilled for geothermal exploration, production, observation, or thermal gradient, or for injection or disposal purposes, obtain a permit from the Division before commencement of operations. Notice of such intention to drill must be given to the governing body of any city, town, or village within the corporate limits of which the well will be drilled. Rule G-102(b). Evidence of this notification must accompany the permit application. Rule G-102(b).

WELL DESIGN

Extensive design requirements and testing procedures must be implemented as precautions against blowouts. Rule G-601. Rule G-107.

DISPOSAL OF SOLID AND LIQUID WASTES

Rule G-116 requires that disposal of highly mineralized waters produced from geothermal resource wells be made in a manner that will not constitute a hazard to surface waters or underground supplies of usable waters. The practice (although not stated in the regulations) is to dump the cuttings in reserve pits and bury them.

WELL PLUGGING

Prior to plugging, notice must be filed with the Division. Rule G-30.2. Before any well is abandoned it must be plugged in a manner that will permanently confine all fluids in the separate strata originally containing them. Rule G-303.

SURETY BOND

Plugging bonds are required prior to drilling any geothermal resource well. Bonds may be either one-well bonds or multi-well bonds. The amount of the bond depends on the depth of the well. Rule G-101.

RESTORATION OF SURFACE

Not addressed in the regulations reviewed.

REFERENCES

State of New Mexico, Geothermal Resources Rules and Regulations, Department of Energy and Minerals, Division of Oil Conservation, 1983.

State of New Mexico, Geothermal Resources Conservation Act, 1978.

Personal Communications:

Roy Johnson, State of New Mexico Department of Energy and Minerals (505) 827-5800

APPENDIX

NORTH CAROLINA

STATE REGULATORY AGENCIES

One agency regulates injection wells in North Carolina:

- Department of Natural Resources and Community Development.

GEOTHERMAL REGULATIONS

North Carolina Administrative Code, Title 15, Chapter 2, Subchapter 2C, and Section .0200 contain criteria and standards applicable to injection wells. At .0209, Classification of Injection Wells, Class II wells are defined as including wells which injectfor recovery of geothermal energy to produce electirc power. Class V wells are defined as including geothermal wells used in heating and aquaculture.

Solid waste disposal is regulated by the North Carolina Department of Human Resources, Division of Health Services, Environmental Health Section.

PERMITS

A permit must be obtained from the Director of the Division of Environmental Management prior to construction, operation, or use of any well for injection. Where the individual injection wells in the well field will be essentially similar in construction, operation, reporting, and abandonment, and are of the same type, the director may issue an area permit. No permit will be granted for the injection of wastes or contaminants. All applications for a new permit or renewal, modification or transfer of an existing permit must be filed in sufficient time prior to construction and operation or expiration, modification or transfer to allow compliance with all legal procedures.

Injection may not commence until construction is complete, the permittee has submitted notice of completion or construction to the director and the director has inspected or otherwise reviewed the injection well and found it in compliance with the permit conditions. If the permittee has not received notice from the director of intent to inspect or otherwise review the injection well within 10 days after the director receives the notice, the permittee may commence injection. A permit may not exceed 5 years. However, the permittee may file for an extension. Also, a permit may be modified, revoked and reissued, or terminated for cause. .0211.

No one may establish a solid waste management facility unless a permit for the facility has been obtained from the Division of Health Services of the Department of Human Resources. A permit is issued only after site and construction plans have been approved and the Department determines that the facility can be operated in accordance with the requirements set forth in the Solid Waste Management Rules, 10 NCAC 10G.

SOLID AND LIQUID WASTE DISPOSAL

As stated above, waste disposal wells are prohibited. NACA Title 15, Chapter 2, Subchapter 2C, Section .0200.

The Solid Waste Management Rules stipulate that solid waste must be disposed of at a solid waste disposal site. No waste that is hazardous, liquid, or infections may be disposed of at a solid waste disposal site, except as may be approved by the division.

A solid waste generator is responsible for (1) the satisfactory storage and collection of solid waste and (2) ensuring that the waste is disposed of at a site or facility which is permitted to receive the waste.

WELL DESIGN

Extensive design requirements and testing procedures are allowed for prevention of blow-outs. .0213(d) and .0213(3)(A).

WELL PLUGGING

Any injection well which has been abandoned, either temporarily or permanently, must follow procedures as stated in the regulations or other alternatives as specified by the Director. .0214.

RESTORATION OF SURFACE

Not addressed.

SURETY BOND

The permittee must maintain financial responsibility and resources, in the form of performance bonds or other equivalent forms of financial assurances approved by the Director, as specified in the permit, to close, plug, and abandon the injection operation. .0208.

References

North Carolina Administrative Code, Title 15, Chapter 2, Subchapter 2C, Section .0200.

Personnel Communications:

Nathanel Wilson, VIC Program Hydrogeologist,
Groundwater Section, Department of Natural Resources and Community Development (919) 733-3221

Carl Bailey, Department of Natural Resources and Community Development (919) 733-3221

OREGON

STATE REGULATORY AGENCIES

In Oregon nine agencies regulate or are authorized to review and approve geothermal activity:

- State Department of Geology and Mineral Industries
- Department of Water Resources
- Department of Environmental Quality
- Department of Land Conservation and Development
- Division of State Lands (on state lands)
- Department of Fish and Wildlife
- Division of Parks and Recreation
- Energy Facility Siting Council
- The County affected

GEOTHERMAL REGULATIONS

Oregon Revised Statutes (ORS) Chapter 522 gives the Department of Geology and Mineral Industries the authority to adopt rules governing the drilling, redrilling and deepening of wells for the discovery and production of geothermal resources. The Department also has the authority to adopt rules which govern disposal, by reinjection or other means, of geothermal fluids derived from geothermal resources from wells of 250 or more degrees Fahrenheit bottom hole temperature.

ORS Chapter 537 gives the Department of Water Resources the authority to adopt rules for the development, use and management of any groundwater, used for its geothermal properties, that is found in wells with bottom-hole temperatures less than 250° F (low-temperature geothermal resources).

Geothermal power plants greater than 25 MW require a site certificate from the Energy Facility Siting Council. Operation of such plants and disposal of production wastes, is provided for in ORS Chapter 469. Local governments can site plants under 25 MW in size.

The Department of Land Conservation and Development is responsible for ensuring that geothermal activities are consistent with Statewide planning goals.

Other agencies that may regulate geothermal resources include (1) the Division of State Lands for development on state lands; (2) the Bureau of Land Management for development on federal lands; (3) the U.S. Forest Service for development on national forest lands; and (4) the Health Division of the Human Resources Department for any heating system connected to a public or community water supply system, although at this time, no community has such a system.

Other regulations that may apply regulate air and water pollution control permits for geothermal well drillings and operations, and exploration, mining, and processing of geothermal resources in areas zoned for farm use. ORS 468.350 and 215.213.

PERMITS

The State Geologist must issue a permit before anyone drills a prospect well (less than 2,000 feet deep) or a geothermal well (greater than 2,000 feet deep). Well drilling permits, even on federal land, are issued by the Department of Geology and Mineral Industries. Protection of groundwater through well construction is included. Copies of both permit applications are circulated by the Department of Geology to the agencies cited on the first page of this Appendix. These agencies may suggest conditions for issuing permits. ORS.522.

The Department of Environmental Quality may require a National Pollution Discharge Elimination Systems Permit for effluent disposal to the surface (except for irrigation purposes).

The Department of Environmental Quality must issue a Water Pollution Control Facilities permit before reinjection whenever: (1) the reinjection is to a different aquifer than the producing aquifer; or (2) the receiving aquifer is of higher quality than the producing aquifer; or (3) contaminants are added to the effluent. The permit requirement may be waived for reinjection into the reservoir from which the fluid came if standards are met and tests are done to ensure that the fluid is uncontaminated. In general, it is state policy to inject spent fluids into production reservoir. The Department of Geology and Mineral Industries, the Department of Environmental Quality, and the Water Resources Department all work together on injection.

The Department of Environmental Quality issues disposal site permits. Section 459.205. The permits may be renewed. Section 459.270.

Energy facilities 25 MW and greater require an Energy Facilities Siting Council (EFSC) Site Certificate. EFSC is intended to be "one-stop" siting process. All above-cited state permits are issued as a part of a Site Certification. ORS Chapter 469.

Standards for the siting, construction and operation of geothermal power plants under EFSC are being developed. Adoption is likely later this year. Issue of wells as supporting facilities is resolved with DOGAMI given lead agency status for such.

EFSC sends application copies to state agencies and any local governments affected by the application. This coordination with other agencies makes siting a one-stop process for the applicant to satisfy Oregon requirements. The agencies must make provisions that they would normally make in their own permitting process. Any stipulations must be included as site certificate conditions, and once a site certificate is granted, the agency permits or licenses must be granted as a matter of course. The applicant, however, does need to apply directly for the necessary permits and licenses. The permitting agency retains the authority to enforce the requirements of the license.

A site certificate authorizes the applicant to construct and operate a geothermal plant under conditions set forth in the certificate. The signed certificate binds the state and all affected political subdivisions to approval of the site for construction and operation of the plant. All necessary permits and licenses must be issued, subject only to the conditions of the site certificate. EFSC can only initiate changes on a site certificate based upon a clear indication of danger to the public health and safety.

WELL DESIGN

Oregon Administrative Rules (OAR) 633-20-175 sets forth extensive requirements and testing procedures for well design. There are special low-temperature geothermal rules in OAR Chapter 690, Division 65. However, all rules in Chapter 690, Division 60-63 pertaining to well construction, maintenance, and abandonment also apply to low temperature geothermal wells.

DISPOSAL OF LIQUID AND SOLID WASTES

Two agencies, the Department of Geology and Mineral Industries and the Department of Environmental Quality, share responsibility through a memorandum of understanding which gives lead agency roles to each for different areas.

The Department of Geology and Mineral Industries has authority for regulating reinjection of geothermal fluids derived from geothermal resources. OAR 632-20-150(1).

The Department of Environmental Quality has authority for regulating other methods for disposal of fluids and wastes derived from geothermal operations. OAR 632-20-150(1).

Local government has the primary responsibility for planning solid waste management. Where the solid waste management plan of a local government unit has identified a need for a landfill disposal site, the state Department of Environmental Quality has responsibility for assisting local government and private persons in establishing the site. ORS 459.017 and ORS 459.047. As stated above, the Department of Environmental Quality also issues disposal site permits. ORS 459.205. When solid waste is no longer received at the site, it must be closed according to statutory requirements and any other requirements imposed by the department. ORS 459.268.

WELL PLUGGING

The State Geologist issues a permit before geothermal well are abandoned. The owner or operator must notify the State Geologist at least 24 hours before the proposed date for beginning abandonment procedures. The method of abandonment must be approved by the Department. OAR 632-20-125.

After discontinuance of use, a waste disposal well must be immediately plugged and sealed to prevent the well from being a channel for vertical movement of water and a possible source of contamination of the groundwater supply. 340-44-040.

RESTORATION OF SURFACE

The State Geologist must determine that the site has been restored as near as possible to its original condition, prior to granting approval for final abandonment of any well drilled for geothermal resources. OAR 632-20-125(2)(b).

SURETY BONDS

<u>For prospect wells</u> - Not less than $5,000 for each hole to be drilled or a blanket bond of $25,000 for all prospect wells which are included in the application. OAR 632-20-035(2).

<u>For geothermal wells</u> - A $10,000 bond for each well or a $50,000 bond for all wells to be drilled. OAR 632-20-035(1).

<u>For reinjection wells</u> - The operator must post a bond in compliance with OAR 632-20-035.

Bonds are conditioned upon compliance with proper abandonment procedures. OAR 632-20-035(3).

REFERENCES

Forcella, Lauren S., Low Temperature Geothermal Resource Management, Oregon Water Resources Department for Oregon Department of Energy, 1984.

State of Oregon, Chapter 522, Geothermal Resources Act, 1981, Department of Geology and Mineral Industries.

State of Oregon, Chapter 632, Division 20, Geothermal Regulations, Department of Geology and Mineral Industries.

State of Oregon, Water Resources Department, Low Temperature Geothermal Resources, 1984.

State of Oregon, Chapter 459, Solid Waste Control, Department of Environmental Quality.

State of Oregon, Chapter 340, Division 61, Solid Waste Management, Department of Environmental Quality.

Personal Communications:

Alex Sifford, Geothermal Program Manager, Resource Development Division, Oregon Department of Energy (503) 378-2778

Ernie Schmidt, Solid Waste Permits Division, Department of Environmental Quality (503) 229-5630

Marshall Gannett, Department of Water Resources, (503) 378-2778.

APPENDIX

SOUTH CAROLINA

STATE REGULATORY AGENCIES

Two agencies regulate the geothermal industry in South Carolina:

- South Carolina Water Resources Commission
- Department of Health and Environmental Control.

GEOTHERMAL REGULATIONS

Chapter 43 of Title 48, of the Code of Laws of South Carolina regulates oil and gas exploration, drilling, production, and transportation. Section 48-43-315 makes the above-referenced statute generally applicable to geothermal resources. Section 48-43-315 states "All provisions of this article regulating the leasing for, exploration for, drilling for, transportation of, and production of oil and gas and their products apply to geothermal resources to the extent possible. The provisions of this article do not apply to wells drilled for water supply only."

The Water Resources Commission's regulations implement the statutes. Although these regulations do not specifically address geothermal resources, these regulations would be applied to the extent possible as required by Section 48-43-315. Section 48-443-30 gives the Commission jurisdiction and authority to administer and enforce this Chapter.

The South Carolina Department of Health and Environmental Control regulates standards for industrial solid waste disposal sites and facilities in PC-SW-2. These regulations are promulgated pursuant to the authority contained in Sections 63-195 to 63-195.36, South Carolina Code of laws and cummulative supplement thereto.

The Pollution Control Act (Section 7) requires the South Carolina Pollution Control Authority to promulgate rules and regulations for the control of pollution. The Pollution Control Authority finds that improper disposal of solid waste pollutes the air and water within the meaning of the Pollution Control Act.

This regulation adopts the definitions set form in the Pollution Control Act of 1970 and adopts the following definition of Solid Waste: "Solid Waste includes garbage, refuse, litter, rubbish, or any waste material resulting industrial, commercial, agricultural, or residential activities not disposable by means of a sewerage system operated in accordance with State of South Carolina regulations."

Section 48-43-520 gives the Department of Health and Environmental Control the power to require containment and removal of pollution resulting from the transfer of pollutants and to otherwise deal with the hazards posed by such transfers. The Department of Health and Environmental Control has also applied for and received primacy from the EPA for the Underground Injection Control Program for all classes of Injection wells. Regulations for classes of injection wells are contained in R61-87. In addition, the Department regulates all wells (except as otherwise specified by State law) under the provisions of R61-71.

PERMITS

No one may explore for oil or gas without first obtaining an exploration permit from the South Carolina Resources Commission. 121-8.4. A well being drilled under an existing permit may be deepened if the existing permit is amended. A new well drilling permit is required to reopen and deepen a plugged and abandoned well. 121-8.5C. No well drilling permit can be issued within the corporate limits of any municipality until the governing authority of the municipality has approved the activity. 121-8.5D.

No system for land disposal of solid waste may be operated without a written permit issued by the State Board of Health. The Board may issue a special permit for disposal of essentially unit materials which do not contribute to pollution and which do not create vector problems or public health nuisances.

No system for the disposal of industrial solid waste may be operated in South Carolina without a written permit issued by the Pollution Control Authority. Applications for permits must be accompanied by an appropriate plan, where applicable, which must be in sufficient detail to support a judgment that the operation of the disposal system will not violate the Pollution Control Act.

Disposal of waste sludge and slurries must be done with special consideration of air and water pollution, and the health and safety of employees. Provisions acceptable to the Pollution Control Authority must be madew for the handling of these waste materials on a case by case basis.

A permit must be obtained from the Department of Health and Environmental Control prior to constructing, operating or using any Class V.A. well for injection. R61-87.13. Class V.A. wells are defined, in part, as "...(f) injection wells associated with the recovery of geothermal energy for heating, aquaculture or production of electric power..." R61-87.11E(f).

No well drilling permits are required under Well Standards and Regulations, R. 61-71. However, the water Resources Commission's Regualtions require well drilling permits for any well, as well as defined in those regulations. R.121-8.5.

SOLID AND LIQUID WASTE DISPOSAL

In addition to the above, the Water Resources Commission's regulations at R.121-8.26, require that after a well has been abandoned, all the drilling mud remaining in the pits must be returned to the well on location or an acceptable adjacent well, or removed to a lawfully approved landfill, or disposed of as directed by the Commission within 90 days of completion of the well, except as otherwise approved by the Commission.

WELL DESIGN

Adequate blow-out preventers and high pressure fittings for keeping the well under control must be attached to anchor and cement casing strings. R.121-8.15. Production testing procedures are required. R.121-8.19. Design requirements for injection wells also apply. R.121-8.22.

Construction, development and materials specifications are outlined in Well Standards and Regulations R.61.71.6 and R. 61-71.7

WELL PLUGGING

When any well is temporarily abandoned, it must be sealed with a watertight cap or seal. The well must be maintained so that it does not become a source or channel of contamination. When the well is permanently abandoned, it must be filled with sand or gravel to within twenty feet of the surface and the remainder filled with cement grout or compacted clay for bored holes. R.61-71.10.

The Underground Injection Control Regulations specify that 180 days advance notice must be given to the Department prior to plugging or abandoning any injection well. A plugging plan must be submitted to the department. Prior to receiving final approval to abandon the injection well, the permittee must demonstrate that movement of fluids between underground sources of drinking water will not occur R61-87.15.

RESTORATION OF SURFACE

All pits and sumps must be properly filled, compacted and leveled, in such a manner so as to be returned to a near natural state. 121.8.26.D.

The UIC regulations specify that the permitte must take all reasonable steps to minimize or correct any adverse impact on the environment resulting from noncompliance with the permit. R61-87.13X.(2).

SURETY BOND

The Water Resource Commission's regulations require a reasonable performance bond before a well drilling permit is granted. The amount of the bond is based on the proposal depth of the well as follows:

Depth In Feet	Amount of Bond Required
0 - 10,000	$20,000
10,000 - 15,000	$30,000
15,000 - 20,000	$40,000
20,000 or more	$50,000

Alternatively, ablanket bond of $100,000 may be allowed.

REFERENCES

South Carolina Well Standards and Regulations R.61-71, Department of Health and Environmental Control.

South Carolina Underground Injection Control Regulations R61-87.

Code of laws of South Carolina Chapter 43 of Title 48, 1976, Water Resources Commission

Personal Communications:

Paul S. League, Legal Counsel, Water Resources Commission (803) 737-6550

Michael E. Rowe, Department of Health and Environmental Control (803) 734-5000

Don Duncan, Director, Groundwater Protection Division, Department of Health and Environmental Control (803) 734-5332

SOUTH DAKOTA

One agency regulates potential geothermal activity in South Dakota:

- South Dakota Department of Water and Natural Resources

GEOTHERMAL REGULATIONS

There are no injection wells used in conjunction with geothermal activities in the State of South Dakota. However, any use of injection wells in conjunction with geothermal energy would be treated as Class V wells and would be regulated by the South Dakota Department of Water and Natural Resource's Board of Water Management. Any geothermal use of water, if more than 18 gallons per minute, would be regulated by the South Dakota Board of Water Management's Division of Water Rights. Solid waste disposal is regulated by the South Dakota Department of Water and Natural Resource's Office of Air Quality and Solid Waste.

Well construction and plugging procedures are outlined in the South Dakota Well Construction Standards.

PERMITS

A water permit is required from the South Dakota Board of Water Management for use of water, except that no permit is required for water distribution systems diverting 18 gallons per minute or less or for geothermal heat for a single household. SDCL 46-1-15,46-5-9, 46-5-10.

A permit must be obtained before construction of a well for which a water permit is required. 74:02:04:21. In this situation, the well owner must obtain a permit for use of water, as specified above. No other construction permits are required.

In general, local governments are responsible for waste management. Standards and liabilities for nonhazardous solid waste management are defined by the local or regional authority. Section 74:27:02:02.

<u>WELL DESIGN</u>

The Well Construction Standards for the State of South Dakota specify minimum cement grouting requirements for wells; (74:02:04:28); other construction standards concerning well casing (74:02:04:42); and pump installation (74:02:04:60). Also, wells must be developed by a method which will remove drilling mud or other aquifer material that will pass through the screen openings or casing perforations.

The Water Rights Law, Section 46-6-10, specifies that wells must be constructed to prevent underground leakage of waters into other reservoirs. The Water Management Board may specify methods of construction or other control devices necessary to prevent waste.

DISPOSAL OF LIQUID AND SOLID WASTES

As previously stated, solid waste disposal is regulated by local governments. Standards and liabilities for frequency of collection, temporary storage solid waste specifications, and maintenance of storage containers are defined by the local or regional person in charge of solid waste management. Section 74:27:02:02. Political subdivisions or regions may apply for solid waste grants for the purpose of developing and implementing an approved solid waste management system plan. Section 74:27:06:02.

Class V wells may inject subject to the provisions governing the prevention of pollution of the waters of the state. Section 74:03:12:03.

WELL PUGGING

The Well Construction Standards for the State of South Dakota specify requirements for plugging artesian wells and test holes with cement grout. Section 74:02:04:67 and Section 74:02:04:68.

The Water Rights Law Section 46-6-18 specifies that any abandoned or forfeited well must be plugged by its owner so that no leaking of its waters occurs underground or over the surface.

RESTORATION OF SURFACE

Not addressed in the regulations reviewed.

SURETY BOND

Not addressed in the regulations reviewed.

REFERENCES

State of South Dakota, Article 74:27, Solid Waste, Chapter 74:27:01, Administration, Department of Water and Natural Resources.

State of South Dakota, Chapter 34A-6, Solid Waste Disposal, Codified Laws, Department of Water and Natural Resources.

State of South Dakota, Article 74:02, Water Rights, Chapter 74:02:01, General Rules, Department of Water and Natural Resources.

State of South Dakota, Chapter 1-40, Water Rights Law, Sections 1-40-15 through 1-40-20, Chapters 43-17 and 46-1 through 46-10A, 1986.

State of South Dakota, Article 74:03, Underground Injection Control - Class I, IV and V wells, Chapter 74:03:12, Department of Water and Natural Resources.

State of South Dakota, Chapter 74:02:04, Well Construction Standards, 1985.

Personal Communications:

Barbara K. Hershly, Hydrologist, Office of Water Quality, Department of Water and Natural Resources (605) 773-3296.

Ron Duvall, Natural Resources Engineer, Water Rights Division, Department of Water and Natural Resources (605) 773-3352.

APPENDIX

TEXAS

STATE REGULATORY AGENCIES

The Texas Railroad Commission, Oil and Gas Division, regulates most areas of the geothermal industry in Texas. The one area which lies outside the Railroad Commission's jurisdiction is the use of groundwater heat pumps, which is regulated by the Texas Water Commission.

GEOTHERMAL REGULATIONS

The following sections of the Texas Annotated Code (TAC) apply to oil, gas, and geothermal wells in Texas:

- 16 TAC, Section 3.5 provides guidelines for the application to drill, deepen, or plug back a well.
- 16 TAC, Section 3.13 gives well design requirements, specifically for casing, cementing, drilling, and well completion.
- 16 TAC, Section 3.8 related to water protection, defines the types of pits that can be used and operational requirements for the pits.
- 16 TAC Section 3.9 sets regulations for injection wells used for disposal.
- 16 TAC Section 3.46 sets regulations for fluid injection into productive reservoirs.
- 16 TAC Section 3.14 establishes well plugging and abandonment procedures.

The Texas Railroad Commission promulgates and enforces all of the above rules.

PERMITS

An application is needed to drill, deepen, or plug back any oil, gas, geothermal, exploratory, or fluid injection well. The application must be made to and filed with the Railroad Commission on an approved form. Operations may not commence until the permit is granted by the Commission. 16 TAC 3.5.

Permits from the Railroad Commission are required for anyone who engages in fluid injection operations in reservoirs productive of oil, gas, or geothermal resources. 16 TAC 3.46.

Oil, gas, or geothermal resource wells drilled for exploratory purposes shall be governed by provisions of statewide or field rules applicable to drilling, safety, production, abandoning, and plugging of wells. 16 TAC 3.8. Since Texas does not have NPDES jurisdiction, NPDES permits must be obtained from EPA for waste discharges.

WELL DESIGN

There are extensive requirements for well casing, cementing, drilling, and completion. In all instances, casing must be securely anchored, with usable-quality water zones sealed off to prevent contamination, and potentially productive zones isolated to prevent fluid migration. Casing must be hydrostatically pressure-tested steel. Wellhead assemblies are required to maintain surface control. A blowout prevention unit or control head is also required. Surface, intermediate, and production casing are all required; specifications for type, installation, and testing apply. 16 TAC 3.13.

Several types of pits can be used during drilling operations:

- Reserve pits, used in conjunction with the drilling rig for collection of spent drilling fluids, cuttings, sands, silts, and wash water used for cleaning the drill pipe and other equipment at the well site.
- Mud circulation pit, used for storage of drilling fluid currently being used in the drilling operation.
- Drilling fluid storage pit, used for storage of drilling fluid which is not currently being used, but which will be used in future drilling operations. Drilling fluid storage pits are often located centrally among several leases.

Drilling fluid storage pits require a permit; mud circulation and reserve pits do not. 165 TAC 3.8. Other types of pits for solid and liquid waste storage and disposal are described in the following section.

SOLID AND LIQUID WASTE DISPOSAL

Disposal of geothermal resource fluids, mineralized waters, brines, and drilling fluids, by any method, is not allowed without a permit.

The following types of pits can be used for storage and disposal of liquid and solid waste, as specified:

- Collecting pit, used for storage of saltwater prior to disposal at a tidal disposal facility, disposal well, or fluid injection well.

- Drilling fluid disposal pit, used for disposal of spent drilling fluid.

- Completion/workover pit, used for storage or disposal of spent completion fluids, workover fluids, drilling fluid, silt, debris water, brine and other materials which have been cleared out of the well bore.

- Saltwater disposal pit, used for disposal of produced saltwater.

Saltwater disposal pits, collecting pits, and drilling fluid disposal pits require a permit from the Railroad Commission. Completion/workover pits do not require a permit; an operator may, without a permit, dispose of wastes in a completion/workover pit, provided the wastes have been dewatered, and they are disposed of at the same well site at which they are generated.

Other types of disposal methods which are authorized without a permit are: disposal of freshwater condensate, disposal of inert wastes (such as glass and concrete), low chloride drilling fluid (less than 3,000 mg/L), drill cuttings, sand, and silt. These types of wastes can be landfilled, provided the landfill is on the site where the wastes were generated and the operator has written permission of the landowner. Water-base drilling fluids with more than 3,000 mg/L chloride, but which have been dewatered, may be disposed of by burial in the same way.

There are extensive dewatering, backfilling, and compacting requirements for the wastes, depending on the classification of the pit. 16 TAC 3.8.

Saltwater may be disposed of by injection into nonproducing zones of oil, gas, or geothermal resources bearing formations that contain water mineralized by processes of nature to such a degree that the water is unfit for domestic, stock, irrigation, or other general uses. Before such formations are approved for disposal use, the applicant must show that formations are separated from freshwater formations by impervious beds. The applicant must submit a letter from Texas Department of Water Resources stating the above. 16 TAC 3.9.

WELL PLUGGING AND ABANDONMENT

Notification of intention to plug any well drilled for oil, gas, or geothermal resources or for any other purpose must be given in writing to the Railroad Commission five days prior to plugging. The notification must include the proposed procedure and complete casing record.

The landowner/operator may file an application to convert an abandoned well for usable-quality water production operations, provided he is willing to assume responsibility for eventual plugging.

General plugging requirements are as follows: Cement plugs must be set to isolate each productive horizon and usable-quality water strata. Plugging must proceed according to

American Petroleum Institute Standards. Specific plugging procedures may apply when well fluids are high temperature, highly saline,and/or corrosive. A ten-foot cement plug must be placed in the top of the well, cut off three feet below the surface. Mud-laden fluids must be placed in all portions of the well not filled with cement. Additional specific requirements apply for wells with surface, intermediate, and/or production casing, and open-hole completions. 16 TAC 3.14.

SURFACE RESTORATION

Requirements for surface restoration are not addrssed specifically in the regulations; they are usually included in the lease agreements.

SURETY BOND

Bonds are not required before wells are drilled. However, a bond will be required for an extension of time to plug an inactive well. A one-year extension may be granted beyond the 90 day time limit for plugging an inactive well if the owner/operator posts a bond in the dollar amount equal to $1.50 per foot times the total depth of the well. Statewide Rule 14-B.

REFERENCES

State of Texas, Statewide Rule 9, Disposal Wells, Railroad Commission of Texas, Oil and Gas Division

State of Texas, Statwide Rule 8, Water Protection, Railroad Commission of Texas, Oil and Gas Division

Texas Annotated Code 16, Section 3.14, Plugging, Railroad Commission of Texas, Oil and Gas Division

Texas Annotated Code 16, Section 3.13, Casing, Cementing, Drilling, and Completion Requirements, Railroad Commission of Texas, Oil and Gas Division

Texas Annotated Code 16, Section 3.5, Guidelines for Drilling, Railroad Commission of Texas, Oil and Gas Division

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APPENDIX

UTAH

STATE REGULATORY AGENCIES

One agency regulates the geothermal industry in Utah:

- The Division of Water Rights, Department of Natural Resources.

GEOTHERMAL REGULATIONS

The Geothermal Resource Conservation Act of 1981 assigns regulatory authority regarding the development of geothermal resources to the Division of Water Rights.

The Rules and Regulations of the Division of Water Rights for Wells Used for the Discovery and Production of Geothermal Energy in the State of Utah gives the Division of Water Rights the authority to regulate all wells for the discovery and production of water to be used for geothermal energy. These rules and regulations are in the process of being revised and at this time, they are not available in draft form.

The Utah State Department of Health, Division of Environmental Health regulates solid waste disposal. The regulations are based on statutory authority conferred by Section 26-14, UCA, as amended, and are enforceable throughout the state. The regulations are designed for adoption and enforcement by local health departments in cooperation with the State Department of Health for the purpose of establishing minimum requirements for the disposal of solid wastes. The term "solid wastes" is defined as garbage, trash and other wastes generated by daily living processes and also includes those produced in commercial, industrial and agricultural operations.

PERMITS

Before drilling an exploratory or production well, an applicant must submit a plan of operation to the State Engineer for approval. These plans must include the methods that the applicant intends to use for disposal of waste materials. Rule 2-1-2. If the owner plans to deepen or modify an existing well, an application must be filed with the Department and written approval received, except in an emergency where the owner must take action to report damage and report his action to the Division as soon as possible. Rule 2-1-3. A permit is also required to convert an existing geothermal well into an injection well. Rule 2-1-4. Permits may be amended upon approval by the State Engineer. Rule 2-1-5. Rule 6-2 requires a permit to abandon a geothermal resource well.

WELL DESIGN

Extensive design requirements and testing procedures must be implemented as precautions against blowout. Rule 2-7 and Rule 3.

DISPOSAL OF SOLID AND LIQUID WASTES

As stated above, the plan of operation must include the methods that the applicant will use for disposal of waste materials. Rule 2-1-2. The owner or operator of a proposed injection well must provide the Department with information necessary to evaluate the impact of injection on the geothermal reservoir and other natural resources. Rule 5-1.

The Utah Code of Solid Waste Disposal specifies that is is unlawful to deposit any solid waste in any place except at a site which has been designated by a city, county, district, or other properly designated agency, and approved by the Utah State Department of Health.

WELL PLUGGING

A notice of intent to abandon must be filed with the Division five days prior to beginning abandonment procedures. Rule 6-2a. A history of geothermal resource wells must be filed within 60 days after completion of abandonment procedures. Rule 6-26. All abandoned wells must be marked and the description of the marker must be included in the history of the well report. Rule 6-2c. Marker and plugging specifications are required. Rule 6-2c - 6-2k. Injection wells must be abandoned in the same manner as other wells. Rule 6-21.

RESTORATION OF SURFACE

The owner is required to rehabilitate disturbed lands. Rule 9-7. Also, a bond is required for proper abandonment in order to:

a. Prevent contamination of fresh waters or other natural resources;

b. Prevent loss of reservoir energy;

c. Prevent damage to geothermal reservoirs, and

d. Protect life, health, environment and property. Rule 6-1.

SURETY BOND

Rule 2-3-1 requires a surety bond of $10,000 per individual well, or a $50,000 blanket bond for all wells, to ensure compliance with plugging and abandonment procedures.

REFERENCES

Utah Code of Solid Waste Disposal Regulations, June 20, 1981, State Department of Health, Division of Environmental Health

Utah Geothermal Resource Conservation Act, 1981

Utah Rules and Regulations of the Division of Water Rights for Wells Used for the Discovery and Production of Geothermal Energy in the State of Utah, 1978

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APPENDIX

VIRGINIA

STATE REGULATORY AGENCIES

The Virginia Department of Mines, Minerals and Energy regulates geothermal operations in Virginia.

GEOTHERMAL REGULATIONS

The Geothermal Energy Regulations, adopted by the Director of the Department of Mines, Minerals and Energy are the primary regulatory guidelines for the exploration, development, and production of geothermal energy. The regulations are promulgated pursuant to Title 45.1, Chapter 15.1, Code of Virginia, and in accordance with the provisions of Title 9, Chapter 1.1:1, Administration Process Act. The regulations cover geothermal resource conservation, permits and fees, plans for operation, well construction and maintenance, well plugging and abandonment, and environmental protection.

PERMITS

Section 3.B of the Virginia Geothermal Energy Regulations requires that geothermal operators obtain a permit for any exploration, production, or injection activities. Along with the application for a permit for exploration, the application must include an inventory of local water resources in the area of proposed development.

A notice of intention to proceed with geothermal production or injection must be filed with the Department, in accordance with the provisions of Section 4. The notice of intent must be accompanied by: (1) an operations plan, (2) a geothermal fluid analysis, and (3) a proposal for injection of used geothermal fluids. The operations plan must consist of detailed information about the site and proposed activities, such as a map of the site, geologic report, method for erosion control, and methods for disposal of all liquid and solid wastes.

WELL DESIGN

Requirements for well construction and maintenance are contained in Section 5 of the regulations. There are extensive requirements for casing and cementing of both projection and injection wells. There are also provisions for the protection of underground freshwater zones. Developers are required to use drilling mud and pressure valves to prevent blowouts. When working pressures on the wellhead connection exceed 1,000 psi, blowout preventers must be used during drilling. Because of the rarity of high-pressure zones in Virginia, more sophisticated blowout-prevention equipment is not required. The regulations require operators to keep well logs during every phase of drilling and production. Logs must identify each well, and include a record of casings, formations encountered, deviation tests, cementing procedures and downhole geophysical information.

DISPOSAL OF SOLID AND LIQUID WASTES

Plans for disposal of all wastes resulting from geothermal operations must be included in the operations plan. All wastes must be handled in such a way as to prevent fire hazards or pollution of surface and groundwater, in accordance with state and federal laws. Geothermal fluids must be injected into the same formation from which they were drawn using a method specified in the regulations. Drilling muds must be removed from the drilling site when the well is completed, and disposed of as specified in the operations plan. All methods of disposal must comply with applicable state and federal laws and regulations.

WELL PLUGGING

Notice of intent to abandon any exploration, production, or injection well must be given at least one day before beginning plugging operations. Specific plugging procedures apply. If drilling operations are suspended for 60 days, the well shall be plugged unless permission for temporary abandonment is given by the Inspector. A written report must follow any plugging operation.

RESTORATION OF SURFACE

The operations plan must present the intended plan for reclamation of land at the production and injection sites. The drilling site and any associated pits must be reclaimed within one year after drilling ceases.

SURETY BONDS

A $10,000 completion bond from a surety company is required for each exploratory and injection well, and a $25,000 bond for each production well. Blanket bonds of $100,000 may be granted. Return of the bonds are conditional upon plugging and abandonment, reclamation, and general compliance with regulations. Land stabilization bonds of $1,000 per acre are required, and are held until drilling and reclamation is completed.

REFERENCES

Virginia Department of Mines, Minerals, and Energy. Geothermal Energy Regulations. May 1, 1984.

Personal Communications

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APPENDIX

WASHINGTON

STATE REGULATORY AGENCIES

Two agencies regulate the geothermal industry in Washington:

- The Washington State Department of Natural Resources administers and enforces most regulations on geothermal activities.
- The Washington State Department of Ecology administers and enforces regulations relating to discharge of produced formation fluids.

GEOTHERMAL REGULATIONS

Washington has specific legislation for geothermal operations in the form of the Geothermal Resources Act (GRA) of 1974. The Act was passed to "further the development of geothermal resources for the benefit of all of the citizens of the state while at the same time fully providing for the protection of the environment." There are provisions for exploration, drilling, production, and abandonment operations, as well as for prevention of damage due to wastes generated from geothermal resources, and for the protection of underground and surface waters, land, and air.

The regulatory authority of the Department of Natural Resources is stated in the introductory paragraph of the Geothermal Resources Act. The regulatory code which the Department promulgates and enforces is in Chapter 332-17 WAC, Geothermal Drilling Rules and Regulations. General rules are statewide in application unless otherwise stated.

PERMITS

Written applications must be filed for a permit to commence drilling, redrilling an abandoned hole, or deepening a hole. Application details must include proposed drilling and casing, survey plat, methods of disposing of waste materials, and a narrative statement describing proposed measures to be taken for protection of the environment. Any well drilled for production is subject to fees, public notice, and possibly a public hearing. A well drilled only for the purpose of obtaining geothermal data must be permitted, but is not subject to fees, notice, or a public hearing, unless the hole is more than 750 feet deep, or in the event that a geothermal zone is discovered. No well will be permitted that will unreasonably decrease access to groundwater for which prior water rights exist. WAC 332-17-100 and GRA Sec. 7,8.

WELL DESIGN

All wells must be equipped with casing and safety devices, as approved by the Department. Specifications are given for surface, intermediate, and production casing, as well as the cementing of the casing. Blowout equipment must be installed, tested immediately, and properly maintained until the drilling operation is complete. The various components required for the blowout prevention unit are described in detail. Sufficient drilling fluid to ensure well control must be maintained in the field area readily accessible for use at all times. The drilling hole must be reasonably full at all times, and a drilling fluid monitoring system is required. Mud cooling techniques must be used as necessary, and mud testing and treatment is required daily. WAC 332-17-110, -120, -130, and GRA Sec. 9.

The owner or operator must provide pits or sumps of adequate capacity and design to retain all fluids and materials necessary to drilling, production, and related operations. There are no specific requirements for lining. When no longer needed, the pits and sumps must be pumped out and the contents disposed of at approved sites. The pits cannot be allowed to contaminate any fresh water bodies, groundwater, cause harm to the environment, persons, or wildlife, or adversely affect the aesthetic value of the area. WAC-332-17-460.

DISPOSAL OF SOLID AND LIQUID WASTES

The application for permit to commence drilling, redrilling, or deepening requires a written plan including a method for disposal of wastes. Waste disposal is then addressed specifically by the affected county, usually through the Department of Public Health, and the Department of Ecology under the State Environmental Policy Act, and disposers are subject to the rules and regulations of each of those agencies.

Surface Disposal

The Department of Ecology sets conditions under which it will grant a categorial exclusion for a class of waste: the class must be exempt under RCRA, and either (1) the class has been demonstrated beyond reasonable doubt to pass all DOE's tests for designation as dangerous, or (2) the class has been identified by DOE as one which would be inappropriate to regulate, due to considerations which demonstrate that the waste class does not pose a threat to public health and the environment. A temporary exclusion was initially provided for oil, gas and geothermal waste. However, due to a lack of sufficient information on drilling fluids, produced waters, and other wastes associated with oil, gas, and geothermal activities, these wastes are now subject to dangerous waste designation tests under WAC, Chapter 173-303. Under DOE's procedures, a waste may be designated a dangerous waste by way of three mechanisms:

1) Dangerous Waste Lists (WAC 173-303-081 through 173-303-084);

2) Characteristics of Dangerous Wastes, including EP Toxicity Test (WAC 173-303-090)

3) Damgerous Waste Criteria (WAC 173-303-101 through 173-303-103).

Wastes must be checked against the various lists and characteristics for chemical constituents and their concentrations to determine if they are designated wastes. Produced wastes from geothermal operations generally are not designated dangerous waste. Some drilling fluids have been designated by charateristics of EP Toxicity, notably high concentrations of barium and chromium.

Concentrations higher than the threshold values for primary drinking water standards (arsenic, barium, cadmium, hexavalent chromium, lead, and mercury) can also result in designation as a hazardous waste. DOE has set concentrations for other chemical constituents found in drilling fluids which could result in dangerous waste designation:

Compound	Concentration* in Waste Which Could Cause Book Designation
Sodium Chloride	10%
Calcium Hydroxide	10%
Sodium Pentachlorophenate	0.01%
Sodium Hydroxide	1.0%
Sodium Bichromate	1.0%
Sodium Bicarbonate	10%
Ammonium Nitrate	10%
Ammonium Bisulfate	10%

*Concentration would be a weight/weight ratio.

Any wastes which are designated as dangerous will be subject to applicable waste management standards. Current management practice for non-hazardous wastes are either to backfill them in practice for non-hazardous wastes are either to backfill them in a pit, or to landspread them and incorporate them into surface soils. These practices are permissble under the state's dangerous waste regulations, but the conditions are more stringent. Liners and caps for disposal pits, groundwater monitoring, and financial assurances for well closure are all required. Management standards provide for less stringent requirements if geothermal wastes are identified by DOE as moderate risk.

Subsurface Disposal

DOE is the primary regulator of liquid waste disposal by injection, although the Department of Natural Resources and the Oil and Gas Conservation Commission provide technical and enforcement assistance to DOE for permit and compliance assurance, and corrective action.

Geothermal injection wells are Class V for the state. A State Waste Discharge Permit must be issued by DOE. Any permit issued by the Department must specify conditions necessary to prevent and control injection of fluids into the waters of the State, and conditions necessary to preserve underground sources of drinking water. WAC-173-218-090.

WELL PLUGGING AND ABANDONMENT

Plugging and abandonment are required when: (1) it is not technologically practical to derive energy to produce electricity commercially, or (2) usable minerals cannot be derived, or owner has no intention of deriving usable minerals. Before proceeding with any plugging and abandonment operations, the owner/operator must file a Notification of Abandonment with the Department for approval of methods. Adequate measures to protect the environment and aesthetic qualities of the disturbed areas are required. All wells to be abandoned must have cement plugs placed in the well as prescribed in the regulations. Open holes must have cement plugs placed across fresh water zones and geothermal resource zones, to isolate formations and to prevent migration and contamination of fluids.

In the event that the abandoned well will be converted to a water well, jurisdiction over the well may be transferred to the Department of Ecology, if that department is willing to assume responsibility for it. This relieves the owner of further compliance with the Geothermal Resources Act, but now makes the owner subject to applicable laws and regulations for groundwater wells. WAS 332-17-200, -300, -310, and GRA Sec. 10.

RESTORATION OF SURFACE

Cellars, pads, structures, and other facilities related to geothermal operations must be removed. The surface must be restored to its natural condition, or to such a condition as prescribed by the Department of Natural Resources. Surface grading and revegetation is the responsibility of the owner or operator. WAC 332-17-300 and GRA Sec. 3(13).

SURETY BONDS

A performance bond, cash deposit, negotiable securities, or an assignment of a savings account is required. A $15,000 bond is required for one well; a $50,000 blanket bond covers a group of wells. Termination or cancellation of any bond will not be permitted until the well, or wells, for which the bond has been issued have been properly abandoned or another valid bond for such well or wells has been submitted and approved by the Department. WAC-332-17-160.

REFERENCES

WAC, Chapter 173-303, Dangerous Waste Regulations. Amended June 1986. State of Washington, Department of Ecology. Olympia, WA 98504

WDOE Position Paper: Discussion of Bases for Not Excluding Oil, Gas, and Geothermal Exploration, Development and Production Wastes. March 1984.

State of Washington, Substitute House Bill No. 135, Geothermal Resources Act. January 24, 1974.

WAC, Chapter 332-17, Geothermal Drilling Rules and Regulations.

WAC, Chapter 173-218, Underground Injection Control Program.

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