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HOT DRY ROCK GEOTHERMAL RESOURCE OWNERSHIP AND THE LAW

LOS ALAMOS SCIENTIFIC LABORATORY
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HOT DRY ROCK GEOTHERMAL RESOURCE OWNERSHIP AND THE LAW

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ABSTRACT

This report provides a basis for changing the design of some legislative definitions of geothermal energy to allow the emergence and implementation of a hot dry rock geothermal energy-producing technology. A study of existing federal and state geothermal statutes has been conducted to determine the extent to which legislation acts to constrain the commercialization of this particular technology. A definitional problem has been identified and a solution presented. This report clarifies the distinctions between the several geothermal resources, describes the recognized resource ownership problem and present state of the law, and presents a solution for consideration including a discussion that establishes the reasons for change.

I. INTRODUCTION

Geothermal energy is the heat that exists within the earth. This heat causes many of the geologic processes that have contributed to shape the earth's surface and created many natural wonders. The motion of the earth's crustal plates, uplifting of mountain ranges, eruption of volcanos, occurrence of earthquakes, and spewing of geysers all owe their origin to the earth's internal heat.

The temperature within the earth's crust rises with increasing depth. This causes a steady outward flow of heat to the surface, where it is radiated to space and lost. Molten or semimolten rocks exist everywhere under the continents at depths ranging from 12.4 to 25 miles (20 to 40 km). For comparison, using present drilling technology, holes can be drilled to depths of about 6.2 miles (10 km) under good drilling conditions.

Geothermal areas are those in which higher than normal temperatures are found at shallower depths. Heat is usually brought to or near the surface by convective circulation of ground water. If temperatures are high enough, steam may be produced, and geysers, fumaroles, and hot springs are common surface geothermal manifestations.

According to the US Geological Survey and other scientific authorities, the geothermal resource is very large in terms of recoverable heat energy, as shown in Figs. 1 and 2.

A. Geothermal Resource Systems

Table I presents a view of geothermal resources characterized by type and temperature.

1. Hydrothermal Systems. Hydrothermal resources are those in which the earth's heat is carried upward by the convective circulation of hot water or

Fig. 1. Comparison of several domestic energy resource bases.1

steam. Whether or not steam actually exists in the geothermal reservoir depends on the temperature and pressure conditions at depth. Presumably the heat is provided by a deeper body of still molten or recently solidified rock that is very hot. Hydrothermal systems may be further characterized as vapor-dominated or liquid-dominated.

a. Vapor-Dominated. Convecting water brings a large amount of heat nearer the surface to a region where boiling takes place at a temperature of approximately 480°F (250°C) under the prevailing pressure conditions. Boiling takes place in a deep subsurface water table as well as in pore spaces within the reservoir. Vapor moves upward and is superheated further by the hot surrounding rock. If an open fracture penetrates far enough, steam may vent to the surface. A well drilled into such a reservoir would produce superheated steam at the surface.⁴

The Geysers geothermal area in northern California is an example of a vapor-dominated resource. Dry steam is produced from depths of 5000 to

Fig. 2. Preliminary areas of known geothermal resources other than geopressured.²

TABLE I
GEOTHERMAL RESOURCES³

<u>Resource Type</u>	<u>Temperature Characteristics</u>
Hydrothermal	
a. Vapor-dominated	above 240°C
b. Liquid-dominated	
High Temperature	150° to 300°C
Intermediate	90° to 150°C
Low temperature	less than 90°C
Hot dry rock	90° to 650°C
Magma	higher than 650°C
Geopressured	150° to 200°C

10 000 feet (1525 to 3050 m), and this steam is fed directly to the turbine generators that produce nearly 1000 MW of electricity.

b. Liquid-Dominated. The source of heat beneath a liquid-dominated system is either molten rock or rock that has solidified in recent thousands of years. This rock lies at a depth of 15 000 to 35 000 feet (4575 to 10 670 m). Natural ground water circulates in open fractures and removes heat from the deep, hot rock by convection. Temperatures are uniform over large volumes of the reservoir. Recharge of cooler ground water takes place at the margins of the system through circulation down interconnected fractures. Surface manifestations of such a system might include hot springs, fumaroles, or geysers, or there may be no surface manifestation whatsoever. A well drilled into such a geothermal system would likely encounter tight, hot rock with water inflow mainly along open fractures.

Virtually all of industry's current geothermal exploration efforts are presently directed at locating vapor- or liquid-dominated hydrothermal systems having temperatures above 392°F (200°C). These are the only resources that are obviously capable of commercial electrical power generation.

The fringe areas of high-temperature vapor- and liquid-dominated hydrothermal systems often produce water of low and intermediate temperature. These lower temperature fluids are more suitable for direct heat applications in space heating, agriculture, or food and chemical processing rather than for power production.⁵

2. Hot Dry Rock Systems. Hot dry rock (HDR) has been defined as naturally heated, unmelted crustal rock, which does not produce natural steam or hot water. At varying depths and temperatures, HDR is everywhere beneath the earth's surface. Estimates indicate that beneath the land surface of the US at depths up to 6.2 miles (10 km), the HDR resource base contains approximately 32 million quads of energy, with 40% (approximately 13 million quads) at temperatures above 300°F (150°C). If as much as 2% of this vast resource base could be exploited economically, it would supply the entire country's nontransportation energy needs at the present rate of consumption for more than 2000 years.⁶

The production technique for HDR is diagrammed in Fig. 3. It requires that a borehole be drilled into low-permeability, hot crystalline rock and

Fig. 3. An HDR system.⁷

that a large, hydraulically fractured region be created near the bottom of this borehole. A second borehole is drilled along a trajectory to intersect the fracture and complete the underground portion of the circulation loop. Pressurized fluid, in this case water, is then pumped down one borehole to the reservoir, where it is heated as it flows across the fractured hot rock. The water, now at elevated temperatures, is brought to the surface and directed through heat exchangers before being recycled through the system. The heat energy that is extracted can be used directly or for generating electricity.

A recent survey of regional heat flow data indicates that an area of about 95 000 miles² (2.46×10^7 km²) in the 13 western states is underlain at a depth of 16 400 ft (5 km) by HDR at temperatures above 555°F (290°C). At these temperatures, geothermally heated water could be used to produce electricity or for industrial processes. Lower temperature rock could be used to heat water for space heating and food processing. This is an efficient system that appears to present minimal water loss, low noise levels, no air pollutants or solid waste, and few of the environmental problems associated with other energy resources.

3. Magma Systems. The extreme case of HDR is a molten lava or magma system that may exist at temperatures higher than 1200°F (650°C) in a pool at the surface or in a contained reservoir at some depth below a recently or potentially active volcano. Aside from a few located in national parks, the existence and depths of such bodies in the earth's crust are generally speculative, but practical means of extracting heat from them are being investigated. However, there is now evidence that magma bodies exist in places where they might be available for commercial development.⁸ If, in fact, some are found at accessible depths, their heat content may be so high that they will add greatly to the country's already large geothermal resource base.

4. Geopressured Systems. A geologically unique combination of factors involving the rapid accumulation and compaction of great quantities of water-filled sand and shale has resulted in the creation of overpressured aquifers referred to as geopressured zones. The water in these zones, occurring at 10 000 to 15 000 feet (1000 to 6000 m) below the surface, possess abnormally high temperatures. These fluids are isolated from shallower permeable zones by impermeable shale and support a large overburden load causing dramatic increases in the pressure within the containing zone. A normal pressure gradient of 0.465 psi/ft is found above these regions, but abnormal pressures (as high as 0.98 psi/ft) are encountered within the geopressured region itself. This pressure gradient indicates possible pressures in the range of 10 000 to 12 000 psi.

The principal geopressured zones are along the gulf coast of Texas and Louisiana as shown in Fig. 4. They are long, linear, high-volume aquifers

Fig. 4. Area of potential geopressed geothermal resources.⁹

compartmentalized by subsidence faults. These zones extend inland approximately 100 miles (161 km) from the coast and occur in successive parallel bands southward into the Gulf of Mexico. The top of the zone begins at depths of about 8 000 to 10 000 feet (1400 to 3000 m), and temperatures as high as 520°F (270°C) have been recorded in south Texas, although the major sands generally contain temperatures in the range of 300° to 350°F (150° to 175°C). The waters within geopressed zones appear to contain substantial quantities of methane or natural gas in solution. Laboratory studies indicate that approximately 30 to 45 cu ft (0.9 to 1.4 m³) of natural gas may be dissolved in each barrel of water. Three sources of energy are contained in this resource: heat, mechanical (due to high pressure), and methane.¹⁰

B. Environmental Impacts

The production of geothermal resources is essentially benign environmentally. It generates small amounts of solid waste (or sludge) and presents

little or no water pollution difficulties. From an air quality standpoint, it is far superior to coal. Figure 5 compares some air emissions from geothermal energy production versus eastern and western coal. Only hydrogen sulfide (H_2S) emissions from the hydrothermal reservoir at the Geysers have presented problems thus far. These emissions appear controllable with technology borrowed from the oil refinery and chemical industries and are now in use on the newer generating units. The liquid-dominated hydrothermal (or hot water) systems will not even face this air-quality hurdle. Most, if not all, will employ a binary cycle technology in which the entire geothermal resource will be maintained in a closed loop configuration, then reinjected directly into the producing formation. The reinjection should also prevent the occurrence of land subsidence. Both land subsidence and earthquake inducement could theoretically occur if large amounts of geothermal fluids were withdrawn from beneath the surface and not replaced.

Geopressured systems are subject to concerns from subsidence as well, but it is believed that either their impermeable rock cap, the expansion of their entrapped gases, and/or reinjection will help prevent such occurrences.

Fig. 5. Comparison of several environmental residuals from geothermal and coal resource usage.¹¹

HDR systems are believed to present no environmental threat.¹² This is due in large part to the technology used to produce the useful energy from this geothermal resource. The transport medium can theoretically be either a liquid or a gas. Because the transport medium does not coexist with the hot rock mass, it must be introduced into the geothermal system to provide a transfer of the heat to the surface and is therefore more easily controlled than naturally occurring hot brines, which contain corrosive substances and noncondensable gases such as H_2S .

II. THE LEGAL PROBLEM

Much has already been written concerning the numerous legal and institutional problems confronting geothermal development.¹³ Federal tax problems, difficulties in obtaining access to the hydrothermal systems beneath the public lands of the west, frustrating delays in state and local permitting processes and many other difficulties have been analyzed. Solutions to these problems have been proposed, and many have been or are in the process of being rectified. The bulk of the previous legal/institutional work focused on the problems confronting hydrothermal systems. Some attention has also been given to geopressured systems. HDR, by contrast, has undergone little in the way of legal exposition. Its more widely dispersed geographic occurrence, the possibility that many large energy users will tap its energy without the aid of a resource extraction firm, and the relatively pristine nature of its creation are all characteristics that have yet to be fully recognized. Consequently, HDR resources have no existing industry constituency to carry their case to state and federal legislators. This should not imply that HDR geothermal systems are not beset by difficulties of a legal or institutional nature. The largest of these may be the most basic of all--legal definition of HDR resources.

What is "HDR geothermal energy" legally? How does a prospective user assure himself that he has the "ownership rights" to the resource? How can he be confident that his use of those rights will not subject him to liability by an adjacent land or water rights owner? Presently, there are few statutes that define any of the geothermal resources. Those that do, often refer only to

the hydrothermal systems. Large energy users are therefore left with a seemingly insoluble quandry as they ponder the large expenditures necessary to convert from fuel oil or coal to HDR to provide process or space heat or electricity generation. A state legislature or trial court could later define HDR resources as the property of the public at large or as belonging to the nearest water or mineral rights holder. The business liabilities are therefore enormous.

Local gas and electric utilities face the same uncertainty. Their own institutional biases, together with those of the regulatory commissions, cause more restrictive action than those for nonregulated industries. The latter, after all, must pay ever-increasing fuel costs to stay in operation. Unlike utilities, they can not simply pass on these costs to their customers with a regulatory commission imprimatur.

The breadth of the problem discussed in this paper does not allow an exposition of several ancillary legal questions, primarily those involving water. The issues posed by inclusion of geothermal resources within state ground-water laws are briefly discussed below. In fact, they are both myriad and imposing and include, at the very least, the ability of an existing water rights holder to block, by court injunction, a geothermal development in the same water basin if a reduction in the ground-water table can be shown.¹⁴

There is also the classic federal-state legal conflict over control of western water. The "Reserved Rights Doctrine," a judicial creation of the federal bench, has dramatically increased the role of the Federal Government in controlling the use of western water.¹⁵ State resistance to the inroads of this Federal common law has been strong; however, recent US Supreme Court decisions reflect a belief that state hegemony in this area should be challenged only when absolutely necessary.¹⁶ Additionally, Congress avoided the question by inserting the following statement into the Geothermal Steam Act: "Nothing in this Act shall constitute an express or implied claim or denial on the part of the Federal Government as to its exemption from State water laws."¹⁷ The model statute put forth below assumes the maintenance of this shaky legal truth.

Indian water rights are another area outside the scope of this report. They are distinguishable from those supposedly retained by the Federal Government when setting aside public lands in that the Tribes reserved aboriginal water rights in their various treaties with the US.¹⁸ The unique barriers

confronting geothermal energy development on Indian lands should be investigated in detail.

Finally, the problem at issue--payment by a geothermal developer for the water or surface rights--is not addressed. The economic impact of those possible payments upon the viability of the geothermal operation is not examined. The Intermountain Power Project, e.g., recently paid in excess of \$1500 per acre-foot for coal plant cooling water in central Utah. If geothermal resource projects were forced to make reparations on a similar scale, it might render the resulting energy uneconomic. Much would depend upon the area in question, its particular water-law doctrines, competing beneficial uses, remaining unallocated waters, etc. The economic feasibility of HDR geothermal development needs to be examined in the light of this problem.

The following sections present an analysis of the various geothermal statutes that presently exist and suggest a "model" HDR definitional statute for states where existing law is perceived as weak as well as for states where no laws yet exist.

III. THE PRESENT STATE OF THE LAW

A. Federal Legislation

1. Geothermal Steam Act of 1970. Only 15 states presently have statutes purporting to define geothermal resources. Before examining their varied approaches, it is useful to examine the corresponding federal statutes upon which many of the state enactments are based.

The Geothermal Steam Act of 1970¹⁹ was enacted after a long struggle in Congress. Bills defining geothermal resources and establishing legal authority for their leasing from beneath the public lands had been introduced regularly since 1962.²⁰ One version was passed by Congress in 1966²¹ but vetoed by Lyndon B. Johnson upon the advice of the Department of Interior.²²

The final version was passed into law four years later. Despite its title misnomer, it contained a fairly complete definition of geothermal resources:

"(c) 'geothermal steam and associated geothermal resources' means: (i) all products of geothermal processes, embracing indigenous steam, hot water and hot brines; (ii) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (iii) heat or other associated energy found in geothermal formations; and (iv) any by-product derived from them."²³

From the perspective of HDR, the definition is salutary in that it covers both "heat" (iii) and "other fluids artificially introduced into geothermal formations" (ii). Therefore a federal geothermal lessee would seemingly obtain the HDR geothermal rights as well as rights to the hydrothermal (steam, hot water and hot brines) resources.

2. Geothermal Research, Development and Demonstration Act of 1974. Unfortunately, the all-encompassing Steam Act definition was not carried through into other federal statutes purporting to define geothermal resources. The "Geothermal Energy Research, Development and Demonstration Act of 1974"²⁴ defined geothermal resources as:

"(1) The term 'geothermal resources' means (A) all products of geothermal processes, embracing indigenous steam, hot water and brines, (B) steam and other gases, hot water and hot brines resulting from water, gas or other fluids artificially introduced into geothermal formations, and (C) any by-product derived from them."²⁵

Although the 1974 Act purported to create a coordinated management structure for the much-needed Federal Research, Development and Demonstration program into geothermal energy,²⁶ Congressional findings were made that:

"the conventional geothermal resources which are presently being used steam have limited total potential; but geothermal resources which are different from those presently being used, and which have extremely large energy content, are known to exist;..." (emphasis added).²⁷

Congress neglected to specifically include the largest of these--HDR--in its actual definitional language. It began the cycle of HDR resource definitional confusion which persists to this day.

3. The Energy Tax Act of 1978. Another statutory definition of geothermal resources was enacted in 1978. The Energy Tax Act of 1978²⁸ purported to define a geothermal deposit that would qualify for depletion and expensing of intangible drilling costs. The results were as follows:

"...the term 'geothermal deposit' means a geothermal reservoir consisting of natural heat which is stored in rocks or in an aqueous liquid or vapor (whether or not under pressure)..."²⁹

HDR resources seem safely included, for tax purposes, in this third statutory version.

Thus, there are three distinct legal statutory definitions on the federal books. The Steam Act defines federal government ownership of the geothermal

resources underlying the public lands. The Research, Development and Demonstration Act gives direction to the federal R & D effort and its managers in the Department of Energy. The third is for the benefit of geothermal developers as taxpayers, and constrains the Internal Revenue Service in its dealings with them.

The Steam Act is the most important for the purpose of our discussion. HDR systems occurring beneath the federal lands would seem to be covered by its scope, and anyone wishing to secure rights to HDR geothermal resources would appear to be secure with the rights conveyed by a federal geothermal lease.

Unfortunately, there have been some published analyses³⁰ that interpret the Steam Act definition as excluding HDR systems because they are identified in (iii) as "heat...found in geothermal formations" and the latter term is not defined in the statute. Therefore, the reasoning continues, a court might define such a geothermal formation as one producing steam, hot water and hot brines, thereby excluding HDR systems.³¹ The absence of HDR in the 1974 R & D Act definition could conceivably be brought in as evidence against the inclusion of HDR geothermal rights in a federal geothermal lease. However, to clarify the point, Congress should amend the R & D Act definition by including in it the phrase "heat or other associated energy found in geothermal formations" as contained in 30 USC §1001 (c) (iii).

B. State Legislation

1. California Statutes. California has had the longest geothermal experience of the states having geothermal statutes. The Geysers steam field has been supporting electricity generation since 1960 and California's first geothermal statute³² was enacted five years later. Basically, it is a drilling methods/waste prevention regulatory scheme and it defined geothermal energy as:

"the natural heat of the earth and the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat."³³

This definition focuses on heat--the key component of geothermal resources. The statute then adds to the definition the various forms taken by that basic heat energy.

Unfortunately, a definitional problem similar to the one just explored at the federal level developed. The need for a state lands lease program for geothermal resources led to a modification of the original statutory definition

in 1967.³⁴ Predictably, the shift in emphasis resulted in the State's law-makers re-defining geothermal resources to meet the particular concerns of the State Lands Commission, which would administer the geothermal leasing program. The State Lands Commission and the California oil and gas industry pressed for additions to the earlier definition. The following language was therefore inserted after "such natural heat," to wit,

"and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substances" (emphasis added).³⁵

The California Legislature also moved the definition into the state lands' portion of the Public Resources Code by repealing the earlier version and placing the new, expanded definition with the sections dealing exclusively with leasing.

This legislative action may have been unfortunate. There seems to be a possible conflict between the state's geothermal resources definition and its general ground-water law.³⁶ Should such a potentiality escalate into litigation, the positioning of the geothermal definition in the state lands' leasing regime might be construed as a legislative statement that was only applicable in that context. This interpretation is supported by a close reading of the section at issue. The definition is preceded by the limiting statement "For the purpose of this chapter,..."³⁷ A similar covenant precedes the reference to the definition that took its place in the drilling/waste prevention scheme.³⁸

As far as HDR systems are concerned, there could be a serious question raised if water indigenous to the HDR itself were used as the transport medium. Because that case would appear to be the exception rather than the rule of HDR utilization, the California statute appears adequate to safeguard HDR ownership rights.

This conclusion is bolstered by the three California-based court cases that have been decided to date on the question of ownership of hydrothermal resource systems.³⁹ Each case sought to adjudicate the ownership of a hydrothermal geothermal resource system as between the competing claims of surface and subsurface estates. Since water, whether in liquid or steam form, is the main component of such systems, the surface owners argued that all subsurface water exists for the enjoyment of the surface estate, assuming its appropriation for

a beneficial use, etc. All three courts found otherwise. Though there was lip service given to the reality of the geothermal fluids being used as a power source (not unlike other subsurface minerals like oil, gas, or coal), the real key was usually a factual finding that the geothermal fluid reservoir was physically cut off from more conventional ground-water aquifers by an impermeable layer of shale rock. Should a contrary factual situation arise, i.e., one where some interconnection of geothermal and nongeothermal fluids is demonstrable, then the hydrothermal geothermal developer could become enmeshed in the state's surface owner-dominated ground-water appropriation scheme. An HDR system should be able to avoid these perils by either purchasing the land with its water rights in fee simple or, if a geothermal resources lease of the subsurface is used, by employing gas or purchased fluids to carry the heat to the surface.

2. States Following the California Model. Following California and the Federal Government into the new and untried field of defining geothermal resources, it is predictable that most of the jurisdictions which followed would choose one or the other as their statutory model. This section briefly discusses Hawaii, Idaho, New Mexico, and Maryland, which selected the California definitional construction.

a. Hawaii. Hawaii enacted its geothermal statute in 1974, borrowing California's definition word for word.⁴⁰ Aware of the omnipresent "is it water?," "is it mineral?" debate, Hawaii specifically included geothermal resources among those substances that it statutorily defines as minerals.⁴¹ Because Hawaii defines all ground water in the state as public property⁴² and lays claim to all minerals found in the subsurface,⁴³ it might seem that any additional statutory distinction between water and mineral was unnecessary. However, Hawaii's surface owners, particularly the large land holding estates, are allowed surface rentals from state mineral lessees.⁴⁴ On the other hand, water rights holders are not bound by any similar constraint.

Presently, Hawaii's HDR geothermal resources is owned by the state, pending a legal challenge by the large surface owners or native Hawaiians.⁴⁵

b. Idaho. Idaho's pre-occupation with maintaining ground-water support for its rich farming economy led it to make certain uniquely local additions when it enacted the Idaho Geothermal Resources Act in 1972.⁴⁶ The Idaho definition provides:

"(C) 'Geothermal resource' means the natural heat energy of the earth, the energy, in whatever form, which may be found in any position and at any depth below the surface of the earth present in, resulting from, or created by, or which may be extracted from such natural heat, and all minerals in solution or other products obtained from the material medium of any geothermal resource. Geothermal resources are found and hereby declared to be sui generis, being neither a mineral resource nor a water resource, but they are also found and hereby declared to be closely related to and possibly affecting and affected by water and mineral resources in many instances" (emphasis added).⁴⁷

Notwithstanding its "sui generis" classification of the geothermal resources, Idaho placed the regulation of geothermal drilling operations under its Department of Water Resources.⁴⁸ The legislature also made a concurrent declaration that "...development of our geothermal resources on a large scale may be associated with risks to...our valuable ground-water resources...."⁴⁹ These two actions, coupled with the partial disclaimer contained in the definition itself "...closely related to and possibly affecting and affected by water and mineral resources in many instances."⁵⁰ leave little room for doubting Idaho's intentions.

A water classification would have been more straightforward, but such a classification may have totally frustrated geothermal development. Water rights in Idaho must be obtained by appropriation from the State Department of Water Resources. In many areas of geothermal promise there are no such rights available. The resulting statutory compromise is tilted heavily towards the protection of existing water rights holders. A potential HDR geothermal user could obtain ownership rights to the resource with little difficulty. However, should operations result in damage to neighboring ground water, that ownership would probably become a hollow right. The water rights holders could enjoin the geothermal user to preserve their senior rights, effectively halting development.

This problem is not anticipated with Idaho mineral rights holders. Avoiding the pitfalls noted above in the discussions of federal and California law, Idaho enacted an identical definition of geothermal resources into its State lands leasing scheme.⁵¹ The following words were then added:

"No right to seek, obtain, or use geothermal resources has passed or shall pass with any existing or future lease of state or school lands, including but not limited to, mineral leases and leases issued under Chapter 8, Title 47, Idaho Code."⁵²

c. New Mexico. New Mexico enacted its first geothermal statute in 1967.⁵³ It copied the California geothermal definition word for word:

"'Geothermal resources' means the natural heat of the earth, or the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, this natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas and other hydrocarbon substances."⁵⁴

Eight years later the legislature enacted a more extensive regulatory framework for geothermal resources development that covered both state and private lands.⁵⁵ Fortunately, the definition of geothermal resources remained the same.⁵⁶ The new act then proceeded to define a geothermal reservoir as:

"...an underground reservoir containing geothermal resources, whether the fluids in the reservoir are native to the reservoir or flow into or are injected into the reservoir."⁵⁷

This action had the salutary effect of clearly covering geothermal systems devoid of any natural transport medium and thus provided for the use of other liquids or gases to transport the heat energy to the surface. The action appears to cover the situation in which a conflict between a geothermal developer and a water rights holder would arise by resolving it in favor of the former.⁵⁸ However, The outcome of a suit brought by a ground-water rights holder who can prove a diminution in his ground-water rights may still be questionable. A New Mexico court ignoring the plight of such an individual is extremely difficult to envision.

Notwithstanding such a factual demonstration, the HDR geothermal resource ownership issue seems positively settled in New Mexico.⁵⁹

d. Maryland. The most recent state to enact geothermal legislation by following the California Model is Maryland. Maryland's action indicates an awareness of both the low-temperature hydrothermal and HDR geothermal resource systems that potentially exist there. Maryland's amendments to the California definition of geothermal resources also indicate an awareness that these types of geothermal resource systems should be developable within its borders.

The Maryland definition is:

"'Geothermal Resources' means the natural heat of the earth higher than 120 Degrees Fahrenheit or 49 Degrees Centigrade, or the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, this natural heat, the natural or artificial medium containing that heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas, and other hydrocarbon substances" (emphasis added).⁶⁰

The two additions are (1) the "higher than 120 Degrees Fahrenheit or 49 Degrees Centigrade" amendment to "the natural heat of the earth" phrase and (2) the "natural or artificial medium" insertion before "and all minerals in solution."

The former is clearly intended, to delineate the difference between ordinary, or conventional ground-water resources, and geothermal resources. As discussed below, the utility of such an arbitrary definition is doubtful. But it is certainly preferable to statutory silence or a clear preference for the ground-water rights holder.

The second Maryland amendment to the California Model, like New Mexico's definition of geothermal reservoir, is directed explicitly at HDR systems. By including systems using a natural or artificial medium within the scope of its statutory definition, Maryland has settled the question of HDR's inclusion in any lease, etc., conveying geothermal resources located within the state on either private or state land.

3. States Following the Steam Act Model. Statutory definitions of geothermal resources in Arizona, Colorado, Louisiana, and Texas follow the model established in the Federal Geothermal Steam Act.⁶²

a. Arizona. Arizona became the first state to follow the Federal Steam Act definition of geothermal resources in 1972. Their slightly amended version provides:

"(a) All products of geothermal processes embracing indigenous steam, hot water and hot brines.

(b) Steam and other gases, hot water and hot brines resulting from water, other fluids or gas artificially introduced into geothermal formations.

(c) Heat or other associated energy found in geothermal formations, including any artificial stimulation or induction thereof.

(d) Any mineral or minerals, exclusive of fossil fuels and helium gas, which may be present in solution or in association with geothermal steam, water or brines" (emphasis added).⁶³

The only noteworthy statutory alteration is in the emphasized language, wherein the scope of HDR systems is extended to include those using artificial stimulation or induction. The reference was to the use of mechanical fracturing or explosives to create openings in large HDR systems and thereby provide pathways through which the transport medium could move. The technique is an extension of the hydraulic fracturing methods used to break up tight oil or gas-bearing formations and thus increase total resource recoverability. A further extension of this technique, fracturing through the use of nuclear detonation, was

regarded by some as the key to unlocking the huge heat content of HDR geothermal systems.⁶⁴

Arizona has settled the ownership question related to HDR systems.

b. Colorado. Colorado added its "Geothermal Resources Act" to the code books in 1974. The definition, taken almost directly from the Steam Act, defined geothermal resources as:

"(6) (a) 'Geothermal resources' means geothermal heat and associated geothermal resources, including but not limited to:

(I) Indigenous steam, other gases, hot water, hot brine, and all other products of geothermal processes;

(II) Steam, other gases, hot water, hot brine, and all other products of geothermal processes resulting from water, brine, steam, air, gas, or other substances artificially introduced into subsurface formations; and

(III) Natural heat, steam energy, and other similar thermal energy in whatever form found in subsurface formations.

(b) For purposes of this article, such term shall not include thermal energy contained in mineral deposits (including deposits of coal, oil shale, crude oil, natural gas, and other hydrocarbon substances and other substances and materials associated and produced in connection with such minerals) which are explored for, developed, and produced primarily for the mineral value thereof and not primarily for the thermal energy contained therein" (emphasis added).⁶⁵

"By-products" was a noticeable deletion. The strong hard rock mining tradition in Colorado caused the substitution of subsection (b), which clearly excludes virtually all recoverable minerals from the definition of geothermal resources.

Hot dry rock geothermal systems would seem clearly included in (III), particularly with the addition of "and other similar thermal energy in whatever form found in subsurface formations."⁶⁶

c. Louisiana. Louisiana's apparent concern in enacting both the "Louisiana Geothermal and Geopressure Energy Research and Development Act"⁶⁷ and the "Geothermal Energy Resources Act"⁶⁸ in 1975 was the geopressured zone geothermal resources systems within its boundaries. The hot geothermal fluids, the dissolved methane gas, and the high pressure were all attractive but, as with HDR systems, security of ownership was seemingly illusory. A potential conflict between existing oil, gas, and mineral lessees and those holding or seeking geothermal resources rights seemed also to exist. Louisiana therefore chose to follow the Steam Act Model but added language further defining geopressured systems vis-a-vis hydrocarbons. Section 30.801 of the Louisiana Revised Statutes reads:

" (1) 'Geothermal resources' means:

(a) All products of geothermal processes, embracing indigenous steam, hot water, hot brines and geopressured waters excepting, however, waters produced incidental to oil or gas exploration or production.

(b) Steam and other gases, hot water and hot brines resulting from water, gas or other fluids artificially introduced into geothermal and/or geopressured water formations.

(c) Heat, natural gas dissolved in formation water or which was dissolved in formation water and is produced at the geothermal and/or geopressured well bore, or other associated energy found in geothermal and/or geopressured water formations.

(d) Any by-product derived therefrom.

(2) 'By-product' means any mineral or minerals, excluding oil and natural gas, which are found in solution or in association with a geothermal resource and which have a value less than seventy-five percent of the value of the total geothermal resource if utilized or not, because of quantity, quality, or technical difficulties in extraction and production of sufficient value to warrant extraction and production by themselves or which production would waste or not fully utilize the geothermal resource" (emphasis added).⁶⁹

The Louisiana-specific additions served to give oil and gas producers an advantage if the dissolved methane gas only was wanted ("...excepting, however, waters produced incidental to oil or gas exploration or production"),⁷⁰ but allow geothermal producers to obtain that same gas if they were at the same time producing geothermal fluids from a geopressured zone ("...natural gas dissolved in formation water...and...produced at the geothermal and/or geopressured well bore...").⁷¹

The 1975 enactment also defined a geothermal lease in order to distinguish these from its state oil and gas or mineral leases.⁷² The Louisiana Legislature attempted to resolve some of the legal conflicts between geothermal and nongeothermal rights holders by stating that,

"in the event of a conflict, the rights of the lessee under any oil, gas, or mineral lease heretofore issued on (state) lands...and in effect on the effective date of this Chapter, shall not be diminished or limited by virtue of this Chapter or any provisions hereof" (emphasis added).⁷³

In addition to this "priority" or "grandfathering" of its existing oil and gas lessees, Louisiana also added the following:

"The provisions of this Chapter are not intended and should not be construed to deny the legal right or remedy of any owner for the protection of his property interests that is otherwise available to such owner under the law."⁷⁴

Louisiana put geothermal resources on a lower level of its statutorily-created property rights, as did Idaho and Montana with water, and Colorado with minerals. Hot dry rock geothermal resource developers must therefore secure

the mineral rights attendant to the acreage of interest in Louisiana if they wish to enjoy the security of tenure.

d. Texas. Texas approached the problem with more subtlety, choosing a strict Steam Act Model definition:

"(4) 'Geothermal energy and associated resources' means:

(A) products of geothermal processes, embracing indigenous steam, hot water and hot brines, and geopressured water;

(B) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations;

(C) heat or other associated energy found in geothermal formations; and

(D) any by-product derived from them.

(5) By-product means any element found in a geothermal formation that when brought to the surface, is not used in geothermal heat or pressure-inducing energy generation."⁷⁵

The Texas draftsmen then inserted language for oil, gas, mineral, and water rights holders:

"It is declared to be the Policy of the State of Texas that:...

(3) consideration shall be afforded to protection of...correlative rights...."⁷⁶

The Texas Railroad Commission, which supervises oil, gas, and geothermal operations in Texas, was then directed to do so in a manner that would serve "the purpose of conservation and the protection of correlative rights,"⁷⁷ and to promulgate rules to that effect.⁷⁸ Specifically, those rules would provide:

"...protection of correlative rights against infringement resulting from the exploration, development and production of geothermal energy and associated resources" (emphasis added).⁷⁹

4. States Utilizing Hybrid Models. Alaska and Oregon combined the Federal Steam Act and the California models. It is tempting to imagine that this merger would result in a secure, settled ownership regime for all geothermal developers. Unfortunately this is not the case in Oregon, as is discussed below.

a. Alaska. Alaska, in 1971, passed the Geothermal Resources Act.⁸⁰ The combination California-Steam Act definition resulted in the following:

"'geothermal resources' means the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, the natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, exclusive of oil, hydrocarbon gas, helium or other hydrocarbon substances, but including, specifically:

- (A) all products of geothermal processes, embracing indigenous steam, hot water and hot brines;
- (B) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations;
- (C) heat or other associated energy found in geothermal formations; and
- (D) any by-product derived from them."⁸¹

Thus, the California definition was used as the general part of the statute, with the Steam Act subsections the specific inclusions therein. The all-encompassing definition found in the Alaska code books would seem to leave little doubt as to the ownership of HDR geothermal systems in that jurisdiction.

b. Oregon. Oregon's statutory definition followed Alaska's verbatim:

"'Geothermal resources' means the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, the natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, exclusive of helium or of oil, hydrocarbon gas or other hydrocarbon substances, but including, specifically:

- (a) All products of geothermal processes, embracing indigenous steam, hot water and hot brines;
- (b) Steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations;
- (c) Heat or other associated energy found in geothermal formations; and
- (d) Any by-product derived from them."⁸²

Unlike Alaska, however, Oregon has a strong agricultural base, scarce water supplies in some sectors, and a strong public ownership sentiment. These factors, coupled with an apparent geothermal industry annoyance with water well permitting processes combined to produce two additional statutory provisions. The first delineated a geothermal well as one which had a bottom hole temperature in excess of 250°F (120°C) and a depth greater than 2000 feet (610 m).⁸³ The well was not to be construed as a geothermal well if its "fluids had been appropriated pursuant to ORS 537.505 to 537.795" (Oregon's water rights appropriation law).⁸⁴ The problem seems obvious. What is a prospective HDR geothermal user to do if his geothermal resource is less than 250°F (120°C), a likely occurrence if a lower temperature space heating use was contemplated? The situation might become even more legally complex if an existing water appropriator believed that his water was being produced. The burden of disproving this claim would be on the geothermal operator under current Oregon law.

The second provision purported to add another element of certainty to the geothermal resources ownership question, but succeeded only in confusing it. The provision states that:

"Ownership rights to geothermal resources shall be in the owner of the surface property underlain by the geothermal resources unless such rights have been otherwise reserved or conveyed. However, nothing in this section shall divest the people or the state of any rights, title or interest they may have in geothermal resources" (emphasis added).⁸⁵

Though Oregon has made no clear statement of public ownership, the non-disclaimer must increase the ownership risk. Resource ownership is therefore unsettled in Oregon.

5. States with Water or Unique Definitions. The five remaining states with legislative geothermal resources definitions--Nevada, Utah, Wyoming, Montana, and Washington State--have developed even more individual models. The first four chose skeletal definitions and inclusion in their ground-water regimes. The Washington State definition owes much to the California Model, but has emphasized the sui generis nature of the resource in a fashion which, like Idaho's, is of no practical use to an industry wishing to utilize geothermal energy and concerned over the security of its ownership and developmental rights.

a. Nevada. Nevada's definition of geothermal resources is simple. It reads: "As used in this chapter, 'geothermal resource' means heat or other associated geothermal energy found beneath the surface of the earth."⁸⁶

The administration of geothermal operations in Nevada is vested in the State Water Engineer.⁸⁷ The possibility, present in the interstices of California law that geothermal resources might be subject to water law appropriation is a statutory fact in Nevada. Section 534A.040 clearly states that: "Any water and steam encountered during geothermal exploration is subject to the appropriation procedures of chapters 533 and 534 of NRS" (emphasis added).⁸⁸ What does this mean for HDR systems? What if a liquid other than water or a gas is used to transport heat to the surface? What if water not contained in the formation itself is utilized in this manner? It would appear that the water, whether of geothermal, conventional, ground, or surface in origin, must be appropriated and that the production from an HDR system will be governed by water law.

To complicate matters further, Nevada did use the Steam Act Model to define geothermal resources in the context of its property right regime.⁸⁹

If you're after an HDR system on either state or private land in Nevada, the simple definition first noted will probably cover the ownership. However, should water be encountered, a water appropriation from the State Water Engineer will be required. Further, approximately 86% of the land in Nevada is controlled by the Federal Government, where the Steam Act prevails.⁹⁰

b. Utah. Utah, like Idaho, Nevada, Wyoming, and Montana, has an intense interest in preserving its ground-water reservoirs. Therefore, an extreme approach to defining "geothermal resources" has been taken. The legislature placed the administration of geothermal resources under the State Water Engineer. The operable section provides:

"(1) The division of water rights is given jurisdiction and authority to require that all wells for the discovery and production of water to be used for geothermal energy production in the state of Utah, be drilled, operated, maintained, and abandoned in such manner as to safeguard life, health, property, the public welfare, and to encourage maximum economic recovery.

(2) In carrying out its responsibility under this act, the division of water rights may utilize personnel, equipment, or other assistance of any division or department and may transfer funds to that division or department to reasonably compensate it for use of its personnel or facilities."⁹¹

This must be seen as a definition of geothermal resources as water only. The opinion is strengthened by another section of the Utah Code, which declares all waters to be public property:

"All waters in this state, whether above or under the ground, are hereby declared to be the property of the public, subject to all existing rights to the use thereof."⁹²

Although Utah has an extensive state lands leasing program for geothermal resources,⁹³ the ownership situation is, implicitly, like that in Nevada. Leases for geothermal resources are available. However, the utilization of any water, whether for geothermal energy content or as a transport medium in a HDR setting, cannot occur without a prior appropriation from the State Water Engineer.

c. Wyoming. Wyoming provided yet another variant on the Nevada/Utah theme. Whereas Nevada defines geothermal separately and then says it's subject to water appropriation laws, Utah did not define this resource, but established its water authorities as geothermal resource administrators. Wyoming pursued a different path and explicitly defines hot water and steam

geothermal resources as part of its ground-water regime: "Underground water" is defined as:

"any water, including hot water and geothermal steam, under the surface of the land or the bed of any stream, lake, reservoir, or other body of surface water..." (emphasis added).⁹⁴

Geothermal operations in Wyoming, particularly if they are pursuing HDR systems, with or without any contained water, are thus on unsteady ground unless they can use gas as a transport medium. Senior appropriators may have exhausted the area's available water rights appropriation and there is no statutorily secure way to obtain even HDR geothermal rights at present. Wyoming, however, like Utah and Nevada, does issue state prospecting permits and leases for geothermal resources on state lands. Not surprisingly, few applications have been received.

d. Montana. Montana followed Wyoming's statutory lead. Geothermal resources are therefore "water" in Montana, as discussed below. However, Montana also adopted a separate definition for state lands leasing purposes. There it borrowed a version of the California Model almost word for word.⁹⁵

Since the definition was contained in "An act to empower the board of land commissioners to lease geothermal resources on state lands," and since Montana, like Idaho, wished to protect its water rights regime and prevent mineral lessees from obtaining geothermal resources rights, it added two further provisions. The first was appended to the definition itself. It stated "No right to seek, obtain, or use geothermal resources has passed or shall pass with any existing or future lease of state or school lands."⁹⁶ The second provision, to secure and protect existing water rights holders, stated:

"If any geothermal development located on state land requires the utilization of water, the lessee may...make application to the board of land commissioners for permission⁹⁷ to secure a water right to the land under his lease" (emphasis added).

Nowhere is there a distinction drawn between geothermal resources and water. The state lands statutory definition of geothermal resources would seem to include water "at any depth below the surface...."⁹⁸

Unfortunately, the statutory definition of water in Montana clearly includes geothermal fluids. It includes:

"all water of the state, surface and subsurface, regardless of its character or manner of occurrence,⁹⁹ including geothermal water and diffuse surface water" (emphasis added).

The situation for HDR is discouraging in Montana, like that in the three other "geothermal is water" states (Nevada, Utah, and Wyoming). Once again, HDR may be successful where hydrothermal systems fail by using a nonwater transport medium.

e. Washington. Washington's definition of geothermal resources would appear closer to Idaho's--the California Model plus a statement on its sui generis nature:

"'Geothermal resources' means only that natural heat energy of the earth from which it is technologically practical to produce electricity commercially and the medium by which such heat energy is extracted from the earth, including liquids or gases, as well as any minerals contained in any natural or injected fluids, brines and associated gas, but excluding oil, hydrocarbon gas and other hydrocarbon substances."¹⁰⁰ "Notwithstanding any other provision of law, geothermal resources are found and hereby determined to be sui generis, being neither a mineral resource nor a water resource."¹⁰¹

A new characterization is the inclusion of "technologically practical to produce electricity commercially." Thus if a hydrothermal or HDR system were to be used for space or process heating it would not qualify as geothermal resources under the existing definition. Additionally, if the hydrothermal or HDR geothermal system developer tried for either a mineral or water classification, the statutory sui generis statement would seem to effectively block them. No one else may own sui generis, but, correspondingly, anyone might. At this time, there simply is no legal way to secure ownership of less-than-electric geothermal resources in Washington.

There are many advocates of public ownership in state government. Similar to Oregon's nondisclaimer pursuant to public ownership, Washington's sui generis statement may be a thinly veiled preface to a forthright claim of public ownership of geothermal resources within the state. This situation would not be as detrimental as first thought. A potential user would at least know who to deal with in obtaining rights to HDR or low-temperature hydrothermal geothermal system resources.

IV. A DEFINITIONAL MODEL

A. Physical Characteristics of Geothermal Energy

Ideally, a model HDR geothermal resources definitional statute would be based on the physical characteristics of such systems. Therefore a further

examination of the characteristics of HDR is necessary to distinguish it from the normal thermal gradient of the earth, found literally everywhere, and from the magma systems, their volcanically younger relatives.

Technically, geothermal resources could be defined to include literally all of the heat contained in the earth except the relatively thin surface crust on which we tread. This would total roughly 260 billion cubic miles of rocks, metals, etc.¹⁰² Obviously not all of this potential resource base is accessible. The deepest oil and gas wells drilled to date have been in the 23 000 to 24 000 ft category, or approximately 4.5 miles (more than 7 km).¹⁰³ For practical purposes it might be assumed that this is the presently available limit for HDR systems. However, as drilling technology continues to be developed, depths will continue to increase. Therefore depth should not be established as a limit.

Additionally, most conventional oil field drilling and logging equipment cannot handle the extremely high temperatures and corrosive brines encountered at such depths. However, these problems are being technologically resolved.¹⁰⁴ The useful portion of the geothermal resource base, though thus limited, is nonetheless very extensive. The National Academy of Sciences recently stated,

"Even this...is an enormous reservoir of thermal energy, which will expand to continually greater depths as the technology for recovering and using it improves and the need for it continues to increase."¹⁰⁵

The dean of geothermal law, Owen Olpin, said more than a decade ago,

"...the most important component of geothermal resources, the energy, is not a thing which can be produced and placed in containers to send to distant markets. The release of geothermal energy is more an event or occurrence than a thing."¹⁰⁶

The key ingredient of HDR, and all other geothermal resources, is heat. The water contained in hydrothermal systems, in reality, is not the primary resource but is more an ancillary resource in that it provides a naturally occurring transport medium by which the heat energy is transferred from the reservoir to the surface. This fact is readily apparent when HDR and magma systems are considered. Further, the economic value of the mineral content of the water is also incidental to the heat energy produced. Heat is the principal commodity.

Since heat is the primary consideration in dealing with geothermal resources, the focus of the issue must shift. Two expert analysts have stated:

"If it is proper, ..., to regard the resource primarily as 'energy' rather than as a 'substance,' then perhaps it is wrong to make reference to

'ownership'.... It might be better, instead, to ask who has the right to use the resource without payment to others?"¹⁰⁷

From this refocused viewpoint, the question then becomes, can an acceptable and workable legal model be constructed which recognizes the geologic and practical reality of geothermal resources and also avoids or provides a means of speedily resolving conflicts with water and/or mineral rights holders?

B. A Legislative Model

The following legal model is proposed, hopefully, to stimulate needed change:

Model Geothermal Resources Ownership and Utilization Act of 1979

- Sec. (1) Whenever used in the laws of this state, "Geothermal resources" shall mean the natural heat of the earth and the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas, or other hydrocarbon substances.
- Sec. (2) Ownership rights to geothermal resources, regardless of the form they may take shall be in the owner of the subsurface, or mineral estate. For lands, including state or school lands, which have been transferred subject to a reservation of all or any portion of the subsurface or mineral estate, such reservation shall be conclusively deemed to include geothermal resources.
- Sec. (3)(a) If any person feels that the exploration, development, or use of geothermal resources has unreasonably interfered with their rights to either the use and quiet enjoyment of the surface of their land or the beneficial use of water rights appropriated by them under the ground-water laws of this state, that person may, within thirty (30) days, notify the State Department of Oil and Gas of their complaint in writing.
- (b) The Department shall then conduct an investigation to determine if the exploration, development, or utilization of geothermal resources has unreasonably interfered with the surface or water rights of the complainant.

- (c) If the Department finds, as a result of its investigation, that there has been "unreasonable interference" with the surface or water rights of the complainant, it shall direct the geothermal resources operator to take such measures as will, in the opinion of the Department, prevent such interference in the future.
- (d) The investigative findings of the Department of Oil and Gas shall be binding upon both the complainant and the geothermal resources operator. No court of this state shall have jurisdiction to hear any appeal from the final decision of the Department.

V. ARGUMENT FOR CHANGE

This study of existing federal and state law has shown that certain non-geothermal considerations have dominated the thinking of the various legislative draftsmen. Although these draftsmen have leaned heavily on pre-existing geothermal legislation in other jurisdictions, local considerations have been their central focus. Prevention of possible interference with the rights of pre-existing mineral and water claimants, as well as those of the public, has been uppermost in the minds of the legislators. Providing a secure ownership regime for prospective geothermal developers and/or users has, of necessity, been a secondary consideration to these preservation drives. Coupled with a possible timidity, preservation interests have created a recurring scenario in which the fears of existing surface water or mineral claimants are the dominant factors. Thus it is not encouraging to consider at the outset either amending existing laws in the jurisdictions we have examined or enacting new statutes in the nearly three dozen states where none now exist.

It is not likely that Montana, Wyoming, Nevada, or Utah--the four states placing geothermal resources squarely in their respective ground-water regimes--would have a pro-geothermal constituency adequate to the task of opposing their powerful ranching, farming, and competing energy fuel interests. Idaho is in a similar position.

Texas and Louisiana moved to protect existing oil and gas interests, while Colorado protected its longstanding and well-established hard rock mining community. None of these statutory biases will be easily changed.

Public ownership advocates in Oregon and perhaps Washington State would doubtless prefer a less pro-geothermal legislative posture than that just proposed.

Nonetheless, it is precisely such an action that is necessary in all the states. Enactment of state laws clearly defining all geothermal resources, with particular inclusion of HDR systems, is needed. This is particularly true in the northeastern and southern states, where commercially exploitable HDR resources are believed to exist, and in which energy demand is both high and heavily dependent upon expensive imported oil.

The relative absence of federally controlled land in these regions is another argument in support of geothermal definition legislation. Although the western states, where interest in geothermal resources has heretofore been concentrated, are heavily laden with federally controlled acreage, the southeast and northeast are for the most part in private hands, as Table II illustrates.

This indicates that the fairly inclusive definition of geothermal resources found in the Federal Steam Act is unavailable in large sections of the country precisely where HDR geothermal resource systems are present and could conceivably make a large contribution towards relieving much of our energy problem.

As for the previously enumerated list of western states, with their non-geothermal "geothermal" statutes, they must make a more sophisticated state-level energy policy choice than that which resulted in the unsatisfactory statutes we have seen, not unlike that currently being made in Congress. Diminishing supplies of oil and gas, the limited availability of additional hydropower sites, popular disaffection with nuclear power and nuclear waste, air quality permitting maze facing coal utilization have all combined to push decision-makers at all levels of government to a crucial point concerning policy. Can they continue to frustrate large energy demand shifts to hydrothermal or HDR geothermal resources in order to prop up agricultural and nongeothermal energy uses which may be of lesser economic, environmental, and public policy value? Those states which perceive this quandry and act positively may well provide themselves, and the country, a large advantage by enacting legislation guaranteeing security of ownership and developmental tenure to geothermal resources. Just as population and industry shifted to

TABLE II¹⁰⁸FEDERAL AND NONFEDERAL LANDS BY STATE
(in millions of acres)

<u>Western States</u>	<u>Federal Acreage</u>	<u>%</u>	<u>Nonfederal Acreage</u>	<u>%</u>
Arizona	31.141	42.843	13.074	57.16
California	45.277	45.184	54.928	54.82
Idaho	32.928	63.744	19.191	36.26
Nevada	60.820	86.559	9.444	13.44
Oregon	32.370	52.550	29.228	47.45
Utah	34.856	66.145	17.840	33.86
<u>Eastern States</u>				
Alabama	1.123	3.438	31.555	96.562
Georgia	2.229	5.978	35.065	94.02
Louisiana	1.058	3.666	27.809	96.53
Maryland	.202	6.116	3.204	96.80
New Jersey	.131	2.723	4.682	97.28
New York	.246	0.804	30.434	99.20

the natural gas-rich southwest after World War II, so might an abundance of secure, environmentally benign geothermal resources provide such a state with an irresistible lure for its own future development. At present, no such encouragement for geothermal resources utilization exists on the code books.

Similarly, those 35 states with no geothermal statute are, in the main, in areas of the country which have suffered serious economic dislocations in the past 25 years as industries and jobs moved elsewhere, partly in search of secure fuel. There is no question that many would return for the same reason.

Nor should these states "model" themselves after existing legislation. First there is the failure of many statutes to adequately cover the various resource characteristics--particularly heat. The outstanding examples are Utah, Nevada, Wyoming, and Montana, which include geothermal in their ground-water regimes.

An additional problem involves the failure of most jurisdictions to clearly assign the rights to geothermal resources to a pre-existing, recognized legal estate--surface, mineral, or water. Included are those jurisdictions which have enacted statements which purport to declare geothermal resources as sui generis. As previously noted, this provision, for practical purposes, obscures the issue rather than resolving it. Certainty is required to obtain developmental use rights. Sui generis resources could, theoretically, be owned by everyone, and that recognition only increases uncertainty and serves to deter industrial firms from developing and using these needed resources.

Coupled with the failure of categorical assignment is an almost complete failure to provide any means of conflict resolution or any statutory preferences to be used as aids in settling such disputes. Stated differently, if a water rights holder seeks to enjoin a geothermal operation, and both are legally protected by the laws of the jurisdiction in question, how is the Court to decide whose rights should take preference? If, as is likely, the court selects a "first-in-time-is-first-in-right" criteria or test, the geothermal operator will lose.

Worse, in those jurisdictions where a statutory preference has been clearly expressed, it has been in favor of existing water or mineral claimants and against geothermal. Only in California has there been any attempt to give priority to geothermal resources. That state's "Certificate of Primary Purpose" procedure provides for a "rebuttable presumption" that any fluids produced by a geothermal well are the property of the geothermal resource rights holder.¹⁰⁹ Unfortunately, a measure of the complexity involved is that no one has ever applied for such a Certificate. When one operator contacted the State Attorney General's office to inquire as to its utility, he was told that initiating such a claim would raise more questions than it would answer.¹¹⁰

Our model statute meets all of these needs by adequately describing geothermal resources, assigning their ownership firmly to the subsurface estate and providing for a binding administrative resolution of conflicts in a pro-geothermal development setting.

VI. SUMMARY

America's geothermal resources could provide an enormous, secure domestic energy base which has few, if any, negative environmental consequences. Moreover, of the four main types of geothermal resources (hydrothermal, HDR, magma, and geopressured), one--HDR--poses a vast geographically diverse energy target. Unfortunately, development of HDR in the near term will be frustrated by the failure of the various states to legally define it in a manner that provides security of ownership and developmental tenure to large energy users who would otherwise switch from oil or other energy sources to HDR. Some 35 states do not have any geothermal resources statute. The bulk of those that do have such laws on their books are in the west, where the legislation leans more heavily to the protection of pre-existing surface, mineral, or water rights holders than to the development of geothermal resources. Almost all of these laws also fail to cover HDR systems in their definitions, focusing instead on hydrothermal geothermal systems. To rectify this situation, a "model geothermal resources ownership" statute is presented. The model covers the various resource types, clearly assigns their ownership to the subsurface (or mineral) estate, and provides for a binding, administrative resolution of possible conflicts between geothermal developers and surface, mineral, or water rights holders.

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8. C. Smith, "West's Many Hot Spots Studied by Scientists As Future Power Source," San Diego Union, June 24, 1979.
9. Adapted from M. Dorfman, "Geopressured Systems" in "Magnitude and Deployment Schedule of Energy Resources," Conference Proceedings, Portland, Oregon, July 21-23, 1975.
10. Dorfman, M., "Geopressured Systems" in "Magnitude and Deployment Schedule of Energy Resources," Conference Proceedings, Portland, Oregon, July 21-23, 1975.
11. G. W. Hinman and J. Robertson, "Comparison of Geothermal Energy and Coal for Selected Uses," Environmental Research Center, Washington State University, (July 1978).
12. E. L. Kaufman and C. L. D. Siciliano, "Environmental Analysis of the Fenton Hill Hot Dry Rock Geothermal Test Site, Los Alamos Scientific Laboratory report LA-7830-HDR, May 1979.

13. The US Congress is currently considering draft legislation that would ameliorate many of the barriers that have already been identified. See S. 1388 (Church) and S. 1330 (McClure).
14. For a thorough discussion of the problems raised by a "water" classification, see: Olpin, O., and Tarlock, A. D., "Water That Is Not Water," Site 13 Land and Water 391 (1978), pp. 421-434. See also the papers included in "Water and Energy Development," at 8 Natural Resource Lawyer #2, (1975), particularly Muys, J. C., "Legal Problems Involved in Developing Water Supplies for Energy Development," and *ibid.*, at p. 335.
15. R. Moses, "The Federal Reserve Rights Doctrine--from 1866 through Eagle County," 8 Natural Resources Lawyer 221, (1975).
16. In Andrus v. Charlestone Stone Products, 436 US 604 (1978), e.g., a 9th Circuit decision allowing the "location" of water under a federal mining claim was unanimously reversed, due to the "havoc" it would create with western states' water laws.
17. G. A. Wilkinson, "Indian Control and Use of Water for Mineral Development," in Institute on Indian Land Development, Rocky Mountain Mineral Law Institute, April 1976.
18. 30 USC §1021 PL 91-581, §22, 84 Stat. 1573.
19. 30 USC §1001-1025, PL 91-581, 84 Stat. 1566, Dec. 24, 1970.
20. S. 883 (introduced by the late Sen. Ernest Gruening, D Alaska, in 1963) was one of the first. Sen. Rept. 1508, 88th Cong., 2d. Sess., Aug. 20, 1964 (Calendar No. 1447). It passed the Senate but not the house.
21. S. 1674 (Bible), "The Geothermal Steam Act of 1966." See Sen. Rpt. 683, 89th Cong., 2nd Sess., Sept. 28, 1966.
22. See Johnson's "Memorandum of Disapproval," Cong. Rec.--Sen. 28863-4 (Oct. 22, 1966),
23. 30 USC §1001 (c), PL 91-581, §2.
24. 30 USC §1101-1164, PL 93-410, 88 Stat. 1079.
25. 30 USC §1102 (1).
26. The responsibility, vested in the "Geothermal Energy Coordination and Management Project" by the 1974 Act, was transferred to the Energy Research and Development Administration (ERDA) but a few months later (PL 95-91, 91 Stat. 567) and to the Dept. of Energy in October 1977.
27. 30 USC §1101 (5) (emphasis added).
28. PL 95-618.
29. PL 95-618, 403 (a) (1), amending 26 USC 613 (b).

30. See, in particular, Renwick, E. S., and Reid, E. L., "Annual Review of Significant Activities-1976," (Geothermal Energy Committee, ABA) 10 Nat. Res. Law 64 (1977).
31. *ibid.*, at p. 99.
32. The Geothermal Energy Act of 1965, Stat. 1965, Ch. 1483, Cal. Pub. Res. Code § 3700, et seq.
33. Stat. 1965, Ch. 1483, § 1, formerly Cal. Pub. Res. Code § 3701 until amended in 1967.
34. The Geothermal Resources Act of 1967, Stat. 1967, Ch. 1398, § 39.
35. Stats. 1967, Ch. 1398, § 39, Cal. Pub. Res. Code § 6903.
36. Cal. Water Code § 102 declares "All water within the state" is owned by the People and subject to appropriation.
37. Cal. Pub. Res. Code, § 6903.
38. Cal. Pub. Res. Code, § 3701.
39. 549 F.2d, § 1271 (9th Cir. 1977), rev. den. sub. nom. Ottoboni v. US, 434 US 930 (1977), rev'g US v. Union Oil, 369 F. supp. 1289 (1973); Pariani v. State of California, S. F. Sup. Ct. 657-291 (December 13, 1977); GKI v. Union Oil, 46 CA 3d 56 (1977).
40. Hawaii Rev. Stat. § 182-1 (9), HB No. 2197-74, Act. 241.
41. Hawaii Rev. Stat. § 182-1 (1).
42. Hawaii Rev. Stat. § 182-2
43. See McBryde Sugar Co. v. Robinson, 54 H. 174 (1963).
44. In the case of geothermal resources, this is spelled out at Hawaii Rev. Stat. § 182-3, HB No. 3033-78, Act. 1.
45. For a more complete discussion of the relevant, geothermal-impacting institutional and political forces at work, see The Legal and Institutional Problems Facing Geothermal Development in Hawaii - Rpt. No. 1006 (J. M. Energy Consultants, Inc., October 1, 1978).
46. Idaho Code, Ch. 40, § 42-4001--42-40155, SL 1972, Ch. 301, § 2, p. 749.
47. Idaho Code § 42-4002 (c).
48. Idaho Code § 42-4002 (a) and (b).
49. SL 1972, Ch. 301, § 1, reprinted following Idaho Code § 42-4001.
50. Idaho Code § 42-4002 (c).

51. SL 1972, Ch. 182, §1, p. 467.
52. Idaho Code, §47-1602.
53. New Mexico Stat. Ann. § 7-15-2, "Geothermal Resources Act of 1967," Laws 1967, Ch. 158, §2.
54. New Mex. Stat. Ann. §7-15-2 (A).
55. Laws 1975, Ch. 272, §1 et. seq.
56. New Mex. Stat. Ann. §65-11-3 (A).
57. New Mex. Stat. Ann. §65-11-3 (D).
58. Regulatory power over geothermal resources in New Mexico resides in the State Oil and Gas Commissioner, another slant away from the water regime.
59. A further statutory distinction between geothermal resources and conventional water resources can be found in the 1975 statute's definition of "low-temperature thermal reservoir":
 "...a geothermal reservoir containing low-temperature thermal water, which is defined as naturally heated water, the temperature of which is less than boiling at the altitude of occurrence, which has additional value by virtue of the heat contained therein, and is found below the surface of the earth, or in warm springs at the surface,..." (New Mex. State. Ann. §65-11-3 (F)).
60. Md. Code, Ann. §8-8A-01 (E).
61. See III (G)(i), *infra*.
62. See III (A), *supra*.
63. Ariz. Rev. Stat. §27-651 (5) (emphasis added).
64. See Kruger, P., "Nuclear Fracturing Stimulation of Hot Rock Formations" in Geothermal Energy (Kruger and Otte, eds.) 1972.
65. Colo. Rev. Stat. §34-70-103(6).
66. Colo. Rev. Stat. §34-70-103(6) (a) (III).
67. La. Acts 1975, No. 735, La. Rev. Stat. §30-681.1 et. seq.
68. La. Acts 1975, No. 784, Amended by Acts 1976, No. 134, La. Rev. Stat., §30.800 et. seq.
69. La. Rev. Stat. §30.801, Added by Acts 1975, No. 784, § 2, amended by Acts 1976, No. 134, §1.
70. La. Rev. Stat. §30.801(1) (a) (emphasis added).

71. La. Rev. Stat. §30.801(1) (c) (emphasis added).
72. La. Rev. Stat. §30.801(3).
73. La. Rev. Stat. §30.809.
74. *ibid.*
75. "Geothermal Resources Act of 1975," Tex. (iv. Stat. Act 5421(s), Acts 1975, 64th Leg., p. 592, Ch. 243, repealed and re-enacted as Vernon's Texas Code Ann. §141.003(4), by Acts 1977, 65th Leg. p. 2689, Ch. 871, Act. I, 2(a) (1), eff. Sept. 1, 1977, enacting the Natural Resources Code.
76. Vernon's Tex. Code Ann. § 141.002.
77. Vernon's Tex. Code Ann. § 141.011.
78. Vernon's Tex. Code Ann. § 141.012.
79. *ibid.*, at subsection (4).
80. § 1, Ch. 71, SLA 1971, as amended by § 6, Ch. 104, SLA 1971, § 34-36, Ch. 71, SLA 1972 and § 40 and 41, Ch. 127, SLA 1974.
81. Alaska Stat. § 38.05.181(q) (6).
82. ORS 522.005(7), (1975, c. 522, § 3).
83. ORS 522.025 (1975, c. 552, § 4).
84. *ibid.*, at subsection (2).
85. ORS 522.035 (1975, c. 552, § 21) (emphasis added).
86. Nevada Rev. Stat. § 322.005.
87. Nevada Rev. Stat. § 534 A.020.
88. Nevada Rev. Stat. § 534 A.040 (emphasis added).
89. Nevada Rev. Stat. §361.027 (added by 1973, 1114). There has already been some controversy over state taxation of geothermal leases on federal land in the State. See "Tax Assessments on federal Leases Challenged in Nevada by Earth Power Corporation," 5 Geothermal Energy Magazine No. 10 (November 1977), at p. 33.
90. Public Land Statistics 1976 (BLM/DOI), at p. 10, Table 7.
91. Utah Code Ann. § 73-1-20 (enacted by L. 1073, Ch. 189, § 1).
92. Utah Code Ann. § 73-1-1.

93. Under the authority of Utah Code Ann. §65-1-1, et. seq.
94. Wyo. Stat., §41-121(b) (emphasis added).
95. Montana L. 1974, Ch. 111, §1 et seq., Montana Rev. Code §81-2602(1).
96. Montana Rev. Code §81-2602(1).
97. Montana Rev. Code §81-2611.
98. Montana Rev. Code §81-2602(1).
99. Montana Rev. Code §89-867(1).
100. RCW 79.76.030(1).
101. RCW 79-76.040.
102. National Research Council, Geothermal Resources and Technology in the United States (1979), at p. 1 hereinafter cited as "NRC Report."
103. Though some holes have been drilled to depths in excess of 13 miles (9 km), none was for commercial purposes.
104. Los Alamos Scientific Laboratory, "Hot Dry Rock Geothermal Energy Development Program, Annual Report, FY 1978," LA-7807-HDR, April, 1979.
105. NRC Report, op. cit., at p. 1.
106. Olpin, O., "The Law of Geothermal Resources," 14 Rocky Mtn. Min. L. Inst. 123 (1968) at p. 131.
107. Schlauch, P., and Worcester, T., "A Primer for the Practitioner," 9 Land and Water L. Rev. 327 (1974), at p. 357.
108. Public Land Statistics--1976 (BLM), at p. 10, Table 7.
109. Cal. Pub. Res. Code §3742.2.
110. Remarks of Dennis Goldstein, Vice-Chairman, Geothermal Energy Committee, Natural Resources Section, ABA, at Committee's 1978 Mtg., San Francisco, CA, Jan. 1978.