Property Rights to Geothermal Resources

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with Technical Analysis by L.J.P. Muffler

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Property Rights to Geothermal Resources†

(Part Two)

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INTRODUCTION

The term "geothermal energy" may be defined broadly as the heat energy of the earth. However, this energy can be harnessed with current technology only in those areas where heat anomalies exist. Geothermal energy is being exploited currently only in areas where fluid is in contact with hot rock formations beneath the surface of the earth. Heat is transmitted from the hot rock to the fluid, which is then extracted from the subsurface formation and used as a source of heat energy. There has been much speculation as to whether the allocation of geothermal resources is governed by a property regime applicable to water or oil and gas.

This article examines the status of the property regime governing geothermal resources and investigates alternative regimes with a view to identifying a system which promotes an efficient allocation of resources. It is divided into two parts. Part One, published in the previous issue of the Ecology Law Quarterly, began with a technical discussion providing geological and engineering information necessary to an understanding of the legal issues raised in the article. This was followed by an analysis of the property rights to geothermal resources under express federal and state mineral reservations, and an exploration as to whether a case for federal retention of these resources could be made even without an express reservation. The final section of Part One concluded with an argument against application to geothermal resources of the common law doctrine that surface ownership carries with it absolute ownership of all that lies beneath the surface of the land, in the absence of a severance of the mineral estate.

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Two decisions relating to the discussion of mineral reservations have been rendered since Part One was written. In *United States v. Union Oil Co.*, the Ninth Circuit Court of Appeals held that geothermal resources are included within mineral reservations under the Stock Raising Homestead Act, reversing the District Court decision discussed in Part One of this Article. The circuit court's decision rested on the conclusion that the Act was a departure from previous government land disposition policy based on the mineral or nonmineral character of the land at the time of disposal. The court held that the Act recognized multiple uses of land and accommodated the government's desire to retain mineral fuels while permitting agricultural pursuits.

The discussion of the California reservation has been advanced by the decision in *Pariani v. State*, which involved the interpretation of California Public Resources Code section 6407, discussed in Part One. The court held that geothermal resources were reserved to the state since they were encompassed within the terms "mineral waters" and "mineral deposits." Because references in governmental documents to "mineral waters" were based on the thermal and mineral quality of the water, the Superior Court concluded that geothermal resources, which are distinguished by their thermal and mineral characteristics, were also "mineral waters." The court also held that geothermal resources were "mineral deposits" because the "geothermal system is so inextricably involved with minerals in its geological development from the commencement of the earth to its present state." It further held that "gas," as used in the statute, referred only to hydrocarbon gas.

Part Two of this article, presented herein, addresses the nature of the property regime that we believe should be considered for geothermal resources. A determination that the government does not own the resources does not necessarily mean that the patentee or his successor has the right to exploit them. Even when the government has no proprietary claims, the sovereign bears the responsibility of providing an allocative regime for the

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312a. 549 F.2d 1271 (9th Cir. 1977).
312c. The essence of the court's reasoning is as follows:
   The agricultural purpose indicates the nature of the grant Congress intended to provide homesteaders via the Act; the purpose of retaining government control over mineral fuel resources indicates the nature of reservations to the United States Congress intended to include in such grants. The dual purposes of the Act would best be served by interpreting the statutory reservation to include geothermal resources. 549 F.2d at 1274 (9th Cir. 1977). The court also stated that all elements of the system—magma, porous rock, and water itself—can be classified as minerals and alluded to the constructional preference in favor of the United States in resolving ambiguities.
312e. 6 ECOLOGY L. Q. 247, 282-84 (1977).
resource. The legislature may fulfill that responsibility by express definition of the nature of property rights in the resource, or the courts may do so through the development of common law property rules. Part Two begins with an examination of the allocative regimes for geothermal resources in several western states. This examination reveals that in many states the law is either ambiguous or based on a rule of capture. Several states have adopted the appropriation system.

The second section of Part Two considers a number of possible models for the allocation of geothermal resources, from the perspective of attaining economic efficiency. The alternatives considered range from complete governmental exploitation of the resource to noninvolvement of the government except to define the property rights of private owners. A major subsection considers property regimes for geothermal resources based not on government ownership but on the sovereign’s responsibility to control the development of geothermal resources through its power to define property rights. Since property regimes for geothermal resources have not yet been established with any certainty in most states, the states have the opportunity to evaluate the efficiency of potential alternative regimes. Here, four models currently applied to oil, gas, and percolating groundwater are examined—the rule of capture, the reasonable use rule, the correlative rights doctrine, and the appropriation system. This study has led us to propose an appropriation system for allocating geothermal resources that would be relatively efficient compared with other regimes.

The final section of the article describes in detail a proposed appropriation system for geothermal resources. The scheme proposed seeks to insure efficient utilization of the resource through three mechanisms: an efficient initial assignment of rights through an auction, the protection of rights acquired and developed through an appropriation system, and flexibility to alter development patterns in the light of new information and changed circumstances through the oversight of an administrative agency.

VI. ALTERNATIVE PROPERTY REGIMES

We initially set forth the actions taken by several states with respect to geothermal resources underlying lands not publicly owned and then proceed to a more theoretical and systematic analysis of alternative models.

A. Existing Allocative Regimes for Geothermal Resources

1. California

In California the allocative regime for geothermal resources is uncertain. Section 3742.2 of the Public Resources Code provides that any

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313. Section 3742.2 provides:
Any person having drilled a well or wells on state, federal or private lands which are producing or, according to the Geothermal Resources Board, are capable of
person who has drilled a well which is producing or is capable of producing geothermal resources on state, federal, or private land may apply to the Geothermal Resources Board for a certificate of primary purpose. If the Board determines that "such well or wells are primarily for the purpose of producing geothermal resources and not for the purpose of producing water usable for domestic and irrigation purposes," the Board must issue the certificate. The certificate establishes a "rebuttable presumption" that "such person has absolute title to the geothermal resources reduced to his possession from such well or wells." This presumption may be rebutted only if it is shown that the "water content of the geothermal resources is useful for domestic or irrigation purposes without further treatment" but not if the production of such water is a "byproduct incident to the production of the geothermal resources."  

Section 3742.2 raises more problems than it resolves. On first reading, the section might give the impression that the legislature has adopted a rule of capture similar to that applicable to oil and gas. But further analysis supports the view that section 3742.2 addresses only the title to resources reduced to possession and does not establish an allocative regime for geothermal resources in place.

In California the basic allocative regime for oil and gas is based on a rule of capture, which recognizes the overlying landowner's right to drill a well on his land to capture whatever oil and gas he can, and recognizes his title to that which he captures. Section 3742.2 at first appears to apply this model to geothermal resources. Additional support for the rule of capture interpretation is present in statutory provisions, similar to those for oil and gas operations, that permit cooperative development and operation of a geothermal area as a unit in order to prevent unreasonable waste. On the other hand, many of the drilling and operational problems of oil and gas and of geothermal resources production are similar, so the legislature may simply have borrowed many provisions regulating oil and gas production.
and applied them to geothermal resource exploitation without intending to adopt any property regime governing rights to the geothermal resources not reduced to possession.

The latter inference may be more persuasive for several reasons. First, section 3742.2 deals only with the title to resources reduced to possession and does not consider who has the continuing right to produce the geothermal resources in place. For example, the section is silent as to whether the certified party may be enjoined from producing or subjected to damage liability in an action by another party.\footnote{318} Second, the section taken as a whole seems to indicate a legislative attempt to resolve potential conflicts stemming from claims based on groundwater rights. Even this effort has been clumsily accomplished. The section initially provides that a certificate of primary purpose may be issued to any person who has drilled a well capable of producing geothermal resources "when the board determines that such well or wells are primarily for the purpose of producing geothermal resources and not for the purpose of producing water usable for domestic and irrigation purposes."

The certificate of primary purpose establishes a rebuttable presumption "that such person has absolute title to the geothermal resources reduced to his possession from such well or wells."\footnote{319} The presumption of ownership may be rebutted "only upon a showing that the water content of the geothermal resources is useful for domestic or irrigation purposes without further treatment thereof, but not by virtue of any production of such water as a byproduct incident to the production of the geothermal resources."\footnote{320} This last provision is crucial. If the geothermal fluid reduced to possession is capable of being used for domestic or irrigation purposes without further treatment, the presumption of ownership appears to be rebutted, and, if rebutted, presumably the established law of groundwater rights would apply.

But there is a further exception. Even if the water is of a quality suitable for domestic and irrigation purposes, the presumption of ownership is not rebutted if the water is a "byproduct" of the production of geothermal resources. Consequently, if the objective of the certified party's activity is to extract the energy from the fluid, the water would be a "byproduct" of the production of geothermal resources and the presumption of ownership would apply. Moreover, the section is silent as to what remedies a superior water right owner might have if geothermal production should interfere with

\footnote{318} The section does not purport to deal with a situation where a landowner drills a well on his land but bottoms the well in the neighbor's land. It should be recognized, however, that even with respect to oil and gas California does not confer upon overlying landowners title to the resources in place.
\footnote{319} \textit{CAL. PUB. RES. CODE} § 3742.2 (West 1972).
\footnote{320} \textit{Id}.
\footnote{321} \textit{Id}. 
his right. Perhaps the purpose of the presumption of ownership was to protect purchasers of the extracted resources from any liability under conditions where rights to the resources are uncertain.322

Third, a person seeking to produce geothermal resources is not required to apply for a certificate. This fact provides further evidence that the legislature did not intend to establish property rights for these resources in place. If a certificate has not been obtained, the possessor does not receive the benefit of the statutory presumption of ownership of the resources reduced to his possession. However, the section does not deal with the rights of uncertified possessors.

Finally, it is unlikely that section 3742.2 was intended to establish a comprehensive regime, for if the legislature had intended to adopt a property regime similar to that governing oil and gas, it could have done so clearly and directly instead of obfuscating the purpose by a certificate.

In conclusion, the allocative regime for geothermal resources in California is not clearly defined. However, even if section 3742.2 were construed to adopt a rule of capture, the efficiency of this rule should be evaluated to determine whether such a reform should be undertaken.323

2. Other States

a. Rights based on overlying landownership

Arizona has adopted provisions which emulate regulations commonly applied to oil and gas.324 They are designed to prevent the adverse effects

322. The water allocation system in California is essentially based on the correlative rights of the overlying landowners with the appropriation doctrine operating upon the water surplus to the needs of the overlying landowners within the average safe annual yield of the aquifer. City of Pasadena v. City of Alhambra, 33 Cal. 2d 908, 925-26, 207 P.2d 17, 28 (1949).

Since the certification provision covers low-temperature geothermal resources, defined in CAL. PUB. RES. CODE § 3703.1 (West Supp. 1977) as having a temperature that is no more than the boiling point of water at the altitude of occurrence, the conflicts between exploiters of geothermal resources and groundwater right owners are increased.

323. The legislature may be able to challenge allocative rules for the future despite assertions that the changes impose unconstitutional takings. Baeth v. Hoisveen, 157 N.W.2d 728 (N.D. 1968); Knight v. Grimes, 80 S.D. 517, 127 N.W.2d 708 (1964) (cases sustaining a statute which changed the water allocation regime from one based on overlying landownership to an appropriation system, although protecting existing uses). But compare Frost v. Ponca City, 541 P.2d 1321 (Okla. 1975), where the city had prohibited the drilling of wells by landowners to protect residents from escaping gaseous vapors from refined hydrocarbon in shallow sands underlying the parcels in question. The city then drilled wells, captured the hydrocarbon, and sold it. The overlying landowners brought an action to recover the proceeds from the sale. The court held that although the city was justified under its police power in prohibiting drilling by private parties and in capturing the hydrocarbon, it was required to account to the landowners for the net revenue. The court reasoned that the city “may not authorize third persons to enter upon his premises and capture minerals underlying same without compensating landowner.” 541 P.2d 1321, 1323-24. The Frost case is not quite apposite since it involved city activity and a city could not alter the basic property rights as defined by the state; but it does shed some light on the Oklahoma courts’ view of the police power, since the discussion is not put in terms of a state-local conflict.

associated with unrestrained drilling operations. The provisions do not directly define property rights in the geothermal resources. However, it is arguable from these provisions that Arizona recognizes the right of landowners to the resources underlying their lands, since many of the provisions are designed to regulate the inefficiencies associated with an unrestrained right to capture the resources.

The Oil and Gas Conservation Commission is directed to "supervise the drilling, operation, maintenance and abandonment of geothermal resource wells [so] as to encourage the greatest ultimate economic recovery of geothermal resources." Other provisions deal with cooperative agreements, unitization upon approval of the requisite number of interest holders, and voluntary and compulsory pooling within a drilling unit upon application of an owner. These provisions are commonly found in oil and gas regulations.

Oregon has recognized rights to geothermal resources in the overlying landowners. Although one might assume that these rights are similar to other rights of the overlying landowner to fluid resources, their status is not entirely clear since the statutory section contains an exception holding that "nothing in this section shall divest the people or the state of any rights, title or interest they may have in geothermal resources." An opportunity for the state to assert its rights to geothermal resources and to devise an alternative property regime appears to be left open.

b. Appropriation system

Montana and Wyoming have amended their groundwater statutes to include geothermal resources so that the method of acquisition of rights to geothermal resources is identical to that applicable to groundwater. The scope of the Montana statute is not entirely clear inasmuch as the statute refers only to "geothermal water." Unless the statute is also applied to vapor-dominated geothermal systems, a gap will be present in the law with respect to such systems. In contrast, Wyoming has explicitly included "hot water and geothermal steam" within its groundwater statute.

325. Id. § 27-652A.
326. Id. § 27-664.
327. Id. § 27-665.
328. Id. § 27-666.
330. Id.
331. MONT. REV. CODES ANN. § 89-867(1) (Supp. 1975). Although a later adopted provision classifies "geothermal resources" as sui generis, being neither mineral or water resources, MONT. REV. CODES ANN. § 81-2602 (Supp. 1975), the definition seems to apply only to state leasing provisions. There is another provision that requires the lessee to obtain water rights if "any geothermal development located on state land requires the utilization of water." Id. § 81-2611. The latter provision is unclear as to whether it refers to the naturally occurring geothermal fluid or to water that may be necessary to extract heat from the hot dry rock.
332. WYO. STAT. ANN. § 41-121 (Supp. 1975).
In both states the procedure for acquiring rights to geothermal resources begins with the filing of an application with a state administrative agency. In Montana the agency is required to issue a permit if (1) unappropriated water is present in the source of supply; (2) the rights of a prior appropriator will not be adversely affected; (3) the proposed means of diversion or construction are adequate; (4) the proposed use of "water" is beneficial; and (5) the proposed use will not interfere unreasonably with other planned uses or developments for which a permit has been issued or for which "water" has been reserved. If the above criteria are met, a permit is issued; upon application of "water" to a beneficial use and compliance with the permit conditions, a certificate of water right is issued.

The filing date of an application determines priority and, as between appropriators, the first in time is the first in right. However, the priority of appropriation does not include "the right to prevent changes by later appropriators in the condition of water occurrence, such as . . . the lowering of a water table, artesian pressure or water level, if the prior appropriator can reasonably exercise his water right under the changed conditions." Upon application of a public entity, the agency may reserve water for future uses. Any transfer of an appropriative right separate from the land to which it is appurtenant requires the approval of the agency, which must assure that others will not be adversely affected.

In Wyoming the agency is required to grant an appropriation permit unless the proposed withdrawal is from a critical area, the proposed means of diversion and construction are adequate, or the granting of a permit as a matter of course would not be in the public interest. In a controlled area, a permit will issue only if unappropriated water is present, the proposed means of diversion and construction are inadequate, the proposed location of the well does not conflict with well-spacing regulations, and the use would not be detrimental to the public interest. A permit is issued with the

334. Mont. Rev. Codes Ann. § 89-885 (Supp. 1975). Of course, these provisions were adopted earlier to deal with appropriation of ordinary water.
335. Id. § 89-888. A certificate will not be issued until there has been a general determination of existing rights in the source of supply.
336. Id. § 89-891.
337. Id.
338. Id. § 89-890.
339. Id. § 89-893.
341. Id. § 41-140. A controlled area may be designated if (1) the use of groundwater is approaching the current recharge; (2) the groundwater level is declining or has declined excessively; (3) conflicts between users are occurring or are foreseeable; (4) waste of water is occurring or may occur; or (5) other conditions exist that require regulation in the public interest. Id. § 41-129. When an applicant requests permission to appropriate from a controlled
condition that the right to appropriate does not include "the right to have the water level or artesian pressure at the appropriator's point of diversion maintained at any level or pressure higher than that required for maximum beneficial use of the water in the source of supply." 342

Under these statutes a rough allocative regime is provided for geothermal resources but many problems must be resolved administratively. The most crucial questions in the allocation of geothermal resources will be the following: when will the reservoir be deemed to be fully appropriated? To what extent must a prior appropriator tolerate a decrease in the enthalpy of the fluid due to withdrawals by subsequent appropriators? Should forfeiture provisions be made applicable to geothermal resources?

**Mixed or unclear allocative regimes**

It is difficult to determine the nature of the property regimes that have been adopted for geothermal resources in Idaho and Washington. In those states geothermal resources are declared to be "sui generis, being neither a mineral resource nor a water resource." 343 The statutes appear to be designed to coordinate the management of geothermal resources with the management of water resources but do not explicate clearly how rights to geothermal resources for power generation are obtained.

In Idaho, a person who proposes to construct or alter a well or an injection well for the purpose of seeking geothermal resources is required to file an application with the Department of Water Administration. 344 Moreover, if the well may yield water to be used for a beneficial purpose other than to extract mineral or heat energy, 345 a permit must also be sought under the statutory provisions relating to water permits. 346 Any person who proposes to use geothermal resources solely for a greenhouse, hot house, swimming pool, hot springs bath, hot water fish propagation facility, space heating plant, or similar facility, need not comply with the geothermal permit requirements if he obtains a valid water right permit for such operation. 347 In any case the Department must refuse a geothermal permit if area, notice is given and a hearing is held to consider objections to the issuance of the permit.

Id. § 41-140.

342. Id. § 41-141.

343. IDAHO CODE § 42-4002(c) (Supp. 1976); WASH. REV. CODE ANN. § 79.76.040 (Supp. 1975).


345. The term used in the statute is "other than as a mineral source, an energy source, or otherwise as a material medium." Id. § 42-4003(b). "Material medium" is defined as:

Any substance, including, but not limited to, naturally heated fluids, brines, associated gases, and steam, in whatever form, found at any depth and in any position below the surface of the earth, which contains or transmits the natural heat energy of the earth, but excluding petroleum, oil, hydrocarbon gas, or other hydrocarbon substances.

Id. § 42-4002(e).

346. Id. § 42-4003(b).

347. Id. § 42-4003(e). If the use for a greenhouse, etc., was made before January 1, 1972, or if the person had a water right on that date, the user is excused from compliance with the
it finds that a geothermal well will unreasonably decrease ground water available for prior water rights for beneficial uses other than mineral extraction or power production, unless the applicant has also obtained a permit to appropriate water. 348

Idaho has attempted to coordinate rights to geothermal resources with rights to water for ordinary beneficial uses on the basis of the functional use of the hot water. If geothermal resource extraction for any purpose will have an adverse effect on prior water right holders, the latter are to be protected. Presumably those who obtain a water rights permit will have their rights integrated into the water allocative system. What Idaho has not done, however, is to establish an appropriative system 349 or any other allocative regime to determine the rights to those geothermal resources that are used for power generation or mineral extraction. There is no provision requiring the Department to deny a geothermal permit if the proposed well will adversely affect an existing geothermal well being used for mineral extraction or power generation, although the Department is authorized to deny a permit if it is against the "public interest." 350 Idaho has evidently authorized the Department to make incremental decisions based on the effect upon the resources or reservoir under a "public interest" standard, 351 with power to compel unitization. 352 The nature of rights obtained under a geothermal permit will depend to a great extent upon the departmental conception of the "public interest" to protect prior producers.

In Washington, by-product water resources available for beneficial uses, including space heating, swimming pools, etc., are governed by the appropriation regime for groundwater resources. 353 As in the Idaho scheme, the agency responsible for regulating drilling and other facets of geothermal development is to grant a permit if it would be in the "best interest of the state." 354 To prevent waste, 355 the agency is authorized to promulgate

permit requirement. Id. § 42-4003(g). However, any well with a depth of 3,000 feet or more in a geothermal resource area must have a geothermal permit.

348. Id. § 42-4005(e).

349. Idaho has adopted the appropriation doctrine with respect to groundwater. See Id. §§ 42-103, 42-226.

350. Id. § 42-4005(b). One of the factors that the Department may consider in determining public interest is a "possibility that the construction and maintenance of the proposed well . . . will damage any geothermal resource . . . by unreasonable reduction of pressures or unreason- able reduction of any geothermal resource material medium or in any other manner, so as to render any geothermal resource of unreasonably less value." Id. § 42-4004(b) (3).

Since there is a specific provision directing the department to reject an application if the proposed operation will unreasonably decrease water available for prior water rights, Id. § 42-4005(e), but none with respect to adverse effects upon prior geothermal wells, it seems that the legislature intended to leave this to be decided under the "public interest" standard.

351. Id. § 42-4005.

352. Id. § 42-4013.


354. Id. § 79.76.080.

355. Id. § 79.76.050(1).
"combining orders, unitization programs, and well spacing."356 Neither the Idaho nor the Washington statute makes clear whether their supervisorial schemes operate against the backdrop of rights in overlying landownership.

The state of the law in Colorado is extremely ambiguous. The Oil and Gas Conservation Commission has authority to establish drilling units and to require the pooling of interests in order to prevent waste of geothermal resources, to avoid the drilling of unnecessary wells, to protect correlative rights, and to encourage maximum economic recovery.357 The term "correlative rights" is defined to mean that "each owner and producer in a common pool or source of supply of geothermal resources shall have an equal opportunity to obtain and produce his just and equitable share of the geothermal resources underlying such pool or source of supply."358 While the term "owner" is left undefined, one may reasonably conclude that the reference is to overlying landowner, in view of the definition of waste. The term "waste" is defined in part as:

Abuse of correlative rights of any owner in a pool due to nonuniform, disproportionate, unratable, or excessive withdrawals of geothermal resources therefrom, causing reasonably avoidable drainage between tracts of land or resulting in one or more producers or owners in such pool producing more than his just and equitable share of the geothermal resources from such pool.359

While the above regime seems to contemplate rights based on overlying landownership, confusion arises because of additional provisions which make water rights law applicable to water produced or used in connection with geothermal resources.360 These provisions extend the authority of the State Engineer or Ground Water Commission to regulate the production or use of water from geothermal wells, whether in liquid or gaseous form.361 Furthermore, before the Oil and Gas Conservation Commission may issue a permit for exploration or development of geothermal resources, the State Engineer must find that unappropriated water is available for withdrawal and that the vested water rights of others will not be injured materially, unless the permittee does not contemplate the appropriation or use of groundwater.362

It is difficult to determine how the above management scheme works. Where the geothermal resources and groundwater are interrelated, it is clear

356. Id. § 79.76.160.
357. COLO. REV. STAT. § 34-70-104 (Supp. 1976).
358. Id. § 34-70-103(3).
359. Id. § 34-70-103(13) (c). Identical definitions exist for oil and gas. Id. § 34-60-103(4), (13)(c).
360. Id. § 34-70-107(1). Id. § 34-70-107(2) provides: "Nothing in this article alters or amends the authority of the state engineer or ground water commission to regulate the production or use of water from geothermal wells, whether in liquid or gaseous form." This is another ambiguous provision which makes a firm conclusion regarding the property regime for Colorado rather difficult.
361. Id. § 34-70-107(4) (Supp. 1975); Id. § 37-90-137 (1973).
362. Id.
that existing water rights are to be protected from subsequent geothermal resource production. It is not clear, however, that earlier geothermal resource production is to be protected from subsequent groundwater production, and, since correlative rights are in terms of just and equitable shares, it would appear that there is no priority of right by priority of use among geothermal producers.362a

B. Possible Models

1. Objective

As we have noted, with the exception of few states, no precisely defined allocative regime for geothermal resources exists in the states examined. In the Imperial Valley and the Geysers area in California, however, private overlying landowners seem to be proceeding on the premise that they have rights to the resources since many have executed leases in much the same manner as oil and gas leases are issued. Because geothermal resources are unique, and existing property regimes are unclear, state legislatures have a rare opportunity to evaluate fully at this early stage the strengths and weaknesses of alternative property regimes. Inaction by the legislatures may lead to later tension when they seek to modify property definitions developed by the courts, which are institutionally limited in the alternatives that they can consider and must decide cases within the confines of litigants advancing their own interests.

The primary objective in defining property rights is to establish a system that tends to maximize net satisfactions derived by society from the use of various resources. Property rights for a given resource, such as geothermal resources, should be conducive to the efficient allocation of that resource. In this context, the term “efficiency” has three components: (1) the resource will be assigned to that use which will yield the greatest net benefit; (2) the present marginal value of current and future consumption will be the same;363 and (3) the cost of other resources consumed or affected

362a. Perhaps the above provisions contemplate that geothermal resources would fall within those aquifers with respect to which the State Engineer, in acting upon a well permit, is bound by the restriction that “only that quantity of water underlying the land owned by the applicant or by the owners of the area, by their consent, to be served is considered to be unappropriated.” Id. § 37-90-137(4) (1973).

Vranesh & Musick, Jr., Geothermal Resources: Water and Other Conflicts Encountered by the Developer, in ROCKY MOUNTAIN MINERAL LAW FOUNDATION, GEOTHERMAL RESOURCES DEVELOPMENT INSTITUTE 6-1, 6-49 (1977), state:

Under these laws it is thus important to distinguish hot water (a geothermal resource) from cooled waters (a geothermal by-product) because it is only the former (hot water) which is controlled by the correlative rights doctrine. In other words, the geothermal owner and producer have an equitable right only as to the heat transfer mechanism and not to the by-product of cooled water. This distinction brings existing water laws into play. Since the water recovered from the geothermal operations would by definition be excluded from regulation by the Act, it is existing water laws that must control.

363. Consider the point made in Herfindahl, Goals and Standards of Performance for the Conservation of Minerals, 3 NAT. RES. J. 78, 83-84 (1963), that market allocation is a static welfare system because future generations are not represented in the current market.
in the exploration and production of geothermal resources will not exceed the capitalized value of benefits from geothermal production.

A competitive market is the theoretical model usually suggested as a means of achieving this efficiency. When a pricing system can be used for allocation, the determining factors are opportunity costs and willingness to pay, both of which are influenced in part by the individual's access to capital. Even though these determinants of the allocation process are influenced in part by the distribution of wealth, the pricing system is intrinsically neither more nor less equitable than any other allocative system. Pricing is, nevertheless, explicit and consistent from one allocation problem to another. Most importantly, pricing permits the ready comparison of one outcome with another in terms of an explicit, readily observable and communicable criterion.

If, however, full opportunity costs are not reflected in the market price—as where costs are external to the exchange process—a profit maximizer who does not bear these costs and realizes positive utility from his activity will consume or produce more than is socially efficient. Conversely, where marginal benefits realizable are not captured in prices, there may be underproduction since the producer is not rewarded for the nonmarket benefits he creates.

For the market to promote efficiency, the property regime governing a resource must satisfy several requirements. First, the right to a given resource must be freely transferable, because the essence of market allocation is the exchange process by which that use promising the greatest net benefits will outbid others. Transferability is enhanced when rights to the resource are defined clearly, avoiding legal uncertainties as to their scope. In addition, the property regime should confer exclusive control over a discrete unit of the resource in order to reduce risk and thus to promote investment in the utilization of the resource. Exclusive control is necessary also to bring about equivalence at the margin of the present value of resource use over various time periods. Without this exclusive control, a person will be discouraged from postponing production, even where the discounted value of future use is greater than the value of current consumption. This may occur because lack of exclusivity will permit others to utilize the resource in the meantime. Finally, as noted above, the full opportunity costs and benefits should be subject to the exchange process to the extent feasible.

The exchange itself, however, is not costless. Information gathering and the process of exchange may be quite burdensome where the costs and benefits are diffused within the community. Property rights should be

364. We are indebted to De Vany, Eckert, Meyers, O'Hara, & Scott, A Property System for Market Allocation of the Electromagnetic Spectrum: A Legal-Economic-Engineering Study, 21 STAN. L. REV. 1499, 1506 (1969), for a succinct analysis of these attributes.
formulated with a view toward minimizing transactional costs, and where the exchange process does not operate effectively, public intervention may be necessary to correct inefficiencies with which the market cannot cope.

We now focus upon geothermal resources. The possible uses of geothermal resources in the Imperial Valley are (1) power generation: (2) production of water of such quality as would be useful for agriculture, municipal purposes, industry, or dilution of salinity of the Colorado River; (3) industrial processing; (4) space heating and cooling; and (5) mineral extraction.

Power generation can complement water or mineral production if unused fluid or fluid which has passed through the turbines is captured and subjected to a desalinization or demineralization process. However, power generation and water production can be competitive if they both are initial uses. Moreover, power generation may permit the reinjection of the extracted fluid, which may prolong the life of the reservoir, whereas the production and delivery of water for export will result in a depletion of the reservoir fluid. The use of resources for either power generation or water production may be competitive with the use for either industrial processing or space heating and cooling to the extent that they are independent initial uses of the resources.

While the value of the geothermal resources in the Imperial Valley for most uses lies in their heat energy, the fluid cannot be transported economically any great distance without excessive loss of usable energy. Consequently, the resources from a particular reservoir must be utilized close to the wells tapping the reservoir. This is true even with respect to the production of water serviceable for irrigation since demineralization is dependent upon the use of the heat energy of the fluid.\textsuperscript{365}

In the exploration and development of geothermal resources, a number of nonmarket costs may be present, depending upon the property specifications established. A number of costs might be imposed upon those not involved in resource exploration and development activity, such as: (1) subsidence of the overlying land and seismic disturbances causing damage to structures and water delivery and drainage facilities; (2) degradation of air quality by emission of odorous or toxic substances; (3) noise which discomforts those who live and work in the neighborhood; and (4) aesthetic degradation depending upon site location.

Nonseparabilities in the production of geothermal resources may result from the interdependence of production sites in the same reservoir. First, since the fluid is migratory, one well may drain the fluid away from another well. Second, one well may cause the fluid to migrate laterally towards another well, and the migratory fluid may be colder or hotter than the fluid that would otherwise have been extracted in the latter well. Third, to a

certain extent, depletion of the fluid might increase the enthalpy of fluid remaining in parts of the reservoir, thereby increasing the utility of the fluid for power generation. On the other hand, depending upon the rate of extraction and recharge, the temperature of the extracted fluid may decrease if the heat must flow from the hot rocks to a greater mass of fluid, thereby lowering the enthalpy of the fluid. Fourth, as a result of reservoir depletion, the fluid may turn from the liquid to the steam phase and the flow rate may increase. Finally, reinjection of the waste fluid or imported water at a given location may adversely affect a producing well.

Whether a reservoir is exploited under a single, unified operation or under multiple, independent operations, there will be production interdependencies if there exist reciprocal nonseparabilities between and among different locations. Thus, the efficient level of output at one location cannot logically be determined independently of the level of output at all other locations on a reservoir. The marginal cost of production at each location is tied to the marginal cost of production at other locations. These nonseparabilities must be taken into consideration in designing a property allocative regime, in order to permit production of the resources at the lowest possible marginal cost. Finally, consideration must be given to the possibility that production nonseparabilities may exist due to drainage or other interdependent effects among reservoirs.

2. Government Exploration, Production, and Sale of Geothermal Resources

The first property regime to be considered is government ownership, exploration and production of geothermal resources. We refer the reader to the earlier discussion relating to rights to the resources, and for the purposes of this discussion we hypothesize a situation in which either the federal or state government has complete rights to the resources. For convenience, the ensuing discussion will refer only to government ownership in general. Apart from ideological preferences for collective public ownership, the case for government ownership, exploration, and production rests upon three arguments: (1) economies of scale; (2) maintenance of competition; and (3) externalities and public goods.

Economies of scale exist when a production process involves decreasing long run marginal costs for production on a massive scale. Production at high levels may even be necessary in order to yield a positive net return. Two types of economies of scale should be considered with respect to exploitation of geothermal resources. First, there may be a natural monopo-

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366. See Part One of this article, published in 6 ECOLOGY L.Q. 247 (1977).
367. The technical literature dealing with these arguments is huge. This literature is ably synthesized in a quasi-technical form in the collection of papers found in 1 SUB-COMM. ON ECONOMY IN GOV'T OF THE JOINT ECONOMIC COMM., THE ANALYSIS AND EVALUATION OF PUBLIC EXPENDITURES: THE PPBS SYSTEM, 91st Cong., 1st Sess. (1969).
ly if production processes are characterized by falling marginal costs when all inputs are variable. Second, large projects may involve risks so substantial that, given the requisite scale of financing, only the purported greater risk-pooling ability of the government can make them economically attractive.

The first argument relating to the economies of scale is that in a natural monopoly industry, characterized throughout the relevant output range by a falling long-run marginal cost curve, only one firm can survive; in the absence of governmental intervention, the firm will exploit its monopoly position. Since our focus is upon the allocative regime for the resources, we are not concerned with natural monopolies arising in the utilization of the geothermal resources, such as electric power generation. Thus, the present inquiry is only whether the exploration, development, and production processes are characterized by a declining marginal cost curve. Our impression is that they are not. These processes do not appear to permit the distribution of fixed costs for equipment over ever larger outputs since drilling equipment, wells and pipelines have relatively small, fixed capacities. In this regard there appears to be very little difference between the exploitation of oil and gas, which cannot be identified as a natural monopoly, and the exploitation of geothermal resources.

The second facet of the economies of scale argument is the greater risk pooling ability of governmental operation. The government is able to spread the risk of geothermal resource exploitation over all its activities and thereby exchange the risk of a proportionately much larger and uncertain cost in one activity for a smaller and more certain cost in a greater number of activities. Assuming that risk aversion is a universal phenomenon, the government's greater ability to spread the risk suggests that the costs associated with any degree of risk are lower for it than for private enterprises. The above argument, however, is not persuasive as applied to the exploitation of geothermal resources. The risks are not so high that governmental intervention is necessary. Firms large enough to spread the risks have entered the field of geothermal resources, and smaller firms may be able to form joint ventures. However, if risks are sufficiently large to create a substantial barrier to entry into the industry, this may lead to the oligopolistic market in geothermal resources, a factor which should be weighed in this argument.

The second argument for governmental ownership and production of geothermal resources perceives governmental control as necessary to maintain competition by counterbalancing the possible monopsonistic market. If only one buyer exists for geothermal resource production—for instance, a single public utility—the buyer would be able to use its market power to

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368. The list of bidders on various federal parcels in the bidding conducted in January, 1974, included Shell Oil Co., Signal Oil & Gas Co., Union Oil Co. of Cal., Occidental Petroleum Corp., Chevron Oil Co., and many others. See Bureau of Land Management, U.S. Dep't of the Interior, Geothermal Lease Bid Record, Sacramento, Cal., Jan. 22, 1974.
purchase energy at less than competitive prices. Accordingly, it might be argued that the government, as sole producer and seller, could force the single buyer to act as if it were part of a large and impersonal market of buyers. However, the single seller can no more induce the monopsonistic buyer to act as a perfect competitor than the single buyer can induce the monopolistic seller to behave as a perfect competitor. No existing economic theory can justify the universal conclusion that changing a monopsonistic market to a bilateral monopoly will benefit either the seller or the customers of the buyer.369

In a bilateral monopoly, price is determined not only by conditions of demand and cost, but also by bargaining skills and other personal characteristics usually outside the realm of economic analysis. Moreover, given the dependence of the outcome upon the bargaining skills of the parties and their willingness to employ resources, it is entirely possible that the value of the resources expended by the bilateral monopolists in attempts to redistribute returns to the advantage of one or the other will exceed any gain in allocative efficiency that is sought. It must also be recognized that, from the perspective of the electric utility and its customers, electricity generated by exploiting geothermal resources is no different from electricity generated by fossil fuels or nuclear power. Because of the availability of substitute energy sources, the government cannot remain a monopoly seller unless it also assumes control over all competing energy resources.

The final argument for governmental ownership concerns externalities and public goods. A public good exists when a producer cannot exclude discrete consumers from using a good or service he furnishes and therefore cannot force them to pay him for its use. National defense is a classic example of a public good since benefits therefrom are necessarily enjoyed by everyone. There is no problem of such consumption indivisibilities with respect to geothermal resources since the fluid can be readily transmitted only to the consumers who desire to purchase it.370

The externalities in geothermal resource production may be internal or external to the reservoir. The possible spillover effects that are external to the reservoir are waste disposal, noise, noxious gases, aesthetic effects, and


370. There is one ultimate use of the geothermal fluid which may present a public goods problem, namely, the use of the fluid to develop high quality water to dilute the salinity of the Colorado River. Such an ultimate use, however, does not impinge upon the immediate problem of the allocative regime for the resource in the ground since the producer of the fluid can transfer the desired units of the fluid to the entity which engages in the desalinization process. The producer of fresh water stands in no different position from the producer of electric power in this respect.
subsidence, and seismic effects, although it is too early to predict the magnitude of the environmental impact associated with geothermal resource production.\textsuperscript{371} In one sense, government operation may reduce the costs of monitoring and enforcing the desired environmental standards since government operation means that the locus of responsibility for any adverse effect may be fixed more readily than where there are a number of operators. This is especially true with respect to land subsidence and seismic effects which may be the result of combined activities of producers over a prolonged period. The interdependence of producer activities with respect to waste disposal, air pollution, noise, and aesthetics may be less significant if regulatory controls are imposed at the source.

Spillover costs may arise within a reservoir if the allocative regime presents common pool problems. For example, if the property regime establishes the rule of capture based on overlying landownership, the experience of the oil and gas industry vividly demonstrates the costs imposed by such an allocative, or more accurately nonallocative, regime. Attempts to mitigate the inefficiencies inherent in the rule of capture have resulted in numerous public regulations and voluntary and compulsory unitization, which in themselves are rather costly in terms of enforcement, coordination, and reduction of competition.\textsuperscript{372}

Another problem in the common pool situation is whether an appropriate investment in information gathering will be made, inasmuch as the information obtained by one owner may be of benefit to a neighboring owner. A dry hole or discovery of resources on one parcel is information of value to the neighboring landowners. This information has public good characteristics since the use of the information by the neighboring owner will not reduce the stock of information available to the first owner. If social costs are involved, governmental exploration and disclosure may obviate them.

The discussion up to this point indicates that government ownership, exploration, development, and production of geothermal resources may result in advantages with respect to certain aspects of economies of scale and externalities. However, these advantages must be evaluated in relation to the alternative property schemes with which government ownership and operation is compared. In considering any type of governmental involvement in the exploitation of geothermal resources, we should consider the effects of differences in the incentive structures for decision makers in the public

\textsuperscript{371} Except perhaps for problems caused by land subsidence and seismic effects, the environmental externalities caused by geothermal resource production superficially appear to be substantially less in geographical impact than with fossil fuel and nuclear energy power generating processes. As Bowen, \textit{Environmental Impact of Geothermal Development}, in \textit{Geothermal Energy} 197-98 (P. Kruger & C. Otte eds. 1973), notes, the reason for this seems to be that all the steps in the energy acquisition, processing, and use cycle are located at the site of geothermal resource extraction from the ground.

\textsuperscript{372} See text accompanying notes 433-499 infra.
versus the private sector. The social and organizational rules and constraints under which a decision maker operates and the monitoring procedures governing his performance help to determine the pecuniary and the non-pecuniary costs that he bears as well as the rewards he receives.\textsuperscript{373} Public as well as private decision makers will be influenced by their evaluation of the explicit or implicit costs and rewards to them of any given decision.

A decision maker who is the major owner of a profit making organization has the right to decide on the uses to be made of the organization's resources, is the residual claimant of the difference between revenues and costs,\textsuperscript{374} and can capture any increase in wealth to the organization by selling his interest. These factors serve to establish a strong link between the production efficiency of the organization and the decision maker's utility or satisfactions. Where management and ownership are separated, this link becomes more attenuated, but competition among current and prospective managers will tend to ensure managerial sensitivity to shareholder desires for a maximum return on their investments. In short, decision making in profit making entities is monitored rather intensively. Moreover, it is not uncommon for such enterprises to provide managers with an interest in the profits through stock option or bonus plans.

In contrast, decision makers in the public sector are severely restricted in their ability to realize the increment of income generated by their managerial skills.\textsuperscript{375} Of course, the decision maker can make choices promoting efficiency if so required, and he derives utility from his position. However, the sources of his utility, besides his salary, may be only nonpecuniary, consisting of elements such as prestige, self-satisfaction, and amenities of office. His utility from the wealth of the organization is diffused. The weakened link between the decision maker's utility and organizational wealth in the public sector simultaneously reduces the cost to him of production inefficiency and increases the value of nonpecuniary amenities the organization might provide. On the other hand, because the public decision maker's utility is not tied to organizational wealth, he may be more willing to take into account the external costs involved in any given option and thereby promote efficiency from the vantage point of the community, in contrast to the private decision maker.

Most public sector organizations are aware of this problem. However, because these organizations' objectives are not confined to wealth maximi-
zation, the decision maker's superiors, even in trying to promote production efficiency, may adopt rules which do not provide measurable pecuniary criteria. Even if pecuniary criteria were to be established, the ultimate monitoring may rest upon elected officials or taxpayers whose oversight may not be continuous or direct.

Accounting practices in the governmental sector may also distort decision making to produce inefficiencies. For example, an agency decision maker might be required to account in his annual budget for the full capital value of any assets he procures during the year. This means that capital goods capable of producing a stream of benefits over several years appear more costly relative to noncapital inputs than is the case in the private sector, where such expenses are capitalized over their useful life. The public decision maker may therefore tend to delay the purchase of capital and to substitute noncapital inputs which yield their benefits over a time interval approximating the accounting period during which he will be charged for them. In contrast, once the capital asset is actually acquired, actual resource costs may be understate because, apart from maintenance and operating costs, the accounting rules do not require the decision maker to pay rent for the use of the asset; he therefore is apt to treat the asset that has been acquired as a free good. In the private sector, ideally, this rent would be equal to the opportunity cost of the enterprise's use. Moreover, if the decision maker is precluded from transferring ownership of the resource to others, he is shielded from considering the opportunity costs of governmental operation. In the case of geothermal resources the objective would

376. Clarkson, *Some Implications of Property Rights in Hospital Management*, 15 J. LAW & ECON. 363 (1972). It should perhaps be noted that if a policy objective is to encourage output irrespective of opportunity costs, the adoption of government production is probably desirable. Since the non-proprietary mode of organization inhibits the appropriation of the residual, the residual will be spent within the organization and is therefore more likely to be used to increase the organization's output rather than merely being used to increase the wealth of the owners as might be the case in proprietary organizations.


378. Incentives can be created for decision makers in the public sector to account for opportunity costs by self-assessment of the value of the reservoir, and the payment of a tax or charge based on this self-assessment. The self-assessment scheme requires that the agency state the value that it places upon the asset over which it is able to exercise discretionary control. The agency is then charged a percentage of that value for its "ownership" of the property during the accounting period. Realistic assessments of value would be obtained by permitting other federal agencies or even private parties to purchase a reservoir at the price stated by the agency. If the agency, in order to inhibit challenges to its control, states a value above the opportunity cost of its discretionary control of the reservoir, it will needlessly be paying a charge in excess of the minimum charge it had to pay to defend its proprietary interest. If it understates the value, two options are available. The agency might be required to turn over its proprietary interest to the public or private party that bids higher, or it might be given the
be to transfer the resources after production, but the opportunity cost of withholding production because of higher discounted future value may be ignored.

These observations militate against government exploration, development, and operation of geothermal fields, but care must be taken that the case not be overstated. People respond to various stimuli and rewards. Nonpecuniary rewards or limited pecuniary rewards may provide a sufficient link between an individual's benefits and organizational efficiency. Accounting procedures for public agencies can be modified to facilitate the efficient use of capital investments. Moreover, even if government operation may be less efficient in the narrow sense of maximizing profits, we cannot conclude a priori that other objectives, which public decision makers may be more likely to seek than private decision makers, do not maximize the satisfactions of the community as a whole. For example, even if it can be concluded that the costs of governmental exploration and production may be greater than those of a proprietary organization because of the weakened link between cost reduction and decision maker benefits, these costs must be weighed against the benefit from the public decision maker's possibly greater concern for environmental externalities. In short, at this abstract level the case for or against government exploration and production of geothermal resources is inconclusive.379

3. Government Exploration and Private Production

A second possible property regime for geothermal resources is also based on initial governmental ownership of geothermal resources in place. Under this system the government would conduct exploration itself, but after discovery it would sell the resources in place to private producers. The choice of turning over its proprietary interest or paying a penalty from its annual appropriation to the general fund. This penalty would be proportionate to the discrepancy between the high bid for the reservoir and the reservoir value stated by the agency. The scheme is self-enforcing, seems to have negligible costs of administration, and creates incentives for each reservoir to be put to its most productive use. The idea of self-assessment apparently was first set forth in Harberger, Issues of Tax Reform for Latin America, in Joint Tax Program, Organization of American States, et. al., Fiscal Policy for Economic Growth in Latin America 119-20 (1965).

379. One report, in considering government exploration for geothermal resources, is quite emphatic in its conclusion:

The government might, of course, try to establish its own operations unit. But this brings us to our second note of caution. Each reader will have his own historical impression of the economics of public works projects, but ours is overwhelmingly skeptical. If experience is a guide, once the government institutionally "geared up" for geothermal operations, the program, securely insulated from real market and operations demands, could become an extravagant boondoggle, into which funds were poured far faster than the benefits merited. One always has to consider, too, that in the selection of operations sites, there is a real risk that considerations of true geologic promise would be compromised with calculations of Congressional District clout.

preceding section considered the argument for government exploration and production based on, *inter alia*, the government’s ability to distribute the risks in geothermal resource exploration and production. In the discussion of this second model, it is necessary to identify more specifically the risks inherent in geothermal exploration and production, inasmuch as the second model separates the exploration and production processes. Accordingly, the risks unique to each must be considered separately. Uncertainties in geothermal exploration and production fall into two categories: physical uncertainties and market uncertainties. Physical uncertainties derive from lack of knowledge concerning the existence of geothermal resources at any given location and, even after discovery, the quantity and the properties of the resources over time. Investments in exploration and drilling may result in dry holes. Investment decisions for establishing generating plants must be based on a prediction of the availability of the resources over a given time frame. These decisions in turn affect the market for the extracted resources. Market uncertainties arise from the uncertainty of future market prices of the inputs and outputs in exploration and production.

Under the first model it appeared that governmental production might reduce costly spillover effects internal to the reservoir in contrast to a system of multiple rights to a common pool. This advantage might be offset, however, by the fact that a governmental decision maker cannot capture the increased returns from his efforts and therefore gives less consideration to the opportunity costs of the resources used by his agency in production of geothermal resources. The second model seeks to retain the advantages and eliminate the disadvantages of the first model. Government exploration to discover the resources will reduce the costs of uncertainty by spreading the risk, as indicated earlier. Furthermore, because costs may be spread over a number of discovered reservoirs, the second model may permit a greater number of potential producers to bid for the right to produce the resources. In contrast, where exploration is private, perhaps only a few large firms, or joint ventures of smaller ones, with sufficient capital and diverse activities over which to distribute the risks of nondiscovery would be able to bid. Moreover, with information as to reservoir characteristics provided prior to the time of auctioning the right to produce, smaller firms may be able to participate in the bidding because they may have greater access to capital if uncertainty as to the reservoir value has been reduced.

380. Legislative proposals for government involvement in oil and gas operations are discussed in STONE, *supra* note 379, at 73-74.

Government exploration need not necessarily mean that government employees perform the work. The government may contract to have the work done. There is precedent for this in Alaska. *id.* at 75.

STONE, *id.* at 54-62, undertakes a rough benefit-cost analysis of government operation of various stages of exploratory work, but the study only utilizes the bonus bid to measure the benefits.

381. The advantages of governmental information gathering have been recognized by some in another resource development program. Currently, any agency of the United States
The public goods problem of information gathering, which may cause underinvestment in this activity if left to the private sector, is obviated since the information would be gathered by public agencies and made available to all. As with any other public good, however, the question remains concerning the amount of government exploration that is economically justified. In one sense, the public good characteristic of information on reservoir potentials will change since information about a productive reservoir will be useful only to the successful bidders for the resource in a particular reservoir. Thus, the public decision maker, in determining the amount to be invested in exploratory work, could be guided by the price expected to be paid by bidders for the right to produce just as any proprietary organization must determine its investment in exploratory work based on expected rewards and costs. The incentive structure for the public decision maker and the system of accounting for the opportunity costs of the inputs employed remain critical problems. Even if the total revenues from the sale of rights were required to equal or exceed the total costs of exploration, troublesome questions remain as to the proper accounting period and the costs to be assigned.382

Market uncertainties with respect to future prices of inputs and outputs in the production process may be handled in various ways. As will be discussed more fully later with respect to current leasing practices of governmental agencies,383 whether market uncertainties and physical uncer-

382. STONE, supra note 379, at 71-72, presents a scenario of the cost of deep exploration by the government in which the benefits to the government from sale of proven acreage would be less than the cost. This is characterized as a multi-million dollar subsidy to industry, and two questions are posed: "(1) how much of a subsidy from general treasuries [sic] are we prepared to risk?; and (2) is a subsidy (of that amount) through a government exploratory program as efficient as subsidies through alternate strategies, e.g., the institution of tax incentives for private geothermal exploration?"

We have some difficulty with this situation. If, as the report constructs the scenario, the costs are greater than the benefits, it is socially inefficient to engage in exploration whether conducted by the public or private sector and we can think of no reason why any exploration should be undertaken. But even if such a situation were to arise, there exists the argument that the government, being able to spread the risk much more than the private sector, may be able to assume the risk at a lower cost than the private sector firms.

383. See text accompanying notes 386-425 infra.
tainties as to the future productive capability of the reservoir are borne entirely by the purchaser or are shared between the seller and the purchaser will depend on the pricing method used. The rights to produce may be sold on the basis of bonus bidding, a percentage of gross income or net income bidding, or some other formula. The formula upon which the bids are based should not affect the duration of the rights.

Because decision makers in the private sector determine the production schedule, the incentive structure for that sector should lead to efficient allocation of resource consumption over time, so long as spillover effects internal to the reservoir are controlled. One model might require the government to sell the right to the resources in a discrete pool to a single purchaser so as to assure single firm management of the reservoir. A rational single firm, in order to maximize its return, would consider the nonseparabilities of quantity, quality and locality of production from the reservoir.

In the second permutation of this model, the government sells rights in a single reservoir to a number of buyers. This alternative presents the problem of defining the rights so as to avoid inefficiencies arising from nonseparabilities in the pool. This problem is the same as the one which arises where the government in its capacity as a sovereign, seeks to define rights to resources it does not own. Unless a property regime which minimizes nonseparabilities in the production of geothermal resources is devised, this permutation is less advantageous than the first.

In the implementation of the first permutation of this model, serious thought must be given to whether the right to the entire pool will be defined in terms of surface acreage or in terms of the resource underground. If surface acreage is used, the government would have to explore the area thoroughly to make certain that the reservoir boundaries are clearly ascertained since the assignment of multiple production rights by mistake will diminish the advantages of this model. On the other hand, if the right is defined as an exclusive right to the entire reservoir, the second purchaser will have to assume the risk of a mistaken determination of the reservoir configurations.

As a result of the application of this model, a single purchaser would have monopoly rights to the entire pool but, assuming that other energy resources are available as substitutes, and, if geothermal resources are available from nearby reservoirs, it is unlikely that the single purchaser will be able to maintain monopoly prices.

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384. See STAN. ENV'T'L. SOC'Y, GEOTHERMAL ENERGY: LEGAL PROBLEMS OF RESOURCE DEVELOPMENT 111-18 (1976), for a discussion of problems relating to major oil companies involved in geothermal resource production. If a reservoir were assigned to a single major oil company, the problems discussed therein would be exacerbated. Additional regulations on the energy-related holdings of eligible purchasers may be required.

385. A third model posits the situation where the state sells the right to explore a defined geographical area. The rights to the resources are sold separately. This model is mentioned only
4. Government Leasing and Assignment of Rights

a. Introduction

Current governmental practices for the allocation of geothermal resources underlying public lands invariably involve leasing with variations in the use of competitive bidding for the selection of buyers and the determination of lease prices. Many states make a distinction between parcels that have a high potential for discovery of geothermal resources and those that do not, competitive bidding being required only for the former.386 The discussion of current leasing practices involves two major issues. First, the nature of the rights granted under present leasing of government-owned lands invites comment. Second, taking the nature of the rights presently granted as given, the efficiency of the present method of disposing of those rights must be examined.

to note its existence but there are so many difficulties with this that only a passing mention of the problems need be made.

Assuming that the right to explore has been sold, what will the explorer do with the information? If the right to the resources in a defined geographical area is to be sold, the explorer can sell the information he has to one or more potential bidders for the production rights. Because the private value of the information lies in its exclusivity, the initial buyer of the information would want an explicit understanding as to how many parties will have access to the information; but even with such contract, the policing costs of such agreement may be so high that there may be no market for the information. Even if an information market existed, it would be like a poker game inasmuch as the potential purchaser would have no idea as to the value of the information although the maximum price offered by the purchaser would be the cost to the purchaser of obtaining the information himself. Moreover, if the information is to be sold prior to the sale of production rights by the state, the purchaser might rightfully be suspicious as to the value of the information if the seller, having the capability of producing, chooses not to make bids on production rights.

If the explorer is to be excluded from bidding for production rights and the explorer is permitted to sell the information only after production rights are sold, the model raises all the uncertainties for the purchasers in bidding for production rights as would have existed had they bid for the exploration and production rights together.

386. Under the federal Geothermal Steam Act of 1970, priority of application determines the right to lease land which is not within any known geothermal resources area. 30 U.S.C. § 1003 (1970). On the other hand, competitive bidding is required for leasing of land in a known geothermal resources area. Id. The Act defines a known geothermal resources area (KGRA) as "an area in which the geology, nearby discoveries, competitive interests, or other indicia would, in the opinion of the Secretary, engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for the purpose." Id. § 1001(e) (1970). The definition is odd, to say the least, since a person who applies for a lease of a tract, whether or not in a KGRA, must believe that prospects for extraction are good enough to warrant expenditures of money for that purpose since he is willing to pay rentals and must intend to engage in exploration activities. The Secretary has in effect required competitive bidding whenever two or more applications have been filed to lease a given parcel during a given filing period. 43 C.F.R. § 3200.0-5(k)(3) (1976).

In California a similar classification is used to determine whether the land is to be leased to the first applicant or by competitive bidding. CAL. PUB. RES. CODE §§ 6909, 6911, 6912 (West Supp. 1977). However, there must be at least one well capable of producing in commercial quantities for the area to be classified as a KGRA, and consequently, it is possible that the entire area might have been leased noncompetitively before a discovery well is drilled.
As to the first issue, the lease gives the lessee the exclusive right to explore and produce within a given geographical area defined by vertical boundaries. Under existing leasing programs, the basic nature of the lessee's right is the right of capture. Without additional regulations, this right does not provide an incentive for the lessee to take account of the non-separabilities discussed previously, nor does it protect him from them. Public entities vary in their approaches to mitigation of these non-separabilities; for example, some permit or compel cooperative or unit operations. In addition, under the federal leasing program the supervisor can enforce well-spacing programs, taking into consideration such factors as "the number of wells that can be economically drilled to provide the necessary volume of geothermal resources for the intended use [and] minimizing well interference." The essence of the present leasing model is the rule of capture, an allocative regime that will be discussed later.

The second issue, the efficiency of the leasing model, will be discussed in some detail here because the allocation of resources through price terms by the government is generally associated with resources "owned" by the government. The significance of the discussion, however, is not confined to these government ownership situations. If, as is assumed here, the legislature is unrestricted in defining property rights and is also free to assign these property rights to different persons, the legislature may grant such rights on the basis of priority of application or competitive bidding or negotiation. In other words, although the method of conferring leases to government land is the principal focus of our discussion here, the broader implications of employing market criteria to allocate rights to resources underlying private lands should not be overlooked.

b. Market and nonmarket criteria

The government may use either market or nonmarket criteria when it allocates rights to resources. These rights may be leases as currently employed on government land, appropriative rights, or some other rights. The nonmarket criteria that are commonly employed include: (1) priority in time of filing an application; (2) a discretionary system whereby an agency

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387. Under the federal leasing program, the Director of the U.S. Geological Survey may compel unit operations if the lease so provides, 30 C.F.R. § 271.1 (1976), whereas, in California the agency is not given the power to compel unitization.
389. See text accompanying notes 500-510 infra.
390. Priority in time of filing is used by a number of states to allocate prospecting permits for geothermal resources. See, e.g., CAL. PUB. RES. CODE § 6912 (West Supp. 1977). The federal government uses priority in time to allocate leases on non-KGRA lands when there is no overlap in the area defined in the application. When there is an overlap of less than 50 percent in area in two or more applications filed on the same date during the filing period, assignment is made by lottery. 43 C.F.R. §§ 3210.2-2, 3210.3(c) (1976). Priority in time was relied upon as the allocative rule in early water appropriation systems in many states before the water agencies
considers a number of factors; or (3) a lottery system.

The principal market criterion for allocation is willingness and ability to pay, as demonstrated in the bid price.

At the outset, we argue that the initial assignment of rights is not economically neutral. Coase has presented the opposite view, that in the absence of transaction and coordination costs, the assignment of property rights is neutral with respect to allocative efficiency because ultimately efficiency will be attained through exchanges. Since the publication of Coase's paper, a large number of qualifications have been appended to the original proposition. Included in these qualifications are the absence of income effects, the availability of capital as a free good, separable production functions, and others. These limitations are taken up in the discussion below.

First, even if production functions were separable and coordination costs were trivial, the ultimate assignment of the rights after one or more transfers will not necessarily bear any resemblance to the assignment that would have resulted from an efficient initial distribution of rights. The initial assignment of rights affects the efficiency of the ultimate distribution. That is to say, Pareto-optimality cannot be defined independently of the initial wealth distribution. The basic reason for this is the influence wealth has upon relative willingness to pay for various goods. Changes in the relative

were granted discretionary authority under broad standards to approve or deny applications for appropriative rights.

391. See, e.g., CAL. WATER CODE §§ 1253-1258 (West 1971). In Idaho geothermal permits are granted if not against the public interest. Many factors may be taken into account to determine the public interest. See note 350 supra.

392. 43 C.F.R. §§ 3210.2-2, 3210.3(c) (1976).


If, for example, overlying private landowners own geothermal resources, it is likely that the wealth of the overlying landowners, viewed as consumers of other goods, would increase substantially. Income effects capable of influencing their relative valuations of different goods would therefore tend to be present. From the producer's perspective, there are few, if any, firms able to obtain their development and production equipment (their capital) at zero prices.

A more recent paper argues that, apart from all the qualifications that have been developed, the original Coase paper was logically inconsistent even given its stated assumptions. In particular, Coase's assumption of zero coordination costs means that an externality making the property right assignment problem economically relevant could never exist. If the act of exchange does not consume valuable resources, then all gains from exchange would already have been exhausted. By definition, an externality means that gains from exchange exist. See Schulze & d'Arge, The Coase Proposition, Information Constraints, and Long-Run Equilibrium, 64 ECON. REV. 763 (1974).

395. Pareto-optimality is a state in which one individual's welfare cannot be increased without reducing the welfare of another individual. It corresponds to a state in which all gains from trade are exhausted. For a rigorous development of the argument presented in the text, see K. ARROW & E. HAHN, GENERAL COMPETITIVE ANALYSIS 91 et seq. (1971), and Dolbear, Jr., On the Theory of Optimum Externality, 57 AM. ECON. REV. 90 (1967).
willingness to pay alter both the set of attainable outcomes and the unique economically efficient outcome. The argument can be extended to point out that the initial distribution of wealth can influence all subsequent distributions of wealth, if only because initial wealth enhances the ability of its holders to shape to their advantage the decision processes employed for the subsequent distributions.\footnote{396}

The second qualification of Coase's argument concerns his assumption that transaction costs are zero. In order to assert correctly that leases would ultimately be allocated efficiently regardless of the initial assignment, the costs of exchanging these leases must be reasonably low. In general, the higher these costs of exchange, the less likely it is that the rights will ultimately be assigned to the most efficient owners. From the perspective of any given owner, if the cost of exchange plus the value of retaining the lease is greater than the potential gain from the exchange, the exchange will not occur. Coase recognizes that transaction costs must be considered.

Governmental leasing regulations impose transaction costs in addition to those normally associated with the negotiation between the parties to the exchange. For example, under the federal leasing provisions, assignments must be approved by the Bureau of Land Management. The approval is designed to make certain that the assignee is qualified, that the maximum acreage holding is not exceeded, and that the leasehold is not carved up into small parcels.\footnote{397} In addition, the approval of the Supervisor must be obtained in order to change the method of recovering production or to redrill, deepen, or plug back wells.\footnote{398} The need to seek these approvals and the possibility of disapproval are costs of undertaking an exchange.\footnote{399}

Coase's indifference theory of initial assignment is qualified by transaction costs and other assumptions. If the difficulties posed by these qualifications can be avoided by an initial efficient assignment of rights, such an assignment should be made. As we shall argue below, a pricing system can accomplish that objective.

The economic literature demonstrates with varying degrees of rigor that price and price alone, when used to allocate claims to the services of a good, can attain a Pareto-optimal allocation.\footnote{400} Because the ultimate arbiters in a pricing system are opportunity costs and willingness to pay, a public leasing agency will have all the information needed to maximize the value to the public of rights to exploit geothermal resources. The pricing system will

\footnote{396} For a discussion of this point, see Crocker, Water and the Economics of Implementing Environmental Objectives, in Water and Community Objectives 276 (D. Field, et al., eds. 1974).
\footnote{397} 43 C.F.R. § 3241.1-2, 3241.1-1 (1976).
\footnote{398} 30 C.F.R. § 270.35 (1976).
\footnote{399} We do not know how substantial these costs may be.
\footnote{400} See K. Arrow & F. Hahn, General Competitive Analysis (1971), for formal, general proofs.
provide the incentive for the leasing agency and the successful bidder to behave in a manner consistent with maximization of the resource’s value. The only assumptions necessary for this proposition to apply are that buyers and sellers seek to minimize their costs for whatever stock of rights is to be made available and that neither buyers nor sellers possess control over bid or ask prices.

If an agency distributing the rights wished to insure an efficient initial allocation of leases or other forms of rights but were to employ nonprice terms to accomplish this end, it would be faced with a severe information problem. The agency would have to ascertain the lessee’s behavior rules under economic conditions of uncertainty, his current and expected future least-cost development and production technologies, the markets to which he has access, and finally, the manner in which the expected activities of each pair of lessees will affect their behavioral rules, their least-cost development and production technologies, and access to market.401

If exchange costs are substantial, the use of a nonmarket criterion such as priority in time or lottery to allocate the rights could cause inefficiencies from overexploitation. The lack of a price makes the geothermal resources appear less scarce than they really are. Production technologies may be employed that do not maximize the true economic value of the resources. In addition, mixes and magnitudes of outputs could be produced for which the true additional costs of production at the time of production exceeded the additional value created by production.

c. The form of bid prices

In the discussion above we have argued that resources should be allocated through a pricing mechanism. A system of bids is such a mechanism. Several alternative forms of bidding might be employed.402 Two with markedly different economic consequences will be considered initially, namely, bonus and royalty bidding. A bonus is a lump-sum unconditional payment made at the time of the purchase of the lease. The maximum bonus that a firm would bid for a lease is the present value of the expected net cash flow from the lease, with the discount rate set at the minimum rate of return acceptable to the firm. A royalty is simply a proportionate share of the

401. In general, the history of grants to valuable resources when no explicit price is employed to allocate the grants and when the grants have been nontransferable does not give great cause to expect an efficient outcome for geothermal resources. See Stigler, The Economic Theory of Regulation, 2 BELL J. ECON. & MANAG. SCI. 3 (1971), for a review of and an explanation of this history.

402. This section draws extensively upon the materials in S. Cheung, The Theory of Share Tenancy (1969); Stiglitz, Incentives and Risk Sharing in Sharecropping, 41 REV. ECON. STUD. (1974). See also Nossaman, Waters, Scott, Krueger, & Riordan, Study of the Outer Continental Shelf Lands of the United States 666-86 (1968) [hereinafter cited as OUTER CONTINENTAL SHELF STUDY], for a discussion of various pricing methods and of exploration and development through contract.
leasing firm's production or its equivalent in money paid at the end of specified accounting periods.

Neither of these bidding systems can be shown to be universally preferable in terms of economic efficiency. This may seem an innocuous or even trivial conclusion; nonetheless, there are many who contend that the bonus bid is always more economically efficient.403

Those who favor the bonus bid argue that the bonus represents a "sunk" cost, and, therefore, the size of the bonus is irrelevant to the production decision once a reservoir has been brought into operation. Once the bonus has been paid, its magnitude cannot be affected by later production decisions. These decisions will be based upon whether the reservoir will offer a return sufficient to cover the current costs of production. In contrast, the argument runs, a royalty may cause early abandonment of a reservoir or perhaps actually cause a reservoir not to be developed at all. If production rates decline over time, as in an oil and gas reservoir, operating costs per unit of output will tend to increase. Because a royalty payment directly reduces the operator's income on each unit of output, it will cause reservoirs to be abandoned earlier than they would be under the bonus bid system. In effect, the argument analogizes the royalty bid to an ad valorem tax, under which a percentage of the price of every unit sold must be devoted to the tax. Since the lessee may be expected to make his production decisions on the basis of income actually accruing to him, the argument concludes that bonus bids, under which the lessee balances marginal costs against the full income generated by each unit of production, will lead to more efficient production decisions than royalty bids under which the lessee balances marginal costs against only a portion of the income so generated.

The royalty bid, however, has substantial economic utility. Under any bidding system, a bidder's estimate of the value of a lease must take into account: (1) the perceived attributes of the geothermal resource; (2) a forecast of the price of energy over the relevant locale; (3) the direct cost of developing the reservoir, producing energy from it, and meeting environmental protection standards; (4) the opportunities that the bidder will forego if he purchases the lease; (5) the lag between the award of the lease and the initiation of commercial production; (6) the rate at which future net returns are to be discounted; and (7) the nature of the property right attached to the lease. The value estimate will be affected by the bidder's endowment in geothermal steam technology, his familiarity with the energy markets, and his degree of risk aversion. These factors are characterized by varying degrees of uncertainty. A royalty form of purchase price permits the pooling of risks due to uncertainties about the physical productivity of a reservoir.

403. For examples of these assertions, see Rooney, Competitive Bidding for Mineral Leases, 8 NAT. RES. J. 650 (1968); Johnson, Resource Allocation Under Share Contracts, 58 J. POL. ECON. 111 (1950); Heady, Economics of Farm Leasing Systems, 29 J. FARM ECON. 659 (1947).
and about future market prices of outputs. A higher risk will reduce the present value of the lease, and will make the royalty provision more attractive in comparison to the bonus lease. In fact, given certain weak assumptions and a degree of mathematical sophistication, it can be shown that, all else being equal, some pooling of risk will always be preferred to no pooling of risks by all parties to an exchange. This means that the estimate of the present value of the lease may be greater under the royalty bid than under a bonus bid.405

However, the royalty bid is not without costs. Monitoring costs arise from the lessor's need to ascertain that the correct royalty is being paid; likewise, the lessee bears the cost of periodic accounting for the royalty. The incentive to early abandonment presents another potential cost, although this might be alleviated by a sliding scale royalty. Moreover, if a royalty is the only price exacted, speculative bidding may result since the payment of the price is entirely contingent upon actual production.

The geothermal leasing statutes generally provide for a combination of the pricing terms discussed above. Under the federal leasing program, the royalty rate is set and the bidding is on the bonus. Other statutes permit bidding on the royalty rate. An efficient geothermal leasing program should attempt to find the combination of bonus and royalty that will maximize the present value of the reservoir. Given that reservoirs differ in their attributes, and therefore in the risks associated with exploiting them, and given that prospective bidders will differ from one lease to the next, this problem must be faced each time a new reservoir is made available for leasing.


405. Some conservation standards, in particular, may serve to reduce rather than increase bidder risk. For example, in a reservoir with multiple lessees whose production activities are nonseparable, any standard that enhances predictability about the behavior of all or some lessees will reduce bidder risk. The bonus lease will then become more attractive relative to the royalty lease.

406. The level of the sliding-scale royalty is a function of the value of a given parameter. For example, the royalty percentage might decline as the marginal costs of extracting a unit of geothermal energy increase over time. Such an arrangement under certain circumstances would reduce the lessee's incentive to inject new fluid into the reservoir. At the initial stages of the reservoir development, the higher royalty rate imposed upon the increased production from injection may not make injection attractive enough to induce investment in such activity. With increased marginal costs of production in subsequent stages of reservoir development, the lower royalty rate may induce investment. To avoid such reduced incentive, the sliding-scale royalty might be paired with an agreement to share the costs of injecting new fluid between the agency and the lessee.


407. Although the regulations are not as clear as they might be, this seems to be the practice in the bidding that has been conducted. See 43 C.F.R. §§ 3205.3-5, 3220.5 (1976); 4 Geothermal Hot Line 2 (Feb. 1974).

leasing. Moreover, the above analysis suggests that the bidders should be permitted to bid on both the bonus and the royalty and that the lease should be awarded to the bid which in combination represents the highest present value. The difficulty is, of course, that no way exists to determine accurately the value of the royalty amounts that have been bid. Consequently, there is no way to monitor the agency awarding the lease to make certain that leases are being awarded on the basis of efficiency criteria rather than on nonprice considerations such as effectiveness of lobbying. This means that the leasing agency must make a rough determination as to whether the bonus or the royalty should be fixed, and at what amount, given the uncertainties arising from the unknown attributes of the lease area, from market uncertainties and from the definition of the property right under the lease. In addition, the leasing agency must evaluate the bidders in terms of their ability and willingness to assume the risk.

The risk-pooling nature of royalty bidding can provide a greater opportunity for small, less well-capitalized economic enterprises to bid successfully, as compared to bonus bidding. Small firms without diversified activities over which they can spread the risk from geothermal resource exploitation will not have to bear the full burden of unanticipated losses. Moreover, since the royalty provision spreads payments over the period of the lease rather than requiring one lump-sum payment at the outset, less well-capitalized firms will find the lease more attractive.

In the preceding discussion, we have assumed that the bonus is always paid immediately upon the awarding of the lease and that the royalty is based on the gross value of the production. In fact, a number of variations on these basic options are available. In contingency (or royalty) bidding, net income rather than gross production can be used as the basis for calculating payments to the leasing agency. Another variant is a periodic rent payment which the lessee is required to pay only if he desires to retain the lease from one period to another.

The net income approach shares risk more effectively than the gross value approach since the lessor shares the cost of exploration, development and production in addition to the risks shared under the gross value approach, namely, risks of discovery and market prices of the inputs and outputs. On the other hand, the lessor’s monitoring effort and his use of

409. It is argued in a study of leasing for oil and gas on the outer continental shelf lands that combination bidding can be used if the resource owner has superior knowledge and that the highest royalty bid should be accepted if the offered tract is believed to be productive. OUTER CONTINENTAL SHELF STUDY, supra note 402, at 682-83. The study, however, recognizes that there can be "no exercise of objective judgment as to the high bid unless one bidder is the high bidder on every variable . . . ." Id.

410. Bonus bidding with the bonus payable in installments has also been suggested as an aid to less well-capitalized firms. Logue, Sweeney & Willett, Optimal Leasing Policy for the Development of Outer Continental Shelf Hydrocarbon Resources, 51 LAND ECON. 191, 201 (1975).
nonprice terms in the agreement generally must be increased in order to reduce the incentive of the lessee to exaggerate his reported costs and to employ input combinations less efficient than those he would employ if responsible for all costs. The advantage of the net income approach over gross value is that it does not increase the production cost per unit and thus should not lead to inefficient abandonment of operations.

As for rental pricing, it retains the low monitoring cost feature of bonus bidding and, in addition, introduces the opportunity to share some risks with the lessor. Since the rental payment can be terminated by the lessee, the risk sharing arises only with respect to his option to terminate. If the lessee continues with the lease, production costs or market uncertainties are not shared. Moreover, a decision to pay the next periodic payment is a decision to incur cost and thus may affect marginal wells. On the other hand, rental bidding enhances the ability of less well-capitalized firms to participate in the bidding process and also offers the opportunity to pay the lease payments from revenues realized from the lease.411

d. Lease duration

It is tempting to argue that leases for geothermal steam reservoirs should be of relatively long duration—at least as long as the typical life of the capital equipment necessary to exploit the reservoir or to harness the energy. Otherwise, the lessee's uncertainty about whether his lease would be renewed would cause him to be reluctant to make investments having an economic life longer than the lease duration. If the most efficient production processes will involve this type of long term investment, the use of short term leases might deter the adoption of the most efficient method of exploiting the resource.412

In fact, however, a government agency trying to structure leases for maximum allocative efficiency within the constraints of the agency's com-

411. S. 521, 94th Cong., 1st Sess. § 203(a) (1975), authorizes the Secretary of the Interior in leasing outer continental shelf lands to employ any of the following for bidding: (1) fixed royalty on value of production with bidding on cash bonus, (2) fixed cash bonus with bidding on royalty on value of production, (3) sliding royalty with bidding on cash bonus, (4) fixed share of net profit with bidding on cash bonus, (5) fixed cash bonus with bidding on net profit share, (6) fixed royalty on value of production and net profit share with bidding on cash bonus, (7) fixed net profit share with cash bonus bids on 1% share of undivided working interest, (8) sliding net profit share with cash bonus bids on 1% share of undivided working interest, (9) fixed royalty on value of production or fixed net profit share with bidding on exploration program, and (10) fixed cash bonus on the basis of cost of adequate exploratory program with bidding on royalty on value of production or net profit share; the cash bonus to be used to make grants to lessee to finance exploratory drilling.

Some of these bidding systems are recognized to be experimental in nature but the “basic thrust of all these new options is to reduce the reliance on large front-end cash bonuses as the means of obtaining a fair price for the public's property.” S. REP. No. 94-284, 94th Cong., 1st Sess. 37 (1975).

412. These points are not entirely straw men. They are common in the literature dealing with agricultural leasing. See, for example, the reference in CHEUNG, supra note 402, at 8-9.
petitive and environmental standards will find no universal answer to the question of whether a long or short lease duration is preferable. Which lease is better depends upon the circumstances. In order to achieve allocative efficiency, the agency must understand why different lease durations occur in perfectly competitive markets. Transaction costs and risks are the factors that determine the length of the lease duration that would be voluntarily chosen by the parties.

Where the economic life of the lessee’s capital equipment is relatively long and where, once the investment is made, the lessor’s and the lessee’s contributions become physically commingled so that it is costly to disentangle them, one would expect relatively long lease durations to be adopted. But the presence of long economic lives for capital equipment is not a sufficient condition to bring about long lease durations if rights to the use of the equipment can be sold in a competitive market with low transaction costs and if the claims of the parties to the lease are separable.

In circumstances where the investment commingling or nonseparability problem arises, the lessee typically will be willing to pay more per unit of time for a long-term lease. A refusal by the agency to grant a long-term lease in these circumstances means that it is foregoing a higher bid price per unit of time than it obtains under a short-term lease. However, under any given set of technological and market conditions, the existence of a positive discount rate ensures that progressive lengthening of lease life will bring about diminishing returns to both the lessee and the lessor since any gain from incremental lease life extensions are discounted more and more heavily. Sooner or later, these diminishing-return effects, even in the nonseparability case, exceed the lessee’s and the lessor’s interests in further extending the lease life. Therefore, in most conceivable circumstances, a finite economically optimal lease life exists. While the long-term lease has advantages, the short-term lease is not without economic advantages. In particular, it permits each party to assess market conditions, reservoir attributes, and the other’s performance, and to use the information so acquired in renegotiating the lease. Renegotiation may involve both price and non-price terms, and given the improved state of knowledge, both lessor and lessee may find themselves better off than under the terms of the previous lease. To some extent, the prospect of facing competition at renewal times gives each party more of an incentive to live up to the terms of the lease. Monitoring costs are therefore reduced.

The opportunity to renegotiate would seem more worthwhile under all forms of contingent lease bidding than under a bonus lease. The relative prices of inputs and outputs frequently change through time, thus making it worthwhile to both parties to alter their previous agreements. As noted earlier, the very essence of the contingent lease is to make the lessor and
lessee interdependent. Under the bonus lease, renegotiation due to changes in relative prices is less important. Bonus bidding would seem to lend itself more readily to leases of long duration since, short of outright violations of the lease terms, the effects of changes in input and output prices will be borne entirely by the lessee.

Despite the fact that both parties can benefit from renegotiation of a contingent lease, frequent renegotiations cannot always be expected to occur. Renegotiation can be costly. The process itself is not without costs; in addition, the outcome can rarely be predicted with certainty. Renegotiation therefore introduces another element of risk which, particularly from the perspective of the lessee, must be considered with his reduced susceptibility to production or output price risks under a contingent contract.

In general, the preceding discussion suggests that, whatever the type of lease, the optimal lease life depends on balancing the reduced risk of a longer lease against the opportunity costs of not being able to negotiate and thus respond effectively to altered circumstances. An optimal lease life is one in which the reduced risk of a longer lease induces investment in geothermal energy production sufficient to equate the incremental social gain from further risk reduction and the incremental social costs. Moreover, where transaction costs are sufficiently high to inhibit ready transfer of the investment, lease life must be of sufficient duration to persuade lessees that termination of the lease will be deferred at least long enough to allow discounted returns to exceed lease and production costs for some positive level of investment.

e. Sealed bidding and oral bidding

The choice between sealed and oral bidding procedures has attracted some attention in the policy-oriented economics literature. In a competitive auction where all parties initially are fully or equally informed about reservoir attributes, the choice is a matter of no significance. The terms arrived at will be those that maximize the present value of the resource to the leasing agency. However, not all parties in an auction are equally informed and not all auction markets are fully competitive. Choice of the wrong bidding procedure can make these markets less competitive.

Although sealed bids turn out to be the preferred alternative in each case, the advantages and disadvantages between the two types of bidding differ according to whether the leasing agency is to conduct a sequence of auctions that include similar prospective bidders from auction to auction or

413. The interdependence is introduced by the lease terms (e.g., the royalty rate) of the contingent lease and not by the nonseparabilities in investment contributions mentioned in the previous paragraph that favor leases of relatively long duration.

whether only a single auction will be held in which every set of prospective bidders will participate.

In the single auction, the key difference between sealed bidding and oral bidding rests in the treatment of individual bidder uncertainty regarding the bidding behavior of potential bidding rivals. Under sealed bidding, the bidder communicates his bid to the leasing agency simultaneously with the submissions of other bidders, and the size of the bid is not automatically communicated to other bidders. In contrast, the oral bid is made by voice in a setting where other bidders are present. Although it is not inherent in either of the procedures, the bidder generally is permitted to bid more than once for the same item in oral bidding, while sealed bidding usually involves only a single bid for the same item.

The greater ability to identify competing bidders and the greater ease of communication with these competitors imply that collusion among bidders about bidding strategies vis-a-vis third parties is easier under oral bidding. Collusion might take the form of overt prior agreements about maximum prices to be paid, assignment of particular leases to certain bidders, or other devices used by oligopsonists to share markets. Collusion may be practiced subtly, involving only the signals embodied in bid prices during the auction.415 This is not to argue that sealed bid procedures make collusion impossible. If the identity of bidders and the amount of the bids are publicly disclosed, as is the usual practice with sealed bids, participants will possess information to enforce collusive agreements against fellow bidders. This is especially the case when the same bidders participate in a series of separate auctions.

Despite the collusion problem, the oral auction offers benefits. The oral auction communicates a bidder's evaluation of the lease to others. To the extent that reservoir attributes and production and market conditions can be inferred from a bid, the desirability of forming a joint venture to pool information is lessened, thereby increasing competition. Of course, the opportunity to use information someone else has acquired introduces the free rider problem into the production of information. Bidders will have a reduced incentive to acquire information by their own efforts, unless there are incentives for information gathering other than winning the bid, as, for example, by profiting from investments in firms that can utilize the information affecting production.416 However, the specific information about reservoir attributes, market factors, and a variety of other economic matters that

415. One could, in fact, analyze the signalling used in this form of collusion as similar to that used by partners in a game of contract bridge. For an analysis along these lines, see Albin, Uncertainty, Information Exchange, and the Theory of Indicative Planning, 81 ECON. J. 61 (1971).

416. The argument is that the information producer can make his investments in firms that stand to profit from such information after the producer publicizes the information. See Hirshleifer, Where Are We in the Theory of Information, 85 AM. ECON. PROC. 31 (1973).
one bidder can infer from the bids of others does not seem substantial. Accurate analysis of a bid requires separating the factors such as reservoir attributes of common interest to all bidders from factors such as the availability of lines of credit that are specialized as to specific bidders. In most circumstances, this would seem to be a complex and costly task, one that cannot readily be performed while an oral auction is in progress. If, on the other hand, information about the reservoir attributes can be inferred from the bids, this imposes no social cost, aside from possible reduced information gathering, since the size of the stock of information is not affected and the uncertainty about future states by the recipient of the information is reduced.

As this analysis reveals, since the benefit from information disclosure in oral bidding is questionable, sealed bidding is probably the better choice since it tends to increase the difficulty of collusion.417

f. Nonprice terms and allocation

The prior discussion was based on the premise that the sole objective of the leasing agency was to promote an efficient allocation of geothermal resources without regard to other objectives. The leasing statutes, such as the Geothermal Steam Act of 1970,418 embody several objectives. These include: (1) assurance of maximum rate of return to the government; (2) efficient allocation of resources; (3) promotion of competition; and (4) protection of the environment. These objectives frequently may conflict. For example, an acreage limitation on a single lease may increase the risk of drainage of the geothermal resource across lease boundaries and thus result in lower bids. Measures designed to protect the environment will increase the costs of exploration, development, and production and will, therefore, reduce the value of the leases from the potential bidders' perspective. In general, an inverse relationship will exist between the severity of restrictions imposed to protect the environment and the dollar amounts of successful bids.419

417. Although a small number of bidders is neither a necessary nor a sufficient condition for noncompetitive bidding, the likelihood of such bidding tends to be inversely related to the number of bidders, if only because smaller numbers require the initial agreement of fewer parties and make violations of the agreement less costly to police. It is interesting to note that no lease unit attracted more than seven bidders in a January 22, 1974, U.S. Bureau of Land Management auction of what is probably the most proven geothermal steam field in the United States, the Geysers of California. Information provided by Mr. George Scarfe of the California State Office of the USBLM.


419. "Competitive" standards could also lower bid prices. By competitive standards we mean restrictions on such matters as the size of lease acreage and the total acreage holding in a given state. The term "competitive" here applies solely to the notion of giving more firms an opportunity to exploit the resource, a notion that is neither inherently compatible with nor contradictory to the technical economic meaning of the term. Such "competitive" standards are for the most part enacted for distributional, rather than efficiency, reasons.
The effect of environmental standards on leasing activity is the subject of analysis here. Assume that the agency can vary the number of (presumed homogeneous) leases it sells at auction. There are two ways to meet any given environmental quality standard. The agency can directly and arbitrarily alter the number of leases it offers or it can alter the environmental restrictions for any particular number of leases offered. The relevant relationships are exhibited in Figure 1. When the quantity of leases, $L$, expected to be purchased is zero (or minimal), the degree of fulfillment of environmental quality, $\tau$, will be at a maximum. If the agency is to expand the number of leases it sells, $\tau$ must decline. The rate at which $\tau$ declines, however, will depend on bidders’ expectations about the agency’s willingness to enforce environmental standards by carefully monitoring the activities of successful bidders. It will also depend upon the agency’s selection of bidders who, on the basis of performance histories and technical endowments, are likely to comply best with environmental restrictions. If the agency is careful about the parties to whom it awards bids, or if it carefully monitors the activities of successful bidders, environmental degradation occurs along the line labelled $\tau$ max. If the agency is non-selective and inattentive, the decline occurs along the line marked $\tau$ min. An infinite number of such lines are, of course, possible between these two polar cases.

**FIGURE 1**

![Diagram](image)

Now fix $\tau$ at some arbitrary level, $\bar{\tau}$. A legislature might, for example, order the agency to keep environmental quality above a certain level. This requirement constrains the agency to operate at some point on $\bar{\tau}$ between B and A, (excluding for the present the possibility of the agency’s adoption of even stricter standards). As a result the agency can expand the number of lease units it sells, moving from B to A, while maintaining the mandated level of environmental standards $\bar{\tau}$ only by progressively more stringent
enforcement to gain compliance with restrictions necessary to maintain the standards.

It is, however, unlikely that the agency will be able to move directly to A. As it moves toward A, its increased selectivity toward those who are awarded leases and its close scrutiny of the operations of successful bidders will cause a decline in willingness to pay for any given quantity of leases offered. Moreover, the monitoring of likely and actual bidder behavior by the agency will itself consume valuable resources. Both the decline in bidder willingness to pay and the increase in the agency's costs will bring about a decline in the agency's revenue.

Unless demand is completely inelastic the agency will maximize present revenue, subject to $\bar{\tau}$, at some point between B and A. This assertion rests on the following argument. For each point between and inclusive of B and A, there is a corresponding demand function relating the quantity of homogeneous lease units purchased to the bid price for each unit. Thus, in Figure 2, $D_A$ is the relevant demand function faced by the agency if it is expected to enforce the standard, $\bar{\tau}$, at the level $\tau_{\text{max}}$. Similarly, $D_B$ is the demand function faced by the agency if bidders' expectations are that it will enforce $\tau_{\text{min}}$. The area under each demand function represents the present value of the agency's total gross revenue. If the present value of the costs of various levels of enforcement is known, the agency's net revenues for each level of enforcement can then be determined by comparing the difference between gross revenues and enforcement costs. In Figure 2, $C_B$ represents the marginal and average costs of enforcement with respect to number of lease units for the level of enforcement, $\tau_{\text{min}}$. $C_A$ represents the same costs for the level of enforcement, $\tau_{\text{max}}$.

**Figure 2**

If the agency seeks to maximize revenue, it will sell $L_B$ lease units because the net revenue associated with $\tau_{\text{min}}$ is the area within the figure.
VC_{Bb} whereas the revenue associated with \( \tau_{\text{max}} \) is only the smaller area within \( VC_{Aa} \).

An analysis similar to that above can be performed for each level of the environmental standard. That is, one can slide the \( \tau \)-constraint up and down the \( \tau \)-axis of Figure 1 and ascertain the level of enforcement and number of lease units to be sold that will maximize the present net revenues for each level of the standard. In doing so, tradeoffs among the severity of the standard, levels of enforcement of the standard, and present value maximization of net revenues are illustrated.

It is of interest to ask what will happen if, for reasons unrelated to the environmental standards, the demand for the agency’s leases increases. Of course, with greater demand for its leases, the agency can increase the total revenue by expanding the number of leases it sells. However, referring again to Figure 1, it can expand the number of leases and at the same time maintain at least the \( \tau \)-level of the standards only by increasing the extent to which it enforces this standard. In the case of geothermal resources, the leasing agency presumably will restrict those allowed to participate in its auctions or increase its surveillance activities of successful bidders’ operations as the demand for the resources increases. Conversely, if estimates of future demand for geothermal energy prove unduly optimistic and if current environmental standards are unaltered, there may not be full compliance with the stated standards. If the agency’s objectives conform to the usual axioms of economic theory,\(^{420}\) and if the agency attempts to maximize present revenue, it progressively will slight the fulfillment of environmental objectives. By the same token, if environmental objectives are pursued with rigor, present revenue maximization must be compromised.

The above discussion leads to several observations. First, under present laws, lessees are required to conform to various environmental standards. These standards are nonprice terms and affect the bid prices. Since this is the case, non-price as well as price terms can be used rationally to allocate leases. The use of these terms for allocative purposes is in no way inconsistent with economic efficiency, since environmental standards are intended to represent values not otherwise quantifiable.\(^{421}\) Second, if the leasing agency attaches primary importance to present revenue maximization, one should be wary as to whether the agency will enforce environmental standards with vigor during times of weak demand.

\(^{420}\) The most important of these axioms is that the objective function (the function that relates the agency’s “utility” to its objectives) is “quasiconcave,” i.e., that as progressively less of an objective is satisfied, the economic agent is willing to give up progressively more of another objective in order to obtain an additional unit of the first objective. See J. Quirk & R. Sapossnik, INTRODUCTION TO GENERAL EQUILIBRIUM THEORY AND WELFARE ECONOMICS 7-27 (1968), for a succinct and reasonably accessible treatment of the complete set of axioms.

\(^{421}\) A more formal argument for the equilibrating influence of nonprice terms is found in Crocker, Contractual Choice, 13 NAT. RES. J. 561 (1973).
Joint Bidding

The experience with bidding for geothermal leases on federal lands has shown that joint bidding occurs with some frequency. It might be inferred that a lease will be operated as a joint venture among the joint bidders.\(^422\) Although inefficiencies may result if competition is reduced, these efforts may in fact promote greater competition. By spreading the risks and capital requirements of geothermal resource exploration and production over a number of firms, joint bidding may permit smaller firms that could not otherwise compete to do so and may permit larger firms to compete over a greater number of geothermal sites. Especially if the bonus bidding method is used, the number of bids can be increased by joint bidding, thereby enhancing the odds that the agency will obtain a competitive price for its leases.

In addition to distributing risks more widely, joint ventures decrease risks for individual firms by reducing the likelihood of overbidding.\(^423\) Economies of scale in information gathering and the aggregation of many independent value estimates are likely to improve the information and estimates relied upon in bidding, and will lead to bids more closely approximating the value ultimately realized than would an individual bid. Overbids and underbids result in inefficiency because either too much or too little will be paid to purchase geothermal rights.

This analysis is not inconsistent with the basic tenet that allocative efficiency will be promoted by competitive bidding. The marginal gain from information pooling decreases as the number of participants increases. Likewise, the marginal cost to each participant increases due to increasing loss of discretion and cost of monitoring the behavior of other participants. Thus it is unlikely that all potential bidders would enter into a single joint venture, creating a monopsony and introducing allocative inefficiencies.

Analytically then, only those joint ventures that do not impose greater costs by lessening competition are desirable. Conceivably, the leasing agency could require each bidder to disclose information to others in order

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422. A joint bid should not be confused with a merger. In a merger, two or more economic agents combine all their resources and thereby become a single, new economic entity. The joint venture results in cooperative efforts for only a subset of all the two agents' activities.

In a January 22, 1974, U.S. Bureau of Land Management lease sale in the Geysers, Mono-Long Valley, and East Mesa "Known Geothermal Resource Areas" in California, 33 units were offered for lease with 12 of these units attracting no bids. A total of 57 bids were received on the remaining 21 units. Of these bids, 19 were from joint ventures and eight of the latter were winning bids. Of the eight winning joint venture bids, five were made jointly by Union Oil Company of California, Magma Power Company, and Thermal Power Company; one was by Getty Oil Company and Mono Power Company; and the remaining two were by Republic Geothermal, Inc., and the City of Burbank, California. The remaining joint ventures, one of which represented 12 northern California municipal power agencies who bid on only a single lease unit, failed to win a bid. We are grateful to Mr. George Scarfe of the California State Office of the U.S. Bureau of Land Management for providing us this information.

to reduce one of the advantages of forming joint ventures, should they decrease competition. However, information disclosure alone does not sufficiently reduce risks to justify prohibiting joint ventures. Joint ventures are formed not only to pool information but also to spread the risks in all aspects of geothermal resource exploration, production, and marketing. Moreover, public disclosure of information may reduce the overall amount of information available since less incentive will exist for any single firm to provide a public good.

Mandatory information disclosure to the leasing agency can be justified economically if the joint venture possesses monopsonistic advantages. Without such disclosure, the distribution of information about a given reservoir could well be asymmetric since most leasing agencies lack either the technical competence or the budget necessary to acquire information on their own. Under those circumstances the monopsonist would make the lowest bid consistent with the agency's subjective evaluation. If information is disclosed to the agency, the agency could set a bid price which approximates more closely that which would be reached in a competitive setting.\(^{424}\)

Another justification for information disclosure to the agency is to avoid overinvestment in information gathering. If the agency establishes a refusal price for a lease unit below its value determined by a bidder with exclusive access to relevant information, failure by the bidder to disclose special knowledge of reservoir conditions serves only to redistribute wealth from the agency to the bidder. Thus, in the absence of required disclosure, the bidder may acquire more information about reservoir attributes than under competitive conditions because the additional information is made to appear more valuable to the bidder than its true social value. In other words, the social cost of additional information can exceed its social value. On the other hand, if information must be disclosed to the agency, the bidder will invest in information gathering to the extent that he wishes to submit a bid based on an accurate estimate of the value of the lease. Disclosure will eliminate the incentive to gather information in order to make the speculative gains which could result from exclusive access to it.\(^{425}\)

5. **Noninvolvement of the Government Except to Define Property Rights**

Even if government ownership of geothermal resources under private lands is not established, the government still cannot avoid the responsibility

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\(^{424}\) The presumed efficiency gains of the information disclosure requirement can conceivably be negated by bidder falsification of information. After the auction has been completed, the agency could monitor reservoir attributes and impose penalties for apparently falsified earlier information. It would nevertheless face some severe problems in distinguishing simply wrong information from intentionally falsified information. Independent sources of information could be obtained before the auction, but this alternative has been ruled out by assumption.

\(^{425}\) These arguments are developed in rigorous detail in Marshall, *Private Incentives and Public Information*, 64 AM. ECON. REV. 373, 373-90 (1974).
of resolving conflicting claims to the resources. The states, either through the courts or the legislatures, must define property rights to the resources. Since property regimes for geothermal resources have not yet been established with any certainty, the states have the opportunity to evaluate the efficiency of various alternatives. In this quest for an efficient regime, we will examine the four types of allocative regimes applicable to other fluid resources—the rule of capture, the reasonable use rule, the correlative rights doctrine, and the administratively supervised appropriation system—to determine whether any of them should be applied to geothermal resources.

a. The rule of capture

The rule of capture, or absolute ownership doctrine, derives from rigid application of the *cujus est solum* principle. Under this doctrine, an overlying landowner has the right to extract resources underlying his land, whether they be groundwater, oil, or gas, and to use or sell the resources anywhere at any time without regard for adverse effects upon other overlying landowners. Because it creates an essentially nonallocative regime when applied to common pool resources, the doctrine has been virtually rejected for groundwater, although some states, such as Texas, continue to adhere to it. Even in Texas, special districts, which are formed by local vote, have been given management powers over groundwater well spacing, waste prohibition, and recharge operations. In several states where the rule of capture for groundwater prevailed until recently, legislatures have adopted the appropriation scheme while protecting overlying users to the

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426. Acton v. Blundell, 12 M. & W. 324, 152 Eng. Rep. 1223 (Ex. 1843). The origin of the absolute ownership doctrine is generally traced to this case, but the case did not involve competing water users; rather, the conflict was between a groundwater user and an adjoining landowner who wished to drain his mine. The court adopted the doctrine based on the fear that if the complainant were successful, the neighboring owners would be pre-empted from developing their own supply regardless of comparative value of uses and regardless of notice to the latter, and also based on the absolute ownership of that which is found on or under one's land. See prior discussion in Part One of this article, 6 ECOLOGY L. Q. 247, 309-21 (1977).

427. Houston & T.C. Ry. Co. v. East, 98 Tex. 146, 81 S.W. 279 (1904). One case has gone so far as to say that a landowner can maliciously waste water to injure his neighbor without liability. Huber v. Merkel, 117 Wis. 355, 94 N.W. 354 (1903).

428. City of Corpus Christi v. City of Pleasanton, 154 Tex. 289, 276 S.W.2d 798 (1955) (court adhered to the doctrine and refused to enjoin an alleged loss of about 63 to 74 percent in transmission from the pumps to the use destination); TEX. WATER CODE ANN. § 52.002 (1972).

429. TEX. WATER CODE ANN. §§ 52.001-.401 (1972). For a discussion of this law, see Comment, The Texas Groundwater District Act of 1949: Analysis and Criticism, 30 TEXAS L. REV. 862 (1952); Comment, Ground Water Management: A Proposal for Texas, 51 TEXAS L. REV. 289 (1973) [hereinafter cited as Ground Water Management]. Several districts have been created by special acts. See Ground Water Management, supra. It is unclear from the statute whether production controls can limit a landowner’s production aside from well regulation. Compare TEX. WATER CODE ANN. § 52.002 with § 52.118(c). Ground Water Management, supra, concludes that the districts have not been very effective.

extent of their use at the time of the change. Other states have adopted the reasonable use rule, the correlative rights doctrine, or an appropriation system as an allocative regime for groundwater.

While the absolute ownership doctrine, or the rule of capture, retains considerable vitality as the basic property regime for oil and gas, legislative measures have been adopted to reduce the inefficiencies arising from this regime. The following discussion focuses on these measures.

(1.) **The rule of capture reformed—the oil and gas model**

(i.) **California**

California common law recognizes the right to produce oil and gas as part of the fee ownership of land. Fee owners, however, do not have title to oil and gas in place because of their fugacious nature. Title to oil and gas does not vest unless the resources have been reduced to possession. Every owner whose land overlies an oil and gas pool has a similar right of capture, but this does not mean that each has a right to a proportionate share of the oil and gas in place. On the contrary, a landowner is entitled to drain the oil and gas from other parcels without liability so long as his well is bottomed within his vertically extended boundaries. Thus, the rule promotes a race to capture the resources as quickly as possible.

The unreformed common law regime for oil and gas causes the following production inefficiencies:

The results are dense drilling, especially along property lines; capacity production of both oil and associated gas; rapid dissipation of reservoir pressure; irregular advance of displacing fluids through the reservoir oil zone; and, therefore, loss of ultimate recovery. Production of oil and gas may outrun the construction of pipelines and gas processing facilities, so that oil produced to avoid adverse drainage must be stored in makeshift tanks or open pits, where it is subject to loss through leakage, overflow, fire, and evaporation, and gas must be vented or flared as produced. The density of activity and the haste to complete wells and get oil to the surface also increase

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431. Kan. Stat. Ann. §§ 82a-701(d), 82a-703, 82a-704 (1969). Kansas has provided an action for damages for injury to common-law claims, that is, rights which were not exercised at the time of change, Id. § 82a-716 (1969), but query what the measure of damages would be. See also S.D. Compiled Laws §§ 46-6-1, 46-6-2 (1967); § 46-6-3 (Supp. 1972).

432. Each of these three regimes is discussed in detail later in this article.


434. Id. One of the important consequences of this property definition is that a transfer of the right to produce the oil and gas, that is, a mineral estate, is deemed to transfer a profit a prendre which is an incorporeal hereditament and thus subject to abandonment. Gerhard v. Stephens, 68 Cal. 2d 864, 442 P.2d 692, 69 Cal. Rptr. 612 (1968).


436. Id.
the likelihood of damages external to the industry. Finally, the certain prospect of high development costs due to dense drilling in new reservoirs restricts the number of exploratory prospects worth pursuing under given price expectations and thus, in the long run, reduces the quantity of petroleum economically recoverable from available natural deposits.\textsuperscript{437}

The rule of capture encourages rapid peak production followed by a rapid reduction due to loss of reservoir pressure. Certain conditions might coincide to produce price fluctuations leading to early abandonment of marginal wells, or creating risks limiting entry into the industry and thus reducing exploratory activities.\textsuperscript{438}

These diseconomies result from a property regime that makes the oil and gas reservoir a common pool—that is, a regime that confers multiple non-exclusive rights with respect to the resource, thus resulting in fragmented management and competitive production in a situation characterized by nonseparabilities. In order to mitigate these diseconomies, California has adopted legislatively a complex set of regulations governing three areas: waste, well spacing, and unitization.

First, the Public Resources Code contains several provisions dealing with waste of natural gas. These prohibit the release of gas without consumptive use\textsuperscript{439} and regulate the amount of gas production in order to husband reservoir energy for oil production.\textsuperscript{440} If the pool were under a single firm management, the manager would be able to calculate the benefits and costs from the production of gas and reinjection of gas; but no operator has the incentive to take conservation measures independently because the benefits are shared by other producers from the reservoir.

Second, California has adopted regulations governing well spacing.\textsuperscript{441}

\begin{footnotesize}
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  \item S. MCDONALD, PETROLEUM CONSERVATION IN THE UNITED STATES: AN ECONOMIC ANALYSIS 31-32 (1971).
  \item Id. at 32-33.
  \item CAL. PUB. RES. CODE §§ 3500, 3502 (West 1972) (misdeameanor for anyone willfully to permit natural gas to escape wastefully into the atmosphere); Id. § 3300 (unreasonable waste of natural gas unlawful).
  \item The constitutionality of these and other similar provisions prohibiting waste has been sustained. E.g., Bandini Petroleum Co. v. Superior Court, 284 U.S. 8 (1931); Ohio Oil Co. v. Indiana, 177 U.S. 190 (1900).
  \item CAL. PUB. RES. CODE § 3307 (West 1972). Control of the gas-oil ratio was sustained in People v. Associated Oil Co., 211 Cal. 93, 294 P. 717 (1930), in which the court justified the regulation to protect the correlative rights of the overlying owners and the public's interest in the resource. The term "unreasonable" was held not too vague since precise criteria can be adopted administratively; the legislature cannot set uniform criteria for the entire state since the characteristics of individual pools will differ. Although the control of production might result in market control, this was held not to be fatal since the primary purpose was conservation. The state supervisor may prescribe the gas-oil ratio for any pool, CAL. PUB. RES. CODE §§ 3307-3308 (West 1972); but it has been reported that the gas-oil ratio has been prescribed only in cases of "drastic" waste. Comment, Private Limitations of Petroleum Production—California's Approach to Conservation, 17 STAN. L. REV. 942, 962 (1965).
  \item CAL. PUB. RES. CODE §§ 3600-3608.1 (West 1972).
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Their purpose appears to be the reduction of the hazards of congested wells rather than conservation of oil and gas. The spacing requirements are uniform throughout the state and seem to be set without regard to the drainage area of a well. Where application of the spacing requirement deprives a small tract owner of the opportunity to drill a well on his land, the statute provides for compulsory pooling with adjoining land subject to an oil and gas lease. The provision is intended to overcome the constitutional prohibition against the taking of property without just compensation.

California's third modification of the common law rule of capture permits a state administrator, the supervisor of oil and gas, to compel unitization of production from a common pool under restricted conditions. Three types of unitization procedures are provided for by statute; these three types are discussed below.

The supervisor may compel unitization of interests when necessary to make feasible repressuring operations to arrest or ameliorate subsidence of land overlying or immediately adjacent to a producing pool when such land is threatened by inundations from the sea and when the subsidence is endangering persons or property.

The compulsory unitization procedure is limited in several respects. First, unitization cannot be ordered unless the parties have failed to enter voluntarily into a unit or cooperative agreement or have not taken individual action to repressure the field according to plans and specifications adopted by the supervisor. In addition, the supervisor must find that (1) the repressuring operations will not substantially reduce the "maximum economic quantity of oil or gas ultimately recoverable from the unit area as a whole," and (2) the estimated cost of the repressuring operations will not exceed the estimated value of the increased production resulting from the operation. Strangely, the amount of damage from subsidence does not enter into this cost-benefit calculation.

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442. Although a one-acre minimum of contiguous land is required for drilling one well, the spacing requirement for large parcels is 150 feet. Id. § 3600. However, the well density is restricted to one well per acre. Id. § 3606.1. A well is generally capable of draining oil and gas from an area far greater than one acre. Moreover, section 3600 has been held to apply only to surface location of the well so that a well might be bottomed closer than 100 feet from the exterior boundary of the tract. Richfield Oil Corp. v. Crawford, 39 Cal. 2d 729, 249 P.2d 600 (1952).


444. Bernstein v. Bush, 29 Cal. 2d 773, 177 P.2d 913 (1947) (denial of equal protection to deny the landowner the right to drill offset wells; the opportunity for voluntary pooling does not cure the defect).


446. Id. § 3317 (West 1972). The supervisor must also determine that repressuring is desirable and the unit operation is feasible. Id. § 3321(b).

447. Id. § 3320.2.

448. Id. Section 3320.3 excludes from this computation of costs the costs which a party agrees to bear in excess of the proportionate share of the costs which he otherwise would bear.
The unitization procedure commences with a hearing held by the supervisor, who must find the need and feasibility of compulsory repressuring operations before an order may issue. The allocation of the production to the separate tracts which have been unitized is based on the value of each tract for oil and gas purposes and its contributing value to the unit in relation to like values of other tracts in the unit. This determination is to be based upon "acreage therefrom, the quantity and quality of oil and gas recoverable, location on structure, its probable productivity of oil and gas in the absence of unit operations, the burden of operation to which the tract is likely to be subjected" and such other pertinent factors as can be reasonably determined. The expense of unit operation is apportioned in the same proportion that the tracts share in the unit production, and provision must be made for carrying those who cannot meet their obligations. Provision must be made for the appointment of an operating committee. The operating committee selects the unit operator, who in turn is able to enforce the required contribution of the tracts by securing a lien upon the debtor's equipment and share of the production. The unitization order becomes effective only if approved by working interests entitled to 65 percent of the production proceeds (before royalty payments) based on the prior year's production.

The second type of unitization established in California, also restricted to lands described under the above compulsory unitization, is voluntary cooperative agreements which may become compulsory. Although binding among the parties even without approval of the supervisor, the agreement may be submitted for his approval, which may be given if the agreement is not inimical to the arrest or amelioration of subsidence. Approval removes the agreement from the purview of state antitrust laws. These agreements, upon certain findings by the supervisor, may assume a compulsory character. Upon approval by the supervisor and ratification by persons who are entitled to 75 percent of the production, a nonconsenting interest may be condemned by a city or a county if inclusion of such land is

The party bearing such excess costs is to be reimbursed with interest at the rate of 3% percent per year compounded semi-annually. The source of repayment is from 60 to 90 percent of the increased production but in a proportion that the excess costs bear to the total costs of repressuring. The rationale of this section appears to be that the state will not be concerned with those costs where the risks of repayment are undertaken voluntarily by any party.

450. Id. § 3322(d).
451. Id.
452. Id. § 3322(e).
453. Id.
454. Id. § 3322(g).
455. Id.
456. Id. §§ 3329, 3330.
457. Id. § 3322.1.
458. Id. § 3320.1(a) (West Supp. 1977).
459. Id.
necessary to the repressuring operations. The condemning entity must, however, commit the condemned property to the agreement or sell it to working interest owners at not less than the condemnation price if the new owners will commit the property to the agreement. A third unitization procedure is available only if the field has been producing for more than 20 years and is at least 75 percent by area within incorporated areas. Under this provision, a voluntary agreement to operate a field or a pool without regard to separate ownership is valid among those parties consenting to it irrespective of the interests represented by them. The agreement may be submitted to the supervisor for approval; if it is approved, the nonconsenting parties will be bound by an agreement covering their tracts unless the nonconsenting parties offer their interests for sale to the consenting parties and the consenting parties refuse. To be approved, the agreement must have the consent of working interests constituting three-fourths of the total working interest in the area proposed to be unitized and a similar three-fourths of the royalty interests. After a public hearing, the supervisor must approve the agreement if he finds that: (1) the appropriate tracts for good oil field practice have been included; (2) the necessary consent has been obtained; (3) unitized management is reasonably necessary for pressure maintenance or replenishment operations, reduction of oil viscosity operations, or other joint efforts to increase the ultimate recovery of oil or gas; (4) increased or accelerated production as a result of unit operations will exceed the costs; (5) the agreement provides for a fair apportionment of production; (6) the agreement provides for an efficient use of surface and facilities; and (7) the agreement is fair in other material respects. The apportionment of the production is to be measured by the value of a tract for oil and gas purposes and its contributing value to the unit in relation to the total value of all tracts. The value is to be determined by considering: (1) the primary value of the tract, that is, the value of future production from the tract under primary means; (2) the secondary value, which takes into account the volume of producing formation under the tract, the amount recoverable by secondary recovery operations, and the value of production; and (3) other factors bearing upon value.

Nonconsenting interests may offer their interests for purchase by the working interest owners, who are entitled to purchase in proportion to their
share of unit production.\(^{471}\) In the event of disagreement over the price, the supervisor must determine the fair market value after receiving an appraisal report from an engineering committee.\(^{472}\) If the consenting parties do not purchase, the nonconsenting parties are not bound.\(^{473}\) No provision appears for apportionment of unit operating expenses, but the indebtedness of a participating interest may be enforced by foreclosure of a lien imposed upon the debtor's share of the production.\(^{474}\)

Other provisions deal with the addition of tracts to the unit\(^{475}\) and the effect of the unit agreement upon existing leases.\(^{476}\) The statute provides that the unit agreement does not bring about a cross conveyance.\(^{477}\) The supervisor's determinations are subject to judicial review.\(^{478}\)

(ii.) Oil and gas models from other states

Although theories of the nature of the landowner's interest in oil and gas in place differ from state to state, including nonownership, qualified ownership, or ownership in place,\(^{479}\) the theories seem to make little practical difference in the allocative regimes for oil and gas. As in California, under the common law a landowner has title to the oil and gas which he produces from a well drilled within the boundaries of his land even though the well might be draining other lands.\(^{480}\) This does not mean that a landowner owes no duty to other landowners. The correlative rights of the

\(^{471}\) Id. § 3647 (West Supp. 1977).

\(^{472}\) Id.

\(^{473}\) Id.

\(^{474}\) Id. §§ 3680-3681 (West 1972).

\(^{475}\) Id. §§ 3650-3652 (West Supp. 1977). In Western Gulf Oil Co. v. Superior Oil Co., 92 Cal. App. 2d 299, 311-12, 206 P.2d 944, 952 (1949), the court held that it was beyond judicial competence to unitize a pool for repressuring operations as a matter of common law.

\(^{476}\) CAL. PUB. RES. CODE § 3657 (West 1972).

\(^{477}\) Id. § 3656.

\(^{478}\) Id. § 3654.

One other provision should be noted. The legislature has declared that it shall be lawful for the Conservation Committee of California Oil Producers, a private organization, to issue recommendations of maximum efficient rates of oil pool production. Id. § 3450. "Maximum efficient rate" is defined as "the highest daily rate of production which can be sustained economically from a particular pool, from existing wells and facilities, for a reasonable period without loss of economically recoverable ultimate production of oil from such pool." Id. § 3451.

The supervisor may in his discretion join in the recommendation, disapprove it, or issue his own. Id. The supervisor's action is not binding on any producer.


\(^{480}\) WILLIAMS & MEYERS, supra note 479, at § 204.4.
overlying landowners generally are protected against waste, loss of oil and gas, or injury to the formation.481

Again, in order to minimize the diseconomies arising from an unrestrained rule of capture, the states have adopted various regulatory measures of which only the principal ones are outlined here.482

"Waste" in one form or another is prohibited by statute in most producing states.483 Generally, these statutes seek to prevent the physical loss of the resources, to protect the reservoir for maximum production, or to protect the interests of other overlying landowners in the common pool. In most states, as in California, regulatory provisions govern the drilling, operation, and abandonment of wells in order to prevent the escape of the resources from the reservoir, to protect the reservoir from water intrusion, or to protect fresh water from pollution.484 A common device is the gas-oil production ratio, set by an administrative agency to ensure proper use of the reservoir energy.485 Waste of gas by permitting it to escape into the atmosphere also is generally prohibited.486

In contrast to California's minimal well spacing requirement, spacing or drilling unit regulations in many states more effectively prevent drainage across tracts, unnecessary wells, and physical loss through excess drilling.487 In order to protect small tracts that do not meet the minimum requirements, most producing states compel pooling.488 If owners pool voluntarily, shares of costs and production are apportioned by negotiation. Where unitization or pooling is compelled, apportionment of costs and production is more troublesome. In addition, provision must be made for calculation of costs, time of payment of the operator, and reimbursement of the operator's expenses either from production or from a lien upon property of the other owners.489 A fairly common provision exempts agency-approved voluntary

481. Id. §§ 204.6, 204.7. As the authors indicate, the difference in the doctrinal basis of the landowner's interest in oil and gas in place may affect the measure of damages. Id. See also SUMMERS, supra note 479, at § 63.

482. Only a broad overview is presented since our purpose is to identify the various types of regulations affecting the allocative regime.

483. SUMMERS, supra note 479, at § 71.

484. SUMMERS, supra note 479, at §§ 73, 74. Texas furnishes examples of these types of regulation in TEX. REV. CIV. STAT. ANN. art. 6008 § 3 and art. 6014 (Vernon 1962). Prohibited are: the drowning with water of any stratum capable of producing oil or gas in paying quantities; physical waste resulting from well activity which reduces the ultimate recovery of the resources; escape into open air of gas in excess of that necessary for efficient operation; surface wastes; and inefficient use of reservoir energy.

485. SUMMERS, supra note 479, at § 76. See, e.g., TEX. REV. CIV. STAT. ANN. art. 6014(a) (Vernon 1962).

486. SUMMERS, supra note 479, at § 77. See, e.g., TEX. REV. CIV. STAT. ANN. art. 6008 § 3(k) (Vernon 1962).

487. SUMMERS, supra note 479, at § 83.

488. 6 H. WILLIAMS & C. MEYERS, OIL AND GAS LAW § 905.1 (1975).

489. Id. See discussion concerning New Mexico and Pennsylvania where nonconsenting parties may be assessed an additional amount, up to twice the apportionable costs, as compensation for the assumed risk by the operator. N.M. STAT. ANN. ch. 65-3-14 (Supp. 1975); PA.
pooling agreements from state antitrust laws. 490

Statutory unitization schemes exist in many states. 491 While the purposes for which unit operations are authorized are fairly broad, 492 variations exist as to whether an administrative agency as well as the owner of a working interest can initiate proceedings to unitize, 493 and, if consent is required, 494 the required percentage of working and nonworking interests that must approve a plan. 495 Among other things, the agency must find that unit operation is necessary for the stated purpose, that the proposed method is feasible, and that the operation will result in increased production exceeding the additional costs of unitization. 496 The apportionment of production varies among the states on the basis, alone or in combination, of such factors as surface acreage, the volume of the producing formation, the number of wells located on the tracts, and others. 497 The costs of operation are allocated among the owners 498 and usually the operator is entitled to reimbursement out of apportioned production for unpaid expenses; a lien may be given to secure payment. 499

(2.) The rule of capture as applied to geothermal resources

As discussed above, the common law rule of capture, in its pristine form, is essentially nonallocative. It encourages rapid, unrestrained

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490. See, e.g., N.D. CENT. CODE § 38-08-09.15 (1972); OR. REV. STAT. § 520.230 (1971).
491. See R. MYERS, THE LAW OF POOLING AND UNITIZATION § 8.02(3) (2d ed. 1967); MCDONALD, supra note 437, at 224-225; Eckman, Statutory Fieldwide Oil and Gas Units: A Review for Future Agreements, 6 NAT. RES. LAW. 339 (1973) (contains a comparative review of existing unitization statutes). The complexities in formulating a unit arrangement can be discerned from Eckman, supra.

492. The following purposes are said to be common: prevention of waste, increasing ultimate recovery, avoidance of unnecessary wells, and protection of correlative rights. WILLIAMS & MEYERS, supra note 488, at § 913.1. However, some states have authorized compulsory unitization for limited purposes. Id.

493. Id. at § 913.3.

494. Eckman, supra note 491, at 340 n.2, informs that only five states are truly compulsory in that other states require the consent of a specified majority before the plan becomes effective.

495. WILLIAMS & MEYERS, supra note 488, at § 913.3. See also id. at § 913.5.
496. Id. at § 913.4.

497. Id. at §§ 913.7, 970-970.4. Eckman, supra note 491, at 384-85, classifies states into those that allocate on the basis of tract value and those that require equitable allocations. However, he observes that:

In practice, their general distinctions can easily wash out amid the conflicting claims favoring allocation on surface acreage, productive acre-feet, productive pore space, primary vs. secondary, structural advantage, prior production histories and many other bases that are genuinely put forth as best showing each tract's relative value or contribution or its fair and equitable share of production.

Id. at 359-60.

498. WILLIAMS & MEYERS, supra note 488, at §§ 972-972.3. Eckman, supra note 491, at 377, observes that very few states specify the method of allocating expenses but those that do specify allocate costs in the same proportion as production.

499. WILLIAMS & MEYERS, supra note 488, at §§ 972.1-972.2.
extraction of resources, resulting in the expenditure of greater effort for less total production and in the inability of producers to maximize the value of the resources in terms of present and future production. Similar inefficiencies could occur in geothermal resource production should a rule of capture be adopted. Nonseparabilities in the production of geothermal resources have been noted earlier. Multiple nonexclusive rights in the reservoir without any legal restriction on their exercise could aggravate uncertainties among producers as to both the quantity and the properties of the fluid they will be able to extract.

It might be argued that the rule of capture will result in an efficient allocation of resources because the parties having access to the resources will bargain with each other to arrive at the most efficient outcome. In other words, if A has already commenced extracting geothermal resources from a given reservoir and B then commences to do the same, A can determine whether noncompetitive production promises greater net benefits than having B enter the pool. Thus if net benefits from noncompetitive production exceed the cost of inducing B not to produce, A will pay B not to produce. B likewise has the choice of paying A not to produce. But this does not obviate other difficulties—for example, the arrival on the scene of other parties. A would have to calculate his costs based on the possibility that other overlying landowners would engage in production. If A and B are in production and C appears on the scene, A and B may assess C’s entry differently and yet each may benefit from C’s forbearance. As the number of parties increases, the problem of free riders will become intractable. Moreover, it would not be enough that one operator acquired all or most of the working interest in the reservoir through acquisition or assignment of leases from the overlying landowners since the lessee operating separate leases would owe a separate obligation to each lessor to protect against drainage from the lessor’s tract unless pooling of separate leases is authorized in the leases and the leases are pooled. Thus, short of pooling the separate leases, transfers to create near single-firm management would be most unlikely.

The rule of capture might also be justified on the argument that corrective actions such as voluntary or compulsory unitization can be taken when necessary. Placing the reservoir under single firm management by unitization will cause the manager of the reservoir to account for the

\[500. \text{See text following note 365, supra.}\]

For voluntary unitization to occur, however, each party to the agreement must perceive that the benefits from unit management with a proportionate sharing of production and costs are greater than the net benefits of independent operation. Such agreements are facilitated the more the conditions affecting each party are similar. If, however, conditions are dissimilar and many parties are involved, an agreement becomes much more difficult and costly.

Many of the impediments to a voluntary unitary operation in oil and gas pools have been described elsewhere. Some of the more serious ones are:

1. contacting all those who have an interest, especially the royalty owners;
2. fear of reduced short-run income;
3. loss of operating experience by some lessees and inability to keep work crews together;
4. cumbersome decision making and frequent disagreements over operating policy;
5. disagreement as to the value of the resources being contributed to the proposed unit operation;
6. differences in structural advantages.

These impediments are equally applicable to a geothermal reservoir.

Moreover, unlike oil and gas which can be transported to distant places for use, geothermal resources must be utilized near the point of extraction and the use facility must be adapted to the properties of the fluid from that given site. The buyers' market for the resources is much more limited than for oil and gas. Consequently, if certain producers already are satisfying high value uses, they are not apt to share their bounty voluntarily with other producers unless the marginal cost of production is increased by neighboring production by an amount greater than the decrease in the marginal benefit. Because the producer and the user have an interdependent relationship, the difficulties in unitizing will be magnified after use facilities have been built. If there is a monopsonist, the monopsonist may be able to exert some control over production through contractual arrangements to assure itself of a continuing supply for its projected needs. If, however, two or more utilities have built generating plants to be supplied by...

502. For an analysis of the comparative economic efficiencies of unit management and unrestrained competition in an oil and gas reservoir, see McDonald, supra note 437, at 76-92.
503. Id. at 213-15.
504. At the Cerro Prieto, Mexico, operation, the maximum distance of any well from the power plant to which the fluid is supplied is one mile. II U.S. DEP'T OF THE INTERIOR, FINAL ENVIRONMENTAL STATEMENT FOR THE GEOTHERMAL LEASING PROGRAM V-377 (1973).
"At Cerro Prieto, some 15 producing wells, distributed over an area of about 1 square mile, supply steam to a 75 MW plant at a maximum distance of 1 mile." Id.
505. II JET PROPULSION LABORATORY, PROGRAM DEFINITION FOR THE DEVELOPMENT OF GEOTHERMAL ENERGY 2-4 (1975).
506. There may be some integration in the production of geothermal resources and their utilization; in several areas of the Imperial Valley the New Albion Resources Co., a subsidiary of San Diego Gas and Electric Co., has entered into a joint venture with Magma Power Co. and its subsidiary for geothermal resource development for power generation. It is anticipated that the resources will be sold to San Diego Gas and Electric Co. Similar arrangements might have been entered into by Southern California Edison Co. Letter from J.W. Aidlin to Sho Sato (Feb. 15, 1974).
different producers from the same reservoir, the interests of the utilities must be accommodated in apportioning production and controlling the properties of the fluid. In conclusion, despite these problems, if the rule of capture is adopted as the applicable property regime compulsory unitization should be authorized wherever the benefits of such action would exceed the costs. 506a

The procedures for unitization and decision making within the unitized group and the basis upon which the production and costs should be allocated and enforced will not be explored here, although a number of existing models applicable to oil and gas production merit careful examination. 507 However, in considering a unitization scheme, the properties of the fluid and the use facilities dependent upon them cannot be ignored. Some geothermal leasing policies incorporate this type of regime. Lessees are given the right to explore and produce from specified geographical areas covered by the lease, and, although production rights are based on a rule of capture, the government may compel unitized operations. 508

Aside from the practical problems of unitization, a serious legal problem exists with respect to voluntary and compulsory unitization. Because unitization results in the formation of a combination of producers, it must be analyzed carefully under the federal antitrust laws. 509 In assessing the antitrust implications, one should note that unitized operations for geothermal resources may in effect involve joint marketing, as well as joint production, if the unit is formed before any production is sold by any one producer. It would seem that a utility purchasing resources for electric power production would contract to take production from the requisite number of wells. Even if each member of the unit were to be apportioned a

506a. On the assumption that the basic allocative regime is the rule of capture, Goldstein makes a persuasive case for a need to unitize geothermal operations. Goldstein, Unitization for Geothermal Resources: United We Save, in ROCKY MOUNTAIN MINERAL LAW FOUNDATION, GEOTHERMAL RESOURCES DEVELOPMENT INSTITUTE 8-1 (1977).

507. For more detailed discussion of unitization, see Myers, supra note 491; L. Hoffman, Voluntary Pooling and Unitization (1954); Meyers & Williams, supra note 489, at 614-23. For a review of the various state laws, see Eckman, supra note 491.

508. 30 C.F.R. § 271.1 (1976). It appears that the Secretary of the Interior may compel participation in a cooperative or unit plan only if the lease so provides. Otherwise, the consent of the lessee is necessary. 30 U.S.C. § 1017 (1970).


Section 7 of the Clayton Act prohibits a corporation engaged "in commerce" from acquiring, directly or indirectly, the stocks or assets of another corporation engaged in commerce where the effect of the acquisition "may be substantially to lessen competition, or to tend to create a monopoly" in "any line of commerce in any section of the country." 15 U.S.C. § 18 (1970). The effect of the recent statute relating to premerger notification, The Hart-Scott-Rodino Antitrust Improvement Act of 1976, Pub. L. No. 94-435, §§ 201-202, 90 Stat. 1383 (1976), on geothermal joint ventures is discussed in Schlauch, Geothermal Resources Joint Ventures, in ROCKY MOUNTAIN MINERAL LAW FOUNDATION, GEOTHERMAL RESOURCES DEVELOPMENT INSTITUTE 4-1, 4-17 (1977).
share of the production from each well and each entered into a separate contract with the utility, it is unlikely that the terms of the sale would differ from one contract to another. The utility would wish to make certain that all contracts were interdependent to assure itself of the amount of resources necessary for plant operation. The federal antitrust problems involved deserve independent treatment and will not be analyzed here, except to note their presence despite state participation in establishing a unit operation.510

b. The reasonable use rule

The second major doctrine offering a potential model for geothermal resources is the American reasonable use rule governing groundwater.511 The principal feature distinguishing this doctrine from the absolute ownership rule is that the reasonable use rule permits an overlying owner to enjoin export of water by another when the complainant is injured by such action.512 It is said that under the reasonable use rule there is no apportionment among the overlying owners using water beneficially on the overlying land,513 so that each overlying owner may extract as much as he needs without regard to injury to other overlying uses. However, there seems to be some uncertainty as to whether such a result would really be sanctioned.514 For our purposes, it is better to identify the rule as not requiring such apportionment in order to distinguish it clearly from the apportionment requirement under the correlative rights doctrine.515 Moreover, while those who extract water for nonoverlying uses are subject to preferential overlying uses, the extent to which a nonoverlying user would be protected against adverse action by another nonoverlying user is not clear.516

510. The most recent decision of the United States Supreme Court on the state action doctrine is Cantor v. Detroit Edison Co., 96 S. Ct. 3110 (1976).
511. For a general discussion of this doctrine, see the literature cited in note 551 infra.
512. Forbell v. City of New York, 164 N.Y. 522, 58 N.E. 644 (1900) (overlying user able to enjoin a city exporting water to his injury); Bristor v. Cheatam, 75 Ariz. 227, 255 P.2d 173 (1953) (use of water restricted on the land from which it is taken). In Jarvis v. State Land Dep’t, 104 Ariz. 527, 456 P.2d 385 (1969), the court enjoined a city from exporting water from a basin designated as critical by the state engineer. It refused to permit the city to pay in lieu damages on the ground that damages would be difficult to determine. Subsequently, in Jarvis v. State Land Dep’t, 106 Ariz. 506, 479 P.2d 169 (1970), the court permitted the city to export water for municipal uses, provided the city acquired the lands overlying the critical groundwater area, to the same extent as water previously withdrawn for use on the overlying lands. This solution represents a departure from the strict American rule. The solution, of course, is intended to leave the complaining overlying owner no worse off than under existing conditions. See Clark, Arizona Ground Water Law: The Need for Legislation, 16 ARIZ. L. REV. 799 (1974).
513. E.g., Canada v. City of Shawnee, 179 Okla. 53, 64 P.2d 694 (1937).
515. We agree with Professor Corker, C. CORKER. GROUNDWATER LAW, MANAGEMENT AND ADMINISTRATION 106, 112 (Nat’l Water Comm’n Legal Study No. 6, 1971), that classifications are dangerous if we are to reason from the label to resolve conflicts. Our purpose for classification in this article is to distinguish the various allocative or nonallocative schemes. We use labels only for convenience of reference to particular allocative schemes.
This judicially developed doctrine appears to impose no restriction on the total quantity of water that may be extracted. As a result, groundwater might be mined. However, at least one state applying the reasonable use rule has by statute restricted pumping for irrigation from critical groundwater basins to use on those lands irrigated or cultivated within five years previous to the time a basin is designated as a critical area. This effectively prevents new irrigation users from tapping the basin without curtailing existing uses.

If the reasonable use rule is defined to permit unlimited extraction without regard to the consequences to neighboring landowners, the rule has all the disadvantages of the rule of capture with the additional disadvantage that permitted uses of resources could be restricted to those appurtenant to the overlying land. This additional disadvantage is apparent in the case of geothermal production. If the parcels overlying the geothermal reservoir are fairly small, it may be necessary to pipe fluid from wells located on a number of parcels to supply an electric generating plant, but the restriction to use on the overlying land may preclude such arrangements. It would also prohibit the desalinization of the fluid for export.

In addition, even if the reasonable use rule imposes some obligation toward neighboring landowners, it affords no certainty as to the share to which each overlying landowner is entitled and thus lacks the certainty needed for an efficient allocative regime. Corrective measures such as those undertaken in Arizona reduce this uncertainty only somewhat and thus do little to improve efficiency, since common pool problems remain with respect to preferred users who are protected at the time the critical groundwater area is declared.

c. The correlative rights doctrine as applied to percolating groundwater in California

(1.) Introduction

Up until the turn of this century, the common law of California recognized rights to percolating groundwater similar to the rights of overlying owners to oil and gas. Water percolating through the soil was treated like a mineral and the overlying landowner was able to extract the water for sale or use on nonoverlying lands. Because of this absolute right, tem-

There does not seem to be any indication that an appropriation system would be superimposed upon the American rule in those states adopting the latter rule as the basic allocative scheme.


518. Gould v. Eaton, 111 Cal. 639, 44 P. 319 (1896); Southern Pac. R.R. v. Dufour, 95 Cal. 615, 30 P. 783 (1892); Hanson v. McCue, 42 Cal. 303 (1871). In these cases, the conflict was between the groundwater user and an interconnected surface supply user.
pered only by a duty not to act maliciously to harm another, the courts refused to integrate the percolating water with the surface flow even though they were interconnected supplies. Since the allocative regime for water in watercourses did not recognize such an absolute right of capture in any landowner, the character of the source of supply was critical to the nature of the user’s rights.

The rule of capture for percolating groundwater was overturned in Katz v. Walkinshaw, which in dictum alluded to apportionment among overlying landowners if the supply were insufficient to meet their needs fully. Landowners who were using water from the artesian belt for domestic and irrigation purposes on their overlying land, sought to enjoin another overlying landowner from extracting the water to be sold for use on lands beyond the basin. In reversing the trial court’s denial of an injunction, the California Supreme Court noted that arid conditions in California differed considerably from the conditions in England where the doctrine of absolute ownership originated. The court noted that the productivity of the overlying lands dependent upon percolating water could be ruined by those who would extract it for export to distant lands. Unlike sand and gravel, which one might extract from beneath his own land without adversely affecting his neighbor’s land, extraction of percolating groundwater could injure other landowners. Consequently, the court held that landowners should be restricted to a use which is reasonable in view of the interests of the other overlying landowners.

On rehearing, the defendant presented a number of arguments in favor of applying the absolute ownership doctrine. First, he argued, the doctrine had been adopted as the law of the state by a statute adopting the common law generally. Second, investments had been made in reliance on the rule. Third, the doctrine of correlative rights would hinder development. Fourth, the reasonable use rule would require an apportionment of water among overlying landowners, a task beyond the competence of the courts. Finally, the defendant concluded, if the reasonable use doctrine were adopted for percolating water, the same rule also must be applied to oil and gas.

The court rejected each of these arguments. Initially, it held that the common law was adaptable to local conditions. It then pointed out that the rule of capture could not promote development since it offered no security to anyone’s investment. The reasonable use rule, on the other hand, was deemed to provide a measure of security because the rule “limits the right of others to such amount of water as may be necessary for some useful purpose

519. Cf. Bartlett v. O’Connor, 4 Cal. Unrep. 610, 36 P. 513 (1894) (plaintiff was a surface user whose supply was adversely affected by the defendant’s draining his land).
520. See note 518 supra.
521. See Lux v. Haggin, 69 Cal. 255, 390-409, 10 P. 674, 753-63 (1886).
522. 70 P. 663 (1902), rev’d on rehearing, 141 Cal. 116, 74 P. 766 (1903).
in connection with the land from which it is taken.\textsuperscript{523} Finally, the court distinguished the allocative regime for oil on the ground that oil was not "extracted for use in agriculture, or upon the land from which it [was] taken, but solely for sale as an article of merchandise, and for use in commerce and manufactures."\textsuperscript{524}

In subsequent cases, the court refused to enjoin export from the basin even where the water level was lowered since the withdrawal did not exceed the annual safe yield and the increased pumping costs of the complaining parties were nominal.\textsuperscript{525} More importantly, the court integrated the allocative regime for percolating groundwater with the law governing surface supplies where the supplies were interrelated by protecting uses on riparian and overlying lands against export.\textsuperscript{526} Water surplus to the present needs of overlying owners could be appropriated subject to the overlying owner's right to future use.\textsuperscript{527}

The distinction between overlying rights and appropriative rights must be clarified. A landowner's rights to groundwater under the doctrine of \textit{Katz v. Walkinshaw} extend only to uses which are appurtenant to his overlying land. Delivery of water to other lands overlying the basin is not protected under the superior overlying rights.\textsuperscript{528} Although \textit{Katz v. Walkinshaw} referred to both reasonable use and correlative rights,\textsuperscript{529} the rights of overlying landowners have been deemed correlative so that overlying landowners must share in the common supply.\textsuperscript{520}

One of the most significant California cases concerning groundwater

\textsuperscript{523} 131 Cal. at 134, 74 P. at 771. Moreover, if the amount of water which could be used on the overlying land were nominal, the court stated that neither an injunction against export of water by others, nor substantial damages therefor would be granted. As between appropriators for export the first taker would have the better right, but the overlying landowner's existing use would be protected against appropriation. The court refused to rule on the situation in which the overlying landowner's use arises after appropriation except to indicate that his rights would be limited to that quantity of water necessary for the enjoyment of the land. If the supply were insufficient to meet all of the needs of the overlying landowners, each would be entitled to a fair proportion since their rights were equal, but the court cryptically remarked that the importance of priority of use between them would have to await future determination.

\textsuperscript{524} \textit{Id.} at 136, 74 P. at 772.

\textsuperscript{525} Newport v. Temescal Water Co., 149 Cal. 531, 87 P. 372 (1906).

Moreover, the later cases began referring to the natural advantages inherent in the overlying lands, as in the case of riparian lands in relation to surface watercourses. \textit{E.g.}, Miller v. Bay Cities Water Co., 157 Cal. 256, 107 P. 115 (1910); Burr v. Maclay Rancho Water Co., 154 Cal. 428, 98 P. 260 (1908). \textsuperscript{526} Hudson v. Dailey, 156 Cal. 617, 105 P. 748 (1909).


\textsuperscript{528} Eden Twshp. Water Dist. v. City of Hayward, 218 Cal. 634, 24 P.2d 492 (1933); City of San Bernardino v. City of Riverside, 186 Cal. 7, 198 P. 784 (1921).

\textsuperscript{529} \textit{Katz v. Walkinshaw}, 141 Cal. 116, 136, 74 P. 766, 772 (1903).

\textsuperscript{530} Eckel v. Springfield Tunnel & Dev. Co., 87 Cal. App. 617, 624, 262 P. 425, 427 (1927). The court described the reasonable use doctrine as permitting the extraction of groundwater, although draining the neighbor's land, for beneficial use upon the overlying land, whereas the correlative rights doctrine requires a sharing of the common supply.
allocation is *City of Pasadena v. City of Alhambra*, 531 which dealt with a situation in which total extraction from the groundwater basin exceeded the natural recharge for a number of years. Rather than enjoining uses in the order of inferior rights—that is, preferring earlier appropriative rights over later acquired rights, and correlative rights of overlying landowners over appropriative rights—the court held that the later users who caused the total extraction to exceed the annual safe yield were acting adversely to the earlier users and such adverse uses for five continuous years ripened into prescriptive rights. 532 Because the earlier users, however, had not been ousted completely but continued to pump as much as they needed, the court held that they had retained rights, either by prescription against those later users who had acquired prescriptive rights against them, or by retention of part of their original rights. 533 Under these circumstances a proportionate reduction by all users was decreed in order to limit the total extraction to the average safe annual yield. 534

531. 33 Cal. 2d 908, 207 P.2d 17 (1949).

532. The period of prescription commences from the time of the overdraft. If, however, there is no adverse use so long as the safe yield is not exceeded, there may be some difficulty in determining when that amount is exceeded in a long cyclical period. In the *Pasadena* case, all the parties stipulated that each party had extracted the water "openly, notoriously, and under a claim of right, which claim of right was continuously and uninterruptedly asserted by it to be and was adverse to any and all claims of each and all the other parties joining herein." 33 Cal. 2d at 928, 207 P.2d at 30. It is unclear what conditions must exist to charge the owner of groundwater rights with notice of the commencement of the overdraft. *City of Los Angeles v. City of San Fernando*, 14 Cal. 3d 199, 537 P.2d 1250, 123 Cal. Rptr. 1 (1975), makes clear that adverse withdrawals commencing an overdraft do not necessarily give notice from that time. The notice problem becomes acute as to an overlying owner who does not have a well and thus may not receive actual knowledge of overdraft conditions for some time. In addition, since an overdraft is determined on the basis of long-term safe yield, it may be difficult to determine whether an overdraft exists without long-term records of basin conditions.


533. Many have construed the opinion as accepting the mutual prescription concept, e.g., C. Meyers & A. Tarlock, *Water Resources Management* 614 (1971); Krieger & Banks, *Ground Water Basin Management*, 50 Cal. L. Rev. 56, 61 (1962), but the court was very careful not to decide this issue. Whether the prior right holders have had their rights diminished or whether they had in turn established prescriptive rights against those who had extracted adversely for five years is not merely an academic issue. For example, an overlying right would not be lost by nonuse, *Orange County Water Dist. v. City of Riverside*, 173 Cal. App. 2d 137, 184, 343 P.2d 450, 476 (1959), but an appropriative right can be lost after five years of continuous nonuse. Moreover, if the concept is mutual prescription, the earlier users before the overdraft would have to use adversely to the adverse users for five years after the adverse users established prescriptive rights; in other words, between five and ten years after the overdraft commenced, the prescriptive users would be fully protected. The matter was clarified in a recent case, *City of Los Angeles v. City of San Fernando*, 14 Cal. 3d 199, 537 P.2d 1250, 123 Cal. Rptr. 1 (1975), in which the court referred to the partial retention of overlapping rights. However, the *City of Los Angeles* case contains language which raises problems as to whom the prescription runs against—that is, against just the overlying owners or the existing nonprescriptive appropriators as well. Id. at 294, 537 P.2d at 1319, 123 Cal. Rptr. at 70.

534. The method of computation was as follows. The average safe annual yield was determined to be 18,000 acre-feet per year but the annual extraction was 24,000. This means
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The method to be used in allocating the supply remains to be determined. Although the courts have referred to the need for a fair allocation among the overlying landowners when their withdrawals exceed supply, no case has been reported where the court has allocated supply on the basis of correlative rights, except in those situations involving prescription. However, because the court in the Pasadena case held that the overlying rights were analogous to riparian rights to watercourses, one court faced with this problem has borrowed the allocative scheme for riparian rights.\textsuperscript{535}

In Half Moon Bay Land Co. v. Cowell,\textsuperscript{536} the court, in allocating a stream supply among competing riparian owners, alluded to the following factors to be considered: the length of the stream, the volume of water in it, the extent of riparian ownership, the character of the soil owned by each claimant, the area sought to be irrigated by each, the practicability and cost of irrigation on respective parcels, and the comparative profit of the different uses on the lands of the litigants. The court also stated that

\begin{quote}
when the water is insufficient for all the land, or for all of the uses to which it might be applied thereon, and there is enough only for that use which is most valuable and profitable, the shares may properly be limited to and measured by the quantity sufficient for that use, and the proportions fixed accordingly.\textsuperscript{537}
\end{quote}

The latter statement is extremely ambiguous because it is not clear whether one riparian owner may be allocated all the water if his intended use is the most profitable or whether the most profitable use of each riparian owner is to be considered. The court probably intended the latter interpretation since it stated that the party taking under the decree allocating the water might "put his share so fixed to another beneficial use if he so desired."\textsuperscript{538} It makes little sense to allocate the water based on the "most valuable and profitable" use while permitting a party who has been allocated a large portion to use the water in contradiction of that standard.

\textsuperscript{535} Tehachapi-Cummings County Water Dist. v. Armstrong, 49 Cal. App. 3d 992, 122 Cal. Rptr. 918 (1975).
\textsuperscript{536} 173 Cal. 543, 160 P. 675 (1916).
\textsuperscript{537} Id. at 550, 160 P. at 678.
\textsuperscript{538} Id.
The basis for apportionment quoted above may not in fact coincide with practice; the actual allocation in the Cowell case as well as in another case where apportionment has been reported was based on the ratio of irrigable acreage of each riparian owner to the total. While irrigable acreage furnishes a common denominator when allocating among competing riparians who desire to use the water for irrigation, these cases provide no guidance as to how the water will be allocated when one claimant seeks water for industrial purposes, another for recreational use, a third for cattle raising, and a fourth for irrigation.

Although the above discussion has been concerned with allocating water quantity among competing users, a related problem arises when extraction by one overlying owner adversely affects the costs of production for others in the same basin. In one case, the means of extraction used by an overlying owner was protected against an appropriator. Although we have not found a case involving interference with the means of extraction of one overlying owner by another overlying owner, one commentator offers the conclusion that the injured owner would not be protected, at least where the extraction does not exceed the average safe annual yield, since there is no priority of right and each overlying owner has an equal right to diversion.

Another facet of the percolating groundwater law relevant to geothermal resource management is the matter of recapture of water introduced into the basin by man's efforts. The law upholds the right of the importer to recapture that quantity which he has added.

Although it was mentioned previously that the courts have resolved disputes by integrating interconnected surface and groundwater supplies, the legislature has refused to coordinate the administration of the interconnected supplies. The acquisition of an appropriative right to surface and underground watercourses is subject to administrative supervision. The

539. Rancho Santa Margarita v. Vail, 11 Cal. 2d 501, 81 P.2d 533 (1938) (trial court considered the irrigable acreage and the water requirement; the Supreme Court appears not to be in disagreement with that approach).

540. In Williams v. Rankin, 245 Cal. App. 2d 803, 54 Cal. Rptr. 184 (1966), conflicting claims of riparian and overlying owners for irrigation and stock-raising uses were involved, but the opinion does not make clear the basis upon which the apportionment was made. Conceivably the court could have determined the requirements of each riparian owner on his riparian land and then determined the appropriate proportion.


543. City of Los Angeles v. City of Glendale, 23 Cal. 2d 68, 142 P.2d 289 (1924); City of Los Angeles v. City of San Fernando, 14 Cal. 3d 199, 537 P.2d 1250, 123 Cal. Rptr. 1 (1975). The person seeking to recapture is required to prove that the quantity sought to be recaptured is due to his recharge.

544. See note 526 supra and accompanying text.

agency may reject an application to appropriate water if contrary to the public interest or may condition the license to protect other interest.\textsuperscript{546} Guidelines for the agency in acting upon an application include use preferences.\textsuperscript{547} In addition, geographical\textsuperscript{548} and municipal reservations\textsuperscript{549} are provided for sources of supply coming within the permit system. In a statutory adjudication of water rights, percolating groundwater rights cannot be included.\textsuperscript{550}

One final point requires emphasis. The allocative regime for percolating groundwater has been developed with respect to rechargeable basins. Thus, the courts permit appropriation of groundwater that is surplus to the needs of the overlying owners since water would be discharged unused if appropriation were denied. With respect to basins having little or no annual recharge under natural conditions, where extraction will result in the mining of stock resources, courts have provided no guidance as to how water will be allocated among the owners of correlative rights or to what extent, if any, appropriation will be permitted.\textsuperscript{551}

(2.) Correlative rights as applied to geothermal resources

The correlative rights doctrine developed by the California courts for percolating groundwater would hardly be an improvement on the reasonable use rule if applied to geothermal resources. If the total annual extraction from the reservoir is restricted to the safe yield computed on a cyclical basis, and if the yield is somehow apportioned among the overlying landowners, each landowner would have a right to a fixed yield of the fluid. For practical purposes the resource might then be regarded as a renewable resource so that

\textsuperscript{546} Id. §§ 1255-1258 (West 1971).
\textsuperscript{547} Id. § 1254 (State Water Resources Control Board is to be “guided by the policy that domestic use is the highest use and irrigation is the next highest use of water”).
\textsuperscript{548} Id. §§ 10505, 10505.5. The state is permitted to make applications to appropriate water, which applications are excused from diligence requirements. Id. § 10500. A release of priority or an assignment of such applications cannot be made if in the judgment of the Board it would “deprive the county in which the water covered by the application originates of any such water necessary for the development of the county.” Id. §§ 10505, 10505.5.
\textsuperscript{549} An application filed by a municipal corporation “for domestic purposes shall be considered first in right irrespective of whether it is first in time.” Id. § 10500. 10500. The statute contemplates that a municipality may be granted a permit in excess of its present needs and the municipality may either distribute the excess as a public utility or another may appropriate until the municipality requires the water. Id. §§ 1462-1464.
the problem of proper temporal distribution of use\textsuperscript{552} so important in the case of a nonrenewable resource, does not arise within this limited scheme. Because each landowner would have control over a fixed annual quantity of the fluid, and all landowners would be limited in their extractions, each owner would have certainty as to his quantity.

Despite the advantage of certainty, numerous problems emerge when the correlative rights doctrine is applied to geothermal resources. As indicated earlier, the court has held that the annual withdrawal of groundwater will be restricted to the safe yield. Even if a reservoir is subject to natural recharge, there is no compelling economic reason why the extraction should be restricted to that amount. It may be more efficient to mine the fluid than to maintain it as renewable—that is, present consumption may be more valuable than the discounted value of future consumption:

If the court were to permit mining and to apportion the resource among the overlying landowners, it would be required to determine what the efficient temporal distribution of use should be, a task generally beyond judicial competence. Even if the court were to make such determinations, the temporal distribution of use would necessarily be the same for all overlying landowners so long as the apportionment were based on annual well production. No particularized determination would be possible unless the court were able to apportion specific total quantities of fluid over the life of the reservoir to each overlying landowner and were able to enforce such an apportionment.

A serious issue remains as to the basis upon which the court should apportion. Since irrigable acreage is wholly irrelevant, assuming the resource is used for power generation rather than desalinization, the apportionment might conceivably be based on surface acreage or on reservoir volume underlying each tract, and in either case the reservoir might be determined as the area in which the enthalpy of the fluid permits a beneficial use of the fluid. Even if the court should apportion the quantity of the fluid on such a basis, however, interdependencies remain since extraction at one location may affect the marginal cost of extraction at another. For example, depending upon permeability, one well may reduce the quantity of the fluid extractable by another, or extraction from one well might cause lateral movement of cooler fluid into another well. Thus, aside from the difficulties of quantitative allocation, a more serious problem is the stress such a system places upon the judiciary’s competence to deal with highly technical matters relating to properties that give value to the fluid. Heat energy is the essential property of the resource. Allocation of enthalpy, rates of extracting heat energy, changes in reservoir configurations—these and many other issues would present difficult questions for a judge.

Furthermore, until adjudication occurs, the effective rule is one of

\textsuperscript{552} "Temporal distribution of use" refers to the distribution of the extraction of a nonrenewable resource over time.
capture. Investments might be deterred until there is apportionment. Moreover, unless the court has fairly complete information with respect to the reservoir at the time of initial apportionment the court may either refuse to apportion or may reserve jurisdiction to reapportion as more facts become available. These uncertainties would not be mitigated even if there were a monopsonist with respect to production from the reservoir since he would be required to make decisions on plant location based on supply conditions as they existed at the time of the initial decision to use geothermal resources.

If the language of the court in *Half Moon Bay Land Co. v. Cowell*553 were to be taken seriously and if a court were able to apportion the quantity and the properties of the fluid on the basis of most profitable use, the court would still have to rely on additional factors if two or more overlying landowners were producing for the same ultimate use, such as power generation. Furthermore, if different uses were to be considered the court would be required to substitute its judgment for the market. More difficulties would arise if uses other than those determined to be most profitable by the court should prove to be more profitable in the future.

This discussion illustrates the uncertainties that would accompany application of the correlative rights doctrine to geothermal resources. A property regime encumbered with such uncertainties cannot be recommended.

d. The appropriation system

The fourth model to consider in designing an allocative regime for geothermal resources is the appropriation doctrine. Unlike the aforementioned doctrines which recognize the right to groundwater as one inherent in overlying landownership, an appropriative right is perfected by beneficial use.554 For both surface water and groundwater the appropriative scheme allocates on the basis of time priority, that is, the earlier use is senior in right to the later. Unlike watercourses, where the flow will set the outer limits of the amount of water which might be diverted, an aquifer might contain naturally stored water in addition to the annual recharge. Under these circumstances, a question arises as to whether the total appropriation is to be restricted to the annual recharge or whether mining is to be permitted.555 In several states where an administrative agency has supervision over acquisition of appropriative rights, the agency has at times defined the amount of total permissible annual extraction as that amount which would lower the water table within a given number of years to a point where the resource would be out of economic reach for agricultural uses and has

553. See text accompanying note 536 supra.
554. See e.g., *Yeo v. Tweedy*, 34 N.M. 611, 286 P. 970 (1930).
permitted appropriations only so long as this rate of total annual extraction was not exceeded.\textsuperscript{556}

Most of the states adopting the appropriation doctrine have placed the acquisition of water rights under administrative supervision,\textsuperscript{557} some conferring extensive powers upon the administrative body. In Oregon, for example, the state engineer may designate a critical groundwater area if the groundwater levels are declining or have declined excessively, if the wells of two or more claimants substantially interfere with each other, if the available supply is or is about to be overdrawn, or if the groundwater is or threatens to become polluted.\textsuperscript{558} Upon designation of a critical groundwater area, the state engineer may: (1) refuse any new appropriation; (2) determine the total permissible withdrawal during any time period and apportion such amount on the basis of priority of rights; (3) ignore priorities and give preference to domestic and livestock uses and then to other uses as he deems advisable; (4) reduce withdrawal by one or more appropriators, evidently without regard to priorities; (5) secure abatement of pollution; (6) rotate uses; and (7) take such other measures as are necessary to protect public welfare, health and safety.\textsuperscript{559}

One of the anomalies in groundwater allocation in some states is the failure to integrate the groundwater allocation with surface supply allocation even when the supplies are physically interconnected.\textsuperscript{560} If one of the

\textsuperscript{556} Mathers v. Texaco, Inc., 77 N.M. 239, 421 P.2d 771 (1966). In Fundingsland v. Colorado Ground Water Comm'n, 171 Colo. 487, 468 P.2d 835 (1970), the following standard, used to determine whether the basin can accommodate additional appropriators, was sustained:

The three mile test was developed for use in the Northern High Plains. It is partly based on policy and partly based on fact and theory. Using that test, a circle with a three mile radius is drawn around the proposed well site. A rate of pumping is determined which would result in a 40% depletion of the available ground water in that area over a period of 25 years. If that rate of pumping is being exceeded by the existing wells within the circle, then the application for a permit to drill a new well may be denied. Id. at 491, 468 P.2d at 836. The 40 percent depletion is the point of reasonable economic limits of withdrawal for irrigation and 25 years was a reasonable, average period during which loans for the construction of well facilities would have to be repaid.

\textsuperscript{557} Clark, \textit{Western Ground-Water Law}, in \textit{WATERS AND WATER RIGHTS} §§ 441-442.3 (R. Clark ed. 1972).

\textsuperscript{558} Or. Rev. Stat. § 537.730 (1971).

\textsuperscript{559} Id. § 537.735.

\textsuperscript{560} Arizona adheres to the appropriation doctrine for watercourses and the American rule for percolating groundwater. \textit{See} Bristol v. Cheatham, 75 Ariz. 227, 255 P.2d 173 (1953). \textit{See also} Canada v. City of Shawnee, 179 Okla. 53, 64 P.2d 695 (1937). Texas originally had adopted a combined riparian and appropriation system for watercourses but has recently revised the system to an exclusively appropriation system. Tex. Water Code Ann. § 5.303(a), (b), (i) (Vernon 1972). The absolute ownership doctrine continues to apply to percolating groundwater. For a criticism of the divergent regimes, see Corker, supra note 515, at 146.

In many states, the allocative rules are the same for interconnected supplies and the rights are integrated. \textit{See}, e.g., \textit{Alaska Stat.} §§ 46.15.030, 46.15.050 (1971); \textit{Wyo. Stat.} § 41-133 (1957); City of Albuquerque v. Reynolds, 71 N.M. 428, 379 P.2d 73 (1963).

requisites for efficient resource allocation is a definition of a property right that grants security to a supply, the lack of integration is a serious flaw.

With any of the property regimes discussed above, the degree of protection given to existing methods of diversion as opposed to the quantity of water which may be diverted, is problematical. The rule of capture and the reasonable use doctrine would probably deny any protection. The law in appropriation states seems to favor a flexible solution, especially where an administrative agency has been entrusted with responsibility to prevent conflicts from occurring.

The appropriation scheme for groundwater attempts to confer a measure of exclusivity to the use of the resource on the basis of temporal priority. Despite its strengths, there are difficulties with the appropriation system. First, the system does not fully resolve nonseparabilities in the production function; the vexing problem remains of how much protection will be given to the prior appropriator against the increased marginal cost of extracting water due to lowering of the water table resulting from subsequent extraction by another user. Second, the system discourages the conservation of resources in the present by its focus on annual extraction quotas. Where groundwater mining has been allowed and the total annual extraction from the reservoir has been based on an agency-determined reservoir life, no appropriator has an incentive to postpone current consumption in favor of future withdrawal even if the discounted value of future use is greater than that of current use, because the rights of the appropriators are defined in terms of annual extraction and any benefit from postponement by any given

562. City of Colorado Springs v. Bender, 148 Colo. 458, 366 P.2d 552 (1961) (senior appropriator required to install reasonable withdrawal facilities by considering the economic reach of the purpose for which water is extracted; junior appropriator must bear any additional expense of the senior if the junior interferes with the senior’s reasonable extraction facility). Compare Current Creek Irr. Co. v. Andrews, 9 Utah 2d 324, 344 P.2d 528 (1959) (senior appropriator relying upon artesian flow protected), with Wayman v. Murray City Corp., 23 Utah 2d 97, 458 P.2d 861 (1969) (although the Current Creek case was distinguished, the court adopted the rule of reasonableness to assure that water was not wasted and the greatest amount of available water put to beneficial use). In Pima Farms Co. v. Proctor, 30 Ariz. 96, 245 P. 369 (1926), the court, applying the appropriation system to an “underground stream,” protected the senior’s means of diversion by enjoining the junior from interfering with the senior unless the junior was willing to supply the senior, presumably at no greater burden to the senior.
563. In Nevada a permit to appropriate water is subject to the condition that the static water level at the point of diversion may be lowered by a reasonable amount, based on the economics of pumping water for the general type of crops grown and the effect of water use on the general economy. Nev. Rev. Stat. § 534.110 (1973).

In Wyoming a permittee does not have the right to have the water level or artesian pressure maintained at any level higher than that required for maximum beneficial use of water in the source of supply. Wyo. Stat. § 41-141 (1957). The provisions of Wyo. Stat. § 41-128 (1971 Cum. Supp.), should be compared; the latter section gives protection to a well which is reasonably adequate for domestic or stock uses but where there is an interference between domestic or stock users, the senior appropriator’s well is protected.
appropriator will inure to other appropriators as well. Although the lack of exclusivity in this respect may not be a shortcoming with respect to those uses for which forbearance or substitution is not economical, it may be important in agriculture since this lack of exclusivity may cause land to be overirrigated even though forbearance or reduction in favor of future consumption might be more profitable. Despite these difficulties with the present appropriation model, an appropriation system as developed below may be a more efficient allocative regime, as compared to other models discussed above, if multiple rights to a single geothermal reservoir are to be recognized.\(^{564}\)

At the outset, it should be noted that the problem of devising an allocative regime for groundwater is simpler than for geothermal resources. Only one dimension of water—quantity—is normally relevant since the natural quality of water does not differ very much regardless of the part of the aquifer from which the water is extracted. Aside from quantitative allocation problems, interdependencies arise primarily from the lowering of the water table\(^{565}\) and from local interference created by cones of depression around the wells.

A property regime for geothermal resources, however, must be sensitive to additional relevant characteristics. As emphasized throughout this article the value of geothermal resources is in their heat energy. Thus, it is not enough that a geothermal appropriative right be defined in terms of a given quantity of the fluid. The property right must take into consideration the physical properties of the fluid as well. Second, the interdependencies among extraction wells and use facilities are much more complex in geothermal reservoirs than they are in groundwater basins. Moreover, it should be recognized that knowledge of groundwater behavior is much more advanced than knowledge of the behavior of geothermal resources.

C. An Appropriation System for Geothermal Resources

The proposed appropriation regime for geothermal resources can be summarized briefly as follows. A person seeking an appropriative right will be required to file an application with a state agency. The application must state the intended location of exploration, give assurance of the applicant’s right to use the surface for exploration, and designate an exploratory work program. The agency will be required to review the application to determine the applicant’s capability, possible interference with prior applications or

\(^{564}\) As mentioned earlier, Montana and Wyoming have adopted the appropriation system for geothermal resources. See text accompanying notes 331-42 \textit{supra}. However, since geothermal resources have simply been added to the groundwater appropriation scheme, the burden will fall upon the administrative agency to devise an appropriate regime for these unique resources.

\(^{565}\) The artesian wells present another facet of the interdependencies in the cost of extraction.
licenses, and environmental impact and to make certain that the work program includes the required standard tests to obtain data about the reservoir. If, after a hearing, the agency approves the application, a permit to proceed with the exploration will issue but the permit will be subject to revocation if the permit conditions are not met. If resources are discovered, the permittee will be required to seek agency approval for its work program for development of the resource. Upon completion of the development work, the agency will issue a license defining the quantity and properties of the fluid that will be necessary to provide energy for the intended use and the period during which the licensee will be entitled to extract the resource. The licensee will have a priority of appropriative right based on the date of filing of his application with the agency. Any license will be subject to prior licenses, with possible exceptions.

Alternatively, the agency might auction the right to explore and develop the resource. Ultimately, this too would result in the grant of a license to appropriate a given quantity of the resource with given properties for a specified period. The area for which the auction is to be held may be determined upon nomination of a private party or by designation of the agency. The advantages and disadvantages of the proposed regimes will be analyzed in some detail below.

1. Administrative Supervision

In any of the appropriation systems proposed here, judicial administration should be rejected in favor of creating an administrative agency primarily responsible for the allocation of appropriative rights. The earlier system of judicial administration of appropriative rights for surface and groundwater has been replaced in practically all states by an administrative agency because of the latter's many advantages. In a system of judicial supervision, the court generally intrudes only after a conflict arises.Ordinarily judges are exposed only occasionally to resource conflicts and they therefore lack expertise in technical matters. Finally, litigation frequently entails substantial expense. On the other hand, a properly empowered and staffed administrative agency, acting upon applications in advance of physical exploitation, can forestall serious conflicts since it will accumulate knowledge about a given reservoir, will have an inventory of outstanding rights, and will have a knowledgeable staff to aid in investigation and decision making. In other words, an agency similar to that established for administering the appropriation system for water should be established to administer the proposed appropriation system for geothermal resources.566

566. We do not express an opinion as to whether one administrator or a multi-member board is better. The political ambiance and experience of each state should dictate this choice.
2. Time of Filing an Application

The scheme proposed here relies upon the administrative agency to issue licenses for the appropriation of geothermal resources, based on time priority. Thus, it is necessary to determine the time at which the right will be recognized. In a water appropriation system the appropriative right is perfected when the water is put to beneficial use but the time priority relates back to the date of filing of the application, provided that the permittee has completed his work within the required period. This makes economic sense, since it is necessary to protect the resources committed to the construction of projects that require a lengthy period before completion. Otherwise, a later commenced but earlier completed project would be able to obtain a priority of right over the first project and thereby undercut the expectancy and the investment of the first project.

To avoid similar inefficiencies, the relation back doctrine should also be applied to geothermal development. Since subsoil and drilling conditions may differ even within a given area, some wells should properly be completed more rapidly than others. If appropriative priorities were based on time of production, suboptimal exploration and development programs might be undertaken for fear that others would win the race to production. Such a situation promotes insecurity, and may lead to wasteful drilling practices. These possibilities suggest that the priority should relate back to a period before resources are committed to exploratory activities. On the other hand, the potential inefficiencies of the relation back doctrine must be considered. A net social cost is imposed by the doctrine when two conditions coincide: (1) a delay occurs in production because the permittee fails to conduct his required activities, necessitating revocation of the permit and its issuance to another person, and (2) the value of foregone earlier production is greater than the discounted value of delayed production. On balance, we believe that the relation back scheme is desirable and that a perfected right should relate to the time when the application to appropriate was filed. It should be emphasized that the relation back doctrine is not intended to confer exclusivity in exploration activities, although its effect may be to do so since there will be little incentive for others to engage in such activities if the permittee has a prior, though as yet unperfected, claim to the resource.

Because the purpose of the relation back doctrine is to protect investments in exploration and development by enabling the permittee to capture the benefits from his investment in those activities, it is necessary to determine what types of exploratory activities ought to be given this protection. There are two major types of exploratory work: (1) reconnaissance activities followed by detailed exploration that does not entail deep drilling

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567. The exclusivity of the right to explore under the permit is a separate issue from whether anyone who proposes to conduct drilling or other activities requiring regulation will be required to obtain a permit to engage in these activities.
of exploratory wells;\(^{568}\) (2) the drilling of exploratory wells, which is much more expensive.

For the purposes of the relation back doctrine, applications should be permitted to be filed at the time detailed fieldwork activities are to be undertaken. The chief argument in support of this position is that unless an incipient claim is recognized at that time, there can be either socially undesirable duplicative investments in these activities, in an attempt to win the race to the agency, or underinvestment because of the risk of losing the race. However, difficulties will exist in administering a program that allows the applications to be filed just before detailed exploratory activities are undertaken. First, the designation of the area for which an application can be filed must be determined by considering the optimal size for conducting detailed exploratory activities. This may be extremely difficult and in all probability some arbitrary acreage designation would have to be adopted.\(^{569}\)

Second, without careful control, applications might be filed by persons who

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568. The Department of the Interior has described the sequence of exploratory activities as follows:

Exploration usually begins with compilation of available data from published literature and proprietary sources. This first phase usually involves a large region, perhaps hundreds or even thousands of square kilometers. Reconnaissance field work follows, to obtain important data on geology and geochemistry unavailable in any other way. This is usually for several closely related prospects that tentatively were selected in the first phase. As this phase identifies the more interesting prospects, detailed geophysical and geologic, and possibly geochemical, field work in the most interesting prospects is undertaken (third phase). The fourth and final phase is deep exploratory drilling in the best prospect(s).


We are not confident as to whether an application should be entertained before the commencement of the second or the third phase. We opt for the third phase in the belief that expenditures for that phase will be much more substantial than earlier phases. The Interior Department report cited above states that the acreage cost for the second phase activity is pennies per hectare, whereas the third phase cost is about four to forty dollars per hectare. DEP’T OF THE INTERIOR, supra, at 72. Another reason is that it seems to be a fair compromise between possible costs stemming from duplicative exploratory activities in the earlier phases and the costs from delay in permitting one applicant to tie up too large an area.

It is interesting to note the difference between federal and state leasing policies. No permit is required to make a "casual use" of federal land. "Casual use" means activities "which do not ordinarily lead to any appreciable disturbance or damage to lands, resources, and improvements." 43 C.F.R. § 3209.0-5(d) (1976). A permit is required for activities that may result in damage to property, such as the drilling of shallow temperature gradient wells, construction of roads and trails, and cross-country transit by vehicle. 43 C.F.R. §§ 3209.0-5(a), 3209.1-1 to 3209.2 (1976). Such permit does not provide an exclusive right to the holder nor does it affect the exclusive right of a lessee to drill upon the land subject to his lease. Id. §§ 3209.0-1(b), 3209.0-5(a).

In contrast, California issues exclusive prospecting permits for a period of three years (with a possible two year extension) for its land which is not classified as known geothermal resources land. The permittee will be entitled, without competitive bidding, to a lease upon discovery of resources in commercial quantity. CAL. PUB. RES. CODE §§ 6909-6912 (West Supp. 1977).

may have no serious plans for conducting exploration in the area designated but who figure that the cost of the filing fee is a cheap price for what amounts to an option. The latter problem of frivolous filings can be met by reviewing information submitted to determine whether the information justifies the granting of a permit, by imposing a definite period within which the exploratory activities must be conducted, and perhaps by requiring a bond to be posted subject to forfeiture unless the applicant conducts the required detailed exploratory activities within the period specified in the permit.

3. The Application, Agency Action, and the Permit

At the minimum, the application should designate the name and address of the applicant, the area in which the detailed exploratory program will be conducted, the nature of the program, and the time within which the activity will be completed. The agency, after a hearing in which interested parties may participate, must determine the applicant’s ability to undertake the proposed program, the reasonableness of proposed detailed exploratory activities, the time within which the program must be completed, whether the exploratory program complies with environmental regulations, and whether ultimate development in the area for which an application is filed may interfere with prior appropriative rights. If, as will be likely at this stage, it cannot be determined whether the applicant’s proposed development program will interfere with prior rights, the applicant should be granted a permit subject to prior rights should further information indicate interference with them. Upon approval of the application, the agency will issue a permit specifying the conditions under which the permit is granted.

After the detailed exploratory activities have been completed, the permittee must disclose all information obtained from them with respect to the area in which deep drilling is to be conducted. If the information

570. It might be argued that agency specification of time period may be less than optimum in terms of investment timing. However, if the timing is not favorable to the particular applicant, it may be efficient for others. Moreover, the cost of delay in development and production in affected areas should not be ignored since subsequent rights would be dependent upon the definition ultimately to be given to the inchoate right of the permittee.

571. Budd, Jr., Steam Production at The Geysers Geothermal Field, in Geothermal Energy 134-35 (P. Kruger & C. Otte eds. 1973), reports the following with respect to the Geysers operation: “The performance of the field has shown that, contrary to earlier speculation, a constant rate of production cannot be sustained for an essentially infinite time. Individual wells have declined in production, and additional wells have been required to maintain the supply of steam to the generating units.”

Because the resource cannot be transported a great distance without undue loss of heat, a given radius from the location of the generating plant can serve to define the area in which the licensee will be able to drill replacement wells in the future. By doing so, localized adverse effects in the future from production by a junior appropriator can be avoided.

If the use is for space heating which does not require a high temperature, the resource may be transported a longer distance. However, a radial measurement based on transportable distance to reserve an area for replacement wells would be unreasonable in this case.
warrants deep drilling exploration and the permittee wishes to proceed, the permittee should be required to file a work program for deep drilling exploration. The agency should designate a period within which the deep drilling program must be completed.

After the permittee has completed his exploratory program, proven discovery of a geothermal resource, evaluated the properties of the fluid, and performed the required tests so as to permit extrapolation of reservoir conditions in the area, the permittee, if he is going to utilize the resource, should then be required to declare the use to which the resource will be put and the tentative number, size, and location of wells, including replacement wells, necessary for that intended use. If the permittee is going to market the resource, he should be given a reasonable time to locate a buyer. With the additional information available at this stage, the agency should determine whether the intended use, the method of use, and the number, location, and size of wells are reasonable. In addition, the agency should specify the time within which the entire development program is to be completed by the permittee.

The agency’s decisions at this point regarding reasonable use and time limits are critical to the proposed appropriation scheme. They must be keyed to the physical and economic realities of geothermal exploitation. For example, if the permittee is planning to sell or use the resource for electric power generation, the complete development program and future requirements should be defined in terms of the fluid properties and quantity that would assure economic production of electricity during the license period. In other words, the ultimate right should be defined in terms of the energy necessary to operate a generating plant or plants scaled to realize economies of scale in construction, operation, and transmission of electricity. If the proposed use is for space heating or industrial processing, the right should be defined in terms of such use.

The above discussion indicates that the appropriator’s right should be defined in terms of the use to which the geothermal resource is to be put.

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572. The required tests might include transient well test analysis which measures the pressure over time in order to determine the critical reservoir parameters. Chemical tests might also be desirable.

573. At this stage, it may be difficult to determine whether the applicant’s ultimate development may interfere with prior rights. However, through information obtained from testing by the permittee and operations conducted by prior appropriators, the agency may be able to determine whether there will be any localized adverse effect upon prior appropriators. Spacing of wells might be important.

574. If the discovery well yields low temperature fluid for which there is no current market, the permit can be held in abeyance until such time as there may be a demand for it. But any licenses that have been granted in the meantime should be given priority since those rights have been perfected before those of the permittee in question.

575. We do not purport to suggest whether the power plant or plants to which the geothermal resource is to be supplied should be of 50, 100, or 200 MW capacity. The necessary incentives for both the developer and the user must be considered.
Rather than selecting predetermined, arbitrary quantities and properties of the fluid that each license will represent, the right granted by the license should be particularized because of the close interdependency between resource production and its use. Unlike most other energy sources, particularly fossil fuels, geothermal resources cannot be sold in a wide market. Users are dependent upon particular producers and production locations. The relationship between the production of geothermal resources and their use is aptly described as follows:

The nontransportable nature of geothermal energy alters this traditional perspective of the market. The developer no longer has an infinite market for his resource; he must sell it to the specific user or users able to exploit the specific characteristics of his resource and willing to locate at the specific site of the resource. The user no longer has an infinite source from which to draw his energy; he must accept the specific resource and its finite limitations, and deal with a single developer. He also must accept the specific site; he has lost all flexibility in location with respect to services such as transportation, market proximity, transmission line location, public services, etc.\(^5\)\(^7\)\(^6\)

Definition of the right in terms of the use will reduce transaction costs that otherwise would have to be incurred to establish a satisfactory relationship between production and use if the right were to be defined in arbitrary terms.

Moreover, after the fortunes of the developer and the user have become intertwined and, on those occasions when one party or the other feels revision of the agreement to be to his advantage, what was a competitive market becomes a bilateral monopoly. All the well-known difficulties and inefficiencies associated with exchange between bilateral monopolists in stochastic market circumstances would appear. By reducing the advantages of opportunistic behavior, the specification of end-use in the developer's property right promotes convergent expectations between developer and user and serves to attenuate those uncertainties that are generated when interdependent parties make independent decisions with respect to changing market circumstances.

It should be noted that the proposed allocative scheme initially relies upon the permittee to make the most efficient use of the resource. The role of the agency is to assure that inefficiencies will not arise from externalities. The principal externality to be avoided in an allocative regime, aside from infringement upon prior appropriative rights, is a definition of a right that imposes social opportunity costs greater than the benefit. For example, fluid extraction without any reinjection in a hot-water, nonrechargeable geothermal reservoir will affect the matrix of the reservoir. The upper portions of the reservoir will gradually become filled with vapor, and temperature and pressure changes of varying degrees will occur at differing levels of the

\(^5\)\(^7\)\(^6\) JET PROPULSION LABORATORY, PROGRAM DEFINITION FOR THE DEVELOPMENT OF GEOTHERMAL ENERGY 2-4 (1975).
reservoir. Because changes will occur with continued extraction and because heat energy and the fluid will be gradually depleted, an appropriative right should be defined in terms of continued extraction of the requisite energy under reasonable methods of use for the period of the license. However, in defining the right of the appropriator, the agency should avoid granting a right in the terms requested if it is possible through a grant of different properties or methods of use to accommodate additional appropriators that would increase the net value of the resource. In addition, the agency should be empowered to require reinjection of waste fluid since, aside from environmental considerations, reinjection could maximize the net social value of geothermal production from the reservoir under certain conditions. Thus, through the licensing mechanism, the agency will be able to guard against an inefficient use or rate of production.

Of course, the agency may not have sufficient information at the outset of reservoir exploitations, and each reservoir will have its own characteristics, such as permeability and the quantity of natural water inflow to the reservoir. We do not, however, attribute greater capability to the agency than is warranted; the agency is being asked simply to exercise its best judgment with the available information at the relevant decision-making stage. In many instances this may mean no more than avoiding the most obvious waste. We reject the notion that agency consideration of externalities is not necessary because bargaining by affected parties can be relied on to arrive at an efficient outcome. The positions from which later bargaining is initiated are influenced by previous investments adapted to given properties of the fluid. These investments would therefore become important determinants of the outcome of the bargaining process. In particular, efficient timing of development can be made inefficient, or technically impossible, by poor initial investment choices. The agency ought to take steps to ensure that such situations do not develop.

In the permit granting process two hearings should be held, one at the time the application is considered and the second when deep well exploratory work has been completed and agency approval of the development work program is being sought. Environmental impacts and the effect on prior appropriative rights can be assessed at these hearings. Any interested party should be permitted to participate in the hearings to support or oppose the grant of a permit or a license. While these hearings may become adversarial,

577. In all probability, the agency would have to depend upon the developer and the user to determine the uses of the resources that would be economically feasible at the earlier stages of geothermal resource development. Much research must still be done to discover means of utilizing the resources most efficiently.

578. Reinjection may be required for surface environment considerations. The agency will have to regulate the place, manner, and depth of reinjection to avoid interference with producing wells and other underground resources, especially groundwater.

579. The interdependent relationship between the resource developer and the buyer is described in the text accompanying note 576 supra.
there is no need to assign burden of proof since the agency, as a guardian of
the public interest, should make its decision based on evidence in the record,
whether submitted by the proponent, the opponent, or the agency.

All information pertaining to well operations and relevant reservoir
conditions required to be submitted to the agency by licensees should be
made a matter of public record. In addition, the permittees should be
required to submit to the agency for public record the information about the
reservoir obtained from their detailed exploratory activities and from deep
well drilling if that has been done. We believe in public disclosure for the
following reasons. First, the integrity and the quality of decision making
would be enhanced. The decision should be made on the basis of evidence in
the record and the agency should not be restricted in the use of information
which it has.

Second, disclosure would not be significantly inefficient. It is doubtful
that public disclosure would lead to substantial underinvestment in informa-
tion gathering since information required to be disclosed will be primarily
particular to the site and the information gatherer stands to benefit from such
activity.\footnote{580} The appropriators already have their rights and the permittees
have incipient claims. Even if the information adds only generally to the
fund of knowledge concerning the occurrence and behavior of the resource
elsewhere, a requirement that the information be made a public good should
not lead to underinvestment if such information has been obtained in the
course of site-specific production and exploration. Disclosure may diminish
the permittee’s or appropriator’s advantage over others seeking permits for
appropriative rights in the neighborhood, but they may protect themselves
by applying for additional appropriative rights as soon as they have dis-
covered valuable information unless an acreage or lease maximum is im-
posed on a licensee’s total appropriation, as under present leasing laws.
Even if there were to be unintended income transfers through public disclo-
sure, the need to maintain integrity in the process and the fact that disclosure
would not be seriously inefficient argue strongly for disclosure.

4. The License

After the development work has been completed, the permittee will be
issued a license as evidence of the appropriative right. An appropriative
right should, however, be limited in time period as well as in total resource

\footnote{580. If the benefits from information gathering cannot be realized from the investment in
such efforts, underinvestment will result. Secrecy permits the capture of such benefits. How-
ever, it has been argued that incentives for information gathering may exist where the informa-
tion gatherer is able to invest in other firms which might benefit from the information. If that is
so, information will be collected and made available. At any rate, it has been argued that
information efforts that do not lead to improvements in production activities are socially
wasteful since they affect only wealth redistribution. See Hirschleifer, \textit{Where Are We in the
Theory of Information?} 63 \textit{Am. Econ. Rev.} 31 (1973); Hirschleifer, \textit{The Private and Social
Value of Information and the Reward to Inventive Activity}, 61 \textit{Am. Econ. Rev.} 561 (1971).}
extraction. The total resource extraction would be the product of the annual permitted extraction multiplied by some fixed number of years.

If, as seems likely, reservoir attributes and behavior initially are not well known, sound economic arguments exist for making the duration of the rights finite, given that renewal rights are ranked according to the seniority of the original rights. Since negotiation cannot be depended upon to correct past mistakes, a finite duration for each right permits the agency to acquire and to use new information about the reservoir in order to correct unanticipated effects of production nonseparabilities and to alter the rate of reservoir heat extraction to enhance resource recovery. For example, if the agency decides to reduce the rate of extraction, junior rights can be permitted to lapse upon their expiration. Although a finite duration of rights makes aged and low-cost capital appear progressively more attractive as the terminal date of the right approaches, the renewal option feature makes the position of senior appropriators quite secure. In any case, if the right duration is twenty years or more, any bias introduced with respect to capital investment programs would be slight.\(^{581}\) For this reason we propose a standard license period of twenty years.

The amount of the resource to which the licensee would be entitled would be computed on the basis of initially agreed upon annual production needs multiplied by twenty years. However, the licensee should be given the right to extend the license period by perhaps five years when circumstances warrant so as to permit him to forbear or reduce production in some years in favor of production in future years. This flexibility given to the licensee would permit him to maximize the net benefits from the resource between present and future production. Such flexibility may not be necessary when production is for electric power generation since the dependent power plant would be producing base-load power at a constant level. But even here, there may be alternative sources of cheaper electricity in any given period if surplus electricity is available from other sources, so some flexibility to delay production should be permitted. If the license is for water deminerali-

\(^{581}\) Where decades are involved, the cost of interest totally dominates the original cost of capital regardless of the length of the production run to which the capital is to be devoted. A passing look at a table of compound interest will illustrate the point. For example, the cash flow required to amortize a capital outlay over twenty years at an interest rate of eight percent is only slightly more than the flow needed to pay interest on it in perpetuity. In short, from the perspective of a potential buyer of a right, it would make little difference whether a twenty or a sixty year duration was employed. However, if the initial specification of rights and quantities has caused inefficiencies, the twenty year duration provides an earlier and therefore more valuable opportunity to make corrections.

The rate of recoupment of capital can be adjusted within market constraints. \textit{Cal. Pub. Util. Code} § 456.5 (West 1975), authorizes the Public Utilities Commission to permit the rapid amortization of the cost of all public utility facilities utilizing geothermal resources, at a rate based on the "estimated usable life of the facilities utilizing geothermal resources, the estimated useful life of the geothermal resource, or on any other basis approved by the commission," whichever is shorter. Thus, the amortization of utility property can be adjusted by the Commission on the basis of license period of the supplier.
zation for irrigation, there might be years of reduced consumption. In conclusion, the license may be for a period of twenty to twenty-five years commencing from initial commercial production but with the total production measured by a twenty-year period, if that length is selected. These licenses would be renewable subject to the agency's right to refuse renewal in inverse order of priority, if efficient management of the reservoir dictates that a reduction in production is desirable.

5. Coordination With Outstanding Rights

One of the more challenging problems in devising an appropriative scheme for geothermal resources concerns subsequent applications. Later appropriations from a producing reservoir could have an adverse effect upon wells in the immediate neighborhood because of the cone of depression effect or because of cooler water inflow at the well bottom. Other effects might be manifested more gradually and upon the reservoir as a whole.

The difficulty of administering the appropriation system is inversely related to the quality of the information available to the agency. If the information before the agency clearly indicates that further development will have an adverse effect upon prior appropriators, the application should be denied. If the information before the agency is insufficient to permit an informed judgment of the effect of the proposed development on prior rights, the applicant should be permitted to proceed with preliminary exploratory activities in order to develop additional information regarding subsurface conditions. Upon completion of the preliminary exploratory activities, the agency may be able to determine whether the permittee is exploring in an area with a discrete reservoir unrelated to others presently being exploited. If a discrete reservoir does exist, the permittee should, of course, be permitted to proceed with deep well exploration. On the other hand, if the information reveals that the wells to be drilled will be in a reservoir that is fully appropriated, the permit should be revoked.

If, even after preliminary exploratory activities, not enough is known to make a well-reasoned decision, the agency should authorize the permittee to drill exploratory deep wells, if he so desires. The agency can extend or revoke the permit upon completion of the wells and performance of required standard tests. The permittee might suffer a large loss, but this loss would merely be analogous to that of drilling a dry hole.

Even after drilling discovery wells, it might be difficult to determine whether further development in the area would have a long range adverse

582. The twenty year exemplary period would begin after the resource is on line. At the present time, it is estimated that about seven years are required before the wells are tested and the generating plant is built. I JET PROPULSION LABORATORY, PROGRAM DEFINITION FOR THE DEVELOPMENT OF GEOTHERMAL ENERGY 1-12 (1975).

583. Situations may develop where junior uses may be more profitable than senior uses and yet renewal on strict time priority may eliminate the junior uses. However, the junior holder may be able to purchase the senior rights.
effect upon prior appropriators. Temperatures and fluid productivity may
decline very gradually in existing wells, and under present technology it
may be difficult to predict the reservoir matrix twenty or thirty years in the
future. Under these conditions the agency may choose one of four alterna-
tives. First, the junior permit might be revoked since it could not be shown
that further development would not have an adverse effect. The social cost
of this alternative would be the loss of heat energy that could have been
recovered earlier had further development taken place.

Second, further development could be permitted with the under-
standing that the licensee would be required to discontinue further prod-
uction should adverse effects develop. However, the costs of prohibiting
further production after dependent generating facilities have been placed in
operation could be quite severe. The producer would suffer the loss of the
unamortized value of drilling costs and production and transmission
facilities. The generating facility would have to be converted to employ a
different energy source, or an alternative generating facility would have to
be found to supply the base-load power previously generated by the discon-
tinued operation. Whether this scenario is realistic depends upon whether
such investments by later appropriators would be made in the face of such
uncertainty.

A third alternative is to let each appropriator bear his own loss since the
adverse effects were not foreseeable when the most junior license was
granted. If the enthalpy of the fluid should decrease, each appropriator
would have to take his own remedial measures such as drilling the well to a
deeper level or pumping fluid from existing wells if such measures were
possible. Perhaps each producer and user could be required to employ the
binary method of heat extraction if such a measure would be economical and
would decelerate the adverse effect. This last alternative resembles the
groundwater appropriation scheme; under that system a prior appropriator
is not assured of a fixed water table, and in fact appropriative rights are
defined so as to preclude a right to the maintenance of the original water
level.

This third alternative is also similar to the present practice for leased
geothermal parcels. Under the present practice of leasing discrete parcels of
land with a right to capture the geothermal resource, it would appear that
each producer and user must bear the cost of adverse development occurring
even after production is on line to discrete users. It is doubtful whether

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584. To the extent that leases are offered more or less simultaneously in a given region, the
exploration and development on one lease may occur reasonably concurrently with that on
another since the primary terms would be the same. The production nonseparabilities might be
discovered before the resource is developed and unitization may be possible. However, if the
lessees are exploring and developing areas distant from each other, which is a distinct possibili-
ty since each lease may cover four square miles, the harmful effects may not be discovered
until production is already on line in both lease areas.
cooperative agreements or unitization would help at this late stage when there are existing use facilities such as electric power generating plants with fixed demands for the resource, but if it should prove helpful there is no reason why unitization cannot be required under the appropriative scheme. The third alternative, however, reduces the priority advantages of the appropriation system.

Without much experience with these problems it is extremely difficult to suggest a priori the proper solution. Perhaps the best solution is for the agency to adopt a cautious stance by requiring adequate testing during a reasonable period and, if indeterminacy still exists, to postpone final action on the permit until a reasonably accurate prediction of reservoir effects can be made. If this solution should unduly delay exploitation, a second solution allowing later appropriators and users to deal in their own ways with the uncertainty can be tried, unless experience demonstrates the social costs of this alternative to be greater than those of the first. As the technology of reservoir exploration and evaluation advances, these problems may be mitigated.

6. Alternatives to Priority Based on Filing Applications

The appropriation scheme discussed above is based on priority of filing applications. In our view, an allocation system based solely upon a race to file with the agency has many disadvantages. First, although the price terms embodied in the work program might serve as a gross allocator of the resource, the race may promote suboptimal resource allocation by encouraging investments at a more rapid pace than would occur under market conditions. Second, because the appropriator need not pay any rent for the resource, inefficient use of the resource may result if transfers of appropriative rights are difficult. Such a system would require the agency to substitute its judgment for that of the market when determining the proper rate of depletion of the geothermal reservoir. Third, multiple applications for the same area may be filed simultaneously, or nearly so, in which case a lottery may have to be used to allocate the reservoir. Finally, the first applicant may not be the most efficient producer.

585. For an interesting discussion of the respective merits of auction and negotiated work program for allocating licenses to explore and produce oil and gas in the North Sea, see Dam, Oil and Gas Licensing and the North Sea, 8 J. LAW & ECON. 51, 61-66 (1965), and for a subsequent study, Dam, The Evolution of North Sea Licensing Policy in Britain and Norway, 17 J. LAW & ECON. 213 (1974).

586. We offer no suggestion as to whether any given firm should be limited by maximum license rights in the state, as has been done in the federal and state leasing provisions. Under the Geothermal Steam Act of 1970, a single lease is limited to 2,560 acres (4 square miles), with some exceptions made necessary by irregular subdivision, 30 U.S.C. § 1006 (1970), and the maximum acreage within any given state is limited to 20,480 acres (32 square miles). Id. § 1006. In California, a single lease is limited to 2,560 acres on dry land but the total maximum acreage is 25,600 acres. CAL. PUB. RES. CODE § 6908 (West Supp. 1977).
A better solution is to grant appropriative rights for a designated area to the highest bidder, requiring the winning bidder to comply with a specified work program for exploration. The area which is to be put up for bid can be selected by the agency or by nomination by a potential bidder. The bid price should reflect the likelihood of discovery, the seniority of the right offered, and the value of the resource to the bidder. Perhaps royalty bidding should be used in those stages or areas of reservoir development where the risk of not being able to secure an appropriative right is great.

There are two apparent problems with the implementation of the bidding system for appropriative rights. The first deals with the subject matter of the bidding and the second concerns the easement on private lands to conduct exploration and development. Both problems may be resolved without great difficulty. The subject matter of the bidding presents a problem because at the time of bidding the nature of the license which might ultimately be granted is indeterminate. Physical and market uncertainties, such as discovery of the resource, its properties and quantity, development and production costs, and market prices for the resource, are, of course, similar to those attendant to bidding under existing governmental leasing practices. There is one difference, however. Under existing leasing practice, the successful bidder obtains the right to capture the resource from a specified parcel although his right is vulnerable to the possibility of drainage of the resource to adjoining parcels because of operations thereon or to adverse effects such as temperature-pressure decrease. Under the appropriation scheme proposed here, the bidder may be uncertain as to the nature of the right the agency will ultimately grant. In order to reduce this uncertainty, the bidder should be assured of a license that will permit economic development consistent with the characteristics of the resource discovered and with prior appropriative rights. In this way, the uncertainty facing the bidder in formulating a bid price would be less under the appropriation system than under present leasing practices which permit the nonseparabilities discussed above.

The problem of easements on private lands to conduct exploration and development is not as troublesome as might first appear. If, prior to the bidding, one person has acquired the exclusive right to conduct exploratory and developmental activities from the overlying landowner, it might appear to make competitive bidding a sham by restricting the number of bidders. But this problem can be resolved by the market. The winning bidder will negotiate to seek a transfer of the easement, a task no different from that of securing an easement from the landowner originally. Alternatively, each

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587. If the appropriation scheme were to be adopted for geothermal resources underlying federal and state lands, the governments would most certainly desire to capture the economic rent from these resources, which is the policy expressed in current leasing provisions.
bidder might be able to secure an easement contingent upon winning the bid.\textsuperscript{588}

We wish to recall the reader's attention to the possibility of government exploration prior to competitive bidding. The argument for government information gathering rests on the desirability of removing or reducing discovery uncertainties and of better enabling the agency to issue subsequent licenses with minimal risk of interference with prior rights. Another advantage stemming from greater certainty is that more firms will have access to capital, thereby increasing the number of firms able to bid for the rights. However, there is the disadvantage of the weak link between the public decision-maker's utility to organizational wealth.

7. Management of the Reservoir

One of the principal advantages of the appropriation system is that it permits an administrative agency to make incremental decisions as new applications and additional information are received, so that a reservoir can be managed to derive the maximum net social value from geothermal resource operations. To drill additional wells to extract geothermal resources only to reduce the resources from other wells, as the rule of capture would permit, makes little sense since it would result in a net social loss through the consumption of resources used to drill excess wells.

The appropriation system permits the application of different management strategies to different reservoirs and flexibility in the management of each reservoir over time. For example, in a hot-water reservoir that has little or no fluid recharge, extraction of the fluid causes changes in the reservoir. Extraction decreases reservoir pressure, and the fluid will vaporize when the pressure decreases below the saturation pressure. This phenomenon continues progressively as more fluid is

\textsuperscript{588} One might question whether the landowner would not extract a price for the easement as great as he might extract for the resource itself, as if he were the owner of the resource; in other words, whether the landowner might not charge the economic rent of the resource. We do not believe so. The bargaining will be within the range of foregone marginal opportunity costs to the landowner and the net value of the resource to the prospective appropriator. In the latter computation, the prospective appropriator would have to take into account the amount that he must pay to the government. The landowner may also face competition from nearby landowners if there are alternative sites for ultimate production.

If difficulties appear in securing easements, consideration should be given to condemnation of easements. It is unlikely that there would be serious constitutional obstacles even if condemnation is conducted by private parties. \textit{See, e.g.}, Clark v. Nash, 198 U.S. 361 (1905); Linggi v. Garovotti, 45 Cal. 2d 20, 286 P.2d 15 (1955).

However, condemnation may not yield a set of easement prices corresponding to those in a competitive market. \textit{See} Munch, \textit{An Economic Analysis of Eminent Domain}, 84 J. POL. ECON. 473 (1976), which develops the analytical basis in detail and presents empirical evidence showing that under condemnation high-valued parcels systematically receive more than market value and low-valued parcels systematically receive less. Munch shows, in addition, that condemnation, relative to the free market, will frequently be an inefficient means for consolidating many contiguous but separately owned parcels into a single ownership unit.
withdrawn. However, as vaporization occurs the enthalpy per pound of steam will be greater as compared to the liquid phase at the same temperature. In managing these reservoirs, the optimal value of geothermal resources might be obtained by extracting the fluid from the vapor level or at the liquid level or a combination of these or by a reinjection system so as to retard the decrease in reservoir pressure.

Where a reservoir is subject to natural recharge of the fluid, one management strategy would regulate extraction of the resource at a rate no greater than recharge. Although the temperature of the fluid will decrease gradually, the heat transfer agent can be maintained indefinitely. On the other hand, it might be wise to extract the fluid at a rate faster than recharge thereby converting part of the reservoir to a vapor system, if the reservoir characteristics permit. Aside from physical changes, mining of the resource might be more efficient.

Thus, there are alternative methods of managing different reservoirs; continuing administrative supervision of the licensing procedure will allow unanticipated production nonseparabilities to be minimized and the rate of heat extraction to be managed. If the agency desires to prolong the productive life of the reservoir, the number of licenses can be limited. In addition, junior licenses can be permitted to lapse upon their expiration. We do not pretend that management will be easy in the current state of technology and information, but as these improve in the future, management can be accomplished with greater precision.

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589. As to natural recharge in Imperial Valley, one study reported:

Recharge to the ground-water reservoir over a substantial period of geologic time has been from floodflows of the Colorado River and ancestral streams and flood runoff from the barren ranges that border the valley. In historic time, seepage from the unlined All-American, Coachella, and East Highline Canals has been the principal source of recharge. In the early days of irrigation, deep percolation recharged the ground-water reservoir. Recharge has exceeded the discharge and substantial water has gone into storage, particularly in a triangular-shaped area bounded on the west by the East Highline Canal, on the northeast by the Coachella Canal, and on the south by the All-American Canal. This area is called East Mesa.


Another report states:

The entire system appears to be continuously interconnected and fed by shallow fresh Colorado River surface flow and deep saline underflow draining the Colorado and Gila River basins. The deep geothermal waters of the basin are very close in chemical composition to the saline underflow of the Gila River system. Eventually large scale fluid production should exceed both the rate of recharge and the expansion capacity of the deeper supercritical waters of the basin.


A third report notes:

The total ground-water recharge to the Imperial Valley area from the Colorado River under natural conditions was probably about 17,000 acre-feet annually . . . . This 17,000 acre-feet does not include the unestimated recharge presently occurring as a result of losses from irrigation canals and from irrigated land.

8. Integration With Water Law

A further advantage of the appropriation system proposed for geothermal resources is that it can be integrated with existing water law. Where groundwater and geothermal reservoirs are physically interconnected, the appropriation scheme for geothermal resources could be integrated more easily with the existing water allocative regime than could a geothermal rule of capture. If the rule of capture were applied, an overlying landowner would have the right to extract the geothermal fluid. The correlative and appropriative rights to water could not be coordinated with the rule of capture because existing water users would have no protection against its extraction as geothermal fluid under the rule of capture for geothermal resources.

On the other hand, under the appropriation scheme, geothermal development can be managed so as to respect existing water rights. Claims of water users to the fluid at the time the licensing system is instituted should be respected since they represent claims upon interrelated resources. Two difficulties with this integration should be noted. First, the lack of records of outstanding groundwater rights in some areas may complicate the process of integration. Another difficulty arises if groundwater is appropriated after the geothermal licensing system is instituted since there is no administrative licensing system for appropriating groundwater in California. This problem can be avoided by placing interconnected geothermal reservoirs and groundwater supplies under a common administrative licensing supervision in order to coordinate geothermal and groundwater appropriations.

9. Integration With Development on Federal Land

If the federal government continues its present leasing policy of conferring a right of capture from a designated parcel, and if the state should adopt the appropriation system for resources underlying state and private lands, problems could develop in common reservoirs similar to those which arise with respect to groundwater extraction from federal reserved lands in an appropriation state. Any appropriation system will be skewed because

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590. In the counties of Riverside, San Bernadino, Los Angeles, and Ventura, a person extracting in excess of 25 acre feet per year must report such fact to the State Water Resources Control Board. CAL. WATER CODE §§ 4999, 5001 (West 1971). A failure to report is treated as nonuse by the person extracting the water. CAL. WATER CODE § 5004 (West 1971); the consequences of nonuse for five years for an appropriative right might be abandonment and for an overlying right in an overdrawn basin the loss of such right.

591. Geothermal licenses should perhaps be treated as rights in perpetuity solely for the purposes of integrating with water rights.

592. The reservation doctrine was explained in Cappaert v. United States, 426 U.S. 128, 138 (1976), in the following terms: "[W]hen the Federal Government withdraws its land from the public domain and reserves it for a federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose
federal lessees have a right of capture of the resource from their wells without regard to any priority. The only solution under these circumstances may be unitization to place the reservoir under single firm management. If the federal government were to adopt the appropriation system for geothermal resources underlying its lands, and if the federal government were to continue its policy of capturing rent from the resources, reservoirs underlying both federal and nonfederal lands should be placed under the licensing supervision of either the federal or state administrative agency with accounting of the proceeds to the appropriate governmental unit.

10. Adjustment of Existing Practice

Leases have been granted by many private and public property owners to private operators who are in various stages of exploration, development, and production under the leases. In instituting the appropriation scheme, consideration should be given to the rights of the lessors and lessees under existing leases since the state, by its inaction, is partially responsible for permitting the parties to form expectancies under the leases.

One solution is to honor existing leases so that the lessors can retain past and future payments under their leases. If the appropriation system is based on priority of filing an application, rather than on competitive bidding, the state does not lose any revenue by adopting this solution. In fact, even if competitive bidding is adopted, bidding should be viewed solely as an allocative mechanism and the lessors' claim to payments under existing leases would be a matter of indifference so long as the lessees are protected from dual payments. The lessees should be given equal priority with respect to any production under existing leases. To the extent that inefficiencies may exist because of production nonseparabilities, cooperative and unitized operations should be compelled. These grandfather rights would be recognized for those leases existing at the date when the bill instituting the appropriation system is introduced in the legislature. However, persons claiming grandfather rights should be required to register their claims and file reports with the administrative agency so that the agency will have a record of outstanding claims and an inventory of the resource.

of the reservation. The *Cappaert* case was unique in that the reservation doctrine was applied to protect against groundwater appropriation. The reservation doctrine raises difficulty in water administration since the reserved water is frequently not quantified.

593. Stone, supra note 379, at 104-05, reports that as of September 30, 1975, in the four states surveyed, there had been placed under lease about six to nine million acres of private land, about 815,000 acres of federal land, and at least 617,813 acres of state lands. However, there is still much land that can be leased. The same report states that the Bureau of Land Management has until now asked for competitive bids on 462,402 acres of the 2.86 million plus acres of federal land in Known Geothermal Resource Areas (KGRA). Id. at 83. About 96 million acres are listed as having "prospective value" for geothermal resources, Hearings on H.R. 8628 Before the Subcomm. on Energy of the House Comm. on Science & Astronautics, 93d Cong., 1st Sess. 59 (1973), so that the adoption of the appropriation system is not without future impact.
Although this solution would give a premium to those landowners who have executed leases, it is preferable to other solutions, which would present immense administrative difficulties. For example, a lessor might be permitted to retain past bonus, rental, and royalty payments but be deprived of the right to future payments except as compensation for surface use. If past payments have been sufficient to compensate for surface use, the lessor would not be entitled to any further payment but in no event would he be required to disgorge any past receipts. Where there has been no past production, the lessor's claim would be restricted to compensation for a surface easement. The drawback of such a scheme is that it would entail the determination of the value of an easement and perhaps require condemnation proceedings. Because of these administrative costs, we prefer the solution suggested earlier in this section.

VII. CONCLUSION

This study was initiated because of our curiosity regarding property rights to a unique resource. Because the geothermal industry is in its infancy, we perceived a singular opportunity to avoid the mistakes that arise from default in analysis and lack of forethought.

Multiple claimants to a geothermal reservoir will find that production from a common pool is characterized by interdependencies. Unless a management scheme or a property regime can be fashioned to accommodate these interdependencies, geothermal resources, as well as other resources consumed in their exploration, production, and utilization, will be allocated inefficiently. Of the available options, some are more legally feasible and politically palatable than others.

The current practice for private land assumes that the right to the geothermal resource initially inheres in overlying landownership. Geothermal reservoirs crossing landownership boundaries thus are subject to multiple claims. Because these claims are based on the rule of capture, each overlying landowner or his lessee may act with little regard for the consequences to others. Similarly, although the federal government could have devised a property regime with respect to federal lands that would take these interdependencies into account, it has created instead a regime that in essence defines the lessee's rights in his discrete leased parcels as a rule of capture. Each may extract as much of the resource as possible from wells within the vertical boundaries of his lease, without regard for the effect upon other producers from the common reservoir. True, unitization provisions are not uncommon in statutes providing for leasing of public lands, and lessees may undertake unitization voluntarily if they desire to establish single firm management for the common pool. However, the efficacy of these remedial measures is somewhat doubtful, especially if the producer's fortunes already have become intertwined with those of the purchaser.
If market forces are to be relied upon to allocate a resource efficiently, it is necessary to establish exclusive and transferable rights to discrete units of the resource insofar as this can be done. By this standard, the rule of capture fails miserably. We have suggested a property regime which seeks to meet that standard as much as possible. By granting rights to the resource through auction, and protecting those rights in order of time priority, the government can insure both that the initial assignment of the right will be efficient and that the right is exclusive with respect to specified quantities and properties of the resource. Although the suggested scheme brings with it the cost of public administrative supervision, and perhaps delays in production, and depends upon the availability of information regarding reservoir characteristics and utilization efficiency, it has the significant advantage of permitting incremental decision making with periodic points of reassessment and adjustment as more information becomes available, thus making it possible to maximize the efficiency of resource use.

We believe our proposal for an appropriative scheme addresses a current problem and should furnish a basis for serious debate. We do not profess that the suggested scheme is the best or the only solution to the vexing problem or that improvements to the suggested scheme cannot be made. Perhaps the current muddling-through process with remedial measures in the future is more efficient in terms of total resources consumed. But perhaps it is not.