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Unitization for Geothermal Resources: United We Save

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Mr. Goldstein argues that cooperative development would at least be as beneficial to the geothermal industry as it is to the petroleum industry. But, he suggests that attempts by the geothermal industry to voluntarily unitize its operations will be subject to the unavoidable obstacles and delays that have reduced the effectiveness of, and sometimes thwarted, voluntary attempts to unitize hydrocarbon extraction operations. Thus, Mr. Goldstein concludes by calling for the timely enactment of compulsory unitization schemes.

UNITIZATION FOR GEOTHERMAL RESOURCES: UNITED WE SAVE†

*Dennis B. Goldstein**

I. INTRODUCTION

Approximately seventeen years have passed since commercial production of electricity began at The Geysers, the only producing geothermal field in the United States. Despite these seventeen years of production, preceded by several years of initial field development, no pooling or unitization has yet taken place there.[1] Indeed, it is only in recent years that references to unitization of geothermal resources[2] appear in the small but expanding literature concerning the law applicable

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1. It has also been reported by the office of the Area Geothermal Supervisor, Western Area, United States Geological Survey, that exploratory unit agreements have been approved by the Secretary of the Interior pursuant to 30 C.F.R. § 271.8 (1976) in the Roosevelt-Hot Springs and Cove Fort-Sulfurdale as known Geothermal Resources Areas in Utah.
2. *E.g.*, Root, *Contents of a Geothermal Lease: Some Suggestions*, 8 NAT. RESOURCES LAW. 659, 667 (1976); Allen, *Legal and Policy Aspects of Geothermal Resource Development*, 8 WATER RESOURCES BULL. 250, 255 (1972). An economic analysis of potential problems arising from the production of geothermal resources in common pools is contained in Franzen, *Property Systems in Geothermal Resources: A Critique and Recommendations*, in PROCEEDINGS OF THE SECOND UNITED NATIONS SYMPOSIUM ON THE DEVELOPMENT AND USE OF GEOTHERMAL RESOURCES 2373 (Lawrence Berkeley Laboratory 1976) [hereinafter cited as PROCEEDINGS].

to geothermal resources.[3] The absence of a geothermal unit or pool at The Geysers might be taken as an indication that such cooperative development is neither necessary nor useful. Nevertheless, it is submitted here that the present lack of unitization or pooling at The Geysers should not be construed as an indication that such cooperative development is unnecessary or lacks utility.[4] On the contrary, an analysis of pooling and unitization in the geothermal context reveals that cooperative field development would be at least as beneficial to the geothermal industry as it is to the petroleum industry.

At the outset, it should be noted that although the terms "pooling" and "unitization" are often used interchangeably, they do have different meanings as oil and gas terms of art. "Pooling" refers to the aggregation of tracts of land for the purpose of creating a single drilling unit, sometimes in connection with a program or requirement of uniform or minimum spacing and its implementation does not necessarily eliminate competition within a single pool or field.[5] "Unitization", on the other hand, refers to an attempt to group all or most of the interests in a producing reservoir so as to enable joint, rather than competitive, operations in all or some part of the reservoir as if it were under common ownership.[6]

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3. Recent articles concerning geothermal resources include not only those cited in note 2, *supra*, but also the following: Aidlin, *Representing the Geothermal Resources Client*, 19 ROCKY MTN. MIN. L. INST. 27 (1974); Bjorge, *The Development of Geothermal Resources and the 1970 Geothermal Steam Act—Law in Search of Definition*, 46 U. COLO. L. REV. 1 (1974); Schlauch & Worcester, *Geothermal Resources: a Primer for the Practitioner*, 9 LAND & WATER L. REV. 327 (1974); Bible, *The Geothermal Steam Act of 1970*, 8 IDAHO L. REV. 86 (1971); Olpin, *The Law of Geothermal Resources*, 14 ROCKY MTN. MIN. L. INST. 123 (1968); Brooks, *Legal Problems of the Geothermal Industry*, 6 NAT. RESOURCES J. 511 (1966); Randall, *Acquisition of Geothermal Rights*, 1 IDAHO L. REV. 49 (1964). A number of additional articles appear in the *Legal and Institutional Aspects* section of the PROCEEDINGS, *supra* note 2, at 2353-2457.
4. The lack of pooling or unitization at The Geysers probably results from the fact that substantial development there has taken place in areas where ownership is relatively unfragmented; for example, considerable development has taken place in The Geysers area on the 3,988.3 acres of land claimed by the State of California through mineral reservations and by private parties through surface ownership and leased to the same operator by all claimants. If the State's mineral claim to the resources is upheld, development of the entire 3,988.3 acres will be controlled by only two leases; while, if the private parties' claim prevails, only five leases will control the same acreage. *See* note 55, *infra*. The operator has no adjacent competitors in production.
5. *See* SULLIVAN, HANDBOOK OF OIL AND GAS LAW 150 (1955); 5 SUMMERS, OIL AND GAS § 950 at 55 (1966) and 6 WILLIAMS & MEYERS, OIL AND GAS LAW § 901 at 2-3.
6. *See* King, *Pooling and Unitization of Oil and Gas Leases*, 46 MICH. L. REV. 311, 312-314 (1948) and Jacobs, *Unit Operation of Oil and Gas Fields*, 57 YALE L.J. 1207, 1208-1211 (1948).

These definitions indicate that the purpose of unitization, in the oil and gas context, is to permit operations as if the field or reservoir has no internal boundary lines. Unitized operations are said to permit maximum use of reservoir energy and increase ultimate recovery and profit in a number of ways.[7] Most importantly, unit operations allow a centralized reservoir manager to set the locations and rates of production without regard to competing property interests. This eliminates the need for offset or unnecessary wells,[8] permits scientific well-spacing and placement, allows reservoir-wide determnation of maximum efficient rates of production, and, in some cases, facilitates various oilfield operations which could be carried out with difficulty, if at all, by individual overlying operators. These operations include waterflooding,[9] pressure maintenance,[10] gas cycling[11] and gas storage. Still another benefit of unitization is the protection afforded to the correlative rights of the participating parties.[12]

The purpose of pooling in the context of oil and gas is to provide for common drill sites; this results in minimizing capital expenditures by preventing the drilling of unnecessary wells, protects the correlative rights of the participants, and, in some cases allows drilling where none of the participating tracts is large enough to qualify for a well permit.[13]

Because the purposes of "pooling" and "unitization" have much in common, current usage tends to ignore their technical differences. Since this paper is concerned with cooperative development rather than technical differences between pooling and unitization, it will follow the current practice.

7. It has been said that oil unitization results in less capital investment, lower development and operating costs, greater per acre oil yield, stabilized business, more control over business, and a savings on plant capacity, pipeline and storage tanks. Myers, *Spacing, Pooling and Field-Wide Unitization*, 18 MISS. L.J. 267, 273 (1947).
8. Jacobs, *supra* note 6, at 1210.
9. Myers, *The Necessity of Unitization*, 33 MISS. L.J. 1, 7 (1961).
10. Myers, *supra* note 9, at 4-7; King, *supra* note 6, at 312-314.
11. Myers, *supra* note 9, at 4-7; 6 WILLIAMS & MEYERS, *supra* note 5, § 901 at 3-4.
12. *See* Kaveler, *The Engineering Basis for and the Results from the Unit Operation of Oil Pools*, 23 TUL. L. REV. 331, 334 (1949). For a discussion of unitization *see* SULLIVAN, *supra* note 5, at 356 *et seq.*
13. For a discussion of pooling *see* HOFFMAN, VOLUNTARY POOLING AND UNITIZATION 87 (1965) and 6 WILLIAMS & MEYERS, *supra* note 5, §§ 901-907 at 3-84 and materials cited therein.

II. A RESERVOIR MODEL

To evaluate the utility of unitization in the geothermal context, it is necessary to have a reservoir model as a reference. The Geysers geothermal field in Sonoma and Lake Counties, California is suitable for this purpose.

A recent and readily available geological, geophysical and engineering analysis of The Geysers geothermal field may be found in the testimony of the expert witnesses in the recent trial in *Pariani v. State of California.*[14] The issue in that case, tried to the court in July of 1976, was whether the State of California reserved the right to extract and exploit the geothermal resources underlying lands which the State had patented to private parties subject to a lengthy reservation of minerals.[15] The court heard expert testimony from several witnesses, including two geophysicists, a geologist, and a reservoir engineer who had reviewed considerable data from wells in The Geysers field. The experts did not agree on all matters, but there was substantial agreement that The Geysers is a so-called "dry steam" field in which all successful drilling has encountered geothermal resources in the steam phase rather than the liquid phase.[16] Despite this "dry steam" nomenclature, the experts also concluded that the ultimate source of the steam produced at The Geysers consists of one or more reservoirs of boiling liquid.[17] The experts reached this conclusion because the volume of steam produced at The Geysers has already exceeded the maximum volume of fluid that can be stored as steam in an area the size of The Geysers[18] even assuming generous field dimensions and high porosity. Since The Geysers nevertheless continues to produce steam, the experts believe that steam is continually fed into the producing intervals of wells after boiling off one or more deep liquid reservoirs.

The producing intervals of successful wells seem to be located at the intersections of the well bores and one or more

14. Trial Transcript, Pariani v. State of California, Superior Court for the City and County of San Francisco No. 657-291 [hereinafter cited as *Pariani Transcript*]. Certain portions of the *Pariani Transcript* were sealed by order of the Court to protect the confidentiality of data; none of the material relied upon herein is drawn from the sealed portions of the transcript.
15. *See* CAL. PUB. RES. CODE §§ 6401 and 6407 (West 1977).
16. *Pariani Transcript, supra* note 14, at 689-691.
17. *Id.* at 225-226, 651.
18. *Id.* at 225-226, 651, 714, 726, 764-765.

fractures which communicate ultimately with the boiling liquids.[19] Such communicating fractures are then the highways of the geothermal system at The Geysers.

The Geysers field, at least to the depths to which it has been drilled, has a fairly uniform initial pressure which has shown some decline over the years as a function of production.[20] This uniform pressure is less than hydrostatic, but considerably greater than atmospheric, and geothermal fluid is forced up the well bore to the area of lower pressure when it intersects a communicating fracture. The pressure differential is great enough that the geothermal fluids expelled through the well bore carry with them energy capable of driving turbines to produce electricity. The underpressured condition of the reservoir is maintained, at least in part, by a nearly impermeable seal of hydrothermal mineral deposits which acts as a barrier between the underpressured fluids within and the normal hydrostatic conditions without the reservoir.[21]

Although present operations extract heated fluid, the vast majority of reservoir heat is contained in reservoir rocks rather than in the fluids.[22]

III. UNITIZATION APPLIED TO THE GEOTHERMAL MODEL

A. *Increasing Ultimate Recovery and Maximizing Use of Geothermal Energy*

Maximizing the use of reservoir energy and increasing ultimate recovery are among the most frequently cited reasons for oil unitization. Long experience reveals that production of hydrocarbon wells at rates greater than the maximum efficient rate of production[23] can reduce ultimate recovery by permanently damaging reservoirs. This is especially clear in gas-drive oil reservoirs where poor or decentralized field con-

19. *Id.* at 649-650.
20. *Id.* at 123-125, 296, 774.
21. *Id.* at 141-142, 291-293, 650-652.
22. *Id.* at 763-764.
23. "Maximum efficient rate" of production is defined as the upper limit of production beyond which any increase will mean a decrease in the amount of oil ultimately recoverable. SULLIVAN, *supra* note 5, at 315. *See* Smith, *The Kansas Unitization Statutes: Part I*, 16 U. KAN. L. REV. 567, 573-580 (1967).

trol, or even simple greed, has resulted in overly rapid depletion of the reservoir's gas causing a loss of the reservoir's natural production force.[24]

Although experience with geothermal reservoirs is far more limited, geothermal reservoir engineering theory nevertheless indicates that the concept of reservoir energy is equally important in the geothermal context.[25] In fact, research already suggests that production rates in geothermal reservoirs affect total geothermal reservoir energy in several ways.

1. Maximizing Total Energy Recovery Through Unitized Operations

If a single geothermal reservoir is exploited to achieve maximum short-term production of fluids, and therefore electricity, the fluids which convey reservoir energy to the surface could be depleted so rapidly as to sharply reduce reservoir pressure and impair a reservoir's ability to carry energy to the surface. If fluid depletion were to occur before a reservoir's total recoverable heat were extracted, the result would be loss of energy. Since the recovery of energy from a geothermal reservoir is dependent upon the reservoir's supply of both heat and fluid, and since geothermal reservoirs are often fluid-deficient relative to heat, maximum fluid production rates over the short-term may result in less than total recovery of extractable energy. Thus, it is pertinent to ask whether limiting the rate of production below the maximum possible will, as it sometimes does in the oil context, result in the extraction of energy not recoverable at higher production rates. If the answer to this question is affirmative, there should exist for each reservoir, a rate of production that will maximize energy extraction.

Although there is now clear evidence from several of the world's commercially exploited geothermal reservoirs that reservoir pressures drop as a function of production over time,[26] the question just posed has not been conclusively re-

24. *See* SULLIVAN, *supra* note 5, at 335-336 and WILLIAMS, MAXWELL & MEYERS, CASES AND MATERIALS ON THE LAW OF OIL AND GAS 9 (3d ed. 1974).
25. The author is indebted to Professor Paul Witherspoon, Director of the Lawrence Berkeley Laboratory's Geothermal Project, and one of the experts who testified in the *Pariani* case, for his advice relative to the technical discussions herein.
26. *See* note 20, *supra*; Budd, *Steam Production at The Geysers Geothermal Field*, in

solved; it has, however, recently generated considerable interest and at least two geothermal researchers who have experimented with this problem have cautiously concluded that for geothermal reservoirs with a finite water volume or geothermal reservoirs with limited water influx:

> [A]n optimum fluid production rate exists which will result in the greatest amount of heat production. Rates above this optimum will both shorten the life of the well and decrease the amount of heat produced while rates below the optimum will result in less heat production and longer well life. In both extremes the economics of the project will be adversely affected.[27]

These same researchers have concluded that extremely high production rates may be desirable in reservoirs with high water influx.[28]

If total geothermal energy recovery is a function of the rate of production, oil unitization experiences provide a model which demonstrates that unitization in the geothermal context will facilitate increased energy extraction by eliminating intra-reservoir competition and permitting application of maximum economic production rates on a field-wide basis.

In addition, even if varying the rate of production will not permit increased energy recovery, geothermal operators may increase ultimate recovery through other means which will be facilitated by unitization. Since the vast majority of geothermal reservoir heat is contained in reservoir rocks rather than reservoir fluids, it is not likely to be extracted before geothermal fluids in place are depleted.[29] Under such circumstances maximum extraction of geothermal reservoir energy will be realized by injecting, or reinjecting, cooler fluids into geothermal reservoirs. The theory is that such fluids will be

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GEOTHERMAL ENERGY: RESOURCES, PRODUCTION, STIMULATION 129 (Kruger and Otte eds. 1973); Celati, Squarci, and Taffi, *Analysis of Water Levels and Reservoir Pressure Measurement, in Geothermal Wells*, in PROCEEDINGS, *supra* note 2, at 1583 (Lardarello, Italy); and Stilwell, Hall and Tawhai, *Ground Movement in New Zealand Geothermal Fields*, in PROCEEDINGS, *supra* note 2, at 1427, 1429 (figure 3).

27. Robinson and Morse, *A Study of the Effects of Various Reservoir Parameters on the Performance of Geothermal Reservoirs*, in PROCEEDINGS, *supra* note 2, at 1772. *See also*, Chasteen, *Geothermal Steam Condensate Reinjection*, in PROCEEDINGS at 1325.

28. Robinson and Morse, *supra* note 27.

29. *See* Chasteen, *supra* note 27.

heated and, when produced, bring out heat not recoverable through extraction of reservoir fluids in place.[30] A technical study has described this theory as follows:

> A reinjection process may be considered as a way of increasing the amount of heat recovered from a geothermal reservoir which does not have a natural water drive . . . .
>
> . . . .
>
> . . . if a reservoir did not contain enough water to remove all of the available heat from the rock, it might be desirable to add more water by injection. This situation could occur in a reservoir with low porosity.[31]

Another study has concluded that "reinjection of water . . . would . . . mak[e] it possible to extract more heat out of the hot reservoir rock, and thus to increase the total energy production over the life of the field."[32]

This theory has already been put into limited practice at, among other places, The Geysers[33] where, in fact, all extracted geothermal fluid not lost to evaporation in the cooling process (approximately twenty-five per cent of the fluid produced) is reinjected.[34] Reinjection began as a technique to dispose of produced fluids that could not be safely or legally discharged to the environment; however, the re-introduction of such fluids beneath the surface has not only disposed of them, but also allowed them to enter the reservoir and become heated, thereby prolonging the reservoir's commercial lifetime.[35]

Injection to increase recoverable energy is likely to become standard practice in the geothermal industry.[36] The operator's goal under such circumstances will be to efficiently

30. This is well illustrated by the so-called "hot dry rock" theory which suggests fracturing "dry" rock and then introducing fluids for the purpose of extracting the same fluids after they have become heated. *See, e.g.*, Smith, Aamodt, Potter and Brown, *Man-Made Geothermal Reservoirs*, in PROCEEDINGS, *supra* note 2, at 1781.
31. Robinson and Morse, *supra* note 27, at 1777.
32. Einarsson, Vides and Cuellar, *Disposal of Geothermal Waste Water by Reinjection*, in PROCEEDINGS, *supra* note 2, at 1349, 1360-61.
33. *Pariani Transcript*, *supra* note 14, at 342.
34. *Id.* at 19.
35. *Id.* at 40-41, 117.
36. One of the technical papers quoted in the text went on to conclude that "The advantages . . . [of] reinjection into the geothermal reservoir are considered to be of

coordinate the rates of production and injection over appropriate time periods so as to extract the maximum economic quantity of energy. This coordination bears some resemblance to the determination of the maximum efficient rate of production in secondary waterflooding oil practices; there, too, the engineer must find and juggle optimum rates of production and injection in order to maximize economic resource extraction.

Many advantageous economic and conservation consequences would flow from the establishment and use of optimum production rates, whether or not brought about in conjunction with injection. The most obvious and perhaps most valuable one is the ability to recover more energy from a reservoir.[37] To accomplish this, however, each reservoir which in fact behaves as a single physical unit must be developed and operated as a unit; planning, data and coordination on a field-wide rather than local basis will be prerequisite.

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such significance that it should be adopted as part of the management of water-dominated steam fields irrespective of whether there exists a disposal problem or not." Einarsson, Vides and Cuellar, *supra* note 32, at 1361. Reinjection has already been utilized in the United States, El Salvador (*id.*), France (Gringarten and Sauty, *The Effect of Reinjection on the Temperature of a Geothermal Reservoir Used for Urban Heating*, in PROCEEDINGS, *supra* note 2, at 1370) and Japan (Kubota and Aosaki, *Reinjection of Geothermal Hot Water at the Otake Geothermal Field*, in PROCEEDINGS, *supra* note 2, at 1379).

In the Kubota and Aosaki paper it was reported that a geothermal power plant with an initial output of 11 Megawatts saw its output decrease to 8.7 Megawatts. When reinjection was commenced, the output of the power station recovered to a level of 10 Megawatts without the drilling of supplemental production wells. *Id.* at 1382.

37. Still other advantages of reinjection suggested in the literature already referred to in notes 27 through 32, *supra*, include pressure maintenance, prevention of subsidence and utilization of heat remaining in geothermal fluids after production of electricity. The suggestion relating to pressure maintenance may prove to be important.

At least in some geothermal reservoirs, water encroachment seems to begin or increase as reservoir pressure declines. *See* Celati, Noto, Panichi, Squarci, and Taffi, *Interactions Between the Steam Reservoir and Surrounding Aquifers in the Lardarello Geothermal Field*, 2 GEOTHERMICS 174, 182 (Nos. 3-4, 1973). Theoretically, this is explained as follows: Until a geothermal reservoir is disturbed by drilling, the relatively cooler water of surrounding adjacent formations is impeded from rapidly invading the reservoir and lowering its temperature by a number of factors which may include pressure differentials. Sufficient production, and subsequent declines in reservoir pressure, however, could modify any existing equilibrium between fluids in and out of the reservoir; since such reservoir pressure declines are tantamount to relative increases in extra-reservoir pressure, water may then migrate into certain types of geothermal reservoirs. The effect of such encroachment is uncertain, but it could range, depending on rate and quantity, from beneficial recharge of fluids produced to a cooling of the reservoir sufficient to impair its commercial usefulness.

Because the unpredictable effect of such encroachment could be harmful, it may be desirable to eliminate it and instead rely on injection to obtain any benefit that might result from recharge. Encroachment which is caused by increasing pressure differentials should be prevented if pressure is maintained by replacing extracted fluids. So long as the temperature of the rocks is adequate to heat injected fluids as they enter the reservoir, pressure maintenance should be feasible.

The established mechanism to accomplish such coordination, by developing reservoirs as if under single ownership, is unitized operation.[38] Unitization would provide, as it does in the oil context, the opportunity for centralized reservoir management decisions unhampered by considerations of intra-reservoir competition. The reservoir operator would be in a position to make all decisions that bear upon maximum recovery by reviewing reservoir-wide data concerning the rate of production, production well location and spacing,[39] rate of injection and injection well location.[40]

2. *Maximizing the Economic Use of Recovered Geothermal Energy*

Apart from increasing total energy recovery, the ability to control reservoir-wide rates of production and injection also will be important in achieving maximum economic use of recovered geothermal energy.

Geothermal energy, unlike oil or gas, cannot economically be transported long distances or stored for long periods of time without significant loss of energy.[41] Thus, unlike the oil producer who may not be concerned with the identity of the consumer, the producer of geothermal resources must be prepared to deal personally with the consumer. He must, if he is to sell his product, convince a consumer to make a capital investment near the reservoir he is exploiting.

Ideally, an energy consumer's decision to make a capital investment at the site of a geothermal reservoir should be based on factors which include the total amount of recoverable energy available to him, the size and cost of a proposed

38. This is not to imply that other tools might not be capable of accomplishing a similar result, as for example, the imposition of field rules or a plan of operation "to ensure . . . maximum ultimate recovery . . . with minimum waste . . . ." *See* 30 C.F.R. § 270.11, 270.15, 270.30, 270.34 (1976). Moreover, it has been suggested that production quotas and use taxes might be possible approaches. Franzen, *supra* note 2, at 2378.

39. Well-spacing appears to be as important for geothermal resources as for oil and gas, with reduced outputs resulting from wells located too close to one another. *See* James, *Optimum Well Spacing for Geothermal Power*, in PROCEEDINGS, *supra* note 2, at 1681. It follows, therefore, that centralized control of the surface overlying a reservoir would permit optimum well-spacing. Although this is a rather obvious benefit to be derived from unitization, it is nonetheless an important one.

40. *See* INTERSTATE OIL COMPACT COMM'N, A STUDY OF CONSERVATION OF OIL AND GAS IN THE UNITED STATES 184 (1964). Injection wells should not be located too close to production wells since localized production may otherwise be impaired through cooling. Einarsson, Vides and Cuellar, *supra* note 32, at 1351, 1360.

41. *Pariani Transcript*, *supra* note 14, at 726-727, 821-823.

facility or facilities and the return he can expect from such facilities over their useful economic life. With adequate data, such a consumer could calculate the size and economic lifetime of an optimal facility, *i.e.*, a facility which would not only permit recoupment of capital investment, but also provide a return sufficient to replace the facility and the energy source at the end of their useful lifetimes.

The larger the energy consumption of the consumer's facility the higher will be the rate of production necessary to sustain it. If the consumer chooses to construct a facility that requires a rate of production high enough to deplete the reservoir before the end of the facility's useful economic lifetime, the relative cost of the facility per unit of consumption capacity will be wastefully increased, and profits per unit of resource will fall accordingly.[42] Thus, it is no surprise to learn that Pacific Gas and Electric Company, the sole consumer at The Geysers, sought expert assurance that the steam supply at The Geysers is adequate to sustain that Company's local generating facilities over a thirty-year useful lifetime, given the production rates required by the design of those facilities.[43]

While the consumer is primarily concerned with the cost and useful lifetime of his facility, the producer deals with different economics. For exampe, the producer will be interested in maximizing the return on his opportunity costs over the shortest possible time period; if profit would not be maximized by postponing current production, this could involve producing wells at relatively high rates of production. While the producing lifetime of the field is a function of its reserves and the selected rates of production, the useful lifetime of the consuming facility is determined by additional factors including its profitability and physical life. Under these circumstances it would be mere chance if the producer's optimum production rate and field lifetime were to coincide with the required production rate and economic lifetime of the consumer's facility.

42. For an economic discussion of the optimal lifetime of a resource *see* Peterson, Economic Factors in Resource Exploration and Exploitation, in PROCEEDINGS, *supra* note 2, at 2233.
43. *See Pariani Transcript*, *supra* note 14, at 726-727, 821-823.

A producer of geothermal resources, therefore, is not likely to be free to determine rates of production solely with reference to engineering data and his own opportunity costs.[44] In order to create a market for his product, he may have to supply energy at a rate of production determined as much by the needs of his consumer as by his own needs. At the very least, he will be called upon by potential consumers to set forth the reservoir's production capability in terms of rates of production and the time periods over which the reservoir can sustain such rates.

In order to deliver energy to a consumer at a specified production rate over a sufficiently long time period, the producer will find it necessary to obtain and exercise complete physical control over the reservoir. A utility or other consumer is unlikely to make a significant capital investment which is the captive of a specific geothermal energy source unless it is convinced that the reservoir's reserves are adequate to supply its requirements over a time period sufficient to justify its investment. Nor is such a consumer likely to be attracted by a producer's offer to sell resources from a reservoir unless all of that reservoir's reserves are under the same producer's complete control.

The degree of physical reservoir control necessary to insure economic reservoir control can be achieved by unitizing to eliminate intra-reservoir competition. With unitized operations both producer and consumer can be secure in the knowledge that operating decisions significantly affecting the economics of their operations will be under their control.[45]

B. Prevention of the Drilling of Unnecessary Wells

An often repeated reason for unitization in the oil context is that it can obviate the need to drill unnecessary wells.[46]

44. *See generally* Dan, Hersam, Kho and Krumland, *Development of a Typical Generating Unit at The Geysers*, in PROCEEDINGS, *supra* note 2, at 1949, 1951. This source provides details concerning the Pacific, Gas and Electric Company's decisions to invest in power plants at The Geysers.

45. Thus, it has been concluded that the success of Pacific Gas and Electric Company's venture at The Geysers is, in part, "due primarily to the availability of a unique and valuable resource, the long-range planning and *close coordination between PG&E and its geothermal steam suppliers*, and the *mutually* favorable economic performance of this project." *Id.* at 1857 (emphasis added).

46. An unnecessary well is one that fails to increase the ultimate recovery from a field by an amount sufficient to return the investment in it plus its cost of operation. *See* King, *supra* note 6, at 312.

Given The Geysers model of a geothermal reservoir, under what circumstances, if any, would a geothermal operator be motivated to drill unnecessary wells? Such motivation could be attributed to an operator who has one or more competitors in a single reservoir; assuming he is permitted to do so, he will continue to drill additional wells so long as his production increases, even though production from the reservoir as a whole might be lowered. His competitors, of course, would have the same motive and right. With numerous competitors in one reservoir, however, none of them is likely to have access to field-wide data adequate to determine whether additional wells are in fact unnecessary. And, even assuming it were obvious that additional wells were unnecessary, such wells might still be drilled since they could nevertheless provide any individual producer with a competitive advantage.

Moreover, where well-spacing is not regulated, as at The Geysers,[47] the well-spacing determination is left, of course, to the operators. From an economic standpoint, the ratio between surface acreage and the number of wells should be based upon considerations of efficiency. Ideally, an operator should determine the maximum acreage that one well would drain efficiently and drill only one well for each multiple of that acreage overlying the reservoir. In application, such determinations will undoubtedly involve more than simple acreage calculations,[48] but in any event it is clear that such determinations can be best made, if at all, with access to reservoir-wide data.

The probability of unnecessary wells would ordinarily be greatest on tracts where overlying land ownership is most fragmented, because the traditional "offset" well problem will appear. From The Geysers model, it can be concluded that a producing interval nestled up to a common boundary might well drain resources from adjacent properties. If the "rule of capture" applies to geothermal steam, the operator, in the absence of unitization, may "only go and do like-

47. The California Public Resources Code does, however, contain minimum set back requirements for geothermal wells. CAL. PUB. RES. CODE §§ 3757 and 3757.1 (West 1977). *See* 14 CAL. ADMIN. CODE § 1934 (1976).
48. In the oil context, this determination may not always be made on the basis of surface acreage alone. *See* SULLIVAN, *supra* note 5, text accompanying n.1 at 297 (1955).

wise",[49] *i.e.*, offset any drainage by drilling a well bottomed equally close to that common boundary, even though it has long been recognized that this is a wasteful practice.[50] Moreover, if the operator is a lessee, he may have a duty as well as a motive to do so.[51]

The rule of capture, which still affects petroleum resources management in the United States, amounts to a license for the oil producer to reduce to his possession as much oil as he can, notwithstanding the fact that the oil produced may be drained from lands subject to exploitation by others.[52] Although the effect of this rule has been moderated by compulsory unitization, regulation, production controls, and the doctrine of correlative rights, it enhances neither central reservoir management nor maximum efficiency.[53] While no case has yet specifically considered the applicability of this rule to geothermal resources, it would not be illogical, even if arguably unwise, for a court to extend application of the rule of capture from oil to other underground fluid sources of energy such as geothermal resources. At least one court has intuitively applied the rule to a salt water recycling operation in Arkansas where the sole purpose of the operation was to extract bromide and other minerals from the water.[54]

49. Barnard v. Monongahela Natural Gas Co., 216 Pa. 362, 65 A. 801, 802 (1907).
50. *See, e.g.*, Bernstein v. Bush, 29 Cal. 2d 773, 177 P.2d 913, 195 (1947) and SULLIVAN, *supra* note 5, at 46, 260.
51. In the oil context, a lessee has a "rigid" duty, as well as a motive, to drill offset wells to protect against drainage. Renner v. Monsanto Chem. Co., 187 Kan. 158, 354 P.2d 326 (1960); 2 SUMMERS, OIL AND GAS § 399 at 568 (1959).
52. *See* Westmoreland and Cambria Natural Gas Company V. DeWitt, 130 Pa. 235, 18 A. 724, 725 (1889).
53. For a discussion of the rule of capture *see* Kuntz, *Correlative Rights of Parties Owning Interests in a Common Source of Supply of Oil or Gas*, SW. LEGAL FOUND. SEVENTEENTH ANNUAL INST. ON OIL & GAS LAW & TAXATION 217 (1966) and Shank, *Present Status of the Law of Capture*, SW. LEGAL FOUND. SIXTH ANNUAL INST. ON OIL & GAS LAW & TAXATION 255 (1955).

An interesting California case which describes some of the mischief that can result from application of the rule of capture in the absence of unitization is Western Gulf Oil Co. v. Superior Oil Co., 92 Cal. App. 2d. 299, 206 P.2d. 944 (1949).

In that case the court was unsuccessfully requested to order common or unit operation of an oil and gas condensate filed for purposes of recycling and pressure maintenance even though the allegations were that non-unitized operations would result in a loss of 61,000,000 barrels of oil; arguments presented to the court were that a cause of action existed to compel such operation in order to prevent waste under California Public Resources Code Sections 3106 and 3300 and to protect the correlative rights of overlying landowners. In rejecting the arguments as possible grounds for legislative but not judicial action, the court noted that the rule of capture is increasingly subject to control and limitation by government regulation. *Id.*, 206 P.2d. at 949.
54. Budd v. Ethyl Corporation, 474 S.W.2d. 411 (Ark. 1972). This case is very interesting for the differing judicial views expressed with regard to the scope of the rule of capture and very amusing for the ingenuity involved. The rule of capture was held applicable to a salt-water recycling operation, the purpose of which was the re-

The most enlightened approach to this issue would probably be the development of a new set of rules tailored to meet the unique problems of geothermal resources. In the absence

moval and sale of commercially valuable minerals from the salt-water. Appellees were producing and reinjecting the salt-water on leases totalling 16,000 acres. Appellant was the owner of a very small interest in a leasehold to extract the salt-water on 40 acres of the 16,000 (no production well was located on the subject 40 acres) and held an undivided interest in the minerals in an adjoining 240 acres. Appellant, who was plaintiff below, asserted drainage for which appellees should account to him for his share of extracted minerals. With regard to the 240-acre parcel, the court rejected his claim, over a dissent, saying:

> That argument is refuted by the law of capture, which we hold to be applicable in this situation . . . .
>
> We do not agree with the appellant's insistence that the law of capture was completely nullified by the statute which permits . . . compulsory unitization in oil and gas fields . . . . Of course the rule of capture does not apply in fact situations where the . . . power to order unitization has actually been exercised. But there has been no unitization with respect to the 240 acre tract in which appellant owns an undivided mineral interest; and furthermore, we find no authority . . . to order the unitization of salt-water operations that have no bearing upon the extraction or conservation of oil or gas. It follows that the law of capture prevents the appellant from maintaining his first asserted cause of action. *Id.* at 412-413.

Surprisingly, the court also rejected the claims with regard to the 40-acre parcel since the appellant's rights were "inchoate" and apparently since no production from that parcel had been reduced to the possession of appellant's cotenant, the appellee. The court said:

> Thus, there is no trespass upon a vested existing property right, as is the case when a tenant in common of the mineral ownership drills a producing oil or gas well without the consent of his cotenant. *Id* at 413.

On what it thought were substantially identical facts, a federal district court reached the same result in a diversity action filed by the owners in fee of 180 acres of land surrounded by the recycling operation. Young v. Ethyl Corporation, 382 F. Supp. 769 (W.D. Ark. 1974). As had the Arkansas court in *Budd*, the district court stressed that appellant had refused a request to share in the risk as well as the potential profits prior to the commencement of the recycling operations.

The Court of Appeals for the Eighth Circuit, however, reversed in what appears to be a correct result reached by a masterpiece of sophistry designed to circumvent the rule in Erie v. Tompkins. Young v. Ethyl Corporation, 521 F.2d 771 (8th Cir. 1975). Concluding that it was clear under Arkansas law (the *Budd* case) that there was no cause of action for mineral loss by drainage, the court nevertheless reversed on grounds that the Supreme Court of Arkansas had not yet considered whether a cause of action would lie for the loss of the "non-fugacious" brine that would not have migrated away from appellant's property, but for the force exerted by appellee's injection operation. *Id.* at 774. The court also distinguished Young's situation from Budd's on the 40-acre parcel since Young held a fee interest while Budd had only a leasehold interest. Free to examine whether such a cause of action was barred by the rule of capture under Arkansas law, the court decided that the Arkansas Supreme Court would decide, if it had the chance, that it was not barred. The court said:

> First, we do not believe that the Arkansas Supreme Court would extend a rule developed in the field of oil and gas to the *forced* migration of minerals of different physical properties. The rule of capture has been applied exclusively, as far as we know, to the escape, seepage or drainage of "fugacious" minerals which occurs as an inevitable result of the tapping of a common reservoir . . . . We agree with the defendants that the Arkansas Supreme Court foreclosed such arguments with respect to the drainage of minerals from adjacent lands. But Young does not claim that he is losing minerals due to seepage or drainage . . . . Rather, he asserts . . . that the brine solution under his land would not migrate to the defendant's production wells but for the force exerted by the injection wells . . . .
>
> Second, even accepting the defendant's contention that the brine . . . must be treated no differently than would oil or gas, the common law rule of capture is not a license to plunder. Rather, it has an important corollary in the doctrine of "correlative rights" . . . . The defendants would have us ignore [the doctrine of correlative rights] by urging

of such legislative or judicial innovation, however, there seems little likelihood of escaping intuitive judicial application of the rule of capture at least by some courts.[55]

Judicial application of the rule of capture could cause waste. First, there is no reason to assume that the social costs

that salt water brine is not governed by oil and gas law. They cannot have their cake and eat it too; if the rule of capture is to be applied to salt water brine, the doctrine of correlative rights must likewise be applied. *Id.* at 774-775.

55. An alternative to the law of capture as a judicial approach to resolution of disputes concerning competing ownership interests in common geothermal pools could be drawn from the rules applied to water reservoirs. Since underground water is not generally managed as an energy-producing resource, however, there is no reason to suspect that the application of such rules would promote efficient energy management.

For an argument that the application of water law models to geothermal resources would produce a race to appropriate with results similar to the unbridled application of the oil rule of capture, as well as poor allocation of the resource due to restrictions on marketability, *see* Franzen, *supra* note 2, at 2373. *See also* STANFORD ENVIRONMENTAL LAW SOCIETY, GEOTHERMAL ENERGY, LEGAL PROBLEMS OF RESOURCE DEVELOPMENT 101-103 (1975).

At least one lower court judge was convinced, without the benefit of a trial or other evidentiary hearing, that geothermal resources at The Geysers are simply "superheated water (or steam)" rather than a mineral for purposes of the federal government's reservation of minerals in patents issued pursuant to the Stock-Raising Homestead Act. United States v. Union Oil Company of California, 369 F. Supp. 1289, 1297 (N.D. Cal. 1973), *rev'd*, 549 F.2d 1271 (9th Cir., 1977). In reversing the district court, the Court of Appeals for the Ninth Circuit relied heavily on the legislative history of the Stock-Raising Homestead Act and held that geothermal resources were reserved to the government by virtue of the reservation of "all the coal and other minerals". The court noted, however, that "All of the elements of a geothermal system — magma, porous rock strata, even water itself — may be classified as 'minerals.' " *Id.* at 1273-74.

Similar results have been reached by two California superior courts. One, after hearing expert testimony, concluded in a written opinion and with written findings of fact that geothermal steam is a mineral within the meaning of a grant of all minerals. Geothermal Kinetics v. Union Oil Company of California (Sonoma County Superior Court No. 75314). Union Oil Company, successor-in-interest of the grantor, has indicated its intention to appeal that case. *Appeal docketed*, December 21, 1976, California Court of Appeals, 1st App. Dist., Div. 3 (Civ. No. 40447).

In the other California superior court action, Pariani v. State of California, note 14 *supra*, the Superior Court for the City and County of San Francisco has ruled after a bench trial that geothermal steam at The Geysers was reserved to the State by virtue of its reservation of "mineral deposits" and "mineral waters" on lands patented into private ownership. *See* CAL. PUB. RES. CODE §§ 6401 and 6407 (West 1977).

Since geothermal resources, like coal, oil and gas, are primarily sources of energy, they should be treated similarly, *i.e.*, as minerals, for purposes of deciding ownership between the owners of surface and mineral estates. The intent of an individual who reserves, or takes a grant of, a mineral estate seems more likely to actually have embraced the use of all underground resources which share their primary function with other "minerals" such as coal, oil and gas. *Accord*, Olpin, *supra* note 3, at 137-141. *See also* Kuntz, *The Law Relating to Oil & Gas in Wyoming*, 3 WYO. L.J. 107 (1948). *Cf.* Reich v. Commissioner, 52 T.C. 700 (1969), *aff'd.* 454 F.2d 1157 (9th Cir. 1972) (geothermal steam a gas for purposes of the tax depletion allowance and intangible drilling and development costs deduction). Of course, it does not follow that characterization of the resource for purposes of adjudicating either (1) ownership between the surface and mineral owner or (2) tax disputes should necessarily be controlling for purposes of adjudicating disputes between those with ownership rights in a common pool.

In deference to former Supreme Court Justice William O. Douglas, who fears for the corruption of law journals by "special pleaders who fail to disclose . . . [they have] axes to grind" (Douglas, *Law Reviews and Full Disclosure*, 40 WASH. L. REV. 227. 228-229 (1965)), it should be revealed that the author pleaded the State of California's case before the trial court in *Pariani* and as *amicus curiae* before the Court of Appeals for the Ninth Circuit in *Union Oil*.

produced by such a rule in the geothermal context would differ from the costs in the oil context where:

> [S]ociety incurred the cost not only of a resource too hastily depleted but also of resources put into unnecessary wells that sometimes lined surface boundaries like fenceposts."[56]

Second, despite the fact that compulsory unitization and other regulatory controls now prevent much oil waste that otherwise would be caused by the rule, these are usually statutory in origin and presumably would require legislative application to geothermal resources.

The problems of offset and other unnecessary wells can be minimized, if not eliminated, by unitized operations which promote centralized reservoir management and realistically apportion production regardless of the locus of extraction. If unitization is unavailable or rejected by the gambler's instinct,[57] the unfortunate American historical experience with oil and gas offset and other unnecessary wells could repeat itself. From this perspective alone, it appears that the economic benefit to be derived from unitization justifies its widespread use where individual geothermal reservoirs would otherwise be subject to wasteful competitive development.

C. *The Need for Drilling Units*

Another reason frequently advanced for oil unitization is the need or desire to create drilling units, sometimes of a prescribed minimum size. That reason applies to geothermal resources as well.

In the first place, where economic benefits are to be derived from uniform or minimum well-spacing patterns, small tracts cannot participate in such benefits without first combining to form larger units. If minimum spacing is prescribed by regulatory controls, it may be necessary to pool simply to reach minimum size to qualify for a permit or other entitlement for use. Moreover, with directional drilling possible in

56. Devany, 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 an economic analysis of the dislocation that can be caused by application of a rule of capture, *see* Franzen, *supra* note 2.
57. *See* Section V, *infra*.

some areas, surface acreage used for geothermal development could be minimized by utilizing centralized drilling locations. Economic and aesthetic advantages would result; and where recent statutory law requires the preparation of an environmental impact report (or statement) incorporating possible measures to mitigate or lessen environmental impacts,[58] centralized drilling sites may play an important role in future geothermal development. Undoubtedly, there will be substantial environmental pressures, both public and governmental, to utilize such sites wherever possible.

In the second place, unlike the oil industry where a ready market exists even for small quantities of the resource, geothermal extraction operations can, with present technology, pay to produce only when carried out on a scale large enough to attract either a utility or another *in situ* consumer. If the primary market for geothermal resources continues to consist of utilities or other relatively large consumers of electricity, tracts with smaller production volumes should unitize in order to enhance their attractiveness to potential consumers and compete with larger geothermal tracts. Although numerous small tracts could each provide a portion of the geothermal resources for one consuming facility, transaction costs should always be lower for the consumer dealing with one unit operator.

Finally, since it is not uncommon for geothermal leases to require the lessee to drill or attempt to drill one or more wells, numerous leases affecting small tracts overlying a common geothermal reservoir could result in the drilling in aggregate of more wells than would efficiently drain the total acreage under lease. In contrast, a unitization agreement traditionally provides that the drilling requirements of the individual leases participating in the unit shall be satisfied by virtue of drilling anywhere in the unit.

D. Protection of "Correlative Rights"

If a geothermal reservoir is successfully unitized, the unit participants can expect the same protection for their rights in

58. *See, e.g.*, the National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321 *et seq.* (1970) and the California Environmental Quality Act of 1970, PUB. RES. CODE §§ 21000 *et seq. See also* 14 CAL. ADMIN. CODE § 15143(c). Some of the impact of CEQA upon oil operations may be absorbed from No Oil, Inc. v. City of Los Angeles, 13 Cal. 3d 68, 529 P.2d 66 (1974).

the geothermal reservoir as is afforded to participants in a unitized oil operation. Moreover, unit profit, and the participant's share of it, should be maximized by the operator's ability: (1) to increase the recovery of energy, (2) to place both production and injection wells in the locations most desirable from an engineering standpoint and (3) to avoid drilling unnecessary wells. Notwithstanding these benefits, however, problems concerning protection of the so-called "correlative rights" in the oil context[59] have counterparts in the geothermal context which raise several interesting issues:

1. Allocation of Unit Production

Probably the most difficult problem of geothermal unitization will concern the method of allocating production among unit participants. A generally accepted criterion for such allocation in the oil context is the proportion of production that could have been extracted from each participating tract in the absence of unitization. Despite recognition of this criterion, a principal obstacle in any oil or gas participation formula, whether voluntary or compulsory, is to provide fair treatment to the owners in the common source of supply when determining the share of production to be allocated to each tract.[60] Since much more is known about the behavior of oil and gas in reservoirs than about geothermal deposits, it follows that similar, if not greater, difficulties will be encountered in the geothermal context.

Since the purpose of allocation in the geothermal context is the same as in the oil and gas context, there is no reason to

59. The phrase "correlative rights" is a term used to describe the reciprocal rights and duties of the owners in a common source of supply. An early attempt at a judicial statement of the oil doctrine by that name is found in Ohio Oil Co. v. State of Indiana, 177 U.S. 190 (1900). A statutory definition is contained in NEV. REV. STAT. § 522.020(2).

It suffices to note here that the doctrine has two major aspects: (1) each overlying landowner has a right to lawfully extract oil and gas from a common supply; and (2) each such landowner has a right to protection against damage to the common supply and a right to a fair and equitable share of the source of supply. Kuntz, *supra* note 53, at 217. Whether the courts will apply this doctrine to geothermal resources remains to be seen, but it seems clear that application of the rule of capture would also require application of this doctrine. *Accord*, Young v. Ethyl Corporation, *supra* note 54, 521 F.2d 771, 774-775 (8th Cir. 1975).

With reference to the possible application to geothermal resources of a water law model, it should be noted that there is a somewhat similar doctrine of the same name applicable to percolating water; in California it derives from Katz v. Walkinshaw, 141 Cal. 116, 70 P. 663 (1902). *See* HUTCHINS, THE CALIFORNIA LAW OF WATER RIGHTS 426-454 (1956).

60. 6 WILLIAMS & MEYERS, *supra* note 2, § 970 at 813. With regard to participation formulae in general, *see* Doggett, *Practical Legal Problems Encountered in the Formulation, Operation, and Dissolution of Field-Wide Oil and Gas Units*, 16 OKLA. L. REV. 1, 52-58 (1963).

vary the criterion for allocation. Differences in geology and reservoir behavior, however, may be significant enough to demand that different factors be considered when making an allocation in the geothermal context. Although lawyers must ultimately rely upon reservoir engineers to identify factors relevant to allocation, it is probable that the following factors will be of some importance:

(1) porosity of formation underlying the tract;
(2) permeability of formation underlying the tract;
(3) quantity of resources in place beneath the tract;
(4) surface acreage of the tract;
(5) well-productivity;
(6) fracture communication with the reservoir (as The Geysers model reveals, lands seemingly well located in relation to a reservoir do not necessarily have good fracture communication with it; thus, information concerning degree of fracture communication would be helpful in evaluating a tract's production potential, if available); and
(7) potential for reinjection (unlike the oil context, where injection is often utilized for secondary recovery operations upon tracts from which no further production would otherwise be possible, geothermal operators may often desire to commence injection in the early stages of production. It may be prudent to consider a tract's utility for increasing ultimate energy recovery through reinjection for purposes of allocating production; and this would be especially true if reinjection sacrifices or reduces the tract's production value for the overall benefit of the unit. This seems possible, if not likely, since reinjection of cool water has experimentally produced a "cold front" where:

> [T]he rock of contact along the path of travel has been cooled more or less to the temperature of the injected water. If this "cold front" reaches the production zone of the reservoir, production will be affected.[61])

The simplest basis of allocation is the proportion that the surface acreage of the tract bears to total unit surface acreage.

61. Einarrson, Vides and Cuellar, *supra* note 32, at 1360.

This basis, however, may be inaccurate if the quality of different tracts turns out to vary widely. Nevertheless, in the case of a unit formed prior to development, it could be the only basis available. In fact, the federal government has already suggested its use for geothermal unit agreements in unproved areas by including it in Article 13 of Section 271.12 of Title 30 of the Code of Federal Regulations, the Department of Interior's "acceptable" but "not mandatory" form of unit agreement.

While such an allocation basis could be reasonable as a starting point, geothermal unit agreements with surface acreage as the sole allocation basis, if not all geothermal unit agreements, should also contain a mechanism for retroactively reallocating production as geothermal engineering techniques become more sophisticated and further reservoir data is gathered. Unfortunately, the Department of the Interior's form of unit agreement does not contain such a mechanism. But its omission from the form is not necessarily a bar to its use, however, since Section 271.4 of Title 30 of the Code of Federal Regulations provides that departures from the form should be submitted for "preliminary consideration and for such revision as may be deemed necessary."[62]

A subsidiary aspect of the allocation problem is the identification of geothermal reservoirs or sub-reservoirs. The model of The Geysers that emerged at the *Pariani* trial was one of a steam-producing district fed with fluid from reserves of boiling liquid. Despite the considerable data available to them, experts in that case were unable to state whether there is more than one pool of such boiling liquid.

Since it is possible that there is more than one reservoir, it is also possible that any two tracts at The Geysers do not produce steam from the same liquid reservoir. Although reservoir identification would ordinarily appear to be a preliminary problem, considerable geothermal development and mathematical modeling may have to be undertaken before

62. Although oil and gas experiences provide a useful model, traditional oil and gas practices ought not to be blindly applied to geothermal resources without a prior examination of the reasons for those practices in the geothermal context. In light of the state of the art, the federal government's predisposition for the proportional acreage allocation mechanism seems premature.

tracts or wells producing from common pools can be identified. Such identification would be important for purposes of coordinating the injection and production rates in any one pool as well as for allocating production. Geothermal unit agreements should provide a mechanism for identifying and measuring the production from tracts or wells which communicate with common pools. Thereafter, to the extent it is possible to identify separate reservoirs, sub-units may be created in order to realistically allocate production.[63]

2. *"Stand-by" Wells*

Since geothermal steam must be utilized near its point of extraction, it will be prudent, if not necessary, to provide a margin of safety in the quantity of steam available to run a power plant. At The Geysers, steam supplies in excess of the production ordinarily needed to operate the power plants are obtainable from wells available for use in the event a producing well is taken off production. These wells are called "stand-by" wells.[64]

If the drilling of such wells is to be industry practice, their economic effect must be taken into account. In a non-unitized operation such a well would be a financial burden to those holding interests in the tract upon which it was located. Thus, where one power plant is fed by steam from several non-unitized tracts which communicate with the same reservoir or sub-reservoir and the sales agreements or leases provide for payments or royalties based upon the volume of steam consumed by the power plant, there will be resistance to investing in stand-by wells on property capable of sustaining paying wells. The State of California has recently drafted a lease provision to deal with this problem on a small tract of leased state land which is surrounded by private lands also under geothermal lease.[65] It is an attempt to insure that the stand-by burden, if any, is not disproportionately imposed upon

63. *See* 30 C.F.R. § 271.12, art. 11.8 (1976).
64. Personal communication with the engineering staff of the California State Lands Division.
65. The California lease provision states:

> If the lessee supplies steam to any electrical generating facility from wells on both leased lands and other lands and there is producible from all such wells in aggregate a quantity of steam greater than the maximum quantity utilizable by said electrical generating facility, lessee agrees to produce and sell or use steam from the leased lands in a propor-

the state property, which has the same operator as the surrounding lands, but is burdened with higher royalties. This provision creates a number of problems which could easily become sources of dispute. A unit agreement would make such complicated provisions unnecessary by allocating unitized substances on the basis of production potential without regard to the location or number of stand-by wells.

3. Injection

Reference has already been made to a number of problems concerning injection in a geothermal field and it has been suggested that injection may become standard practice in the geothermal industry.

Additional problems relating to injection, however, will arise if the operator desires to locate injection wells on lands which have no value for production. Such injection well locations might be desirable to avoid cooling in the production zone. Although injection into non-productive lands might prove beneficial to the unit as a whole, no single tract owner would necessarily stand to benefit sufficiently to acquire the rights necessary to carry out the injection operation. A unitized operation, on the other hand, can minimize the impact

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tion no less than the proportion that the absolute open flow potential (the absolute open flow potential as used herein is the rate of flow in pounds of steam per hour that would be produced by a well if the only pressure against the face of the producing formation in the well bore were atmospheric pressure) of the wells on the leased lands bears to the total absolute open flow potential of all such wells from which lessee supplies steam to such electrical generating facility. For purposes of this section the lessee supplies steam from a well which is not on the leased lands to an electrical generating facility when the steam produced from such a well is delivered to said electrical generating facility at least twenty-five days out of every month. For purposes of this section it shall be deemed that the lessee supplies steam from a well which is on the leased lands to an electrical generating facility when such well is capable of producing geothermal resources in commercial quantities. The absolute open flow potential of all such wells whether on leased lands or other lands shall be determined by the State Lands Divisions and shall be based upon tests performed by the lessee as prescribed by the State Lands Division. In this regard, lessee shall, upon completion of each of such wells, and prior to the placing of such wells on commercial production, perform, and deliver to the State the results of, the following tests:

a. Pressure-buildup tests to determine static reservoir pressure and well bore conditions. If pressure-buildup tests are based on shut-in wellhead data, then static well bore temperature surveys must also be conducted;

b. Isochronal flow tests or two rate flow tests to establish a back pressure curve and the absolute open flow potential;

c. Other tests as deemed to be necessary by the State Lands Division.

After commencement of commercial production from each of such wells, lessee shall annually, or more frequently if requested by the State Lands Division, determine static reservoir pressure and complete any other tests as specified by the State Lands Division.

of such acquisition by apportioning its costs and benefits among unit participants.

4. Rights-of-Way

For tracts not themselves large enough to produce quantities of steam sufficient to support a power plant, pipeline easements or rights-of-way across adjoining properties will have to be obtained to reach nearby power plants or other consuming facilities. A small tract, surrounded by another producing tract or tracts, could not be reached by a nearby consumer in the absence of some right of passage. The right of the consumer to use his producer's lands for rights-of-way to transport resources produced from other lands should be included in contracts for the sale of geothermal resources. Such a mechanism will not deal with all situations, however, since resources from lands between any producer's lands and his consumer may be sold to a different consumer. Indeed, such intervening lands may not even be in production.

Utilities, municipalities or other consumers with condemnation powers could resort to eminent domain proceedings to resolve such difficulties, but they are likely to desire early resolution in order to raise capital; and condemnation proceedings can be time-consuming and expensive. Where consumers lack condemnation power, one landowner could hold out his monopoly position for exorbitant compensation. Early commitment to a unitization agreement providing for field-wide pipeline rights-of-way would eliminate these problems, avoid delay and probably prevent litigation.

IV. STATUTORY LAW APPLICABLE TO GEOTHERMAL UNITIZATION IN CALIFORNIA

Since California is the only state with large scale commercial production, an examination of the law concerning unitization there is of special interest. But statutory law applicable to geothermal unitization there is sparse.

California Public Resources Code Section 3756 requires that agreements for the purpose of "bringing about cooperative development and operation" or "fixing the time, location, and manner of drilling and operating of wells for the production of geothermal resources" must be approved by the California Geothermal Resources Board. Pursuant to the statute, such approval must be based upon a finding by the Board that such an agreement is "in the interest of the protection of geothermal resources from unreasonable waste". No agreement has yet been presented to the Board for its approval pursuant to this statute.

Also applicable, but of uncertain breadth, is Public Resources Code Section 3700, which states that California, acting through its Oil and Gas Supervisor, "should exercise its power and jurisdiction to *require* that wells for the discovery and production of geothermal resources be drilled, operated, maintained and abandoned in such manner as to encourage maximum economic recovery" (emphasis added). Language directing the Oil and Gas Supervisor to encourage the greatest "ultimate economic recovery" so as to prevent waste is found in Public Resources Code Section 3714. Section 3712 of the same Code states that the chapter in which all three sections are found shall be liberally construed to meet its purposes and that the Supervisor "shall have all powers which may be necessary to carry out the purposes of this chapter."

Interestingly, while California Public Resources Code Sections 3712 and 3714 have oil and gas counterparts in Public Resources Code Sections 3013 and 3016 respectively, the "require" language of Section 3700 has no oil and gas counterpart. The inclusion of this language in a statutory scheme that in many respects parallels the oil and gas regulatory provisions in effect at the time of its enactment[66] seems to have bestowed upon the California Supervisor greater regulatory authority with respect to geothermal resources than to oil and gas. No case has yet construed these provisions, but it seems certain that a court would find broad regulatory power vested in the Supervisor, and a sympathetic court could even construe them as authority to order non-voluntary unitization.[67] Since the Supervisor's rules and regulations now make

66. Public Resources Code § 3700 was enacted in 1965. At that time, there was no general oil and gas compulsory unitization statute in California. Subsequently, however, in 1971 California Public Resources Code §§ 3630 *et seq.* were enacted. They provide for compulsory unitization in twenty-year-old fields, three-quarters of which are within incorporated areas.

67. For a discussion of implied authority to compel unitization, *see* Whittier, *Com-*

no provision for non-voluntary unitization, however, the latter point may be academic.[68]

Unitization affecting state-owned land in California is addressed by Public Resources Code Section 6923; this statute authorizes the State Lands Commission to consent to its lessees' "adopting and operating under a cooperative or unit plan of development or operation" for the purpose of more properly conserving the natural resources of any geothermal resources area. This statute incorporates by reference Public Resources Code Section 3756, thus requiring approval of the Geothermal Resources Board as well as the State Lands Commission for unitization of state-owned geothermal lands.

Section 18 of the Geothermal Steam Act of 1970[69] applies to unitization agreements affecting federal lands in California as well as other states. It permits voluntary pooling and unitization of federal geothermal lands for the purpose "of properly conserving the natural resources of any geothermal pool, field, or like area" whenever the Secretary of the Interior determines it to be "necessary or advisable in the public interest". The same statute seems to authorize compulsory unitization in that the Secretary "may prescribe such a plan under which such lessee shall operate . . . ." Pursuant to that statute, the Department of the Interior has promulgated rules and regulations which unambiguously assert the federal government's authority to order unitized geothermal operations.[70]

V. PRACTICAL OBSTACLES TO VOLUNTARY UNITIZATION

Unitization of geothermal resources would provide, as it does in the oil context, valuable benefits in the form of increased energy recovery, increased profits and protection of

pulsory Pooling and Unitization: Die-Hard Kansas, 15 U. KAN. L. REV. 307, 320-323 (1967).

There is authority for the proposition that a regulatory agency may not order non-voluntary unitization of oil or gas fields without express enabling legislation. *E.g.*, Dobson v. Arkansas Oil and Gas Comm'n, 218 Ark. 160, 235 S.W.2d 23 (1951) and Republic Natural Gas Co. v. Baker 197 F.2d 647 (10th Cir. 1952). Although Western Gulf Oil Co. v. Superior Oil Co., *supra* note 53, is sometimes cited for the same proposition, it would be distinguishable since (1) the State was not a party and (2) the California Supervisor's authority with regard to geothermal resources differs from his authority with regard to oil and gas, as discussed herein.

68. The geothermal rules and regulations of the California Oil and Gas Supervisor begin at 14 CAL. ADMIN. CODE § 1900.

69. 30 U.S.C. § 1017 (1971).

70. 30 C.F.R. § 271.1 (1976).

correlative rights. Voluntary unitization, however, is not likely to be completely successful in achieving the desired results since those considerations which make unitization most desirable are often obstacles to its voluntary implementation. It is almost certain that voluntary attempts at unitization in the geothermal context will be no more successful than in the oil context where such attempts are too often frustrated.[71] Perhaps the most serious obstacle is the necessity to secure the consent to unitize of all persons having an interest in the producing formation.[72]

In part, the inability to achieve full consent to unitization has been attributed to gambler's instinct or "rugged individualism".[73] This may be the demand of an overlying landowner for concessions that adjacent landowners are unwilling to make; but it may also be his willingness to wager that his lands will support production volumes in excess of his proposed share of unitized production.

This obstacle is well illustrated by the facts reported in *Western Gulf Oil Co. v. Superior Oil Co.*[74] In that case, the unsuccessful plaintiffs sought court-imposed unitization to force defendants to take part in a gas recycling operation that was allegedly capable of increasing ultimate oil recovery by at least 61,000,000 barrels of oil — then valued at $166,000,000 — which would otherwise be wasted. Plaintiff's share of the loss was estimated to be in excess of $66,000,000. There, one of the defendants offered to participate only under a proposal that "would allot to it a part of the total production equal in value to more than twice the value of the recoverable oil and gas and other hydrocarbons under the leases."[75]

A second cause of failure to achieve full consent is extremely fragmented ownership. An example of the difficul-

71. *See* INTERSTATE OIL COMPACT COMM'N, *supra* note 40, at 182; Smith, *supra* note 23, at 568; Whittier, *supra* note 67, at 310-311; Myers, *supra* note 9, at 7-13; and 6 WILLIAMS & MEYERS, *supra* note 2, § 910 at 85-89.
72. *See* INTERSTATE OIL COMPACT COMM'N, *supra* note 40, at 185 and 6 WILLIAMS & MEYERS, *supra* note 2, § 910 at 85.
73. Whittier, *supra* note 67, at 310.
74. 92 Cal. App. 2d 299, 206 P.2d 944 (1949). *See* notes 53 and 67, *supra*.
75. Western Gulf Oil Co. v. Superior Oil Co., *supra* note 74, at 947; The INTERSTATE OIL COMPACT COMM'N, *supra* note 40, at 185, states that more than one unit has been created at the cost of a "pound of flesh". *See also* Hunter v. Hussy, 90 So.2d 429 (La. App. 1956) where holders of one and one-half percent of the producing interests and five percent of the royalty interests frustrated plans for unit operations.

ties arising from such ownership is *Gilles v. Yarbrough*[76] where the mineral rights to 572½ acres were jointly owned by about 200 people whose interests ranged from 1/10 to 1/3,888. There, in an unsuccessful action by 150 of these people to terminate a receivership, it was reported that a court had previously appointed a receiver to execute an oil and gas lease because:

> [S]aid mineral estate is owned by so many so widely separated that it would be impossible to obtain an oil and gas lease from all such parties . . . .[77]

Still another cause of failure to achieve full consent is inability or delay due to the fact that the agreement of minors, incompetents[78] or unlocatable parties is required.[79]

VI. CONCLUSION: THE NEED FOR COMPULSORY GEOTHERMAL UNITIZATION

It has been argued here that the benefits of unitized operations would be as valuable in the geothermal context as in the oil and gas context. Refusal to unitize where reservoirs will otherwise be subject to internal competition will result in impaired efficiency, increased expenses and reduced energy recovery. It has also been suggested here that attempts by the industry to voluntarily unitize geothermal operations will be subject to the unavoidable obstacles and delays that have reduced the effectiveness of, and sometimes even thwarted, voluntary attempts to unitize hydrocarbon extraction operations. It is therefore concluded that the timely enactment of compulsory unitization schemes is necessary. Failure of the various state jurisdictions to do so will condemn the geothermal industry to unnecessary inefficiency and waste.

76. 224 S.W.2d 720 (Tex. Civ. App. 1949).
77. *Id.* at 720.
78. *See generally* Warren, *Policy Limitations on Oil and Gas Leasing*, 3 U.C.L.A.L. REV. 474 (1956).
79. *See generally* Smith, *Methods for Facilitating the Development of Oil and Gas Lands Burdened with Outstanding Mineral Interests*, 43 TEXAS L. REV. 129 (1964).