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SALINITY MANAGEMENT ALTERNATIVES FOR OIL SHALE WATER SUPPLIES

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INTRODUCTION

Considerable attention has been given recently to the problem of salinity in the Colorado River. Increasing salinity concentrations are threatening the utility of water resources in the downstream areas of Arizona, California, and the Republic of Mexico. Detriments to agricultural water users are primarily being encountered in Imperial and Mexicali Valleys, while the primary urban detriments are occurring in Los Angeles and San Diego. The U.S. Environmental Protection Agency[1] reports that existing damages to Lower Basin users would increase from $16 million annually in 1970 to $51,000,000 annually by the turn of the century if planned developments do not include appropriate salinity control measures, while more recent estimates by the U.S. Bureau of Reclamation[2] show present damages at $53,000,000 annually, which is projected to be $124,000,000 annually by the year 2000.

The Upper Colorado River Basin, because of its vast reserves of oil shale and near-surface coal, is becoming one of the most important areas in the Nation for energy development. However, energy development will also result in increased salinity levels in the Colorado River unless mitigating alternatives are employed. Consequently, since energy-related developments will further impair water quality, it becomes essential to formulate policies which coordinate both water management and energy development. This interfacing must subsequently be employed in technological planning and designs, as well as in the development of institutional mechanisms which direct implementation of the policy.

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1. U.S. Environmental Protection Agency, *The Mineral Quality Problem in the Colorado River Basin,* Summary Report and Appendices A, B, C, and D. U.S. Government Printing Office (1971).

2. M. Bessler and J. Maletic, *Salinity Control and Federal Water Quality Act,* Journal of the Hydraulics Division, Proc. of ASCE, vol. 101, No. HY5, Paper No. 11321, at 581-94 (May, 1975).

EFFECTS OF SALINITY SOURCES

The salt load at any point along the Colorado River is the result of salt concentrating effects and/or salt pickup. Salt concentrating results from water depletions, while salt pickup results from taking salts into solution during moisture movement (primarily subsurface) through soils and geologic formations.

Salt Concentrating Effects

Evapotranspiration from irrigated lands in the Colorado River Basin constitutes the largest water depletion from the Basin, 2,100,000 acre-feet,[3] which accounts for ten percent of the salinity concentration at Lee's Ferry. Also, evapotranspiration by phreatophytes, particularly in the Lower Basin, contributes to increased salt concentrations. Another important water depletion is evaporation from water surfaces, particularly large reservoirs, which amounts to more than 300,000 acre-feet annually in the Upper Basin and nearly 1,000,000 acre-feet in the Lower Basin. In contrast, water depletions by municipal and industrial uses are relatively small (50,000 acre-feet).

An extremely important salt concentrating effect is interbasin transfers. Numerous interbasin transfers from the Colorado River Basin to adjoining watersheds have been made. The diversion of municipal water supplies to Los Angeles and San Diego constitutes the largest interbasin transfer from the Colorado River. Present exports from the Colorado River Basin amount to approximately 600,000 acre-feet from the Upper Basin and more than 4,000,000 acre-feet in the Lower Basin.

Recent planning and construction of water resources development projects by Upper Basin states has involved the transfer of Colorado River waters to adjoining basins. Usually, these interbasin transfers are high quality waters having a low salt load. Consequently, although both water and salt are removed from the Basin by these transmountain diversions, the salt load is low in comparison to the quantity of water, and there is then less dilution water downstream.

Energy development will also result in salt concentrating effects if good quality water is diverted. In-plant consumption will deplete a portion, or all, of the diverted water. For example, it is estimated by the U.S. Dept. of the Interior[4] that a 1 million barrel/day oil shale industry will require 145,000 acre-feet of water annually.

3. Colorado River Board of California, *Need for Controlling the Salinity of the Colorado River*, The Resources Agency, Los Angeles, Cal. (August, 1970).

4. U.S. Dep't. of the Interior, *Proposed Prototype Oil Shale Leasing Program*, Draft Envt'l Statement (September, 1972).

Salt Pickup

Natural diffuse salt sources are the result of precipitation percolating through the soil over a large area and taking natural salts into solution. In contrast, natural point sources are mineralized springs which discharge at a single outlet or over a very small area.

Municipal water uses result in salt pickup. For example, laundering and bathing add salts to municipal return flows.

Irrigation return flows usually result in salt pickup, particularly in the Upper Colorado River Basin. Surface return flows result in minimal salt pickup, while subsurface return flows consisting of seepage from canals[5] and deep percolation from irrigation[6] can produce significant quantities of salt pickup.

Many of the alluvial soils in the Upper Colorado River Basin are high in natural salts because they were derived from erosion and weathering of marine formations. Also, many of these soils are underlain by shales of marine origin. These shales rapidly weather when exposed to air. Operations, such as surface mining, which expose fresh geologic material to the atmosphere, will result in significant additional salt pickup by surface and subsurface runoff.[7]

SALINITY CONTROL MEASURES

The intent herein is not to describe all of the salinity control measures that might be employed. Rather, the intent is to briefly describe a sufficient number of the most important measures to demonstrate how one water use sector might interact with another water use sector in order to achieve a coordinated balance between water development and water quality (salinity) goals.

For highly mineralized flows, such as mineralized springs or drainage from irrigated lands, the flows can be conveyed to ponds and evaporated, or desalting can be used. In either case, consideration must be given to brine disposal. Another possibility is deep well injection.

To reduce salt pickup by subsurface irrigation return flows, the volume of subsurface flow must be reduced. Seepage losses can be reduced by lining canals and laterals while deep percolation losses

5. G. Skogerboe, and W. Walker, *Evaluation of Canal Lining for Salinity Control in Grand Valley,* Envt'l Protection Tech. Ser., Report EPA-R2-72-047, U.S. Environmental Protection Agency (October, 1972).

6. G. Skogerboe, W. Walker, J. Taylor, and R. Bennett, *Evaluation of Irrigation Scheduling for Salinity Control in Grand Valley,* Envt'l Protection Tech. Ser. Report EPA-660/2-74-052, U.S. Environmental Protection Agency (June, 1974).

7. D. McWhorter, R. Skogerboe, and G. Skogerboe, *Water Quality Control in Mine Spoils Upper Colorado River Basin,* Envt'l Protection Tech. Ser., Report EPA-670/2-75-048, U.S. Environmental Protection Agency (June, 1975).

can be reduced by improved irrigation methods (either capital investments, increased labor input, or improved management practices). Also, tile drainage can be used to skim the less saline groundwater flows near the water table surface.

Salinity concentrations can be decreased by adding dilution water. This could be accomplished by importations (or conversely, by reducing out-of-basins transfers), weather modification, phreatophyte eradication, or reducing evaporation from reservoirs.

SALINITY POLICY

The Reconvened Seventh Session of the "Conference in the Matter of Pollution of the Interstate Waters of the Colorado River and Its Tributaries," with representatives from the seven basin states and the U.S. Environmental Protection Agency[8] adopted in Denver the following recommendation on April 27, 1972:

> A salinity policy be adopted for the Colorado River system that would have as its objective the maintenance of salinity concentrations at or below levels presently found in the lower main stem. In implementing the salinity policy objective for the Colorado River system, the salinity problem must be treated as a basin-wide problem that needs to be solved to maintain Lower Basin water salinity at or below present levels while the Upper Basin continues to develop its compact-apportioned waters.

Subsequent to this declaration, the federal government adopted the Colorado River Basin Salinity Control Act on June 24, 1974 with the purpose of constructing, operating, and maintaining salinity control works on the lower Colorado River for users in the United States and Mexico.[9] This action was followed by a policy declaration of the Environmental Protection Agency approved December 18, 1974 for salinity control on the Colorado[10] that:

> It shall be the policy that the flow weighted average annual salinity in the lower main stem of the Colorado River system be maintained at or below the average value found during 1972. To carry out this policy, water quality standards for salinity and a plan of implementation for salinity control shall be developed and implemented in accordance with the principles of the paragraph below.
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> The States of Arizona, California, Colorado, Nevada, New Mexico,

8. U.S. Environmental Protection Agency, *Conference in the Matter of Pollution of the Interstate Waters of the Colorado River and Its Tributaries,* Proceedings, Seventh Session Reconvened (April 26-27, 1972).

9. Colorado River Basin Salinity Control Act, 43 U.S.C. § 1571 (Supp. 1976).

10. Envt'l. Protection Agency Policy Requirements, Regs. and Standards on Salinity Control for the Colorado River, 40 C.F.R. § 120.5 (1976).

Utah, and Wyoming are required to adopt and submit for approval to the Environmental Protection Agency on or before October 18, 1975.

(1) Adopted water quality standards for salinity including numeric criteria consistent with the policy stated above for appropriate points in the Colorado River System.

(2) A plan to achieve compliance with these standards as expeditiously as practicable providing that:

(i) The plan shall identify State and Federal regulatory authorities and programs necessary to achieve compliance with the plan.

(ii) The salinity problem shall be treated as a basinwide problem that needs to be solved in order to maintain lower main stem salinity at or below 1972 levels while the Basin states continue to develop their compact-apportioned waters.

(iii) The goal of the plan shall be to achieve compliance with the adopted standards by July 1, 1983. The date of compliance with the adopted standards shall take into account the necessity for Federal salinity control actions set forth in the plan. Abatement measures within the control of the States shall be implemented as soon as practicable.

(iv) Salinity levels in the lower main stem may temporarily increase above the 1972 levels if control measures to offset the increases are included in the control plan. However, compliance with 1972 levels shall be a primary consideration.

(v) The feasibility of establishing an interstate institution for salinity management shall be evaluated.

Based upon this position and policy, the strategy for any type of development should require maintaining a net salt balance reaching the lower stem (below Hoover Dam) of the Colorado River. Thus, any development which would create an increased salinity concentration at Hoover Dam should be offset by a corresponding decrease in salinity somewhere else in the system.

UPPER COLORADO RIVER BASIN SALINITY POLICY

There are a number of approaches that can be taken to satisfy the basin-wide salinity policy. For example, salinity standards could be imposed. Since the Upper Colorado River Basin must deliver 75,000,000 acre-feet every 10 years to the Lower Basin,[11] along with half of the required annual delivery of 1,500,000 acre-feet to

11. T. Whitmer, *Documents on the Use and Control of the Waters of Interstate and International Streams: Compacts, Treaties, and Adjudications,* Colorado River Compact of 1922, Article III (d), at 54, U.S. Government Printing Office (1968).

the Republic of Mexico, a maximum mass (volume) of salts that could be conveyed past Lee's Ferry every 10 years could be estimated.

In turn, a mass of salts that would be allowed to leave the boundaries of each state during any 10 year period could be established. The basis for distributing the allowable salt load at Lee's Ferry among each of the Upper Basin states would become highly controversial. Would the allowable salt load for each state be comparable to that states entitlement of Upper Basin flows as specified by the Upper Colorado River Basin Compact? Or would the percentage of the allowable salt load at Lee's Ferry be apportioned in accordance with the natural salt load from each state, with the remaining allowable salt load being apportioned with its percentage of entitlement to the Colorado River? Or would state salinity standards be set in accordance with salinity levels existing in 1972 when the basin-wide salinity policy was adopted?

The simplest and most straightforward policy would not utilize salinity standards but would require that any detrimental salinity effects resulting from any new water developments be offset by salinity control measures in order to achieve a net salt balance (non-degradation) of present quality. For example, if a large dam and reservoir is constructed which benefits all of the Upper Basin states, then the salinity detriments should be offset by salinity control measures applied in each state in proportion to the benefits to each state. Or the Upper Basin states might choose the lowest cost salinity control measure(s), which could mean that all of the offsetting investments in salinity control be made in one state, but with each state participating in the costs.

STATE SALINITY POLICY

None of the Upper Basin states have fully developed their entitlement to the Colorado River. Water development in each state can proceed, and at the same time satisfy the basin-wide salinity policy, if each development is required to achieve a net salt balance. Each state would be allowed to establish its own criteria for achieving a net salt balance. For example, state policy might require that each project achieve a net salt balance within the project area. However, additional benefits could be gained by providing the flexibility to allow one water use sector to offset its salinity detriments by investing in salinity control measures in another sector. And credits or some form of remuneration could be provided to the individual or entity that, through economies of scale in their salinity control approach, improve the water quality above the net salt balance. This amounts to accounting for the externalities (salt loading) associated with water use by all sections, selecting the most cost-effective solutions and designing a compensation system paid from an assessment account generated from benefactors causing deterioration to water quality.

The detrimental salinity effects of a coal strip mining operation, for example, could be offset by irrigation improvements. Not only would this likely be the least cost solution for the coal company, but the irrigation improvements will result in greater agricultural productivity. Also, the diversion requirements for the irrigation system would be reduced, which could allow additional diversions for other uses upstream from the irrigation system.

Projects involving interbasin transfers could offset their salt concentrating effects at Lee's Ferry by investing in salinity control measures within the Colorado River Basin. A significant consideration in this policy is that the "basin of origin" is compensated for giving up a portion of its natural resources.

The above examples illustrate that state water development could proceed while satisfying the basin-wide salinity policy. In addition, there are other benefits in this proposed state policy that result in improved water management, which in turn facilitates further water development.

WATER LAW

Technological innovations, improved water use practices and economic accounting of water use externalities through policy changes are among the most critical factors in salinity management, but one factor remains significantly influential in any program where allocations and reallocations of water resources among the sectional users is proposed. This factor is the water law systems (the plural is used here to recognize the states' rights to adopt a law of water control of their choice. and to emphasize that significant differences in water laws exist from state to state) of the states and federal government.

Two basic doctrines for surface waters are found in the western states: prior appropriation, which has been adopted by each of the 17 western states, and the riparian doctrine, which is sometimes applied in conjunction with prior appropriation. Prior appropriation evolved out of resource control and development needs, where the lack of natural precipitation often required extensive and expensive diversion and delivery systems to produce crops. (Even though the doctrine's origin goes back to early gold and silver mining, the concepts for allocation were quickly adopted by agriculturalists.) Protection of investment and security of tenure in water use were the impetus for this doctrine.

The primary principle of the appropriation doctrine is priority in right. This principle has been states as "first in time is first in right" and means, basically, that when a water deficit occurs allocation diversions among users are closed in an inverse order (i.e., the latest allocation right granted is the first to be closed). This order is followed regardless of the type of use being made of the water. Deviation from this order of control can occur, however, if a use is given preferred status (i.e. domestic), but usually such deviation results in compensation to the non-preferred users.

A second principle of prior appropriation is that the water in question must be the subject of a diversion. This is usually a man-made mechanical diversion but may be a simple opening in the water course bank which will permit and cause the water to be withdrawn. As a result of recent recognition given to recreation, fish and wildlife habitat protection, and aesthetic values, many in-stream uses are now permitted which do not require out-of-water course diversions.

A third principle of prior appropriation is that a beneficial use must be made of the water apportioned. The doctrine of beneficial use was developed to limit the amount of water diverted to that reasonably needed for use—the assumption apparently being that if a use was "reasonable," it was beneficial. There is no precise definition of beneficial use that can be applied to all water uses so the measure of "reasonableness" is crucial. It thus becomes circular—what is beneficial is reasonable and what is reasonable is beneficial. The main function of the principle is, however, to place a *condition* of use upon all water rights and serve as a cornerstone to water use efficiency as technology progresses and water demands increase. In view of the dynamic state of American water law and the additional demands placed on water by growth in this country, it is perhaps wise not to make definitions of crucial concepts too rigid.

A fourth principle is that a valid appropriation of water is a property right. This right of property can readily be recognized as an impediment to changing existing water use arrangements in spite of the demands of a dynamic society. This property right is not absolute but is, rather, a usufructary right to have the water flow so that some portion of it may be reduced to possession and be made the personal property of the individual during the period of possession. The right can be lost through non-use.

Finally, an appropriative right in water is for a specified amount and particular use, which together place a time dimension on the use of the water right. For example, an irrigation right in Wyoming is for the growing season (180 days) and would not allow the right holder to divert his entitlement 365 days a year.

The riparian doctrine, in contrast, was introduced from the Eastern humid states and is primarily the common law of England, modified to meet the needs of the new world and subject to judicial interpretations in application. The doctrine exists in the West only as a companion with the prior appropriation doctrine, and thus confusing complexities occur. Basically, it grants to the landowner bordering natural water courses and other bodies of water, the right to share in the resource in proportion to all other users regardless of when the right is initiated. Thus, no fixed quantity exists in the riparian right and it is not lost through non-use, although it can be transferred through sale or lease.

Some states have enacted statutory provisions clarifying the nature of riparian rights and conditions of use or have totally integrated riparian and appropriations rights into a permit program.

In addition to these two surface water law systems, there exists four ground water doctrines which may operate independent of the surface laws. These doctrines are: (1) absolute ownership rights allowing uncontrolled withdrawal of water under one's land; (2) reasonable use rights in light of other users utilizing the same ground water source; (3) correlative use rights, or proportional withdrawals during scarcity, according to the amount of overlying lands utilizing the same source of ground water supply; and (4) prior appropriation rights, which apply the same principles as the surface water prior appropriation laws. The lack of uniformity between surface and ground water doctrines causes both intra- and inter-state administration problems.

Several states have adjusted statutory criteria for allocating the amount of water. This is known as a "duty of water" and serves to quantify the doctrine of beneficial use by setting a maximum consumption which will be recognized as a reasonable use. This right or duty of water is usually expressed in terms of flow rate, but it may also be stated in terms of volume, time, season of the year, or the amount of beneficial use which can be made of the water. The statutory provisions prescribe the maximum amount allowable, but it is understood that if the reasonable use is less than this amount, the need will prescribe the limit.

OIL SHALE WATER SUPPLIES

Salinity Concentrating Effects

In order to evaluate the effect of any water resource development upon salinity in the lower stem of the Colorado River, the present salinity levels must be known. Studies by the U.S. Environmental Protection Agency[12] shows that the mean annual salinity at Hoover Dam is 730 mg/l (0.993 tons per acre-foot). Further downstream, at Imperial Dam, the mean annual salinity is 850 mg/l.

The annual water depletion from the Colorado River (water diverted minus return flows) for an oil shale plant having a capacity of 50,000 barrels per day is 7,200 acre-feet. Thus, an annual water depletion of 7,200 acre-feet must remove nearly 7,200 tons of salt annually if there is to be no salinity detriment at Hoover Dam.[13]

A means of mitigating any salinity increase at Hoover Dam is to satisfy a portion of the oil shale water requirements with a water source which is tributary to the Colorado River having a salinity greater than 730 mg/l. Ideally, the proportion between Colorado River water and the more saline water source (approximately 0-30 percent of the water supply for an oil shale plant can be of poor quality) would be such that the average salinity would be exactly 730 mg/l (or greater than 730 mg/l). Possible saline water sources would be ground water flows presently returning to the Colorado River, or municipal effluents.

Another possibility, although remote, would be to import water supplies from outside the Colorado River Basin. If there were no return flows (zero discharge), then there would be no impact upon the Colorado River.

Salt Pickup Effects

The principle problem regarding return flows from oil shale plants will occur as the result of processed shale waste disposal piles. Here, the potential exists for polluting surface and ground water flows from rainfall and snowmelt on the waste pile, thereby resulting in runoff, infiltration, and leaching. Upward movement of salt laden water in response to evaporation will result in an accumulation of salts on the embankment surface. Thus, surface runoff would result in an increase of total dissolved solids (salinity), as well as suspended solids.

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12. U.S. Environmental Protection Agency, *supra* note 1.

13. G. Skogerboe, *Colorado River Salinity: Impact of Parachute Creek Oil Shale Plant and Alternatives for Mitigation,* Appendix 12 of Envt'l. Impact Analysis for Shale Oil Complex at Parachute Creek, Colorado, Colony Development Operation (March, 1974).

Any water percolating through the waste pile will result in considerable salt pickup. Fortunately, with low permeabilities, the quantity of water percolating through the waste pile will be relatively small.

In order to alleviate the potential for surface runoff and erosion, revegetation is required. In order to achieve a substantial vegetative stand, proper irrigation management will be required. With low infiltration rates, there is difficulty in getting sufficient moisture into the root zone. Also, sufficient moisture is required to achieve a net downward moisture movement in order to prevent capillary rise and resultant increases in root zone soil salinity which would hinder plant growth. At the same time, over-irrigation would result in additional percolation through the pile and consequently increase salt loads leaving the pile and entering shallow alluvial ground water aquifers.

There are numerous on-site measures that can be used to minimize water quality degradation. Revegetation and proper irrigation will do much to alleviate surface and subsurface return flows. Surface return flows could be collected in detention reservoirs, where evaporation would prevent the water from returning to the river system. Removing subsurface return flows is much more difficult; however, skimming wells could be used to remove ground water flows, which in turn could be used as part of the water supply to the oil shale complex. Also, subsurface return flows could be discharged from the skimming wells into the same detention reservoirs used for collecting surface return flows. Other possibilities include desalination or deep well injection.

OFF-SITE ALTERNATIVES FOR MITIGATION

As alluded to earlier, there may be some advantages in allowing the water quality degradation resulting from an oil shale complex to be offset by improvements at another location in the river system, usually within the same state boundaries.

An immediate possibility would be ponding and evaporation, deep well injection, or desalination of mineralized springs. These same measures could be utilized in conjunction with pumping of saline ground waters which are presently reaching the Colorado River.

One of the most viable off-site alternatives is irrigation improvements in agricultural areas. Most of the irrigated valleys in the Upper Colorado River Basin contribute significant salt loads to the river system resulting from salt pickup by subsurface return flows. Irrigated agriculture accounts for roughly 37 percent of the total salt load leaving the Upper Basin.[14] The most significant salt loads from irrigated agriculture occur from the Grand Valley and Gunnison River Basin in western Colorado, as well as the Duchesne River Basin in eastern Utah. In particular, the Grand Valley and Duchesne River Basin offer unique opportunities for coordinating oil shale development with improved irrigation water management.

Each state within the Colorado River Basin is entitled to a portion of the flows within the Basin. Each of the states (Colorado, Utah, and Wyoming) involved in proposed oil shale development programs have not utilized their full share of Colorado River entitlement. Also, the irrigation return flows from such irrigated areas as the Grand Valley and lower Duchesne River are not utilized again in the "state of origin." Thus, irrigation improvements in such areas would decrease the diversion requirements, which could in turn be transferred upstream.

For example, the "Cameo Demand," which is the amount of natural flow which must be left in the Colorado River to satisfy water rights in Grand Valley, restricts upstream diversions during low-flow months of drought years. Therefore, irrigation improvements in Grand Valley which would decrease the "Cameo Demand" would enhance upstream water rights.

The lining of canals and laterals[15] as well as on-farm irrigation improvements,[16] would reduce the salt loads from many of the irrigated valleys in the Upper Basin. Therefore, an oil shale complex could make sufficient investments in irrigation improvements to exactly offset the salinity detriments resulting from the oil shale operation, thereby satisfying the non-degradation policy for the basin. Such investments have the added advantage of increasing agricultural productivity. Also, the diversion requirements for such an irrigation enterprise would be decreased. This decreased diversion requirement provides additional opportunities for improved basin-wide water management provided changes in western water laws can be achieved.

MODIFICATIONS TO WESTERN WATER LAWS

What is needed is a means of allocating and reallocating water within the irrigation system by an organization cognizant of the needs of water users within the system, the state water development plan, and the basin and the international impacts. Two approaches are suggested. The first is the development of a centralized state or

14. U.S. Environmental Protection Agency, *supra* note 1.
15. Skogerboe and Walker, *supra* note 5.
16. Skogerboe, Walker, Baylor, and Bennett, *supra* note 6.

basin brokerage system to operate as a market center for the exchange and sale of water rights or renting of water available under the rights held.[17]

This brokerage system could be organized as a public or private institution. It would permit water users to divert only that amount of water necessary for their operation without fear of losing the unused decreed or historically diverted quantity, and lease or rent the difference to other users. Hence, there would be an economic incentive to implement the most efficient water management practices in their operation in an attempt to reduce the necessary quantity of water applied.

A brokerage system created as a public entity could be established in an existing agency of the state responsible for water distribution, administration and regulations. This office, or subdivisions in the various basins within the state, would list all available water for rent, lease, exchange or sale. The location of available waters will determine the impact upon other vested rights, but the responsibility for delivery and protection of such other rights would rest upon either the water right holder or water acquirer. Uniform prices of units of water could be established, or the available water could be transacted to the highest bidder. A percent of the transacted price would be retained for the operation and maintenance expense of the brokerage system. The adoption of such a system in state organization would require changes in agency laws to permit this type of activity.

The second suggestion is a gradual shift to contract water rights versus traditional allocation of water under a property rights concept. Contract water rights are not new! All of California's share in the Colorado River diverted to the five primary users in California is administered by contracts between the Interior Department and the users; likewise, several states have agencies which contract out the use of water.

The administration of contract water rights would best be handled by the same state "brokerage" office. The advantages to the contract right in terms of permitting necessary energy and other water resources related developments, and protection of existing uses, is that states could now shift to a truly "water management" program on a planned and programmed basis according to the state and national priorities. Presently, a few states can legitimately say they are managing their water supplies. Financial and manpower constraints

17. G. Radosevich, *Water Right Changes to Implement Water Management Technology, Proceedings of Nat'l. Conf. on Managing Irrigated Agriculture to Improve Water Quality*, at 265-80, sponsored by U.S. Environmental Protection Agency and Colorado State University (May, 1972).

make it nearly impossible to closely monitor uses for improved efficiency. Contract water rights partly spreads the cost to those who receive the benefits of use.

The other significant advantage of contract water rights is that both parties to the contract have specified rights and obligations as opposed to the present nebulous responsibilties of the parties under traditional water rights. However, it would be imperative that the state retain or be provided the power to purchase, condemn, or receive water rights in the name of the state. This would allow the state to take action against appropriators who refuse to implement efficient practices, acquire their unused rights, retain them for future use, or contract the use for a period of time according to an integrated state plan. Likewise, it would enable the conscientious user to proudly protect his right to continued use against the persistent claims of new demands.

The economic advantages of these propositions include the continual improvement of present water use systems in order to meet new water demands, which in turn can be satisfied by the allocations to be released with such improvements. Thus, positive economic incentives could exist for improved water management based upon market demand for water, while at the same time taking into account externalities. Certainly, water supplies for oil shale would be one of the significant demands for such water.

CONCLUSIONS

Oil shale development will occur in the Upper Colorado River Basin. The basin-wide, non-degradation salinity policy for the lower stem of the Colorado River requires that each development, including oil shale, offset any salinity detriments by making improvements on-site or somewhere else in the basin (off-site).

Salt concentrating effects will occur if the salinity of the oil shale water supply is less than the salinity in the lower stem of the Colorado River. Such effects can be eliminated by mixing a saline water supply with a high quality water source in such proportions that the average salinity is equal to present salinities in the lower stem of the Colorado River.

The processed shale waste disposal pile has potential for salt pickup from either surface runoff or subsurface percolation. Good management practices will alleviate much of this potential water quality degradation. Surface return flows can be collected, ponded, and evaporated. Subsurface return flows can be collected by using skimming wells.

There are advantages in allowing the salinity detriments resulting from an oil shale complex to be alleviated by off-site improvements. One possibility is the collection of mineralized spring flows, then ponding and evaporation, or deep well injection, or desalination. One of the most viable alternatives is to make improvements in an irrigation system including canal lining and on-farm irrigation improvements. Such investments benefit agricultural productivity, as well as decreasing irrigation diversion requirements. With modification to western water laws, economic incentives and administrative programs could be provided so that decreased diversion requirements could be sold, contracted, or rented to other water demands (e.g., oil shale) with the revenues being used largely for further irrigation system improvements.