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MANAGING THE COLORADO RIVER IN A SEVERE SUSTAINED DROUGHT: AN EVALUATION OF INSTITUTIONAL OPTIONS[1]

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ABSTRACT: This paper presents a summary of the findings and recommendations of the studies of severe, sustained drought reported in this special issue. The management facilities and institutions were found to be effective in protecting consumptive water users against drought, but much less effective in protecting nonconsumptive uses. Changes in intrastate water management were found to be effective in reducing the monetary value of damages, through reallocating shortages to low-valued uses, while only water banking and water marketing, among the possible interstate rule changes, were similarly effective. Players representing the basin states and the federal government in three gaming experiments were unable to agree upon and effect major changes in operating rules. The conclusions are (1) that nonconsumptive water uses are highly vulnerable to drought, (2) that consumptive uses are well-protected, (3) that drought risk is greatest in the Upper Basin, (4) that the Lower Basin suffers from chronic water shortage but bears little drought risk, (5) that opportunities exist for win-win rule changes, (6) that such rule changes are extremely difficult to make, and (7) that intrastate drought management is very effective in reducing potential damages.
(KEY TERMS: drought; water policy; water institutions; Colorado River; systems analysis.)

INTRODUCTION

The Colorado River is one of the most highly controlled and most intensively utilized river systems in the world. Two large federal reservoirs, Lake Mead and Lake Powell, are capable of storing nearly four times the mean annual flow of the river. Smaller reservoirs, both federal and non-federal, add additional storage and hydroelectric power generation capacity. Transbasin diversion facilities divert Colorado River water to Southern California, Eastern Colorado, Western Utah, and Eastern New Mexico. In most years, the flow of the river is so intensively utilized that none discharges into the Gulf of California, its outlet to the sea.

The "Law of the River" is the term often used to refer to the existing complex of Colorado River water allocation and management rules contained in two interstate compacts, one international treaty, several acts of Congress, and the operating criteria for system reservoirs promulgated by the Department of the Interior. This complex of rules for operating the basin's "plumbing system" has evolved over more than 70 years (as has the system itself), but its ability to cope with a severe sustained drought has never been tested. Such a drought could produce hydrologic and social stresses far greater than those experienced in more normal periods. Droughts more severe than those of the last hundred years have occurred in the more remote past, and they will surely occur again in the future.

Investigators from several Colorado River Basin states have been engaged for about a decade in a major program of research designed to evaluate the capability of the region's water management structures and institutions to cope with a severe sustained drought (SSD). This research program has included the following: tree ring reconstructions of historic runoff conditions; hydrologic analyses of the probability distribution of river flows; engineering simulations of the functioning of the water management facilities and institutions under various runoff scenarios; legal and other institutional analyses of current interstate water allocation rules, and possible changes in them; studies of potential environmental impacts of different hydrologic scenarios; economic projections of

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water-related benefits and costs of such scenarios; explorations of the social impacts of drought in the basin states; and a gaming experiment in changing rules for managing the system as the drought progresses.

The methods and findings of all of these studies are described in companion papers to this one. Our purpose here is to provide a synthesis of the findings from all of these studies which bear upon future management of the system, to highlight their implications, and to provide policy recommendations based upon those implications.

Our findings, conclusions, and recommendations derive largely from our computer simulations of the behavior of the physical-institutional water management system when subjected to the stress of a 38-year severe drought, a drought resembling one which occurred late in the sixteenth century, and the most severe drought which presently available technology allows us to identify. These findings, conclusions, and recommendations fall into three groups: those which pertain to the existing operating rules (the Law of the River); those which pertain to potential changes in the existing rules; and those which pertain to the feasibility of making such changes (through negotiation, legislation, or litigation).

FINDINGS

Drought Performance of the Law of the River

The SSD hydrologic models predict that, under present institutional arrangements (the Law of the River), Lake Powell and other major Upper Basin reservoirs would be emptied, and Lake Mead nearly so, after two decades of severely reduced runoff. Water deliveries for consumptive uses in the Upper Basin would fall to about half of normal levels, *albeit* for only a few years. Consumptive uses in the Lower Basin would be largely unaffected, save for those served by the Central Arizona Project. Until recently, California was able to use about a million acre-feet of Colorado River water annually beyond its regular compact entitlements. After the completion of the Central Arizona Project canal, such "surplus" usage is unlikely to recur reliably, and we do not include chronic inability to divert this surplus as a drought-caused shortage. In all, basin-wide shortages would be less than 25 percent of normal demands, even at the depth of the drought (Harding *et. al.*, 1995). California, in its recent droughts, has coped with more severe shortages.

So-called instream, or nonconsumptive, water uses (hydroelectric power generation, water-based recreation, environmental protection, and salinity control) would fare less well. Predicted power generation declines during the low flow years and would cease altogether at the depth of the drought. Water-based recreation at Lakes Mead and Powell and at five other system reservoirs would decline with decreasing water levels in those reservoirs. Instream flows would be inadequate at times for the survival of some endangered species at some locations. Riparian wetlands would be seriously affected. Salinity levels in drinking and irrigation water would rise to levels higher than experienced since the completion of Hoover Dam.

The single largest predicted economic impact of the drought was the loss of electricity, with an average value of 600 million dollars annually. Reductions in water deliveries to municipal, industrial, and agricultural users would also be substantial, and benefits to those users would be significantly reduced due to salinity increases. Recreational benefits would fall by lesser but still appreciable amounts. Lower Basin states would experience minimal losses to consumptive water uses but would suffer major losses to nonconsumptive uses. Just the opposite was true of the Upper Basin states. The estimated present value of discounted economic damages, excluding salinity, for the entire drought was $5 billion, only 45 percent of which was to consumptive uses (Booker, 1995). To say that nonconsumptive uses would sustain 55 percent of the drought damages is an understatement because it ignores both salinity and nonmonetary damages, such as extirpation of endangered species. Both local extirpations of endangered species and loss of wetlands occurred as a result of the drought and may have been aggravated by management measures taken to protect consumptive uses. Most instances of environmental deterioration are to some degree reversible. In the case of threatened and endangered species, however, losses are not so easily reversible. Complete extinction of a species is clearly irreversible, but localized extirpations are probably reversible, given enough time and effort, provided that breeding stocks exist elsewhere in the system. Localized extirpations were predicted in Flaming Gorge, Navajo, and Lake Powell reservoirs, and in the Green River below Flaming Gorge. All of the reservoir extirpations were eventually reversed, but that in the Green River was not (Hardy, 1995).

Drought Performance of Alternative Operating Rules

Several potential revisions to the Law of the River were formulated and evaluated, both by SSD

institutional researchers and by those who participated in the gaming experiment. Among these changes were (1) adoption of a reverse equalization rule, which would tend to maintain similar water levels in Lakes Mead and Powell (the existing equalization rule protects Mead at the expense of Powell); (2) temporarily ignoring the Upper Basin's delivery obligation to the Lower Basin to avoid Upper Basin shortages at times when no shortages were imposed upon the Lower Basin (in effect sharing system-wide shortages proportionally among the basin states); (3) revising reservoir operating rules to store water in headwaters reservoirs as long as possible (thus minimizing evaporative losses); and (4) permitting water banking and marketing between states, so long as no other states were harmed thereby (Booker, 1995; Henderson and Lord, 1995; MacDonnell *et al.*, 1995).

Changes in water allocation and management rules within basin states were also considered. In general, these changes took the form of proportional sharing of shortages or water marketing, under which water was transferred from senior agricultural rights to junior municipal rights, something which was not permitted under the base line analysis representing existing institutions. Responses in Arizona were more complex, however, reflecting that state's several options for managing its allocation of Central Arizona Project (CAP) water (Henderson and Lord, 1995).

Two types of changes in the Law of the River could provide major reductions in overall losses. Changing the Law of the River to require water to be stored high in the basin, thus minimizing reservoir evaporation, could reduce drought damages by about one fourth. Equally effective were intrastate and interstate water banking and water marketing because they allowed Arizona to transfer CAP water, the agricultural use of which would otherwise require subsidization, to municipal uses in the other Lower Basin states. Otherwise, changes in the Law of the River were not very effective in mitigating drought damages. However, changes which would reduce consumptive uses further, with the intent of mitigating damages to nonconsumptive uses, remain to be explored (Booker, 1995).

Changes in intrastate water allocation and management were more effective in mitigating drought damages than were those changes in the Law of the River which we analyzed. In particular, transferring water from low-valued agricultural uses to higher-valued municipal and industrial uses shows considerable promise. Such reallocations did occur in the recent California drought and have long been observed in Colorado. Indeed, reducing agricultural water use during drought could go beyond preventing shortages to higher-valued municipal uses and could also partially sustain nonconsumptive uses, such as hydropower, recreation, and environmental protection. Our studies showed that the gains from managing system reservoirs to maintain hydropower production would outweigh concomitant consumptive water use damages if those damages were suffered only by agriculture. Shorting consumptive uses is most effective if concentrated in the Upper Basin because more downstream nonconsumptive uses can benefit (Booker, 1995; Henderson and Lord, 1995), so measures that redistribute shortages away from the Upper Basin for reasons of increased equity would increase the system-wide damages from the drought.

Despite the mostly temporary extirpations, there was a net improvement in conditions for the four threatened and endangered species whenever the operating rules were interpreted to include invoking the Endangered Species Act to modify reservoir release rules and protect these species whenever it appeared to be necessary. To do so, of course, causes some reduction in water deliveries for offstream consumptive uses to the Upper Basin.

Institutions for Changing Operating Rules

The kinds of changes in the Law of the River which were explored in this research can be accomplished in several different ways, as is shown by the history of the evolution of that institution. The first way is by interstate negotiation. This is how the two interstate compacts were formulated. The second way is by federal legislation. This is how the major reservoirs were constructed and how the 1922 Upper Basin-Lower Basin apportionment was originally put into effect. The third way is by judicial decision, as represented by the far-reaching 1968 decree in Arizona v. California. The fourth way is by administrative rule-making, represented by the promulgation of the Interior Secretary's operating criteria for Hoover and Glen Canyon dams (Henderson and Lord, 1995; Kenney, 1995; MacDonnell *et al.*, 1995).

Our studies suggest that institutions which possess (1) sufficiently broad responsibility and authority to deal with all interrelated problems, (2) provide for appropriate representation and participation of all major affected interests, (3) generate and distribute objective and technically sound information, and (4) facilitate communication and bargaining between states are most likely to adopt and implement operating rules which resolve conflict and achieve efficient and equitable resource allocation. The single federal administrator model which is predominant in the complex of existing collective choice institutions in the Colorado River Basin largely fails to meet these criteria (Kenney, 1995).

Our gaming experiment placed players acting as representatives of the seven basin states and the federal government in three collective choice situations where they were required to agree upon changes in the Law of the River in order to mitigate drought impacts. In essence, each of these situations was governed by rules which were variants of the interstate negotiation model. The participants achieved only minor rule changes, and even less substantial mitigation results, perhaps due to perceived restrictions in the scope of their responsibilities and to information deficiencies. They were most successful when permitted to engage in bilateral water banking and water marketing transactions. Their greatest achievements in reducing drought damages resulted from the intrastate water management changes which they were able to make independently (Henderson and Lord, 1995).

IMPLICATIONS

Nonconsumptive Water Uses Are Highly Vulnerable to Drought

Existing operating rules and those changes which we examined favor consumptive water uses over such nonconsumptive uses as hydroelectric power generation, environmental protection, salinity control, and recreation. The extent of this favoritism (technically, the tradeoff ratio) is out of all proportion to what are, arguably, the public values involved. This conclusion emerges even when such nonmonetary values as environmental protection are discounted completely. It is even stronger if reasonable weight is given to these nonmarket factors.

Both absolute and relative declines in the monetary values of nonconsumptive water uses are far greater than is true for consumptive uses, taken as a whole. In other words, the nonconsumptive uses are far more vulnerable to drought than are consumptive water uses, at least when the system is managed pursuant to current rules or pursuant to the variants on those rules which we examined.

Hydropower is seen to be highly vulnerable to the representative severe sustained drought. However, this is not to say that drought-caused losses could be avoided through adopting different water management institutions, as was largely possible in the case of consumptive water uses. Because there is less inflow in drought years, there is bound to be less hydropower generation, even if all withdrawals for consumptive uses were to cease. However, by sustaining withdrawals for consumptive uses (especially in the Upper Basin) above levels which would have characterized an unmanaged drought, the Colorado River management system substantially increases the severity of drought-related hydropower losses.

Monetary losses to hydropower, recreation, and water quality are not the only damages suffered by nonconsumptive water uses. Endangered species, wetlands, and other environmental attributes are also affected adversely.

Consumptive Water Uses Are Well Protected from Drought

The severe sustained drought does produce damages or losses to consumptive water users (farmers, industries, and municipalities), even if only in the Upper Basin, and there only for a few years. A substantial drop in water deliveries to consumptive uses occurred when the drought was at its worst. However, when states managed their intrastate waters efficiently, the drop in monetary benefits was much smaller, in relative terms, than was the shortage which produced that drop (Booker, 1995; Henderson and Lord, 1995).

The players in the three drought managment games did not act effectively to limit drought-caused losses to nonconsumptive water uses, even though it appears that the opportunity costs associated with such mitigation, in the form of increases in losses to consumptive uses, would have been less than the benefits to be achieved. We believe (without direct evidence to confirm this belief) that the players, in attempting to simulate the behavior of state engineers and other state water decision makers, focused overwhelmingly upon their ability to achieve the diversions of Colorado River water which were their presumed entitlements under the Law of the River. In so doing, they overlooked other factors which might be thought important to interests which were neither directly (nor even indirectly) represented in our experiments. In reality, of course, environmental, recreational, and, especially, energy interests would be expected to exert considerable political influence to protect their own presumed entitlements, and would have ample time and channels to do so in the course of a sustained drought. The potential effectiveness of such efforts is another matter.

Drought Risk Is Greatest in the Upper Basin, But in Normal Years Supplies Are Abundant

The 1922 Colorado River Compact essentially gives the Lower Basin states seniority in claiming the first

7.5 million acre-feet of Colorado River flows, although it is often held that half of the delivery obligation to Mexico must come out of that allotment. Only after the full Lower Basin obligation has been met can the Upper Basin states begin to satisfy their rights administered under the compact. Thus, the Lower Basin has a legal right to at least the first 6.75 million acre-feet of water flowing in the Colorado, after the Upper Basin present perfected rights of approximately 2.2 million acre-feet have been satisfied. This Lower Basin priority effectively transfers all of the drought risk to the Upper Basin.

In normal times, the Upper Basin share may be expected to amount to about 5.5 million acre-feet (including present perfected rights, and depending upon what one takes to be the mean annual flow of the river, itself an ambiguous concept when referring to a nonstationary time series like this one). Current Upper Basin depletions amount to over four million acre-feet annually (including present perfected rights). Therefore, at the present level of development, the Upper Basin uses far less than its entitlement as long as runoff is near normal.

The Lower Basin Suffers Chronic Water Shortages But Bears Little Drought Risk

California could be said to be in a state of chronic water shortage, but at current demand levels it and the other Lower Basin states are virtually immune to a Colorado River Basin drought. By the 1922 compact agreement, the Lower Basin gained the assurance of a stable water supply at the expense of limiting its long-term mean withdrawals to less than the amount needed to meet its potential demands. Conversely, the Upper Basin states gained a long-term limitation on the Lower Basin's share of the system yield, at the cost of assuming almost the entire drought risk of the entire basin. From a drought protection standpoint, and considering only consumptive water uses, the Lower Basin states enjoy a remarkably superior position to that of the Upper Basin. By the same token, the price paid for that advantage has been high, both in terms of foregoing greater long term access to normal flows and in terms of impacts upon non-consumptive water uses (these impacts bear most heavily upon the populous Lower Basin).

Opportunities Exist for Win-Win Rule Changes

Existing operating rules needlessly limit California's long-term water supplies while needlessly increasing the upper basins' vulnerability to short-term drought. It would be relatively inexpensive for the Upper Basin and Arizona to reduce their long-term claims upon Colorado River water in order to enable California to meet demands which already exist. It would be similarly inexpensive for California to agree to share the burden of accommodating future drought shortages more equally, thus relieving what could be traumatic shortages in Upper Basin states, particularly Colorado. This finding suggests a possibility for grasping that most desirable of conflict resolution possibilities, the positive-sum solution in which there are only winners and no losers.

Existing decision-making institutions for interstate water allocation and management are designed to resolve conflicts between states acting exclusively in their own self-interests. They are not designed for discovering what the collective or common interest may be, unless that common interest is taken to comprise only resolution of such interest conflicts. Still less are they designed to facilitate action in the common interest, should it be revealed.

Only Minor Changes Can Be Made Under Existing Rules

The SSD gaming experiments were conducted within the limited context of those changes in interstate water allocation (operating rules) which institutional specialists believed to be attainable without changes in statutes or judicial interpretations. The gaming was conducted under collective choice rules which approximate those currently in effect and then was repeated twice, each time under a modified set of operating rules but, again, including only those changes which were thought to be attainable without legislative or legal action.

The most striking aspect of the outcomes of the three SSD drought gaming exercises is their similarity. The players simply were unable to change those outcomes very much through negotiating changes in the operating rules, even though a great deal of communication occurred in both the second and third games, and many water transfer deals were successfully struck in the third game.

The players employed a very narrow set of decision criteria throughout all of the games. We believe that the players attempted almost single-mindedly to maximize Colorado River water deliveries to their respective states, within and up to the limits of their compact entitlements. We further believe that, with the exception of the equalization rule, the existing operating rules are hard to improve upon, from the limited perspective of coming as close as is possible to fulfilling compact entitlements.

Intrastate Drought Management is Most Effective

Two state players, those representing Arizona and Wyoming, were more successful in managing drought, at least by some criteria, than were most others. The Arizona player was able to reduce Arizona's demand for consumptive uses of Colorado River water progressively, from 2-1/2 to under 2 million acre-feet annually as he played the three games, while at the same time virtually eliminating drought-caused water shortages. In doing so, he was able to reduce drought-related monetary losses to his state by $23 million, on an average annual basis (the reduction was much greater for the worst drought years). His success was due to his astute *interstate* water marketing transactions in the third game, coupled with his choice of *intrastate* water management rules, including conjunctive management of surface and groundwater resources, which were consistent with them.

The Wyoming player in the first game was able to achieve significantly higher water-related net benefits than the (different) player in the third game, despite the fact that Wyoming demand (for consumptive uses), supply (diversions), and shortages were identical in both games. That player also achieved a higher level of benefits than did the (different) player in the second game, even though the player in the second game was able, acting in concert with the other players at the collective choice level, to adopt a reverse equalization rule and thereby reduce upper basin shortages appreciably.

The reason for the difference is that the player in the first game selected a change in intrastate water allocation rules which enabled free marketing of water between agriculture and municipalities. The resultant drought-year leases increased benefits to both farmers and municipalities, and constituted a more effective drought management strategy, from a monetary perspective at least, than Wyoming was able to achieve through actions taken at the collective choice level in the second game or by interstate water banking and marketing transactions in the third game.

RECOMMENDATIONS

We recommend that the basin states and the federal government explore the possibility of replacing the 1922 compact with a federal interstate compact which:

- establishes an interstate compact commission, perhaps modeled after that now in place in the Delaware River Basin;
- provides that this commission be served by a technical staff, either within the present Bureau of Reclamation or apart from it, whose mission should be to conduct technical studies for the commission aimed at discovering common interest solutions to drought and other water management problems;
- establishes an advisory committee to the commission composed of representatives of all major water user groups, including agricultural, industrial, and municipal water consumers, hydroelectric power interests, environmental organizations, recreational users, and, last but certainly not least, Indian tribes;
- mandates consideration of meeting nonconsumptive water demands and uses on a no less urgent and important basis than that of serving consumptive uses;
- establishes long-term allocations of Colorado River water in proportion to current demands, rather than to 1922 allocations;
- provides for proportional sharing of short-term (drought) shortages, much as does the current upper basin compact;
- is empowered to encourage and facilitate interstate water banking and marketing; and
- is authorized to conduct joint explorations with Mexican entities of possibilities for restoring and maintaining the estuarine ecosystem of the Gulf of California (Sea of Cortez). Equitable cost sharing provisions should be an important part of such an innovation.

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