River Basin Indicators: a Framework for Evaluation in the Rio Grande

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Purpose and Objectives

The American West has been the front line of river basin management challenges for more than one hundred and fifty years. Many of the world's water policy challenges and responses originated in the West, including the need to develop innovations in water law, establishment of interstate water-sharing agreements, and the search for measures to settle and develop river basin economies in dry and isolated places. These challenges facing the West continue today, with debates focusing on policy responses to climate change, measures to meet the needs of endangered species, and growing demands for a scarce resource resulting from unprecedented regional population growth. This paper aims to provide economists and other water policy practitioners with insights into measures of effectiveness for designing and evaluating river basin management programs.

River basin management is emerging in the American West and elsewhere as a focus for natural resources management (White 1997; Chave 2001; Howe 2005). The thrust is on collaborative decision-making (Michaels 2001; Sabatier et al. 2005), promoting best practices (World Bank 2006), strengthening decision-making (Hooper 2005) and international agreements for basin collaboration (e.g., the United Nations Convention on the 'Law of the Non-Navigational Uses of International Water Courses' and the European Water Framework Directive). There are growing calls for a national dialogue and interagency coordination in the United States and elsewhere to establish, facilitate and maintain basin management (Loucks 2003; American Water Resources Association 2005; Vigmostad et al. 2005; Howe 2005; Jacobs 2005).

Despite these advances, there has been limited development of evaluation frameworks of river basin governance, especially in basins experiencing critical water shortages. This paper seeks to begin addressing this gap. The aims of this paper are twofold: (1) to develop a framework for identifying potential performance indicators that reflect the key governance aspects of effective water allocation in drought prone basins, and (2) to describe an application of the performance indicators to the Rio Grande Basin of North America, a basin currently experiencing its seventh consecutive year of drought.

Development

Key Performance Indicators

The framework described in this paper was developed from the results of an international review of experiences of practitioners, consultants, basin managers, aid agencies, and water resources managers. This review was conducted as part of a separate project reported in detail by Hooper (2006). The sources of these data were an extensive review of the literature for the period 1970 to present; a review of experiences of practitioners, consultants, basin managers and water resources managers in the field; a review of previous experiences in developing evaluation frameworks for

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Australian catchment management; lessons learned from large scale restoration projects in North America; structured and unstructured discussions with UNESCO Hydrology for Environment, Life and Policy program staff; and comments solicited from independent basin management experts and U.S. Army Corps of Engineers staff.

The review revealed 115 indicators of best practice integrated river basin management. The majority of the indicators emanate from studies and experiences that cite successful implementation methods to improve governance at the basin level. The basin management performance indicators described in Table 1 are a selection of those derived from this review and were chosen because of their relevance to water allocation, water use efficiency, mission accomplishment, conflict resolution and social welfare. These form key performance indicators (KPIs) of basin governance. The intention is that these indicators form the basis of effective natural resources management in U.S. river basins where there is an emerging crisis due to water shortages and potential overuse.

Table 1. Key performance indicators of integrated, adaptive basin governance for water allocation decisions in basins of hydrological uncertainty.

Benchmark Criteria	Indicator Implementations
1. Coordinated, adaptive decision-making	1. Decision-making is consensual and coordinates across sectors in the basin 2. Decision-making optimizes water use amongst competing demands and allocations are realized according to real-time information about resource availability 3. Roles and responsibilities of stakeholders in decision-making are specified and understood 4. Decisions are reviewed and improvements made when new information becomes available
2. Reduction in water allocation conflicts	5. Public involvement processes are effective: provide for joint decision-making and conflicts are resolved
3. Achievement of mission goals	6. Objectives are specified and achieved through feasible options in a river basin management plan
4. Functioning information management system	7. The information management system reports on condition and trend in basin water resources
5. Water use efficiency	8. Evidence that water use has produced higher returns from less water
6. Stakeholder welfare	9. Evidence of improved well-being among basin residents resulting from water allocation decisions

Source: Adapted from Hooper (2006)

The first group of indicators (1 to 4, benchmark 1) refers to the ability of the basin's social decision system to coordinate between sectors to achieve societal goals through a consensus-based approach to decision-making. The sectors include agriculture, industry, environmental requirements, and domestic and recreation users.

Decision-making is frequently conflict-laden and the decision system can be aided by optimization procedures, using real-time information. This process requires transparency, accountability, and specificity about the roles and responsibilities of each stakeholder group. The challenge for the social decision system is to be able to respond to new information which emanates from many sources (such as the impacts of natural catastrophes (drought), new legislation, political pressures, demands from pressure groups, and technological improvements in water use and the capture and provision of resource information). The ability of the social decision system to achieve this is a hallmark of its adaptability. Mature organizations are characterized by their adaptability, quickly responding to new information and making more effective decisions in the face of new knowledge (Comfort 1999; Hooper 2005).

The ability of the social decision system to resolve conflicts is a second benchmark. This is characterized by an effective, workable public involvement program which facilitates dialogue and consensus. The prime outcome of the social decision system in the basin is the third benchmark: its ability to achieve mission goals. These are important as they address the primary goals of water use and conservation in the basin; mission goals provide leadership direction in addressing common concerns.

The function of an information management system is a fourth benchmark and is important as it supplies knowledge to the social decision system and improves its ability to be a learning, adaptive organization; information needs to be accessible, appropriate to the setting and updated. The fifth benchmark is an efficiency measure: evidence that the social decision system has generated land and water use practices that produce higher economic returns per unit water volume. The sixth benchmark refers to improvements in the social welfare of the basin community which can be directly related to improvements in the water allocation decision system. This benchmark is challenged by the way water allocation decisions can produce both negative and positive welfare outcomes, i.e., winners and losers in prior appropriated systems. So care is needed to develop an indicator which can capture the types and the degree of impacts of well-being in the basin community.

Data Sources – User Preferences

Much of the data needed to measure the indicators can be assembled from secondary sources, including published reports of river basin organizations and performance reviews of water resources systems. However, these data are often scarce, especially where there is no formal river basin organization and/or in basins where most of the water sharing arrangements are based on informal practices or formal rules such as a river basin compact that spells out the sharing mechanism for water resources.

Data on water user preferences have considerable potential to measure the effectiveness of each of the table's governance indicators. User preferences indicate the degree to which stakeholders in a water allocation decision system are satisfied with the performance of the decision system's process and/or its outcomes. User preferences are a valuable tool in public involvement and have been used to inform natural resources policy in many settings (Priscoli and Homenuck 1986; Saleth and Dinar 2004). These preferences, the human judgments regarding the current state of a basin compared to where it should be, reveal what stakeholders want in comparison to the current status of the economic, social and biophysical environments. This distinction raises the question: What kind of correlation is there between human and nature-centered indicators? Will enacting basin management policies based on one also produce high marks (low marks) on the other? Short term political decisions typically ignore ecological values, and ecological criteria are often politically unacceptable. We separate changes in the biophysical and economic condition of the river basin, called state of the environment reporting, from the performance assessment of basin governance.

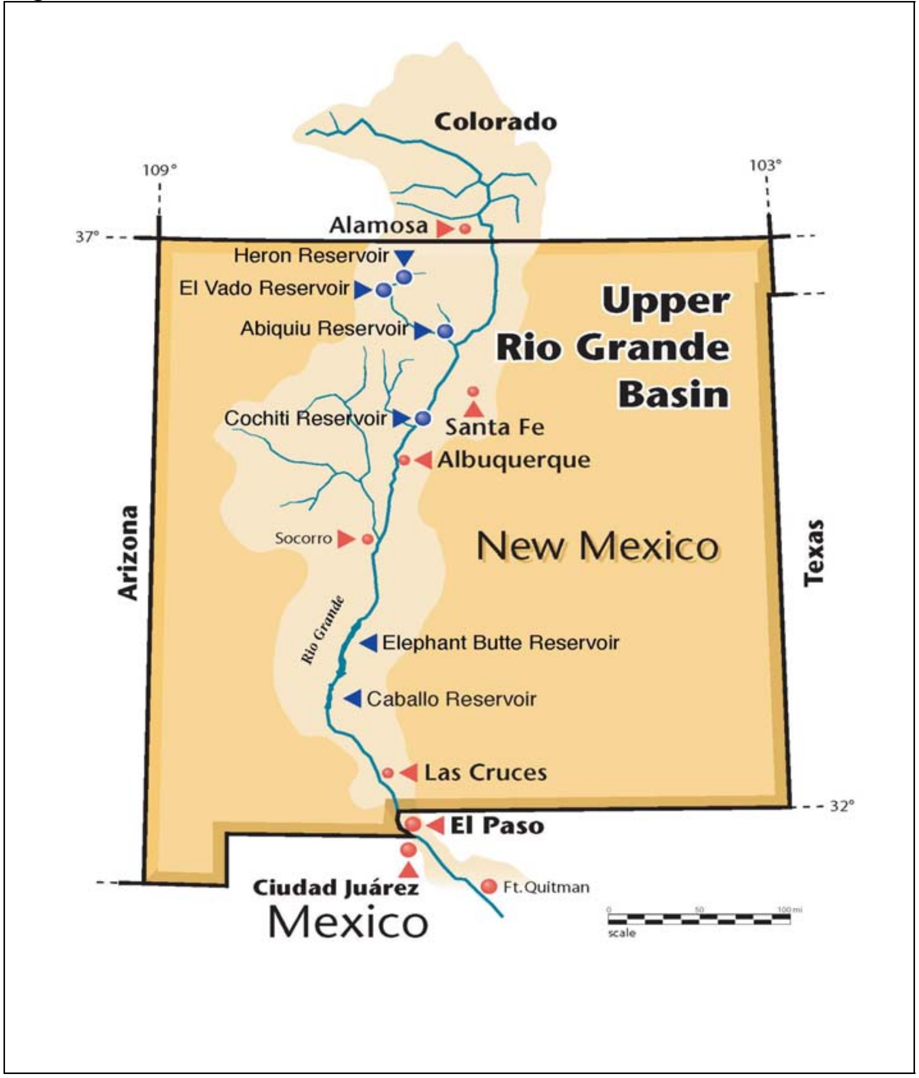
To address these issues, one method for developing a human preference based set of basin governance indicators is described. We apply that framework to a basin for which we describe a method to evaluate effectiveness of an adaptive, integrated approach. That performance evaluation is based on stakeholder preferences for basin performance indicators as well as their preferences for the basin's system for implementing management decisions.

Application to the Rio Grande Basin

In the Rio Grande Basin, water is over-appropriated, and demand for water grows while supplies of acceptable quality are constrained by drought and climate change. The basin consists of 615,100 km^2 and extends over three states (Colorado, New Mexico, and Texas) and northern Mexico (Figure 1). It is currently in its seventh year of drought, and reservoirs are at historically low levels. Continuing through

2006, agricultural and municipal river diversions have been sharply curtailed; low flows threaten endangered species. A central policy challenge is the design and implementation of plans that efficiently and fairly allocate the basin's water supplies. One special challenge is the derivation and measurement of aggregate indicators of stakeholder welfare associated with drought and with various measures for coping with drought. This challenge points to the importance of linking basin preference patterns by individual stakeholders to overall basin indicators that could function as measures for successes and failures.

Figure 1. Location of the Rio Grande Basin in the southwestern United States.



The challenge presented by the benchmarks in Table 1 is to apply them to a river basin operating under a well-enforced trans-boundary water-sharing compact, namely the Rio Grande Compact. Interstate compacts present a unique scenario in U.S. water and international water management. They operate under tight rules of engagement among each involved state, in which the rules are enforced by the federal government. While each compact has unique features, each compact specifies roles and responsibilities of the affected states as well as specifying water sharing arrangements. Hence, understanding the effectiveness of a compact will provide important insight into water resources management among participating players. Furthermore, knowing stakeholder preferences for water resources management in a compact-run basin may influence how the river management options stated in a compact can be managed to become more congruent with changing basin stakeholder preferences.

The 1938 Rio Grande Compact between Colorado, New Mexico and Texas was ratified by all three states and by the U.S. Congress. It is the most important institution for interstate water allocation in the Upper Basin, the area shown in the map. The Compact provides that a set percentage of changing river flow is allocated to each state, essentially maintaining water allocations among the three states that existed prior to 1929. The foundation of the Compact is a set of supply indices specifying the proportion of inflows from one state delivered to the downstream state. For example, Colorado may use varying percentages of its total runoff measured at the Del Norte, Colorado stream gauge, from 40% at high flows to 80% at low flows (Booker et al. 2005).

The achievement of the benchmarks described in Table 1 suggests a small number of critical factors determine basin management effectiveness (Saleth and Dinar 2004). The benchmarks shown in Table 1 are the key performance indicators. The indicator pattern that can be assembled from values assigned to each of these benchmarks is the aggregation of group preferences regarding the basin's performance. The development of the indicator pattern is the first task of a proposed study based on this paper. We therefore propose to identify the dimensions of stakeholder preferences for:
(1) The effectiveness of the nine governance indicators in Table 1, and (2) The efficacy of different water resources management options in the basin under the Compact.

The first task will be developed using preferences generated in stakeholder workshops where they identify what have been the best elements of each of these nine items. Stakeholders will be asked to identify and agree to common measures of collaborative decision-making, conflict resolution, mission achievement, information use, water use efficiency and welfare. Knowing these measures, it will then be possible to develop and use a rating scheme in which the stakeholders provide their evaluation of how the social system has performed for each measure.

The second task is achieved using stakeholder preference scores for policy options summarized by the development of a basin-wide optimization tool to maximize water-related benefits in a river basin (Booker and Young 1990; Ward and Lynch 1996). Recent work (Booker et al. 2005; Ward et al. 2006) developed and applied a basin-wide optimization model to the Rio Grande basin and showed how total system benefits can be increased over historical benefits. This increase in system benefits can be achieved by exploiting complementarities between agriculture, municipal and industrial uses, recreation uses and instream flow requirements for endangered species.

The performance indicators selected for this paper include a range of total basin-wide stakeholder preferences for economic, social and ecosystem benefits. Total economic benefits are commonly measured in dry regions for judging the success of a basin's water allocation decisions. Total economic benefit, sometimes referred to as the economic efficiency objective, presents the advantage of being a metric of considerable importance and interest in policy debates. It has the disadvantages of ignoring the distribution of those benefits as well as ignoring many important non-economic social goals. The particular policy proposal for which economic benefits in the Rio Grande Basin are judged for this paper is a proposal in which additional carryover storage at the Elephant Butte Reservoir is established for use in dry years.

Under the current method of operating the river (Law of the River), the scheduled full release for the Rio Grande Project on U.S. lands downstream of Elephant Butte Reservoir (see map) is 790,000 acre-feet per year. However actual historical releases to these lands fall considerably with reduced water available in Rio Grande Project storage at the reservoir. These releases are shared by three U.S. users: Elephant Butte Irrigation District agricultural users in New Mexico, El Paso area municipal and industrial (M&I) users, and El Paso area irrigated agriculture (Table 2). While not explicitly stated in the Rio Grande Compact, the method of sharing this water allocates 57% to New Mexico lands and 43% to Texas lands, based on proportions of historically irrigated acreage.

Table 2. Long-run average annual drought damage mitigation from alternative institution, by state, location, and user ($1000s).

Alternative Institution: **Carryover Storage--Reduce Elephant Butte Releases in Full Years by 25,000 Acre-feet Per Year for Use in Drought**

Drought Scenario: **1942-1985 Historical Inflows (1.40 million acre-feet per year**

	Colorado	**New Mexico**				**Texas**	
	San Luis Valley Ag	MRGCD Ag above Albuq.	Albuq. M&I	MRGCD Ag below Albuq.	EBID Ag	El Paso M&I	El Paso area Ag
	($1000s per year)						
Average annual economic drought damage mitigated	0	(112)	(18)	(35)	(35)	(425)	(8)
Average annual recreation drought damage mitigation, summed over 5 Basin reservoirs: Heron, El Vado, Abiquiu, Cochiti, Elephant Butte	84						
Average annual economic drought damage mitigation totaled by state	0	(200)				(433)	

Notes: Results of the drought damage mitigation are reductions in economic losses, expressed as positive numbers. Negative numbers are in parentheses, which mean that the mitigation is negative. A negative mitigation means that total economic benefits for that user are lower with the carryover storage institution than with the baseline Law of the River.

The institutional change considered for this policy analysis would reduce the historical release by 25,000 acre-feet per year, using the concept of a savings account. Current water release is reduced with the intent of putting additional water in the project storage savings account. The effect of increasing storage by 25,000 acre-feet in wetter years is to make more water available for use in drought years, when project storage would have otherwise fallen to critically low levels had the stored water summed over previous years been unavailable.

This proposed carryover storage would slightly reduce water use in full years, when its economic value at the margin is small, leaving the saved water instead in Elephant Butte Reservoir. In dry years this accumulated saved water would be available for beneficial use, when its economic value at the margin is higher because of its considerably greater scarcity. However, unlike ordinary bank accounts, Elephant Butte Reservoir pays negative interest in the form of nearly 10 feet of evaporation per year. So reducing wet year releases by 25,000 acre-feet per year contributes to less than 25,000 acre-feet available for future use, since a small amount of it will evaporate.

Table 2 shows the impact on long-run average annual economic drought damages brought about by the carryover storage management institution for coping with drought, described above. Additional details on the motivation for and measurement of these benefits at the basin scale are in Booker et al. (2005). The economic damage gained or lost is the basin indicator metric used for this analysis. However, we propose to identify non-economic benefits, articulated as user preference scores, and incorporate them in the model too.

Policy Implications

Results of the basin-wide optimization model described above integrate economics, hydrology, and institutions at the basin scale. The model provides a powerful tool to identify integrated river basin management options and to inform national and regional water policy debates. Varying scenarios can be created and after the model is developed it can be run to identify different benchmark conditions. This can be used to characterize a landscape of preference scores. A short list of potential criteria include: (1) maximum support (e.g., maximum 'yes' votes), (2) maximum economic benefits subject to hydrologic and institutional constraints as summarized in Table 2, (3) maximum ecological performance, (4) maximum recreation benefits, (5) maximum municipal benefits, and (6) minimum dissent (fewest 'no' votes). When tested over a range of sites and with known hydrological data, institutional constraints, and economic values of water, various drought-coping policy measures can be identified and the above basin indicators can be applied, which flag where effort can produce the most socially-preferred drought-coping measures.

Results of the modeling exercise whose results are described above are based on a basin-wide economic benefits optimization model. However, other approaches to improving the basin's governance can be imagined, including a survey of stakeholder preferences. Results of any systematic common denominator evaluation of the performance of a basin's governance can be interpreted as a number of new governance indicators, or replications of the proposed indicators shown in Table 1. That is, the results can then be compared and contrasted with the stakeholder preferences scores for the KPIs, which allows for modification of the KPI criteria to represent preferred governance achievements.

One benchmark for water resources management is how the total social performance of existing or proposed water use patterns can be maximized across competing interests, and among stakeholders with different values. An important question is whether or not different water allocation scenarios can be developed which reflect this maximum social efficiency of use and how effectively the decision system of the basin and its stakeholders have adopted these optimal solutions. High adoption rates, based on practices developed by measurable and testable economic analysis, are an important step to verifying good governance in a basin, which would be recognized as having higher governance indicator values. The successful application of modeling results to difficult and challenging water conflicts increases the likelihood of implementing programs indicated by the modeling exercise as producing success. Additional activity can productively identify the range of intended adoption behaviors of resource managers, agencies and other water stakeholders, both with and without the existing rules, such as those specified by the Rio Grande Compact. An important activity is to identify the actual and predicted behaviors of individuals, organizations, and water users with respect to specific policy options considered.

This research offers a diagnostic on the problem of river basin management in a specific setting: testing performance indicators which have been identified, refined and applied, based on stakeholder preferences towards an existing or proposed institution. Our example evaluates the effectiveness of the Rio Grande Compact by tracing through the implications of altering its water allocation rules.

Conclusions

This paper describes a method by which stakeholder preferences can be incorporated into a basin-scale modeling system which determines a range of scenarios for managing drought, and compared the modeling results with stakeholder preferences for nine indicators. This work in progress will require considerable testing, experimentation, and implementation. When tested over different sites and with known hydrological data, institutional constraints, and economic values of water, various drought-coping policy measures could be identified and basin indicators could be developed which flag where effort can produce the most socially-preferred drought-coping measures. Success in the development of these basin indicators based on stakeholder preferences will provide water policy makers with a useful resource to inform decision-making. Development of this information is important in managing the impacts of drought, where water supply and institutional constraints increase pressures to find workable solutions to manage a scarce resource.

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