

CHAPTER 4 -- RESULTS

Analysis of Institutional Adequacy for Drought Response in the Rio Grande Basin

Summary

Existing institutions for managing water supply have considerable room for improvement in reducing economic damages from severe and sustained drought in the Rio Grande Basin. Multi-disciplinary data development teams, such as used for this study, have great potential in being used to develop common databases for understanding river systems by basin. Examples are presented for what has occurred in another major river systems in the southeastern United States and shows how that approach has evolved through decision support methods like computer generated models that reflect the operations of the river systems. The detailed operation of the Rio Grande Compact and how it serves as a regional water allocation mechanism is described. Next, this section explains how this study is the first step in developing a river operations and policy evaluation model that could serve in the Rio Grande Basin. Finally, it sets out the components of such a model and concludes that this study and the economic analysis conducted could serve as a first step toward the development of such a complex river operations and policy evaluation model.

Background

On virtually all of New Mexico's stream systems, water utilization is nearing or has reached physical limits. Water resources conflicts are increasing accordingly and, most often, where waters cross or define political boundaries. Thus, inter-jurisdictional water disputes are a possibility facing every county, independent water district, town, city, tribal reservation, government agency, and state in the country. Today those conflicts also include conflicts between environmental groups and agencies promoting those agendas and traditional water users.

Need for New Water Management Approaches in the Rio Grande Basin

For most of the 20th century, water issues revolved around development of reservoir and diversion projects. In the last thirty years, the spectrum of demand for water has broadened dramatically: the needs of cities have grown faster than the ability to serve them, while water pollution and wildlife and river protection have become serious public concerns. Reduced slack in the system has reduced the range of workable choices available to water managers. A season's drought, a new flow regulation, a jump on the population chart, may trigger a full-fledged public controversy or a multi-party lawsuit over water rights, water regulations, or water allocation.

Many water management institutions are poorly suited to address today's complex, high-risk, high-consequence water conflicts. The legislation establishing government institutions with management authority lack the scope and resources to arbitrate competing water claims that go beyond traditional water rights and, often, are active claimants themselves on behalf of particular constituencies or traditional principles of water law. Water markets, while serving to allow water to move to higher valued economic uses, are criticized as insensitive to the external costs of water delivery and consumption and, therefore, unsuitable to the task of comprehensively resolving the issues. The courts often fare no better. The costs of lawyers and the litigation process have become prohibitive.

As we enter the next century of water management, there is a tremendous need for mechanisms that address these conflicts that can reach resolution and do so with at a minimum: 1) impartiality; 2) early intervention to diffuse tensions; 3) development of multi-disciplinary technical-support teams; and finally, 4) a fact-driven consensus process through which local water users) develop a common data set and indices of desired future conditions, negotiate compatible objectives, reach a provisional agreement, and establish mechanisms for continuing cooperation.

Scarcity uncovers latent discord. When water budgets tighten, users and values that are compatible in times of abundance realize a capacity for opposition. The following are specific examples.

Historic vs. New Water Uses – Value in Tradition vs. Economic Value

In economic terms, new water uses may have greater value than historical water uses. That is, the ratio of monetary value produced/unit of water consumed tends to be higher in new water uses (urban domestic, recreation, light industry such as semi-conductor production) than in most historical uses (agriculture, ranching, transportation, and heavy industry). At the same time, our society respects traditional uses of water and does not allow the market alone to determine how it will be distributed. Reduced water supplies bring to the surface the tension between these two values.

Material Standards of Living vs. Sustainable Quality of Life

Urban vitality depends on a continuing expansion of municipal revenues, fed by ever-improving standards of living. Cities with large tax bases can offer residents dependable infrastructure and services, well-equipped schools, and many other amenities. These benefits give residents reason to stay and attract new ones, including corporations bringing high-salaried jobs.

The desirable results of expanding cities are not guaranteed indefinitely, however. There are points of diminishing returns. Water availability is such a milestone, a physical constraint on municipal growth. Water quality is another. Prosperity at the cost of degraded ground and surface waters eventually will unravel. Such prospects raise questions of inter-generational equity. That is, when multiple water needs push hard enough against one another, and cannot all be satisfied, water consumers may end up choosing—for their children, if not for themselves—between economic security and a high quality of life.

Needs of Human Species vs. Needs of Other Species

No living thing survives long without water. River basins were home to wildlife and flora before they were to people. Water quantities needed by these other life forms vary widely and differ from our own requirements. Whose needs should come first? In dry places, when spring runoff is stored for planting-schedule releases, a river's flow can be slowed to a trickle. Such practices, like dumping wastes

in a channel, reduce the survival odds of riverine ecosystems and, in the short-term at least, decimate them. Aside from questions of their irreplaceable contributions to their ecosystems, plant and animal communities claim water resources. It has become increasingly clear that these claims are important matters for people to decide.

Streams as Aquatic Systems vs. Utilitarian Plumbing and Power Systems

Dams and other waterworks accentuate the role of streams in storing and delivering water and generating power. In addition to these engineered functions, however, hydrosystems have other values, some of which require noninterference with their natural behavior. For example, aesthetic appreciation of rivers and lakes—hearing water splash rocks or lap the keel of a boat, seeing light and shadow play on a still pool, being cooled by a breeze across an undisturbed stream surface--may clash with their more utilitarian purposes.

All surface and groundwaters are part of a relatively discrete hydrologic system. For purposes of water management, however, stream systems are often subdivided not by hydrologic units, but by political units. That is, water management superimposes on hydrologic systems another policy system. And, in perfect twenty-twenty hindsight, we would have devised regulator streams that integrated issues of conjunctive use of ground and surface water, anticipated new federal regulatory rights in water under laws such as the Clean Water Act and the Endangered Species Act. Of course that did not happen and we now face the consequences of these growing tensions among demands.

Types of Disputes in New Mexico

Interstate

Incompatible claims in inter-state rivers, lakes, and groundwater aquifers. Incompatibility may derive from mutually exclusive time of use (use now v. store for later release), type of use (consumptive v. non-consumptive), place of use (use upstream v. use downstream), or an interaction of all three variables. No better example of this kind of conflict exists than on the Rio Grande System.

Interagency

Missions, jurisdictions, and corresponding water demands of various government agencies may overlap. The resulting tensions may strain relationships within or among federal, state, tribal, municipal, or county offices. The demands for better water quality by the Isletas and the conflicts between the New Mexico Department of Fish and Game, the United States Fish and Wildlife Service, and the Office of the State Engineer provide good examples.

Federal/Tribal-State

Many state and local governments regard federal water rights (reserved and non-reserved, tribal and public land), which for the most part are unadjudicated, as limiting their own property rights in water. Issues between the non-Indian water users and the Navajo Nation provide an excellent example of this type of dispute.

Federal/State-Tribal

Tribal interests in on-reservation water use or in off-reservation water leasing may conflict with federal laws, reserved rights, or other priorities or with state water claims. Certainly, the Jicarillas and the long-term needs and goals of the Rio Grande Pueblos fall into this category.

Groundwater-Surface Water Conflicts

These conflicts are a final example of the inability of our institutions and laws to keep pace with the reality of man-created scarcity in aquifers hydraulically connected to surface waters.

Sorting out policies and science related to stream-related aquifers presents a particularly difficult issue. While all would agree that the need to conjunctively regulate ground and surface water together is evident—what this means in terms of policy and science is far from clear. For example, the State Engineer has recently drafted proposed guidelines for the Middle Rio Grande Basin. Some strenuously

press to have all existing permits modified retroactively to reflect the new and "correct" knowledge of the aquifer. While retroactive application may appear to be a logical result, it is premised upon the assumption that we in fact have the final answer. In truth, the science of hydrology continues to evolve and is held back by the lack of underlying factual data to place into the models we have developed.

There is no issue more complex and more important to the residents of New Mexico and of the middle Rio Grande valley than understanding the hydraulic connection between the groundwater pumping in the region and the flows of the Rio Grande. Fortunately, New Mexico water law has made New Mexico a pioneer in this area.

In the 1950s, then State Engineer Steve Reynolds took the position, at the time unheard of in water law, that because of the hydraulic connection between the ground and the surface water, all new wells drilled by the City of Albuquerque must ensure that the total of water withdrawn from them did not deplete the flows of the Rio Grande. This meant simply that the well owner would have to do two things. First, calculate the amount of water that would come from the river by way of the well when the well was pumping at capacity and second, make sure that sufficient surface water use was retired from the river so that the new wells did not deplete the river's flow.

This was essential for three basic reasons. First, the Rio Grande Compact commits an amount of water to our downstream users in Texas and Southern New Mexico. Second, senior Pueblo water users rely on its flows. Third, senior non-Indian irrigators who use surface water are protected by the prior appropriation doctrine. These facts still prevail and for many years, the amount of protection to be provided the river from groundwater pumping has been calculated by a conservative mathematical method called the Glover-Balmer calculation.

The State Engineer has recently proposed adoption of a numerical model utilizing sophisticated computer techniques that further refine our understanding of the hydraulic connection between the pumping of wells and the river. This new model, generated by Teideman and others (U.S. Geological

Survey) in 1998 has been modified by Barroll, of the office of the State Engineer in 1999 and is contained in the draft guidelines for review of water rights applications in the Middle Rio Grande Administrative Area.

Out of a sense of caution and in an exercise of conservative management, the State Engineer, for an interim period of five years, has tentatively chosen to not apply the new model retroactively. He is apparently not presently willing to relieve all existing well pumpers of their obligation to protect the river as calculated by the original method. This decision has raised concerns from the City of Albuquerque.

This is plainly an area where agreement on this risks of error associated with different data bases and methodologies could be helpful. The State Engineer would no doubt argue, that computer model results are not facts; they predict outcomes which may or may not ultimately be consistent with what occurs in the future. While some models are better than others, a change in input either as to the properties of the soils or sediments in the ground where the well is located or a change in the assumptions as to the velocity with which water moves through these soils can result in widely varying predictions. For example, as recently as 1995, Kernodle and others (1995), predicted that pumped wells would have between 44% and 66% of their water pumped from the river by the year 2020. Teideman and others (1998) model suggested there would be a 90% long-term impact, while the proposed Barroll modifications suggest around 75%. Thus, while all would agree that the revised numerical models are superior, they will continue to be refined and improved, and there is no final truth that has been learned from these models.

The State Engineer would also argue that any responsible administrator should have a safety factor built into all decisions. We now see through hindsight that Steve Reynolds was not so far wrong in applying the Glover-Balmer method since it probably results in a retirement requirement about 20% more conservative than the new Barroll model. Stated more simply, it may be prudent to ensure that in

providing protection to the river, at least for the next five years while the matter is still under study, to err on the side of river protection by retaining a method that preserves the possibility of a 20 % margin of error. If there is error to be made, then it should probably be made on the side of protecting river flows rather than development of municipal and industrial water supply from wells.

Finally, there are practical reasons for not modifying all existing permits in place. All of those permits were granted only after notice and hearing to the public. If those permits are to be modified, recent law suggests they would have to be modified only after the public at large contributes. The administrative costs and the risks to those permits would seem to far outweigh any considerations to the contrary.

Wells, once pumped, may deplete the aquifer adjacent to the river and depending upon their distance from the river, create debts the river pays back over periods of thirty to fifty years. While one would wish to avoid allowing model errors to make that debt any larger than it should be, one should not be optimistic about relieving that debt while allowing pumping to continue.

The City would argue, just as strongly, that once a superior model is developed for calculating well impacts, we should use it immediately and that the risks of uncertainty are outweighed by the added water made possible by the new model calculations.

The Use of Multi-Disciplinary Technical Teams

The immediate result of uncertainty is distrust and from this distrust comes conflict. The remainder of this section describes a method of looking beyond conventional boundaries for water management in the 21st century built around development of common data sets first, and conflict resolution second. Such a system should include the following parameters: in the current climate of water scarcity, new agreements for the common use of transboundary streams are best constructed under the following conditions:

- a. Participants in the common data collection process represent all stakeholder groups.
- b. Fact-finding and technical modeling and negotiation is assisted by impartial expert outsiders.
- c. The planning process advances from step to step by consensus.
- d. Hydrological modeling is based on the most complete and accurate hydrologic record available
- e. Legal, ecological, economic, and cultural implications of agreement provisions are fully explored.
- f. Long-term hydrologic scenarios are precisely and variously modeled and validated.
- g. Agreement provisions anticipate and adjust to many and diverse contingencies.

Hydrologic modeling is based on the most complete and accurate hydrologic record available. Critical to this process if it is to work is impartiality. Parties anticipating conflict over rivers, groundwater basins, or other shared resources will need impartial technical assistance in understanding the various kinds of issues involved in jointly planning a basin management strategy and implementing a related agreement. Predictably, this work will engage hydrological, ecological, economic, cultural, social, political, and legal issues. This multi-disciplinary team will be charged to complete the following tasks:

Construction of a Common Data Set

Compile and assess the most complete and accurate records available and, as necessary, collect new information, to arrive at a common data set concerning water supplies and water demands throughout the drainage basin.

Among other records, the common data set will include information such as the following:

- a. hydrologic data: historical base flow in the watershed, relative contributions to the watershed's annual yield from rainfall and from tributary and groundwater inflow, and relative amounts and locations of annual diminution of water quality due to pollution.
- b. climate and weather data: seasonal temperatures, precipitation averages, evaporation rates
- c. formally permitted water rights: quantities of permitted water rights for diversionary and instream uses for all ground and surface sources
- d. tribal water rights claimed but not permitted by the state engineer
- e. seasonal or annual quantities of use in each type of use
- f. continuing scheduled water delivery obligations: compact and treaty responsibilities, reservoir holding and release agreements
- g. demographic statistics: basin area population, growth projections, and associated water-use information
- h. measures of ecological resilience: in the watershed and general stream health

Build, Test, and Calibrate a Hydrologic Model of the Water System

Using as a base one of the industry standard hydrologic models such as HEC V, construct a model of the clients' drainage basin that takes account of tributaries and distributaries as well as requisite in-stream flow, and, of course, all withdrawals for municipal, industrial, agricultural, and riparian uses.

Model Water Quantity - Water Quality Conditions to Achieve or Avoid

Using the common data set, model flow rates and annual yield, at selected seasons and locations in the basin, under various water-use scenarios. For example, produce wet- and dry-year hydrographs for

various stream reaches of particular interest. Or, explore and combine future possibilities involving increases and decreases in agricultural water demand, municipal and industrial water use, stream health, water-centered recreational activities, navigation, and wildlife habitat.

Run the model as many times and in as many ways as necessary to answer clients' questions.

Negotiate Tough Issues

In view of the constraints identified through exhaustive data collection and repeated modeling, thoroughly explore and weigh:

- a. values in water as expressed by the clients' constituents,
- b. related short- and long-term situations each client group wishes to achieve or avoid, and
- c. legal factors affecting any water-management or water-sharing agreement by the clients.

The discussions and exercises immediately above, together with the previous, modeling steps, will have provided insights into water-use tradeoffs between, for example, river health in certain reaches and specific economic development possibilities. Thus, although the choices to be made will be no easier than they would have been without the steps described above, participants will make those choices with a clearer understanding of the likely consequences. Moreover, having taken pains to cooperatively construct knowledge about their shared water systems, the participants will have had numerous opportunities and every reason to acquire mutual understanding of each other's values and water needs and, in turn, to develop the mutual respect that is the hallmark of sustainable agreements.

Once negotiation results have been finalized and agreed upon they should be integrated into a memorandum of agreement containing monitoring and oversight responsibilities, routine updating of the database, regular meetings of an executive group chosen by the participants, and any other mechanisms needed to ensure continuing cooperation.

The agreement should provide all basin stakeholders with desk-top access to the common data base and the watershed- modeling software as well as simple instructions about how to use these materials to better appreciate the sources and uses of their common waters.²¹

Use of Multi-disciplinary Teams and Modeling – the Georgia Experience

An example of where this multi-disciplinary team approach has had some success is in the Apalachicola-Chattahooche-Flint (ACF) river basin in the south eastern United States.

The ACF basin originates in north Georgia and Alabama and terminates in Florida in Apalachia Bay. It extends a distance of approximately 385 miles and encompasses an area of 19,600 square miles. The drainage area is comprised of the Apalachicola, Chattahoochee, and Flint Rivers and their tributaries. During the last 160 years, the water resources in the basin have been developed to meet various demands for municipal and industrial water supply, flood control, hydropower, navigation, fish and wildlife conservation, recreation, and agricultural water supply. There are hundreds of reservoirs in the basin, but 16 (5 Federal and 11 non-Federal) are located on these three principal rivers. They provide for regional uses of the basin water resources for navigation, hydropower, flood control, water supply, recreation, and fish and wildlife.

Rapid growth in the metropolitan Atlanta area and north Georgia since 1950 has caused large increases in water demands. As a result, the US Army Corps of Engineers (Corps) received requests from several local municipalities in the 1980s to reallocate water in its north Georgia reservoirs. Droughts that occurred in 1981, 1986, and 1988 heightened the public's concern and awareness of water management in the basin. In the late 1980s water supply reallocations were being studied by the Corps for Lake Allatoona, Carters Lake, and Lake Lanier. In November 1989, Alabama requested suspension of the reallocations studies pending completion of comprehensive economic and environmental impact

²¹While these resources would be desirable to possess, few if any water conflicts have been resolved with access to such data, software, or instructions on their use.

analyses. In 1990, the Corps completed the Carters Lake report and recommended reallocation of reservoir storage to water supply for the City of Chatsworth, and the State of Georgia submitted plans for a water supply reservoir on the Tallapoosa River. Subsequently, the State of Alabama filed litigation challenging the proposed water reallocation in north Georgia. The states of Alabama, Georgia, and Florida and the Corps met to resolve this conflict outside the legal system. The initial meetings of the states and the Corps led to initiation of the Comprehensive Study of resources in the ACF basin and in the Alabama-Coosa-Tallapoosa River Basin (ACT basin) in 1992.

The Comprehensive Study was undertaken by Alabama, Florida, Georgia, and the Corps for both the ACF and ACT basins, as directed by a memorandum of agreement (MOA) among the three states and the U.S. Department of the Army. The study was consensus based, requiring the approval of all participants on all elements. The purpose of the Comprehensive Study was:

... to determine the capabilities of the Water Resources of the basins, to describe the water resource demands of the basins, and to evaluate alternatives which utilize the Water Resources to benefit all user groups within the basin.

The Comprehensive Study has provided technical understanding of the water resources in both river basins and basin-specific tools to evaluate the water management alternatives. Table 4-1 presents the various elements of the Comprehensive Study that were approved and funded.

Table 4-1. Elements of the ACT/ACF Comprehensive Study			
Process Support Elements	Water Resources Availability	Water Demand Elements	Comprehensive Management Strategy
Population and employment forecasts Database Public involvement	Surface water	Agriculture water demand	Basinwide management
	Groundwater	Environmental water demand Power resources water demand Navigation water demand Recreation water demand Water quality water demand	Coordination mechanism
Source: Comprehensive Water Resources Study Partners, September 1995			

In 1996, Alabama, Florida, and Georgia agreed to develop and implement an interstate water

compact for the ACF basin with the purposes stated above. State negotiations for the compact began in September 1996, with a series of negotiating sessions held through January 1997. On January 13, 1997, each of the states and the Federal government, represented by the Department of Justice, reached agreement on the compact language.

The ACF River Basin Compact was passed by the Georgia legislature in January 1997, by the Alabama legislature in February 1997, and by the Florida legislature in March 1997. In a joint letter dated May 14, 1997, the three governors submitted the ACF Compact to the three States' congressional delegations, which introduced the Compact into Congress on June 27, 1997. On November 7, 1997, Congress passed the Compact and sent the bill to the President, who signed it into law (Public Law [PL] 105 -104) on November 20, 1997.

The Compact creates an interstate administrative agency, the ACF Basin Commission, which is composed of the Governors of Alabama, Florida, and Georgia (who make up the State Commissioners), and a Federal Commissioner appointed by the President of the United States.

The Compact directs the parties to the Compact to:

...develop an allocation formula for equitably apportioning the surface waters of the ACF basin among the States while protecting the water quality, ecology, and biodiversity of the ACF, as provided in the Clean Water Act, 33 U.S. Code (U.S.C.) section 1251 et seq., the Endangered Species Act, 16 U.S.C. Sections 1532 et seq., the National Environmental Policy Act, 42 U.S.C. Sections 4321 et seq., the Rivers and Harbors Act of 1899, 33 U.S.C. Sections 401 et seq., and other applicable federal laws.

After the water allocation formula is developed and unanimously approved by the State Commissioners, it becomes binding:

...upon receipt by the commission of a letter of concurrence with said formula from the Federal Commissioner. If, however, the Federal Commissioner fails to submit a letter of concurrence to the commission within 210 days after the allocation formula is agreed upon by the State Commissioners, the Federal Commissioner shall within 45 days thereafter submit to the ACF Basin Commission a letter of nonconcurrence with the allocation formula setting forth therein specifically and in detail the reasons for nonconcurrence; provided, however, the reasons for nonconcurrence as contained in the

letter of nonconcurrence shall be based solely upon Federal law. The allocation formula shall also become effective and binding upon the parties to this Compact if the Federal Commissioner fail to submit to the ACF Basin Commission a letter of nonconcurrence.

In ratifying the Compact, Congress clarified that:

...the Federal Commissioner may submit a letter of concurrence with the allocation formula adapted by the State Commissioners 255 days after such adoption.

The competition for the river resource includes interests ranging from navigation for barges to water retained upstream for recreation and from consumptive uses from Lake Lanier above Atlanta to minimum flows to sustain the Apalachicola Bay in Florida. Based upon the results of the comprehensive study, a model was constructed that integrated all of these factors by allowing manipulation of various scenarios while holding others constant. Thus, one could include in the model a scenario that limited hydropower and navigation use and honored first delivery of water for municipal and industrial uses. These could also be limited further by allowing river releases to mimic the traditional hydrograph to the greatest degree possible. The flow duration curves attached to this paper demonstrate the results of a such a scenario offered by the State of Georgia in these negotiations. According to Georgia officials, the operation of the model in this manner optimizes both economic and environmental values while diverting water from the lower valued uses such as barge traffic and navigation. At the same time, it closely mimics the traditional hydrograph to address the concerns of environmentalists.

The central point is not whether Georgia is correct. Rather, the point is that all parties are starting with the same baseline—the comprehensive study results and the common model. A disagreement will not be resolved on the accuracy of the data being used, but whether, in fact, the value judgments as to relative value of uses within each state are correct.

The way in which we think today cannot solve the problems we will confront in the future. It may be time to acknowledge that the way we are thinking about resolution of water problems today is no different from how we were thinking about those issues twenty years ago. And, for these and other

reasons, we still have many water problems to solve. A multi-disciplinary technical team approach may provide a first step in addressing these issues that will take us properly into the next century. The following section addresses how this approach can be utilized in the Rio Grande Basin.

The Rio Grande Compact

In a famous article, Ray Hill describes the development of the Rio Grande Compact.²² A little background on Mr. Hill's involvement is useful because it gives some measure of the accuracy of Mr. Hill's article. "Mr. Hill was intimately connected with the investigations that led to the Compact" and with the Compact negotiations.²³ Mr. Hill was asked, on behalf of the Attorney General of Texas, to prepare the report for use in Texas and New Mexico v. Colorado.²⁴ His assignment was to "review the history of the Rio Grande Compact of 1938 and to analyze its provisions for the benefit of those who wish to clarify their understanding of the Compact."²⁵

History

Pre-1938 Compact History. The motivating factor behind the Compact negotiations was the insufficient supply of water in the Rio Grande for irrigation in the three states and Mexico. By 1896, irrigated lands in the San Luis Valley used all of the natural flow of the Rio Grande.²⁶ Increasing diversions from the

²²Raymond A. Hill, *Development of the Rio Grande Compact of 1938*, 14 Nat. Resources J. 163 (1974). Another excellent history of the Rio Grande Compact was conducted by Littlefield (1987).

²³*Id.* at 163

²⁴*Id.* at 163. 386 U.S. 901 (1967), 389 U.S. 1000 (1967), 390 U.S. 933 (1968), 391 U.S. 901 (1968).

²⁵*Id.* at 163.

²⁶*Id.* at 166.

Rio Grande in Colorado and New Mexico caused water shortages in the Mesilla and El Paso valleys beginning in the early 1890s.²⁷ The water shortages quickly led to legal disputes.

The Mexican Government, alleging that the water shortages near Juarez were caused by increasing diversions in Colorado and New Mexico, filed a claim against the United States for damages.²⁸ This dispute between Mexico and the United States was settled by the Treaty of 1906. Under the Treaty, Mexico relinquished all claims for damages.²⁹ In return, the United States guaranteed an annual delivery to Mexico, in perpetuity, of 60,000 acre-feet of water in the Rio Grande.³⁰ The Treaty, however, did not resolve the disputes between Colorado, New Mexico and Texas.

One result of the U.S. Department of State's investigation of the Mexican claim was the "embargo" of 1896.³¹ An order by the Secretary of the Interior suspended all applications for rights-of-way across public lands in Colorado and New Mexico for use of Rio Grande water.³² The order prevented further irrigation development in the Rio Grande Basin in both states by not allowing for storage of water.³³ In Colorado's San Luis Valley, storage was needed not only for further development but also to maintain existing irrigation developments.³⁴ Colorado's attempt to get permission to build reservoirs continued up to the date of Hill's report, 1937. New Mexico and Texas also had problems.

²⁷*Id.* at 165.

²⁸*Id.* at 165.

²⁹*Id.* at 166.

³⁰*Id.* at 166.

³¹*Id.* at 165.

³²*Id.* at 166.

³³*Id.* at 166.

³⁴*Id.* at 166.

The decreased flow in the Rio Grande caused by depletions in the San Juan Valley affected New Mexico and Texas in two ways. First, and most obvious, there was a shortage of water for irrigation.³⁵ Second, the decreased flow resulted in aggradation of the river bed by deposition of sediment that caused the water table to rise under the valley floor.³⁶ Saturation of the land by the rising water table resulted in failure of irrigated acreage.³⁷ Colorado, New Mexico, and Texas decided to negotiate a compact which would provide for the equitable apportionment of the river.

The Compact of 1929 served as a guideline for the Compact of 1938.³⁸ In fact, "many of the provisions in the 1929 Compact were incorporated verbatim or substantially so in the Rio Grande Compact of 1938."³⁹ The basic goal of the 1929 Compact was to maintain the status quo on the river.⁴⁰ But remember, none of the three states was happy with the status quo. Colorado could not increase storage, New Mexico was water-logged, and Texas was water short. The solution to this problem was initiated by President Franklin D. Roosevelt.

Based on information from the National Resources Committee, President Roosevelt concluded that future federal investments in the Rio Grande Basin that promote increased use of water would have several detrimental effects.⁴¹ Because the reliable water supply in the basin had already been completely appropriated, future investments promoting increased use would impair the security of extensive prior investments of Federal funds, violate an interstate compact to which the Federal Government is a party,

³⁵*Id.* at 166.

³⁶*Id.* at 166.

³⁷*Id.* at 166.

³⁸*Id.* at 167.

³⁹*Id.* at 167.

⁴⁰*Id.* at 167.

⁴¹*Id.* at 169

and promote social insecurity.⁴² The President's solution was to require that applications for projects using Rio Grande waters be approved only after getting a thorough opinion from the National Resources Council.⁴³

The National Resources Council proposed a conference with the three states to see if there could be a cooperative effort to gather facts that might be helpful in solving the interstate water problem on the Rio Grande.⁴⁴ The three states agreed and the result was the Rio Grande Joint Investigation. The cooperative effort, including Federal funds and services, was summarized in a massive, five-part report. The report, prepared by the U.S. Geological Survey, the U.S. Bureau of Agricultural Engineering, the U.S. Bureau of Plant Industry, and the U.S. Bureau of Reclamation, provided the scientific/engineering basis for negotiations of the 1938 Compact.⁴⁵ The Rio Grande Joint Investigation was completed in July, 1937 with a final report submitted to the President in December. Negotiations for the 1938 Compact began on September 27, 1937.

The Rio Grande Compact of 1938. The Rio Grande Compact Commissioners signed the final Compact on March 18, 1938. The Compact was designed to provide for the maximum beneficial use of water in the basin of the Rio Grande above Fort Quitman without impairment of any supplies beneficially used under the conditions prevailing in 1929.⁴⁶

The preamble indicates that the Rio Grande Compact was developed by the states of Colorado, New Mexico, and Texas because of their desire to remove all causes of present and future controversy

⁴²*Id.* at 169.

⁴³*Id.* at 169

⁴⁴*Id.* at 169.

⁴⁵*Id.* at 170.

⁴⁶Raymond A. Hill, Development of the Rio Grande Compact of 1938, 14 Natural Resources Journal 163, 198 (1974).

with respect to the use of the waters of the Rio Grande above Fort Quitman, Texas.⁴⁷ Another purpose of the Compact is to effect an equitable apportionment of the waters of the Rio Grande.⁴⁸ The articles in the Compact were agreed to by the three states after negotiations.⁴⁹ The first five articles of the Compact operate without any regard to the amount of water in, or releases from, project storage. Article I provides definitions of terms used in the Compact. Article II describes the maintenance, operation and location of stream gaging stations. Article III establishes Colorado's obligation to deliver water at the Colorado-New Mexico state line. Article IV establishes New Mexico's obligation to deliver water at San Marcial.⁵⁰ Article V requires that the replacement of gaging stations not affect rights or obligations to deliver water.

The next three articles operate based on the releases from, and the amount of water in, project storage. Article VI describes the requirements on the credits and debits of Colorado and New Mexico. Article VII precludes Colorado and New Mexico from increasing water in storage under certain conditions. Article VIII allows Texas to demand that Colorado and New Mexico release of water in storage under certain conditions. These three articles were negotiated and agreed to by Colorado, New Mexico, and Texas, and are discussed in detail below.

None of the remaining nine articles describe any rights or obligations that are conditioned on the amount of water in, or releases from, project storage. In Article IX, Colorado consents to diversion of San Juan into Rio Grande so long as Colorado's uses by other diversions from the San Juan River are protected. The United States, Colorado, and New Mexico are credited for any water they import into the Rio Grande Basin under Article X. In Article XI, New Mexico and Texas agree that all controversies

⁴⁷Preamble, Rio Grande Compact.

⁴⁸Preamble, Rio Grande Compact.

⁴⁹Preamble, Rio Grande Compact.

⁵⁰The 1948 Resolution adopted by the Rio Grande Compact Commission abandoned the San Acacia and San Marcial gaging stations, and replaced them with the Elephant Butte Effective Index Supply.

between them relative to the quantity and quality of the water of the Rio Grande are settled. Article XII establishes the Rio Grande Compact Commission and describes the administration of the Compact by the Commission. Article XIII provides for periodic review of Compact provisions. Article XIV states that the delivery schedules and water quantity allocations will not change by reason of any change in delivery to Mexico. Article XV reflects the states' agreement that none of the provisions in the Rio Grande Compact establishes any principle or precedent applicable to other interstate streams. Article XVI states that nothing in the Compact shall be construed as affecting the obligations of the United States to Mexico under existing treaties, or to Indian tribes or as impairing rights of Indian tribes. Article XVII establishes the effective date of the Compact.

Rio Grande Compact Commission Rules and Regulations. The Rio Grande Compact Commission has adopted rules and regulations for the administration of the compact. Those rules and regulations fall under the following headings: Gaging Stations;⁵¹ Reservoir Capacities;⁵² Actual Spill;⁵³ Departures From Normal Releases;⁵⁴ Evaporation Losses;⁵⁵ Adjustment of Records;⁵⁶ New or Increased

⁵¹The gaging station rules define the responsibility for the operation of the gaging stations.

⁵²The reservoir capacity rule requires that States file the areas and capacities of the reservoirs with the Compact Commission and that the Commission check the accumulation of silt in Elephant Butte Reservoir periodically.

⁵³Defines how water released from Elephant Butte in excess of Project requirements is deemed to be an actual spill.

⁵⁴Does not allow for any difference between actual and hypothetical evaporation in the hypothetical spill computation and deems under-releases of usable water in excess of 150,000 acre-feet as equal to that amount.

⁵⁵Defines evaporation losses.

⁵⁶Requires that records be kept for each gaging and evaporation stations. When the location of stream gaging stations are changed, the change in flow between the locations must be ascertained for all stages.

Depletions;⁵⁷ Transmountain Diversions;⁵⁸ Quality of Water;⁵⁹ Secretary;⁶⁰ Costs;⁶¹ and Meeting of Commission.⁶²

The Goals of the 1938 Compact. The primary goal of the Compact is to divide the waters of the Rio Grande among users in Colorado, New Mexico and Texas.⁶³ A secondary goal is to maximize the beneficial use of water in the Rio Grande Basin above Fort Quitman without impairment of pre-existing uses.⁶⁴ The Compact divides all the waters of the Rio Grande, from its headwaters down to Fort Quitman, among Colorado, New Mexico, and Texas, except for the annual delivery of 60,000 acre-feet guaranteed to Mexico under the 1906 treaty. While this simple description neatly summarizes the general goals of the 1938 Compact, the specific goals of the three signatory states are more interesting and provide a basis for interpreting the provisions of the 1938 Compact as agreed to by the individual commissioners.

Colorado basically felt that there was enough water in the Rio Grande Basin to maintain the status quo of 1929, so long as the water was properly regulated and used.⁶⁵ But Colorado had a problem.

⁵⁷The Commissioner of a state which constructs new works, which may alter the flow at a gaging stations must file all available information to the Commission in order that appropriate adjustments may be made to the delivery schedules.

⁵⁸Water imported into the Rio Grande Basin shall be measured at the point of delivery with allowances made for losses in transit to the index gaging station.

⁵⁹Samples of any water delivered from the Closed Basin into the Rio Grande must be analyzed to determine whether the quality is within Compact limits.

⁶⁰Requires the Commission to employ the U.S. Geological Survey for engineering and clerical aid necessary for the administration of the Compact. The duties of the U.S. Geological Survey are defined.

⁶¹Requires the Commission to adopt a budget each year with the costs allocated equally to the three states.

⁶²Requires the Commission to meet at least annually and states that no action of the Commission shall be effective until approved by each of the three states.

⁶³*Id.* at 167.

⁶⁴*Id.* at 168.

⁶⁵*Id.* at 171.

The works of the Middle Rio Grande Conservancy District and the Rio Grande Project from Elephant Butte to Fort Quitman provided the middle and lower Rio Grande Basin with a relatively constant supply of water, that is, storage of excess water in wet years that could be used later in dry years.⁶⁶ Colorado, as a result of the "embargo," had been denied the right to increase storage and thereby regulate the supply of water to irrigate lands that Colorado had developed prior to the construction of the works in the middle and lower reaches of the Rio Grande Basin. Colorado estimated its losses over the previous 40 years at \$200,000,000.⁶⁷ Colorado's goal was to "construct and operate the reservoirs required in the San Luis section of the Basin to place the water supplies of that section on a parity with the water supply of the Middle and Elephant Butte-Fort Quitman sections of the river."⁶⁸ Colorado maintained that it could increase its storage to a sufficient capacity without adversely affecting water supplies in New Mexico and Texas.⁶⁹

New Mexico was in a unique position by having to negotiate with both an upstream and a downstream state. New Mexico also had the most detailed position. With respect to Colorado, New Mexico would agree to increased storage in the San Luis Valley with two provisos, the first being that the interests of New Mexico users be protected and the second being that the San Juan/Chama diversion be made.⁷⁰ With respect to Texas, New Mexico was willing to negotiate as to the right to use water claimed by Texans under the Elephant Butte Project.⁷¹ With respect to both states, New Mexico had

⁶⁶*Id.* at 171-172

⁶⁷*Id.* at 172.

⁶⁸*Id.* at 172.

⁶⁹*Id.* at 172.

⁷⁰*Id.* at 173.

⁷¹*Id.* at 173.

three additional requirements.⁷² First, that the Middle Rio Grande Conservancy District would not be deprived of its existing rights.⁷³ Second, that all existing rights to use water in the Rio Grande Basin in New Mexico be recognized.⁷⁴ And third, that New Mexico be allowed to construct flood protection works.⁷⁵

Texas did not really insist on much. Texas recognized that it was impracticable to separate the requirements of Texas from those of lands in New Mexico below Elephant Butte.⁷⁶ Texas felt "it should share in the benefits from new works for the augmentation of the water supply of the Rio Grande, (but) it will not insist thereon, provided that" Colorado and New Mexico deliver enough water at San Marcial to assure the annual release from Elephant Butte of 800,000 acre-feet of the same quality as during the past 10 years.⁷⁷

So, Colorado wanted to increase storage, New Mexico wanted to protect existing users and get San Juan/Chama water, and Texas wanted a guaranteed annual release from Elephant Butte reservoir to irrigate lands in New Mexico and Texas. With these state-specific goals, and the general goal of maintaining the status quo conditions of 1929, in mind, the negotiations proceeded, and the Compact of 1938 was concluded.

How the 1938 Compact Achieves Those Goals. The 1938 Compact achieves the goals of the individual states by two means, delivery schedules and an accounting system. Both are oriented toward maximizing beneficial use of the Rio Grande and avoiding adverse effects to users in all three states.

⁷²*Id.* at 173.

⁷³*Id.* at 173.

⁷⁴*Id.* at 173.

⁷⁵*Id.* at 173.

⁷⁶*Id.* at 173.

⁷⁷*Id.* at 173

The first way the 1938 Compact achieves some of the states' goals is through delivery schedules. There are two schedules; one for the amount of water that Colorado must deliver to New Mexico and the other for the amount of water that New Mexico must deliver to the primary storage facility for Texas, Elephant Butte Reservoir. The Colorado delivery schedule is based on the relationship between the natural flow of the Rio Grande and Conejos rivers from the mountains into the San Luis Valley and the depleted flow of the Rio Grande across the state line into New Mexico under the "status quo" conditions of 1928-1937.⁷⁸ The New Mexico schedule⁷⁹ reflects the relationship between the discharge of the Rio Grande above the principal agricultural areas in New Mexico, Otowi Bridge, and the inflow to Elephant Butte Reservoir at San Marcial. Later, because of difficulties in maintaining the San Marcial gaging station, the New Mexico delivery schedule was modified to use the gaging station below Elephant Butte Dam.⁸⁰

The delivery schedules achieve one goal of the states, that is, to maintain the status quo conditions of 1929. Because there was no increase in irrigation development after the 1929 Compact, fluctuations in the annual discharge of the Rio Grande from 1929 -1937 presumably reflected natural factors such as increased precipitation and drought. Thus the delivery schedules apportion the waters of the Rio Grande between Colorado, New Mexico, and the lands below Elephant Butte Dam by setting the status quo conditions down on paper for wet and dry years. The Compact does not apportion the water released from Elephant Butte Reservoir between New Mexico and Texas. Contracts between irrigation districts in both states and the Bureau of Reclamation have resulted in a constant ratio of irrigated land,

⁷⁸*Id.* at 175. Rio Grande Compact of 1938, Art. III.

⁷⁹Rio Grande Compact of 1938, Art. IV, modified by resolution adopted February 22-24, 1948.

⁸⁰*Id.* at 180.

57% in New Mexico and 43% in Texas.⁸¹ Although the delivery schedules provide a measuring stick by which to determine the status quo condition for subsequent years, they do nothing for some of the other goals of the states.

For example, New Mexico's goal to import San Juan/Chama water to the Rio Grande Basin is not achieved via the delivery schedules. This goal was, however, easily achieved by Article IX of the 1938 Compact where Colorado agreed to consent to the diversion provided that Colorado's uses of San Juan River water were protected. A related article of the Compact gives credit to any state importing water into the Rio Grande Basin.⁸² A far more interesting and challenging problem was that of achieving Colorado's goal of increasing storage while at the same time satisfying Texas with a guaranteed annual delivery to Elephant Butte Reservoir of about 800,000 acre-feet, later deemed to be 790,000 acre-feet.

The problem was challenging because in a normal year, Colorado could not increase storage without decreasing the amount of water delivered to Elephant Butte below the normal annual delivery. Dry years were worse because the delivery to Elephant Butte Reservoir would be less than the normal standard of 790,000 acre-feet. The Compact negotiators recognized that the solution to this problem was the storage of flood waters in wet years.

During some wet years, more than 790,000 acre-feet of water would be released from Elephant Butte Reservoir. Because the 790,000 acre-feet standard was determined from the status quo conditions, that amount of release would satisfy the irrigation needs in Texas and New Mexico below Elephant Butte Dam. Any amount over 790,000 acre-feet would exceed the irrigation demand and thus would flow unused down the Rio Grande past the irrigated lands. If Colorado and New Mexico could capture that

⁸¹*City of El Paso ex rel. Pub. Serv. Bd. v. Reynolds*, 563 F.Supp. 379, 383 (D.N.M. 1983). "The two irrigation districts and the Reclamation Service entered into water contracts for irrigation of approximately 66,500 acres of land in Texas and 88,350 acres in New Mexico. This ratio of irrigated lands -- 57% in New Mexico and 43% in Texas -- has remained constant"

⁸²Rio Grande Compact of 1938, Art. X.

excess water, they could increase storage without any adverse effects on users in Texas and New Mexico below Elephant Butte Dam.

Now the problem became one of predicting the future. If Colorado or New Mexico wait until year's end to determine if there is excess water, then it is too late to capture and store it. On the other hand, if Colorado and/or New Mexico increase storage early in the year, and it is a normal or dry year, the delivery to Elephant Butte will be less than the 790,000 acre-feet standard. To solve this problem, the negotiators essentially turned Elephant Butte Reservoir into an escrow account with its own set of accounting rules.

Article VI of the Compact, gives Colorado and New Mexico the flexibility to deviate from the delivery schedules. Each year the amount of water delivered by Colorado and New Mexico is compared to the appropriate delivery schedule. A state delivering more water than required is given credit for the excess water. Likewise, a state that delivers less than the required amount of water accrues a debit. Each year, the annual credits and debits for the previous years are combined to determine the total accrued credits or debits of each state. The benefit to Colorado and New Mexico is that they can store water early in the year without risking a violation of the Compact. If it happens to be a wet year, then Colorado and New Mexico have captured excess water, that is, water above that needed to meet the 790,000 acre-feet irrigation demand below Elephant Butte.⁸³ If it happens to be a dry year, a state that stores water has the choice of either accruing a debit thus owing water to Elephant Butte Reservoir or releasing water from storage to meet its delivery obligation.

The Compact has several provisions that protect the interests of irrigators below Elephant Butte Dam. First, the Compact limits the accrued debits of Colorado and New Mexico to 100,000 and 200,000

⁸³If a post-Compact reservoir stores water during a year that is not released, that water is added to the index station below it and is considered as if it had crossed the index. Therefore the obligation goes up accordingly. When the water is released it is deducted from the index supply. Rio Grande Compact of 1938, Art. VI.

acre-feet, respectively,⁸⁴ thereby preventing both states from draining the river dry every year and from having ever increasing accrued debits. Second, both states are required to retain water in storage equal to the amount of their accrued debits.⁸⁵ The stored water is essentially security for the debt the states owe to Elephant Butte Reservoir as a result of not meeting their delivery obligations. Texas can demand that Colorado and New Mexico release that stored water, up to the extent of their accrued debits, when there is less than 600,000 acre-feet of water stored in Elephant Butte.⁸⁶ In other words, irrigators below Elephant Butte Reservoir can collect the water owed by Colorado and New Mexico when the amount of water in Elephant Butte will not be sufficient to meet the 790,000 acre-feet irrigation demand. Should the amount of water stored in Elephant Butte drop below 400,000 acre-feet, then neither Colorado nor New Mexico can increase the amount of water stored in their reservoirs, unless they relinquish their accrued credits with Texas' approval.⁸⁷ Thus, these provisions achieve Texas' goal of being assured an annual release from Elephant Butte Reservoir sufficient to meet the irrigation demand below the Reservoir.

The Compact also helps Colorado achieve its goal of increasing storage. In a really wet year, it is possible that Elephant Butte Reservoir will be full to the point of overflowing. The term "actual spill" refers to times when water is released in excess of the current irrigation demand, either via the spillway

⁸⁴Rio Grande Compact of 1938, Art. VI.

⁸⁵Rio Grande Compact of 1938, Art. VI.

⁸⁶Rio Grande Compact of 1938, Art. VIII. New Mexico can also demand that Colorado release water from storage to the extent of Colorado's accrued debits. Actually, the 600,000 acre-feet criterion refers to the amount of water in "Project Storage" which is defined in the Compact to include storage in reservoirs below Elephant Butte, for example Caballo Reservoir, but above the first diversion to project lands. For practical purposes, and to be less confusing, I refer to Elephant Butte Reservoir instead of using the term "project storage." The same applies to the 400,000 acre-feet criterion that prevents Colorado and New Mexico from increasing storage.

⁸⁷Rio Grande Compact of 1938, Art. VII.

or via operation of the dam.⁸⁸ Thus, under the status quo irrigation conditions, the actually spilled water, because it exceeds the irrigation demand, flows down the river unused and is essentially wasted in terms of project goals. Colorado and New Mexico would increase the amount of water wasted if they released water from storage to decrease their accrued debits when Elephant Butte Reservoir is filled. The Compact avoids this problem and allows Colorado, and New Mexico, to increase the amount of water in storage by canceling all accrued debits whenever there is an actual spill.⁸⁹ On the other hand, an actual spill will reduce any accrued credits by the amount of the spill. Table 4-2a summarizes debit cancellation and credit reduction based on the accrued status of Colorado and New Mexico.

⁸⁸Rio Grande Compact of 1938, Art. I (p).

⁸⁹Rio Grande Compact of 1938, Art. VI.

Table 4-2a. DEBIT CANCELLATION AND CREDIT REDUCTION BY SPILL ⁹⁰		
ACCRUED STATUS		RESULT
NM	CO	
Credit	Credit	Accrued credits of both states are reduced in proportion to their respective credits by the amount of the actual spill. ⁹¹
Credit	Even	NM's accrued credits reduced by the amount of the actual spill
Credit	Debit	NM's accrued credits reduced by the amount of the actual spill. If the amount spilled exceeds NM's credits, then all of CO's accrued debits are canceled. ⁹²
Even	Credit	CO's accrued credits are reduced by the amount of the actual spill.
Even	Even	No debits to cancel and no credits to reduce.
Even	Debit	CO's accrued debits are canceled.
Debit	Credit	CO's accrued credits reduced by the amount of the actual spill. If amount spilled exceeds CO's credits, then NM's accrued debits are canceled.
Debit	Even	NM's accrued debits are canceled
Debit	Debit	NM's and CO's accrued debits are canceled

Similarly, when the amount of water in Elephant Butte Reservoir is close to capacity but does not actually spill, releases by Colorado and/or New Mexico to reduce their accrued debits could cause an actual spill, thereby wasting water. The Compact reduces both states' accrued debits to an amount equal

⁹⁰Debit cancellation applies when there are actual or hypothetical spills. Art. VI. However, the distinction between actual and hypothetical spills is relevant to the issue of whether annual credits or debits are computed. "[I]n a year of *actual* spill no annual credits nor annual debits shall be computed for that year." Art. VI (emphasis added). Presumably, in a year of *hypothetical* spill annual credits or annual debits are computed for that year because "actual spill" does not include "hypothetical spill." Art. I(p), (q).

⁹¹"[P]rovided, that the amount of actual spill shall be deemed to be increased by the aggregate gain in the amount of water in storage, prior to the time of the spill, in reservoirs above San Marcial constructed after 1929; provided, further, that if the commissioners for the states having accrued credits authorized the release of part, or all, of such credits in advance of spill, the amount so released shall be deemed to constitute actual spill." Art. VI.

⁹²Accrued credits are canceled only when there is an actual spill of usable water. Art. VI. An actual spill of usable water occurs only after all credit water has been spilled. Art. I(p). Further, to be an actual spill of usable water, the water spilled must be in excess of the current demand on project storage and cannot be stored in another reservoir. Art. I(p).

to the minimum unfilled capacity of Elephant Butte Reservoir.⁹³ In other words, Colorado and New Mexico can keep any water that would cause an actual spill if they were to release that water in order to reduce their accrued debits. Table 4-2b summarizes debit reduction to an amount equal to the minimum unfilled capacity based on the accrued status of Colorado and New Mexico.

Table 4-2b. DEBIT REDUCTION WHEN THERE IS NO SPILL⁹⁴		
ACCRUED STATUS		RESULT
NM	CO	
Credit	Credit	No debits to reduce.
Credit	Even	No debits to reduce.
Credit	Debit	If CO's debits exceed minimum unfilled capacity ⁹⁵ of project storage, then CO's debits reduced to an amount equal to the minimum unfilled capacity.
Even	Credit	No debits to reduce.
Even	Even	No debits to reduce.
Even	Debit	If CO's debits exceed minimum unfilled capacity of project storage, then CO's debits reduced to an amount equal to the minimum unfilled capacity.
Debit	Credit	If NM's debits exceed minimum unfilled capacity of project storage, then NM's debits reduced to an amount equal to the minimum unfilled capacity.
Debit	Even	If NM's debits exceed minimum unfilled capacity of project storage, then NM's debits reduced to an amount equal to the minimum unfilled capacity.
Debit	Debit	If the aggregate of NM's and CO's accrued debits exceeds the minimum unfilled capacity, then NM's and CO's debits are reduced proportionally to an aggregate amount equal to the minimum unfilled capacity.

⁹³Rio Grande Compact of 1938, Art. VI.

⁹⁴Annual debits or credits computed for the year for each case in this table.

⁹⁵"Unfilled capacity" is the difference between the total physical capacity of project storage and the amount of *usable* water then in storage. Art. I(n) (emphasis added). "Usable water" is all water, *exclusive of credit water*, which is in project storage and which is available for release in accordance with irrigation demands, including deliveries in Mexico. Art. I(l) (emphasis added).

Of course, whether or not an actual spill occurs depends on the balance of inflow to outflow. The Compact negotiators recognized that a greater than normal release rate from Elephant Butte could prevent an actual spill from occurring. The hypothetical spill computation is performed to determine if a greater than normal release rate prevented an actual spill from occurring.⁹⁶ If a greater than normal release, which is a departure from the status quo conditions, prevented an actual spill from occurring, then all accrued debits of Colorado and New Mexico are canceled just the same as if an actual spill occurred.

Delivery Obligations in Drought

During drought years there will be less than normal flow in the Rio Grande in Colorado and northern New Mexico. Consequently the amount of water obligated to be delivered to Elephant Butte Reservoir decreases. With continued normal releases from Elephant Butte during drought years, the amount of water in project storage will decrease. When the amount of usable water in project storage decreases below 600,000 and 400,000 acre-feet, two articles of the Rio Grande Compact become relevant and may increase the amount of water in project storage. Usable water is all water, exclusive of credit water, which is in project storage and which is available for release in accordance with irrigation demands.

Less than 600,000 Acre-Feet of Usable Water in Project Storage. When the amount of water in project storage falls below 600,000 acre-feet (23 percent of capacity), Texas may demand that both Colorado and New Mexico release water from storage. New Mexico may also demand that Colorado release water from storage. The amount of water that Colorado and New Mexico may be required to release is limited by the amount of accrued debits and may be less if both Colorado and New Mexico

⁹⁶Rio Grande Compact of 1938, Art. I (q).

have accrued debits. The demand to release water must be made in January and applies only to reservoirs constructed after 1929.

The goal of Article VIII is to have a normal release of 790,000 acre-feet from project storage each year. Article VIII tries to achieve its goal by requiring Colorado and New Mexico to release water in storage from post-1929 reservoirs when the amount in project storage is too low. If both Colorado and New Mexico have accrued debits, then the amount of water each state must release is determined proportionally according to the amounts of each state's accrued debits until the amount of water in project storage reaches 600,000 acre-feet by March 1 and remains at 600,000 acre-feet until April 13. Table 4-2c shows when Colorado, New Mexico, or both, may be required to release water from storage. Article VIII releases may be demanded when the total amount of water in project storage exceeds 600,000 acre-feet so long as the amount of *usable* water in project storage is less than 600,000 acre-feet. The amount of credit water in project storage must be subtracted from the total amount of water in project storage to determine the quantity of usable water in project storage. However, even when the amount of usable water in project storage is less than 600,000 acre-feet, there are two limitations on Article VIII releases.

Table 4-2c. REQUIRED RELEASE WHEN THERE IS LESS THAN 600,000 ACRE-FEET OF USABLE WATER IN STORAGE ⁹⁷

ACCRUED STATUS		RESULTS
NM	CO	
Credit	Credit	TX cannot require either state to release water. NM cannot require CO to release water.
Credit	Even	TX cannot require either state to release water. NM cannot require CO to release water.
Credit	Debit	TX cannot require NM to release water. TX and/or NM may require CO to release water up to the amount of CO's accrued debits.
Even	Credit	TX cannot require either state to release water. NM cannot require CO to release water.
Even	Even	TX cannot require either state to release water. NM cannot require CO to release water.
Even	Debit	TX cannot require NM to release water. TX and/or NM may require CO to release water, up to the amount of CO's accrued debits.
Debit	Credit	TX cannot require CO to release water. TX may require NM to release water, up to the amount of NM's accrued debits.
Debit	Even	TX cannot require CO to release water. TX may require NM to release water, up to the amount of NM's accrued debits.
Debit	Debit	TX may require CO and NM to release water in storage, up to the amount of their respective accrued debits, and in proportion to the total debit of each. NM may also require CO to release water.

⁹⁷"Usable water" is all water, *exclusive of credit water*, which is in project storage and which is available for release in accordance with irrigation demands, including deliveries in Mexico. Art. I(l) (emphasis added). Thus, total amount of water in storage could exceed 600,000 acre-feet.

TX and NM may only demand release of water from storage reservoirs constructed after 1929. Art. VIII. Such releases "shall be made . . . at the greatest rate practicable under the conditions then prevailing, and in proportion to the total debit of each [state, CO and NM], and in amounts, limited by their accrued debits, sufficient to bring the quantity of *usable* water in project storage to 600,000 acre-feet by March first and to maintain this quantity in storage until April thirtieth" Art. VIII.

Demand to release water must be made in January. Art. VIII.

The first limitation is that a state must have accrued debits before it can be required to release water from storage. The maximum amount of water that Colorado and New Mexico must release is limited to the amount of their accrued debits. A state without accrued debits cannot be required to release water from storage.

The second limitation as contained in a clause in Article VIII, requires Colorado and New Mexico to release water at the greatest rate practicable under the prevailing conditions. The prevailing conditions clause may limit any release required of Colorado due to the timing of the required releases. Under Article VIII, Texas may, during the month of January, demand the release of water by Colorado and New Mexico. In order to reach and maintain the goal of 600,000 acre-feet of water in project storage for March and April, Colorado and New Mexico must release water, up to the amount of and in proportion to their accrued debits, from some date after Texas' demand in January until late April at the latest. Thus, the release would occur during the winter and early spring when prevailing conditions are likely to include frozen rivers and streams. Release of water from storage into frozen rivers could cause flooding. Thus, any releases under Article VIII may be limited to rates that would not cause flooding. Less than 400,000 Acre-Feet of Usable Water in Project Storage. Colorado's and New Mexico's ability to increase the amount of water in upstream storage is limited by the amount of water in project storage. When the amount of water in project storage is less than 400,000 acre-feet (about 15 percent of capacity), Colorado and New Mexico may be prevented from increasing the amount of storage in reservoirs constructed after 1929.

Article VII derives from two premises. The first is that lands in New Mexico and Texas supplied with water from Elephant Butte Dam have a superior right to storage of flood waters of the Rio Grande. The second is that flood waters cannot be stored in new upstream reservoirs when the supply in Elephant

Butte Reservoir is insufficient to meet the needs of downstream users, in order to maintain the status quo as of 1929 conditions of development.⁹⁸

There are two exceptions in Article VII that would allow Colorado and New Mexico above Elephant Butte to increase storage when the amount of water in project storage is less than 400,000 acre-feet.

The first of two exceptions to the limitation on increasing storage relates to larger than normal releases from Elephant Butte Reservoir. Normally, Colorado cannot increase the amount of water in storage whenever there is less than 400,000 acre-feet in project storage. However, when releases from project storage are greater than the average 790,000 acre-feet per year, the time when project storage goes below 400,000 acre-feet is adjusted to compensate for the increased release rate. So, with a greater than average release rate and the amount of water in project storage less than 400,000 acre-feet, Colorado and New Mexico would be allowed to increase storage until some later time. That later time is the calculated time project storage would have gone below 400,000 acre-feet had the release rate been at the average of 790,000 acre-feet per year.

The second exception to the limitation on increasing storage also allows Colorado and New Mexico to increase storage when the amount of water in project storage is less than 400,000 acre-feet. This exception only applies to either state when that state has accrued credits, relinquishes those credits, and Texas accepts the relinquished water. In that case, the state relinquishing credits can store water in amounts up to the amount of the credits relinquished provided that Texas accepts the relinquished credits.

Table 4-2d shows that the limitation on increasing storage applies when the amount of usable water in project storage drops below 400,000 acre-feet, unless a state relinquishes credits that are

⁹⁸ Hill, 194.

accepted by Texas. Because "usable" water does not include credit water, the limitation on increasing storage may apply when the total amount of water, usable plus credit, in storage exceeds 400,000 acre-feet. In addition to the limitation on increasing storage, low amounts of usable water in project storage may result in Colorado or New Mexico, or both, being required to release water from storage.

Table 4-2d. LIMITATION ON INCREASING STORAGE WHEN THERE IS LESS THAN 400,000 ACRE-FEET OF USABLE WATER IN STORAGE⁹⁹		
ACCRUED STATUS		RESULTS
NM	CO	
Credit	Credit	CO and NM can increase storage by the amount of credits they relinquish if TX accepts the credits.
Credit	Even	NM can increase storage by the amount of credits NM relinquishes if TX accepts the credits. CO cannot increase the amount of water in storage.
Credit	Debit	NM can increase storage by the amount of credits NM relinquishes if TX accepts the credits. CO cannot increase the amount of water in storage.
Even	Credit	CO can increase storage by the amount of credits CO relinquishes if TX accepts the credits. NM cannot increase the amount of water in.
Even	Even	Neither CO nor NM can increase the amount of water in storage.
Even	Debit	Neither CO nor NM can increase the amount of water in storage.
Debit	Credit	CO can increase storage by the amount of credits CO relinquishes if TX accepts the credits. NM cannot increase the amount of water in storage.
Debit	Even	Neither CO nor NM can increase the amount of water in storage.
Debit	Debit	Neither CO nor NM can increase the amount of water in storage.

⁹⁹Limitation on increasing storage applies only to reservoirs constructed after 1929. "Usable water" does not include credit water. Art. I(1). Thus, total amount of water in storage could exceed 400,000 acre-feet.

Limitation is subject to two provisions. First, "if the actual releases of usable water from the beginning of the calendar year . . . following actual spill, have aggregated more than an average of 790,000 acre-feet per annum, the time at which such minimum stage is reached shall be adjusted to compensate for the difference between the total actual release and releases at such average rate . . ." Art. VII. Thus, all credit water must be released and then some "usable water" must be released for this provision to operate.

Second, "Colorado or New Mexico, or both, may relinquish accrued credits at any time, and Texas may accept such relinquished water, and in such event the state, or states, so relinquishing shall be entitled to store water in the amount of the water so relinquished." Art. VII.

General Provisions

The 1938 Compact divides the waters of the Rio Grande between Colorado, New Mexico, and Texas. In doing so, it maximizes the beneficial use of the water without impairment of any beneficial uses under the conditions prevailing in 1929. Colorado and New Mexico can increase their storage using excess flood water and Texas is assured that 790,000 acre-feet will be released to the lands below Elephant Butte Reservoir. However, as noted above, during drought conditions Colorado and New Mexico may be required to release water from storage and may be precluded from increasing the amount of water in storage. Whether or not these Compact requirements apply to either state during a drought depends on the accrued debit/credit status of each state, the ability of each state to enforce the Compact vis a vis the other state and a host of other factors as yet undefined, except by ad hoc practice. It is at this point that the models such as those developed in the ACF may be helpful.

Role of Models in Drought Policy Analysis

This project has developed a model that responds to relative scarcity as those scarcities are reflected through Compact deliveries and other institutions. While the model is not designed to generate the exact detail as to how all of the institutions would respond and with what economic consequences, it is in fact a first step toward the kind of effort that has been generated in the ACF basins involving Georgia, Alabama and Florida. There is no doubt that a great deal of value could be generated by beginning with the basic effort of this study, and expanding it to integrate with existing detailed hydrologic models. And, while this integration between the economic models and the hydrologic models is critical, the problems with these hydrologic models generate their own concerns. The work on the middle Rio Grande is a case in point. A debate is currently raging between the City of Albuquerque and the New Mexico State Engineer on which hydrologic model to use in calculating the amount of surface water that is being withdrawn each year by the City of Albuquerque through its wells.

This example is relevant because in designing a drought model that predicts outcomes in times of drought, someone must make a choice. Or, at a minimum run a set of scenarios. Of course, too wide a range of scenarios is no prediction at all. Thus, we must reluctantly conclude that hydrologic modeling is no less "certain" than economic modeling and is only as valuable as the accuracy of the assumptions that go into the model.

Still, this discussion does not argue against constructing the model and developing the common data set. Rather, it argues in favor of continued testing and validation of the model when possible and caution in describing its results. What then would be the form of this ideal model? At a minimum it should contain:

- A mass surface water balance for the region studied so that when various rates of snow pack run off and flood events occur at the upper reaches and should reach the accounting point at the end of the compact at Elephant Butte.
- A set of hydrologic assumptions regarding the impacts of groundwater pumping on the system based upon the best data available using estimates that reflect good water conservation policy.
- A set of hydrologic assumptions regarding return flows, evaporation losses, transpiration losses, seepage and all other losses to the system.
- A set of institutional entitlements under the Rio Grande Compact that permit or do not permit storage and withdrawal at key points in the river such that one is able to estimate rates of flow at various points in the river system.
- A set of the best estimates of environmental needs in the river for rates of flow throughout the system that most closely resemble the traditional hydrograph, since these amounts will be required in the future by environmental interests.
- A set of anticipated consumptive needs throughout the system broken down by user and coupled with calculations of return flows from each type of user.

Based upon the above hydrologic supply and demand, a prediction can be made of where and under what circumstances the water will be allocated among the above listed users, including an analysis of priority dates and relative legal strengths of the positions of the parties intrastate, the bulk water entitlements will be allocated under the Rio Grande Compact. These allocations in New Mexico include the Middle Rio Grande Conservancy District, the municipalities, the Indian Pueblos, and the Middle Rio Grande Silvery Minnow.

Tied to the above outcomes as to where the water goes in times of shortage and to whom, is the kind of economic analysis contained in this report that ties economic outcomes to water scarcity. This should be supplemented by an analysis of the impact on water quality at various reaches of the river.

Finally, once this model is constructed and running, it must be capable of being altered by various institutional adjustments to the current Law of the River, for example, water banking as a form of transfer of interests in water, water leasing, forbearance programs and any other hydrologically realistic institutional fix that could move water to other uses.

All of the model pieces must be tied together so that if we move water, for example, from farming to municipal in response to drought, the effect on all other variables is reflected including stream flow, water quality and other institutional consequences.

The drought study performed under this grant is only a beginning in this direction, but it is, we believe, a step in the right direction.

Law of the River, Normal Inflows
Water Use Patterns

Table 4-3 shows long-run average annual model-forecasted water use patterns by major system users and inflows to the system for the next 44 years.¹⁰⁰ Long-run average annual gaged inflows to the

¹⁰⁰These forecasts do not match historical use patterns because of projected population growth in Albuquerque and El Paso.

basin were 1.57 million acre-feet per year.¹⁰¹ These six long-run average flows are as follows: 659,000 acre-feet per year from the Rio Grande at Del Norte; 345,000 from the three Conejos Index gages; 581,000 from the Chama watershed; 45,170 from the Jemez; 32,238 from the Rio Puerco; and 40,515 from the Rio Salado.

Under the scenario that the above long-run average flows recur over the next 44 years, Colorado agriculture diverts about 857,000 acre-feet per year of total water, of which about 678,000 comes from surface water and the remaining 179,000 from groundwater pumping.¹⁰²

In New Mexico, the major users divert the following amounts: Middle Rio Grande Conservancy District (MRGCD) agriculture above Albuquerque: diverts 513,630 acre-feet surface water per year; Albuquerque area M&I use: diverts 158,240 acre-feet of groundwater pumping and 63,360 acre-feet of surface diversions; MRGCD agriculture below Albuquerque: diverts 207,220 acre-feet surface water; Elephant Butte Irrigation District: diverts 495,000 acre-feet of surface water and 115,900 acre-feet of pumping. Albuquerque water uses are based on future projected population growth and on planned surface water treatment development beginning in year 10.

In Texas, El Paso M&I diverts 140,080 acre-feet of surface water and 77,830 of groundwater (El Paso population growth included); while El Paso agriculture diverts 236,800 acre-feet of surface water.

¹⁰¹Runoff from the Sangre de Cristo mountain range in northern New Mexico to the Rio Grande in New Mexico below the Lobatos gage produces a significant amount of water for New Mexico.

¹⁰²The model underestimates Colorado's historical water use. Historically Colorado records show diversions of about 1.5 million acre-feet per year of total water, of which about 1.0 million comes from surface water and 500,000 from groundwater (Vandiver, 2001). Still, with considerable groundwater pumping and recharge and surface water and groundwater return flows to the river, measurement of 'use' is difficult, both in the model and on the ground. The model correctly produces the right quantity of Colorado's index flows (supplies) to meet its delivery obligations to New Mexico at the Lobatos gage.

Table 4-3. Long Run Average Annual Water Use Patterns in Drought, by State, Location, and User (1000s acre-feet)							
Baseline Institution: <u>Law of the River</u>							
Drought Scenario: <u>Long-Run Average Flows (1.57 million acre-feet per year at six headwater gages)</u>							
	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuq	Albuq M&I	Middle Rio Grande Ag below Albuq	Eleph Butte Ag	El Paso M&I	El Paso Ag
Average annual total water use ¹⁰³ (surface diversions + pumping)	857.49	513.63	221.60	256.82	610.90	217.41	236.80
Average annual surface water use (diversion)	678.17	513.63	63.36	256.82	495.00	140.08	236.80
Average annual groundwater use (pumping)	179.32	0.00	158.24	0.00	115.90	77.33	0.00
Elephant Butte Volume	685.55						
Average total water use by state (surface diversions + pumping)	857.49	1,602.95				454.21	
Average surface water use by state (diversion)	678.17	1,328.81				376.88	
Average groundwater use by state (pumping)	179.32	274.14				77.33	

¹⁰³In these results, the term 'use' means surface diversions plus groundwater pumping. It does not refer to net consumption.

Economic Benefits

Table 4-4 shows economic benefits produced by water use patterns when long-run average inflows to the system are available. Results are shown by state, location, and user. These are the benefits produced by the institution of the current Law of the River, when this level of inflow, equal to the long-run average inflow to the Basin, occurs over the next 44 years.

Colorado agriculture in the San Luis Valley earns about \$72 million in net income from its 145,000 acres in potatoes, alfalfa, and barley by diverting 857,490 acre-feet of water predicted by the model. This is an average of about \$84 per acre-foot diverted.

In New Mexico, Middle Rio Grande Conservancy District (MRGCD) agriculture earns about \$6.9 million per year in the region above Albuquerque and about \$2.1 million south of Albuquerque from the 770,000 acre-feet of water diverted, about \$11 per acre-foot diverted. Albuquerque area M&I water use produces about \$1.25 billion in total benefits from a predicted 221,600 acre-feet of water use.¹⁰⁴ This total benefit amounts to slightly over \$5,600 per acre-foot diverted. Elephant Butte Irrigation District agriculture earns about \$31.1 million per year of net income producing its major crops of alfalfa, chile, pecans, onions, lettuce, and cotton, on about 82,600 acres of irrigated land, which is about \$50 per acre-foot diverted.

In Texas, El Paso M&I water use produces about \$1.06 billion of total benefit, of which less than 10 percent accrues as a direct water bill to ratepayers. Like Albuquerque, the very high percent of total benefit accruing as consumer surplus occurs because the price elasticity of demand for water is quite low, and the price is quite low compared to what people would pay as a maximum. El Paso area agriculture earns \$18.5 million per year in farm income from 236,800 acre-feet of water, or about \$ 78 per acre-foot.

¹⁰⁴Most of this M&I benefit accrues to water buyers as consumer surplus because of the relatively low price of water compared to what people are willing to pay rather than go without.

Table 4-4. Long-Run Average Annual Economic Benefit from Water Use Patterns, by State, Location, and User (\$1000s)**Baseline Institution:** Law of the River**Baseline Water Supply:** Long-Run Average Inflows, Period of Record (1.57 million acre-feet per year at six headwater gages)

	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuquerque	Albuquerque M&I	Middle Rio Grande Ag below Albuquerque	Elephant Butte Ag	El Paso M&I	El Paso Ag
	----- (\$1000s per year) -----						
Average annual <u>economic benefit</u> , from surface + groundwater	72,193	6,941	1,246,362	2,153	31,111	1,059,073	18,532
Average annual <u>recreation benefits</u> summed over five basin reservoirs: Heron, El Vado, Abiquiu, Cochiti, Elephant Butte	9,761						
Average annual <u>economic benefit</u> (from surface diversions + pumping) totaled by state	72,193	1,286,567				1,077,605	

Law of the River, 1942-1985 Drought Inflows
Water Use Patterns

Table 4-5 shows water use patterns in the system under drought inflow conditions. These drought inflows replicate historical drought flows of the 1950s through late 1970s. In order to have a "lead up" and "wind-down" period, the 'spill to spill' period of 1942-1985 was included. Elephant Butte Reservoir spilled in both 1942 and 1985. Under the Rio Grande Compact, a spill wipes out all accumulated debts and credits. For these reasons, future drought inflows to the system were defined to equal the historical 1942-1985 headwater flows. That is, this section's analysis is based on a drought of 1942-1985 repeating itself in absolute water quantities, but with economic activity in the region based on future expected population growth of Albuquerque and El Paso. The method of coping with this drought is based on the current Law of the River.

Historical inflows for 1942-1985 averaged about 1.4 million acre-feet per year. By headwater gage, these long-run average flows were as follows: 617,402 acre-feet per year from the Rio Grande at Del Norte, 309,000 from the three Conejos Index gages, 390,757 from the Chama watershed, 44,735 from the Jemez, 32,238 from the Rio Puerco, and 40,515 from the Rio Salado.

Over this drought period where the system is operated under the Law of the River, Colorado agriculture diverts about 788,000 acre-feet per year of total water, of which about 616,000 comes from surface water and the remaining 172,000 from groundwater pumping.

New Mexico water users who face 1942-1985 drought flows in the future are forecasted to divert different amounts than they diverted in the actual 1942-1985 period because of expected growth in Albuquerque M&I use and because Albuquerque plans to start using surface water, assumed to occur in year 10. The future New Mexico long-run average annual water use under the drought condition described is estimated as the following amounts, averaged over all 44 years: MRGCD agriculture above Albuquerque: 471,000 acre-feet surface water per year, Albuquerque area M&I use: 153,330 acre-feet of groundwater pumping and 68,280 acre-feet of surface diversions; MRGCD agriculture below

Albuquerque: 235,500 acre-feet surface water; Elephant Butte Irrigation District: 428,010 acre-feet of surface water and 133,960 acre-feet of groundwater.

Long-run average future Texas water use is projected as follows: El Paso area M&I diverts 120,180 acre-feet of surface water and 93,370 acre-feet of groundwater, which is 16,000 acre-feet/year more pumping compared to non-drought conditions. This increase in pumping is to make up for the surface water shortfall. El Paso area agriculture diverts a long-run average of 205,700 acre-feet of surface water per year, about 31,000 less the 236,800 diversion under long-run average flows. The reduced diversion occurs because of less surface water available under drought conditions than under normal supplies.

Table 4-5. Long-Run Average Annual Water Use Patterns in Drought, by State, Location, and User (1000s acre-feet)**Baseline Institution:** Law of the River**Drought Scenario:** 1942-1985 Historical Inflows (1.40 million acre-feet per year)

	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuq	Albuq M&I	Middle Rio Grande Ag below Albuq	Eleph Butte Ag	El Paso M&I	El Paso Ag
Average annual total water use (surface diversions + pumping)	787.85	471.00	221.6 1	235.50	561.97	213.55	205.70
Average annual surface water use (diversion)	616.27	471.00	68.28	235.50	428.01	120.18	205.70
Average annual groundwater use (pumping)	171.58	0.00	153.3 3	0.00	133.96	93.37	0.00
Elephant Butte Volume	477.21						
Average total water use by state (surface diversions + pumping)	787.85	1,490.08				419.25	
Average surface water use by state (diversion)	616.27	1,202.79				325.88	
Average groundwater use by state (pumping)	171.58	287.29				93.37	

Economic Benefits

Table 4-6 shows annual economic drought damages brought about by changed water use patterns in drought flows compared to normal flows, assuming, as before, projected future population growth in the Albuquerque and El Paso areas.. Results are presented as economic losses, defined as the reduction in economic benefits under drought conditions compared to similar economic benefits produced by long-run normal flows. Drought damages are presented by state, location, and user in which the current Law of the River deals with the above-described drought inflows.

Colorado agriculture in the San Luis Valley suffers drought losses from reduced flows of about \$5.8 million in net income per year. In New Mexico, MRGCD incurs long-run average losses of about \$479,000 per year from the reduced flows above Albuquerque and about \$149,000 per year below Albuquerque. Albuquerque area M&I water use is virtually unchanged, but substitutes surface water for groundwater of about 5,000 acre-feet per year, thereby reducing costs by about \$49,000 compared to conditions under normal flows. Elephant Butte Irrigation District agriculture suffers drought damages of about \$2.8 million per year due to reduced surface water flows, although groundwater pumping increases slightly to mitigate drought damages.

In Texas, El Paso M&I use suffers losses of about \$6.1 million per year (0.6 percent of benefits under normal flows). Total M&I use is reduced by about 3,000 acre-feet per year over the long-run, with groundwater pumping increasing by about 16,000 acre-feet per year to make up for reduced surface water diversions of about 19,000 acre-feet. El Paso area agriculture incurs \$1.8 million per year in direct farm income losses (10 percent of benefits under normal flows) due to the reduced surface flows under drought.

Table 4-6. Long-Run Average Annual Drought Damages by State, Location, and User (\$1000s)							
Baseline Institution: <u>Law of the River</u>							
Drought Scenario: <u>1942-1985 Historical Inflows (1.40 million acre-feet per year)</u>							
	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuq	Albuq M&I	Middle Rio Grande Ag below Albuq	Eleph Butte Ag	El Paso M&I	El Paso Ag
	----- (\$1000s per year) -----						
Average annual <u>economic drought damage</u>	5,803	479	(49)	149	2,800	6,106	1,884
Average annual <u>recreation drought damage</u> , summed over 5 Basin reservoirs: Heron, El Vado, Abiquiu, Cochiti, Elephant Butte	419						
Average annual <u>economic drought damage</u> totaled by state	5,803	3,379				7,990	

Carryover Storage at Elephant Butte for Use in Drought

Under the current Law of the River, the scheduled "full release" for the Rio Grande Project is 790,000 acre-feet per year. However, as described earlier in this report, actual historical releases made by the districts have fallen considerably with reduced water available in Rio Grande Project storage. These releases are shared by three U.S. users: Elephant Butte Irrigation District in New Mexico, El Paso area M&I, and El Paso area agriculture. While not 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.

The Institutional Adjustment considered for this policy analysis reduces the historical release by 25,000 acre-feet per year, using the concept of the 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 not been available.

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.¹⁰⁵ In dry years this accumulated saved water would be available for use, when its economic value at the margin is much 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.¹⁰⁶

¹⁰⁵Rio Grande Project storage occurs at both Elephant Butte and Caballo reservoirs. The model was coded to treat these as a single reservoir, with storage capacity equal to the sum of the two volumes. We refer to Project storage as occurring at Elephant Butte reservoir, recognizing that both reservoirs contribute.

¹⁰⁶If the storage reservoirs had vertical canyon walls, the negative interest rate would be zero because releasing less water increases water in storage, but does not increase evaporation, which depends only on exposed surface area. However Elephant Butte reservoir exposes larger amounts of surface area with higher volumes of water, so increasing carryover storage also increases evaporation slightly; hence the interest rate on water saved is slightly negative.

Water Use Patterns

Table 4-7 shows water use patterns throughout the system, under the carryover storage management institution for coping with drought. It also shows the equations coded into the model to compare the institutions of current law of the river to carryover storage.

Over this future period, Colorado agriculture diverts the same 788,000 acre-feet per year of total water, of which about 616,000 comes from surface water and the remaining 172,000 from groundwater pumping. The carryover storage at Elephant Butte has no effect on Colorado delivery requirements and therefore has no impact on water use in Colorado.

In New Mexico above Elephant Butte Reservoir, for the reasons described previously, New Mexico pays for the slightly increased evaporation at Elephant Butte resulting from the carryover storage institution. So, for a long-term 44 year average, MRGCD diverts 8,380 acre-feet less above and 4,190 acre-feet less below Albuquerque per year, for a total of 12,570 fewer acre-feet diverted. MRGCD's depletions from the river fall by much less than the 12,570 acre-feet, since only a small part of their reduced diversions are reduced stream depletions needed to offset increased evaporation at Elephant Butte.

Albuquerque M&I water use is virtually unaffected by the carryover storage program, diverting 66,400 acre-feet of surface water with and 68,280 acre-feet without Elephant Butte carryover storage (1,780 acre-feet net reduction), and 155,200 acre-feet of pumping with and 153,330 acre feet without the carryover storage. M&I is a higher valued use of water, at the margin. Because the model is coded to seek the the least cost method to deliver water, increased delivery requirements to Elephant Butte Reservoir are produced mostly by reduced diversions by MRGCD agriculture, equal to 88 percent from MRGCD and 12 percent from Albuquerque M&I.

In New Mexico below Elephant Butte Reservoir, EBID agriculture uses about 1,000 less acre-feet surface water on average under the carryover storage program. Therefore, one can conclude that the

proposed carryover storage program is not a significant help to EBID water users in getting through the drought, in terms of promoting more average long-run surface water use.

Future Texas water use under carryover storage is projected as follows: El Paso M&I has no significant change in surface or groundwater use under carryover storage. El Paso agriculture diverts an average of 205,380 acre-feet per year under carryover storage compared to the slightly lower 205,700 acre-feet of surface water per year under Law of the River.

The table also shows that carryover storage produces a considerably higher long-run average storage volume at Elephant Butte Reservoir. The reservoir increases from an average of 477,210 acre-feet over a typical year under the law of the river to an average of 527,530 under the carryover storage program. So, while the increased carryover storage produces a higher average reservoir volume, it does not produce higher use.

Table 4-7. Long-Run Average Annual Water Use Patterns under Drought Mitigation by State, Location, and User (1000s of acre-feet)							
Alternative Institution: <u>Carryover Storage--Reduce Elephant Butte Releases in Full Years by 25,000 Acre-feet /Yr for Use in Drought</u>							
Drought Scenario: <u>1942-1985 Historical Inflows (1.40 million acre-feet per year)</u>							
	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuquerque	Albuquerque M&I	Middle Rio Grande Ag below Albuquerque	Elephant Butte Ag	El Paso M&I	El Paso Ag
Ave annual total use (surf diversions + pumping)	787.85	462.62	221.60	231.31	564.09	213.76	205.38
Average annual surface water use (diversion)	616.27	462.62	66.40	231.31	426.96	119.69	205.38
Average annual groundwater use (pumping)	171.58	0.00	155.20	0.00	137.13	94.07	0.00
Elephant Butte Volume	527.53						
Average total water use by state (surface diversions + pumping)	787.85	1,479.62				419.14	
Average surface water use, totaled by state (diversion)	616.27	1,187.29				325.07	
Average groundwater use, totaled by state (pumping)	171.58	292.33				94.07	
Current Law of River: release = 672,000 + (0.14 * project storage) - (1.55 * tributary inflow), with enough water in storage							
Modified Institution: release = 672,000 - 25,000 + (0.14 * project storage) - (1.55 * tributary inflow), with enough water in storage							

Economic Benefits

Table 4-8 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. We refer to these economic impacts of carryover storage as the value of drought damage mitigation accruing to that institution.

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.

Colorado agriculture in the San Luis Valley gains zero drought mitigation benefit under the carryover storage institution, because, under the Rio Grande Compact, Colorado's delivery obligations at the Colorado-New Mexico state line, in non-spill drought years is unaffected by operation of Elephant Butte Reservoir.

MRGCD agriculture in New Mexico suffers small losses from increased carryover storage at Elephant Butte equal to an average of \$112,000 per year above Albuquerque and \$35,000 below Albuquerque. This small loss occurs because of reduced agricultural diversions described above. This reduced water use in agriculture produces economic values in agriculture of \$13 less per acre-foot not diverted ($\$112,000/8,380$). This small loss in MRGCD agriculture per acre-foot of water not diverted occurs because reduced irrigated agriculture acreage in that part of New Mexico comes mostly at the expense of alfalfa and other cattle feed displaced. These enterprises produce low farm incomes per added acre-foot diverted.

Table 4-8. 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	Middle Rio Grande Ag above Albuquerque	Albuquerque M&I	Middle Rio Grande Ag below Albuquerque	Elephant Butte Ag	El Paso M&I	El Paso Ag
	----- (\$1000s per year) -----						
Average annual <u>economic drought damage mitigated</u>	0	(112)	(18)	(35)	(35)	(425)	(8)
Average annual <u>recreation drought damage mitigation</u> , summed over 5 Basin reservoirs: Heron, El Vado, Abiquiu, Cochiti, Elephant Butte	84						
Average annual <u>economic drought damage mitigation</u> totaled by state	0	(200)				(433)	

These reduced diversions of 12,570 acre-feet per year on average result in a much lower reduction in river depletions, as described in some detail below. This "second order" effect of the carryover storage institution results from the treatment of evaporation charges under the Rio Grande Compact. Under the Compact, New Mexico is responsible for increased deliveries into Elephant Butte resulting from actions that increase its evaporation.

The model follows the Compact, under which New Mexico is responsible for deliveries into Elephant Butte as a function of flows at the Otowi gage. New Mexico deliveries to Texas are defined as "...the recorded flow of the Rio Grande at the gaging station below Elephant Butte Dam during the calendar year plus any net gain in storage in Elephant Butte Reservoir during the same year or minus the net loss in storage in said reservoir, as the case may be..." (1948 resolution adopted by Rio Grande Compact Commission regarding changing the gaging station and measurements of deliveries by New Mexico).

This passage of the Compact has important implications for who is responsible for making water deliveries resulting from actions producing increased evaporation at Elephant Butte. A simple example taken directly from the Compact delivery table linking Otowi flows and Elephant Butte effective supply clarifies the issue. If the Otowi index supply is 1.2 million acre-feet, then New Mexico is responsible for delivering 800,000 acre-feet at the Elephant Butte gage plus the net gain in storage at the reservoir.

Suppose the net gain in Elephant Butte storage is zero, with New Mexico complying with the Compact by delivering annual flow at the Elephant Butte gage of 800,000 acre-feet. Now, if Rio Grande Project water users downstream of Elephant Butte set up a carryover storage plan that reduces releases to 700,000 acre-feet, then for the same inflows into the reservoir delivered by New Mexico, the gain in storage at Elephant Butte is higher. But the gain is less than the full 100,000 acre-feet reduction in flows

leaving the reservoir. The gain in storage is less than 100,000 because with the now higher volume of water at the reservoir, evaporation is also slightly higher. And under the Compact, New Mexico will deliver more water into Elephant Butte to avoid being out of compliance.

What all this means is that policies taken by Rio Grande Project water users that reduce releases from Elephant Butte also increase evaporation at Elephant Butte slightly, and this added evaporation must be made up by increased inflows to the reservoir delivered by New Mexico. Similarly, when project water users enact policies that increase releases from Elephant Butte, the reservoir falls in volume, evaporation falls slightly, and New Mexico needs to deliver less water into the reservoir.

Albuquerque area M&I users receive slightly negative benefits (\$18,000 per year) from the proposed carryover storage program because they too deliver slightly more surface water to Texas. The model is set up to allocate shortages among users by minimizing total economic losses from drought, while being consistent with the Rio Grande Compact. Since agriculture produces fewer economic benefits per acre-foot of water used than M&I uses, economic losses from shortages are minimized by taking more water from agriculture than from M&I. And when New Mexico delivers extra water into Elephant Butte to pay for added evaporation under the carryover storage proposal, the least costly way to deliver the water from the reservoir is to take most of the water from agriculture and less from M&I.¹⁰⁷

Elephant Butte Irrigation District agriculture loses about \$35,000 per year from the carryover storage program. Over the 44-year time horizon, EBID diverts on average 2,050 less acre-feet of surface water per year under the carryover storage program. This reduced water diversion produces an economic loss of water in EBID agriculture of about \$17 per reduced acre-foot diverted ($\$35,000/2,050$) due to the program.

¹⁰⁷In fact, MRGCD arguably has more senior water rights than Albuquerque M&I, so some or all of the added Compact required deliveries to Texas may come from Albuquerque.

In Texas, El Paso area M&I use incurs a loss due to the program of about \$425,000 per year, resulting from reduced reservoir releases and an increased cost of substituting more groundwater for less surface water. However, since this result depends strongly on the assumptions of the relative cost of pumping versus surface water delivery, it is difficult to assign much precision to this damage estimate.

Similarly, El Paso agriculture incurs a small loss of \$8,000 per year under the carryover storage program for the same reasons that EBID loses. There is an annual average of 320 fewer acre-feet of surface water available for agriculture (205,700 compared to 205,380), with low-valued surface water used less in wet years and high-valued surface water used more in wet years. The \$8,000 gain to El Paso area agriculture of the carryover storage program is valued at \$19 per acre-foot of reduced water ($\$8,000/0.42$).

Increase Irrigation Efficiency in Middle Rio Grande Conservancy District

The next institutional adjustment considered is increased irrigation efficiency in the Middle Rio Grande Conservancy District. This could occur from better irrigation scheduling, more efficient technology, gated pipes, or installation of sprinkler systems. Any of these measures would reduce the river diversion required to deliver a given quantity of water to crops.

Under the current Law of the River for MRGCD, the return proportion is taken to be 0.557,¹⁰⁸ which means that 55.7 percent of its diversions in that year from the river return to the river in the same year. The seepage proportion is taken to be 0.19, in which 19.0 percent of water diverted percolates into deep groundwater in the same year. A reduction of the seepage proportion reduces the proportion of

¹⁰⁸The model is designed to permit interaction between surface and groundwater. Each region is defined to have a known proportion of both return flow and seepage. The return flow proportion is the proportion of surface water diversion that returns to the river in the same period. The seepage proportion is the proportion of the diversion that percolates into deep groundwater in the same period. Percolation in the current period together with groundwater pumping determines net seepage for the region. Net seepage determines the lagged response of the river to pumping.

diverted water that returns to the river in the same period. Numerically, one minus the sum of these two coefficients is the proportion of diverted water that returns to the river.

The institution of increased irrigation efficiency was defined to reduce the base return proportion from 55.7 percent to 45.7 percent of MRGCD's diversion. The seepage proportion was held constant. This institution would maintain constant crop water consumption (evapotranspiration) and constant crop yields, while reducing river diversions required to maintain that constant crop water use.

The net effect on the river of the increased irrigation efficiency proposal is to increase river flows but only slightly, because of two virtually offsetting effects. They are the reduced diversion and a reduced return flow percentage on the water that is diverted.

Water Use Patterns

Table 4-9 shows water use patterns throughout the system, under the increased irrigation efficiency management institution for coping with drought. It also shows the pre- and post-irrigation efficiency return flow percentages for MRGCD.

Over this future period, Colorado agriculture diverts the same 788,000 acre-feet per year of total water, of which about 616,000 comes from surface water and the remaining 172,000 from groundwater pumping. Thus, increased irrigation efficiency at MRGCD in New Mexico has no effect on Colorado delivery requirements and therefore has no impact on water use in Colorado.

In New Mexico above Elephant Butte Reservoir, increasing MRGCD irrigation efficiency by 10% has a considerable effect on reducing river diversions both above and below Albuquerque. Recall that under the current Law of the River, MRGCD diverts 471,000 acre-feet per year on average above and 235,500 acre-feet below Albuquerque (Table 4-5). However, under the increased irrigation efficiency plan, MRGCD diverts 336,500 acre-feet above and 168,250 acre-feet below Albuquerque. Most of those reductions in diversions are not reductions in river depletions, since much of the

diversions under the Law of the River by MRGCD return to the river through seepage. Reductions in diversions are not necessarily reductions in depletions to the river. In fact, estimates produced by our model show that average annual inflows to Elephant Butte Reservoir under Law of the River are about 669,410 acre-feet per year. Under the increased irrigation efficiency program at MRGCD, inflows increase slightly to 688,407 acre-feet per year, so reduced river depletions due to the program are only 18,996 acre-feet per year. This reduced depletion puts a long-run average of 18,996 more acre-feet per year into Elephant Butte Reservoir.

A comparison of tables 4-7 and 4-11 shows that total Albuquerque M&I water use is unaffected by the irrigation efficiency program, diverting 68,280 acre-feet of surface water with and without the program, and 153,330 acre-feet of pumping with and without the program. Municipal and Industrial is a higher economic valued use of water at the margin, than agriculture. Since the model is programmed to seek the least cost method to deliver a given amount of water consistent with the Rio Grande Compact, reduced depletions by MRGCD agriculture causing increased deliveries to Elephant Butte Reservoir are produced by reduced diversions by MRGCD agriculture.

The above-mentioned 18,996 acre-foot per year increase into project storage permits Rio Grande Project water use by EBID agriculture to increase on average very slightly from 428,010 to 428,160 acre-feet per year. El Paso area M&I surface water use increases slightly from 120,180 to 120,220 acre-feet per year, while El Paso area agriculture surface water use increases from 205,700 to 205,770 acre-feet per year on average.

Although not shown in Table 4-9, flows at the Elephant Butte gage show a very small increase from an average of 642,250 to 642,500 acre-feet per year. Maximum project releases past this gage to project users are unchanged at 790,000 both under Law of the River and under increased irrigation efficiency. However, releases past this gage are increased slightly in drought years, by about 250 acre-feet in drought years when larger project releases are not possible.

Table 4-9. Long-Run Average Annual Water Use Patterns under Drought Mitigation by State, Location, and User (1000s of acre-feet)							
Alternative Institution:		<u>Increase Irrigation Efficiency at Middle Rio Grande Conservancy District by 20%</u>					
Drought Scenario:		<u>1942-1985 Historical Inflows (1.40 million acre-feet per year)</u>					
	Colorado	New Mexico				Texas	
	San Luis Valley Agr	Middle Rio Grande Ag above Albuquerque	Albuquerque M&I	Middle Rio Grande Ag below Albuquerque	Elephant Butte Ag	El Paso M&I	El Paso Ag
Average annual total water use (surface diversions + pumping)	787.85	336.50	221.61	168.25	562.07	213.54	205.77
Average annual surface water use (diversion)	616.27	336.50	68.28	168.25	428.16	120.22	205.77
Average annual groundwater use (pumping)	171.58	0.00	153.33	0.00	133.91	93.32	0.00
Elephant Butte Volume	478.70						
Average total water use by state (surface diversions + pumping)	787.85	1,288.43				419.31	
Average surface water use, totaled by state (diversion)	616.27	1,001.19				325.99	
Average groundwater use, totaled by state (pumping)	171.58	287.24				93.32	
Percent MRGCD irrigation diversion returned to river in same year, baseline efficiency	56						
Percent MRGCD irrigation diversion returned to river in same year, increased efficiency	46						

Economic Benefits

Increased irrigation efficiency has only a small impact on mitigating drought damages. The impact on drought damages mitigated is small because the impact on reducing depletions to the river below MRGCD is small -- reduced diversions of 174,150 acre-feet reduce depletions by only 1,340 feet since such a large percent of the diversions reduced are also a large reduction in return flows to the river.

Like the institution of increased storage at Elephant Butte, Colorado agriculture in the San Luis Valley gains zero drought mitigation benefit under increased downstream irrigation efficiency. Under the Rio Grande Compact, Colorado's delivery obligations at the Lobatos gage at the Colorado-New Mexico border, in drought (non-spill) years is unaffected by downstream action in New Mexico.

Table 4-10 shows that drought damage mitigation for MRGCD, through increased irrigation efficiency is zero. This zero impact measure is based on the assumption that MRGCD farmers experience no change in crop yield, but that total water applied to crops is unchanged. Any of these technologies for conserving on river water delivered to crops would come at a cost to the irrigators.

Over the 44-year period of analysis, average flows at the Elephant Butte gage increase from 642,250 to 642,500 acre-feet per year, for a slight gain in agricultural benefits to EBID, measured as drought damage reductions. Table 4.8 shows these damage reductions average a modest \$7,000 per year, which permit a slight increase in crop production from economically marginal crops.

Table 4-10 shows the economic effect of the small addition of water to Rio Grande Project deliveries. This added water is allocated in the amount of 43 percent to Texas and 57 percent to New Mexico lands. Within Texas, the water allocation between El Paso area M&I and El Paso agriculture occurs to maximize the total economic gains across the two sectors. That water allocation produces added benefits (drought damages mitigated) of about \$11,000 per year to area M&I, with a much smaller increase in El Paso area agriculture of \$4,000 per year.

Table 4-10. Long-Run Average Annual Drought Damage Mitigation from Alternative Institution, by State, Location, and User (\$1000s)							
Alternative Institution: <u>Increase Irrigation Efficiency at Middle Rio Grande Conservancy District by 20%</u>							
Drought Scenario: <u>1942-1985 Historical Inflows (1.40 million acre-feet per year)</u>							
	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuquerque	Albuquerque M&I	Middle Rio Grande Ag below Albuquerque	Elephant Butte Ag	El Paso M&I	El Paso Ag
	----- (\$1000s per year) -----						
Average annual economic <u>drought damage mitigated</u>	0	0 ¹⁰⁹	0	0	7	11	4
Average annual recreation <u>drought damage mitigation</u> , summed over 5 Basin reservoirs: Heron, El Vado, Abiquiu, Cochiti, Elephant Butte							3
Average annual economic <u>drought damage mitigation</u> totaled by state	0	7				15	

¹⁰⁹Assumes no change in water applied to crops and no reduction in yields, but a smaller diversion from the river. In fact, the cost of the water savings technology, such as sprinklers, gated pipes, irrigation scheduling, is an added but unknown cost, which makes drought damage mitigation negative.

Build Reservoir Storage in Northern New Mexico

One widely discussed option throughout the west for saving water is to build more reservoir storage in high mountain areas, where evaporation is lower. For this study area, increased storage in southern Colorado or northern New Mexico would reduce evaporation compared to storage in hotter, lower desert areas. Evaporation in the low-desert areas of New Mexico consumes large amounts of water. For example, Elephant Butte Reservoir loses nearly 10 feet to evaporation, or nearly 300,000 acre-feet per year when the reservoir is near its capacity of about 30,000 surface acres. To implement this institutional option, we modified the model to build 100,000 added acre-feet of reservoir storage above Cochiti Reservoir in northern New Mexico. Despite the added storage, we required the river system to be operated consistent with the Rio Grande Compact.¹¹⁰ The Rio Grande Compact permits New Mexico to build added storage as long as deliveries to Texas are maintained. There are two potential advantages to Mexico of building added storage: (1) New Mexico need not overdeliver to Texas in wet years when high flows at Otowi are beyond its maximum capacity to beneficially use water; (2) total evaporation inside New Mexico can be reduced, thereby making more water available for use inside the state. In fact, both of these benefits are borne out as shown below.

Water Use Patterns

The overall impact of building 100,000 acre-feet of added storage in northern New Mexico is to reduce overdeliveries to Texas in wet years, increase agricultural water use in New Mexico above Elephant Butte Reservoir, reduce use by agriculture below Elephant Butte, increase surface water use by El Paso area M&I use, and increase reservoir-based recreation benefits (Table 4-11).

¹¹⁰For example, this scenario does not consider reallocating Rio Grande Project storage at Elephant Butte and Caballo reservoirs upstream in any way.

Table 4-11. Long-Run Average Annual Water Use Patterns under Drought Mitigation by State, Location, and User (1000s of acre-feet)**Alternative Institution:** Build 100,000 Acre-Foot Reservoir on Rio Grande Mainstem above Cochiti Reservoir in Northern NM**Drought Scenario:** 1942-1985 Historical Inflows (1.40 million acre-feet per year)

	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuquerque	Albuquerque M&I	Middle Rio Grande Ag below Albuquerque	Elephant Butte Ag	El Paso M&I	El Paso Ag
Average annual total water use (surface diversions + pumping)	787.85	480.74	221.60	240.37	562.10	213.66	205.32
Average annual surface water use (diversion)	616.27	480.74	70.55	240.37	427.45	120.13	205.32
Average annual groundwater use (pumping)	171.58	0.00	151.05	0.00	134.65	93.53	0.00
Elephant Butte Volume	444.82						
Cochiti Volume + New Reservoir Volume	116.01						
Average total water use by state (surface diversions + pumping)	787.85	1,504.81				418.98	
Average surface water use, total by state (diversion)	616.27	1,219.11				325.45	
Average groundwater use, totaled by state (pumping)	171.58	285.70				93.53	

Reduced overdeliveries to Texas in wet years occur through reduced average inflow to Elephant Butte at San Marcial from about 704,591 to 694,522 acre-feet per year (not in table). MRGCD agriculture water use increases, on average to 489,740 acre-feet above Albuquerque and 240,370 acre-feet below Albuquerque. Under the current Law of the River MRGCD's average use would have been 471,000 above and 235,000 below Albuquerque. The composition of Albuquerque M&I water use is affected only slightly by the reservoir construction, in which surface water uses increase from 68,280 to 70,550 acre-feet per year, thus prolonging the life of Albuquerque's aquifer.

EBID's long-run average agricultural use falls to 427,450 surface water from 428,101 under the Law of the River, while El Paso area agriculture similarly falls to 205,320 from 205,700. El Paso M&I use also falls very slightly from 120,180 acre-feet of surface water to 120,130.

Recreation benefits expand under the added storage. This added benefit occurs because the gain in reservoir volume in northern New Mexico is about 63,010 acre-feet compared to 53,000 acre-feet average storage at Cochiti under Law of the River, while Elephant Butte storage falls from about 685,550 acre-feet on average to about 444,820 acre-feet, for a net basin-wide loss of about 126,720.

Economic Benefits

Table 4-12 shows that drought damage mitigation overall for New Mexico is \$134,000 per year with Texas gaining \$685,000 per year. Colorado is unaffected. Reservoir recreation benefits gain \$158,000 in drought damage mitigation because the recreational value of added storage in northern New Mexico is larger than the recreational value of lost storage at Elephant Butte.

In New Mexico, MRGCD agriculture receives \$99,000 net gain per year in farm income above Albuquerque and \$31,000 per year gain in farm income below Albuquerque. The major cause of this increased benefit produced by building this added storage is to reduce New Mexico's overdeliveries in wet years to Texas at Elephant Butte Reservoir. The largest overdeliveries occur in high-flow years, and

are most pronounced when Otowi flows exceed 1.5 million acre-feet per year. These wet year overdeliveries increase storage volume at Elephant Butte, increasing the basis for evaporation in future years. The increased delivery requirements by New Mexico in those years reduces water used by New Mexico agriculture. With the added storage built above Cochiti, average deliveries at San Marcial are 694,522 acre-feet, still consistent with New Mexico's Rio Grande Compact delivery requirements to Texas.

Below Elephant Butte, Rio Grande Project releases are reduced slightly from a long-run average of 642,250 to 640,068 acre-feet per year, because of the reduced overdeliveries to Texas described above. Drought damage mitigation accruing to EBID agriculture is a small negative \$19,000 per year on average, with a similar negative mitigation for El Paso area agriculture of minus \$5,000 per year, both due to reduced overdeliveries by New Mexico to Texas. El Paso M&I experiences positive drought damage mitigation to the amount of \$690,000 per year.

Table 4-12. Long-Run Average Annual Drought Damage Mitigation from Alternative Institution, by State, Location, and User (\$1000s)							
Alternative Institution: <u>Build 100,000 Acre-foot Reservoir on Rio Grande Mainstem above Cochiti Reservoir in Northern NM</u>							
Drought Scenario: <u>1942-1985 Historical Inflows (1.40 million acre-feet per year)</u>							
	Colorado	New Mexico				Texas	
	San Luis Valley Ag	Middle Rio Grande Ag above Albuq	Albuq M&I	Middle Rio Grande Ag below Albuq	Eleph Butte Ag	El Paso M&I	El Paso Ag
	----- (\$1000s per year) -----						
Average annual economic <u>drought damage mitigated</u>	0	99	23	31	(19)	690	(5)
Average annual recreation <u>drought damage mitigation</u> , summed over 5 Basin reservoirs: Heron, El Vado, Abiquiu, Cochiti, Elephant Butte							158
Average annual economic <u>drought damage mitigation</u> totaled by state	0	134				685	