

# The Rio Grande

Rethinking Rivers in the 21st Century



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# Executive Summary

This year marks the 100th anniversary of the construction of Elephant Butte Reservoir on the Rio Grande in south-central New Mexico. It was one of the first reservoirs built in the 20th century in an attempt to overcome the critical limitation of water availability on where, when, and how humans could settle the American West. Elephant Butte is the largest reservoir in New Mexico, with the ability to store more than 2.2 million acre-feet of water. An acre-foot is equivalent to 325,851 gallons and is enough to supply water to a family of four for one year. While this reservoir was a marvel in 1916—at the time the largest irrigation reservoir in the world—its utility in the 21st century is now called into question due to rising temperatures and a stark reduction in the Rio Grande's flows due to human consumption and climate change.

Elephant Butte Reservoir is in the Chihuahuan Desert five miles north of Truth or Consequences, New Mexico. This massive reservoir is approximately four miles wide and 40 miles long. Due to its size and vast surface area, it evaporates 250,000 acre-feet of water per year when it's full. The evaporation at Elephant Butte far exceeds that of any of the other reservoirs in the Rio Grande Basin and is nearly double that of other high-elevation reservoirs on the Rio Chama in northern New Mexico.

The current evaporation from Elephant Butte Reservoir will only increase as the climate warms. Average annual temperatures in the Basin increased by 2.5 degrees Fahrenheit (°F) from 1971 to 2012 (0.7°F per decade). The U.S. Bureau of Reclamation predicts that by the end of the 21st century, temperatures will increase an additional 5°F to 7°F, and precipitation will decrease.

Flow declines will result from such rises in temperatures. By 2100, it is predicted that flows in the Rio Grande overall will decrease by at least one-third and could decrease by 50 percent in southern New Mexico and Texas. Such flow changes will have a significant impact on the amount of water available for storage in and evaporation from the reservoirs in the Upper Rio Grande Basin, especially those located at lower elevations, like Caballo and Elephant Butte reservoirs.

Storing water in a low-elevation reservoir like Elephant Butte is extremely inefficient and wasteful and will only become more so, especially given the predicted temperature increases in the Basin. A





feasible alternative is to store water upstream in the four high-elevation reservoirs on the Rio Grande and Rio Chama, including Heron, El Vado, Abiquiu, and Cochiti.

Storing Rio Grande Project water in high-altitude reservoirs, even in a dry year like 2013, could save about 40,000 acre-feet of water from evaporating. In an average-rainfall year, like 2010, the savings would be far greater, an estimated 85,000 acre-feet. The conserved water would help offset the impacts of climate change and, if managed wisely, could create significant environmental benefits for the Rio Chama and the 175-mile segment of the Middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir.

Implementing our vision of conserving water in the 21st century by moving reservoir storage upstream and managing our reservoirs in an integrated fashion will require navigating both institutional and legal challenges. Congressional reauthorization will be required in some instances to change how and where water is stored and released. Further, the Rio Grande Compact Commission (representing the three Basin states) will need to approve many of the necessary changes in water storage and management in the Basin.

The looming water scarcity associated with climate change is predicted to sink the Rio Grande Basin into a permanent drought. The solutions of the past century will not serve us in the future. Just as the construction of Elephant Butte Reservoir 100 years ago began a new era of water development, the next 100 years will require us to think equally boldly and to act to overcome the institutional and legal hurdles that currently prevent these necessary solutions from being implemented.

A long-overdue comprehensive evaluation of the reservoirs in the Middle Rio Grande in New Mexico is necessary to bring this idea to fruition. The requested congressional direction and funding mechanisms are already in place in the New Mexico Drought Preparedness Act of 2015, introduced by Senator Tom Udall (D-NM). The concept is sound and with the right backing and implementation could serve as one of the key solutions to ensure water for existing users as well as to ensure environmental flows to protect a living Rio Grande for centuries to come.



# I. Introduction

In an analysis of four of the most iconic river basins in the West, the authors of a recent study advised that:

Nineteenth-century water law, twentieth-century infrastructure, and twenty-first-century population growth and climate change are on a collision course throughout the West. The sooner and more comprehensively we can address the historical water difficulties that define the region, the more likely we will be able to meet and accommodate the new challenges that climate change will bring.<sup>1</sup>



Figure 1.—Map of the Rio Grande Basin.

The collision course described is nowhere more evident than on the Rio Grande. The authors concluded—despite considering the dire state of the Colorado, Klamath, and Sacramento-San Joaquin Bay Delta systems—that the Rio Grande offered “the best example of how climate-change induced flow declines might sink an admittedly smaller, multistate, water system into permanent drought.”<sup>2</sup>

## Rio Grande Basin

The Rio Grande is the third-longest river in the United States, flowing 1,900 miles from its headwaters in the San Juan Mountains of Colorado to the Gulf of Mexico. Along its course it bisects New Mexico and forms the international border between Texas and Mexico.



The Rio Grande was historically characterized by its extreme and highly dynamic flows, which varied by an order of magnitude “from less than 100,000 acre-feet up to well over 1,000,000 acre-feet.”<sup>3</sup>

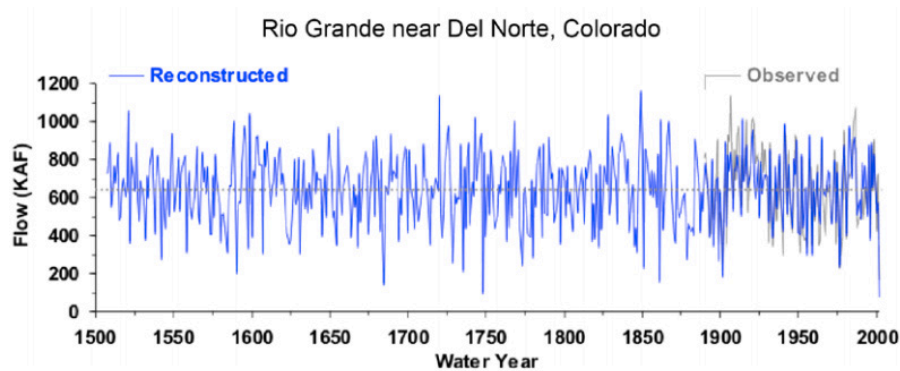


Figure 2.—Rio Grande flows reconstructed from tree rings 1500 to 2000.<sup>4</sup>

These dynamic conditions shaped the habitat and behavior of a diverse array of native fish, wildlife, and plants that inhabited the river and riparian corridor for centuries. Prehistoric fish species, such as the shovelnose sturgeon and American eel, inhabited the waters of the Rio Grande from the Gulf of Mexico to northern New Mexico.



Figure 3.—Shovelnose sturgeon<sup>5</sup> (*Scaphirhynchus platyrhynchus*).

The river served as the lifeblood of the arid Southwest, but its dynamic character challenged human communities that sought to reside along its banks. Pueblos thrived for centuries before the Spanish settled the area, farming the rich fertile soil along the river and in its vast floodplain. The Pueblos worked with the natural flooding and meandering of the river, taking advantage of all it had to offer, as evident by the eighteen Pueblos still clustered along the Rio Grande from Taos to just north of Socorro. However, as Spanish and other European settlers began to inhabit the Rio Grande Valley in the 1600s, this harmony between the mighty river and human communities began to fracture. The river became largely viewed by those new settlers as simply another “resource” to be exploited, and the modern problems that plague the river were born.





## II. The Problem

### 19th-Century Water Law

By the 1800s, those newcomers settling the valley began to siphon the seemingly endless waters of the Rio Grande to sustain mining, livestock grazing, and irrigation.<sup>6</sup> Based on the developing state law around mining at that time, the system of prior appropriation was established for allocating water. Generally, the doctrine creates private rights in the public water resource when an individual puts water to a “beneficial use.” The oldest or “senior” right established is the highest priority right on that river and will receive water before any other “junior” rights established later in time. While each state developed its own nuanced system, the law is simple and rigid and does not provide much, if any, flexibility.

The strict doctrine has several key flaws. First, it does not provide any rights to ensure that river ecosystems have enough water to properly function or that rivers are not sucked completely dry. Second, without this critical precaution in the law, the system of allocation awards far more “rights” to water than the river system can support in any given year. For example, in California’s San Joaquin River, “people have rights to nearly nine times more water than flows down from the [mountains].”<sup>7</sup> Thus, the law is designed to over-promise water to more uses than a river can possibly deliver, based on the assumption that the states will police the rights according to the long line of users based on the priority of the right and the water available. As more people got in line and supplies began to be stretched beyond their limits, this flawed system resulted in the destruction of the natural flows in our rivers and the adjacent riparian ecosystems. The final defect of the system is that rivers do not heed arbitrary political boundaries and often cross several states before reaching the ocean. This makes it difficult for one state to administer the priorities without harming downstream users in another state.

In the late 1880s, these problems began to play out for the Rio Grande in the form of severe water shortages in New Mexico, Texas, and Mexico due to the booming irrigation in Colorado’s San Luis



Valley. However, the system of prior appropriation provided no mechanism for ensuring that upstream states did not take all the water from their neighbors to the south. The problem was so severe that the federal government was forced to intervene. In 1896, the Secretary of the Interior placed an embargo on all water development in the Rio Grande Basin until a comprehensive solution could be fashioned. However, the solution to address the problems of the 19th century became measures well outside the system of prior appropriation. These measures involved the negotiation of an interstate water compact (the interstate “law of the river”) to allocate the Rio Grande’s water among Colorado, New Mexico, and Texas; the signing of the 1906 treaty clarifying the United States’ obligation to deliver a certain amount of water to Mexico each year; and the beginning of the plan to construct the first major dam and reservoir on the Rio Grande.

## 20th-Century Infrastructure

By the early 1900s, the Rio Grande’s waters were already over-promised, as was much of the surface water throughout the West. The strategy for dealing with this water scarcity was not finding ways to live within our means by reducing or conserving water or limiting human communities to areas where water was available. Instead, the plan was to pour concrete and reengineer our rivers to further stretch water supplies to irrigate farms in the desert and prevent the natural flooding of the river. Congress ushered in this new era of water development with the passage of the Reclamation Act of 1902<sup>8</sup> and the Flood Control Acts of 1948, 1950, and 1960.<sup>9</sup> These acts authorized and funded the construction of irrigation infrastructure across the West as well as dams and levees to provide flood and sediment control.



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Elephant Butte Reservoir was the first large reservoir constructed on the Rio Grande at the turn of the century. The reservoir was part of one of the first federally funded, large-scale water development projects in the West (the Rio Grande Project). At the dam's declaration on Oct. 19, 1916, the director of the Reclamation Service (now the U.S. Bureau of Reclamation) explained the variability in flows of the Rio Grande and the susceptibility of the Basin to a series of dry years followed by several wet years and justified the need for Elephant Butte Reservoir<sup>10</sup> as follows:

[T]he full utilization of this water supply could not be obtained without a reservoir of immense dimensions—one large enough, first, to hold the waters of those great years when 2,000,000 acre-feet were discharged, and to provide for evaporation and hold that water here until a dry year should come. Then, in addition to the great capacity necessary for that purpose, it would be necessary to provide for the entire time storage of the large amount of sediment that passes down the river.

This attitude dominated the 20th century of water development on the Rio Grande and sparked the construction of massive infrastructure that led to the draining of this iconic river.

From 1916 to 1975, the federal government embarked upon the construction and rehabilitation of more than 20 additional dams and reservoirs along the Rio Grande and its tributaries. Eight of these dams—those located in the middle Rio Grande (Heron, El Vado, Abiquiu, Cochiti, Jemez Canyon, Galisteo, Elephant Butte, and Caballo reservoirs)—created five million acre-feet of storage in the Rio Grande system.

This additional infrastructure was not without its consequences. First, by significantly changing the timing and amount of water flows in the Rio Grande, the dams and reservoirs destroyed the

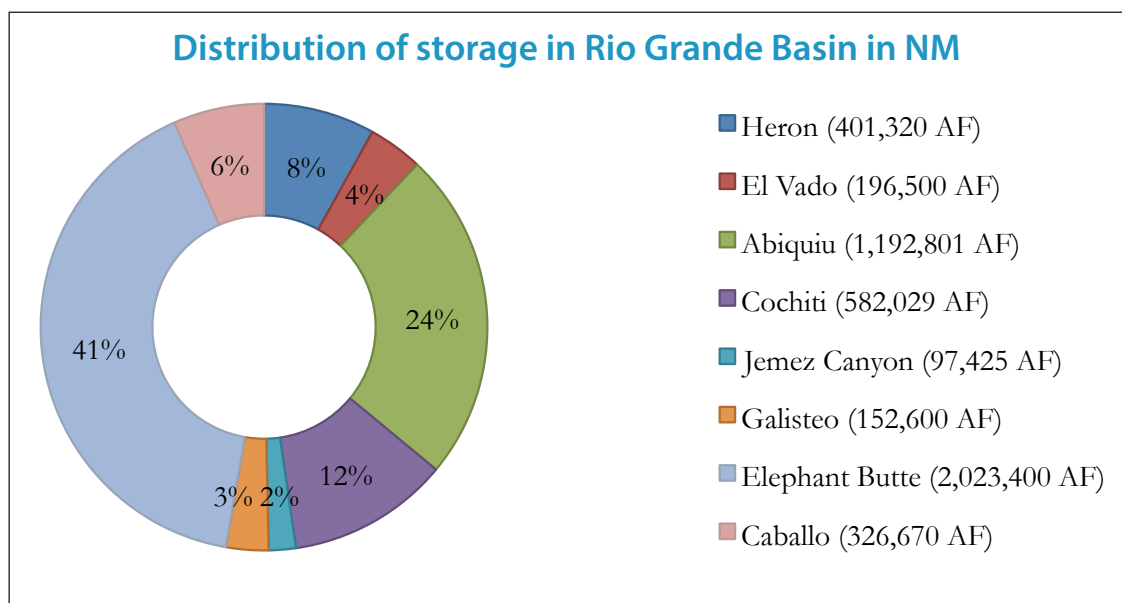


Figure 4.—Distribution of available storage in the Rio Grande Basin in New Mexico.



dynamic flows that had characterized the river system and segmented aquatic habitat of native species of fish and wildlife. Dams also trapped “significant amounts of sediment,” changing the structure of the river and the availability of aquatic and riparian habitat.<sup>11</sup> These fundamental changes to the river inhibited native species from carrying out basic life functions (such as breeding, feeding, and finding shelter) and resulted in the extirpation or extinction of a total of seven native fish species, including the Rio Grande bluntnose shiner and shovelnose sturgeon. Many additional plants and animals were pushed to the brink of extinction, including the Rio Grande silvery minnow, Southwestern willow flycatcher, yellow-billed cuckoo, New Mexico meadow jumping mouse, and Pecos sunflower, among others. Further, these same reservoirs are responsible for adding methane emissions into the atmosphere that are fueling climate change.<sup>12</sup>

In addition to these impacts, one of the most significant effects of damming the Rio Grande and its tributaries is the considerable increase in open water evaporation in the Basin. This became apparent from the S.S. Papadopoulos & Associates, Inc. study prepared in 2000 that evaluated the water supply and demand in the 175-mile reach of the Rio Grande from Cochiti Reservoir to Elephant Butte Reservoir. That study also developed a water budget and examined whether New Mexico could meet its delivery obligations to Texas under the Rio Grande Compact in the future.<sup>13</sup> The study found that reservoir evaporation makes up about 20 percent of the mean depletions in the river system and is highly variable.<sup>14</sup> Based on these significant changes in the volume and associated surface area, evaporation from the reservoir can range from 10 percent to 30 percent of the overall Basin depletions.

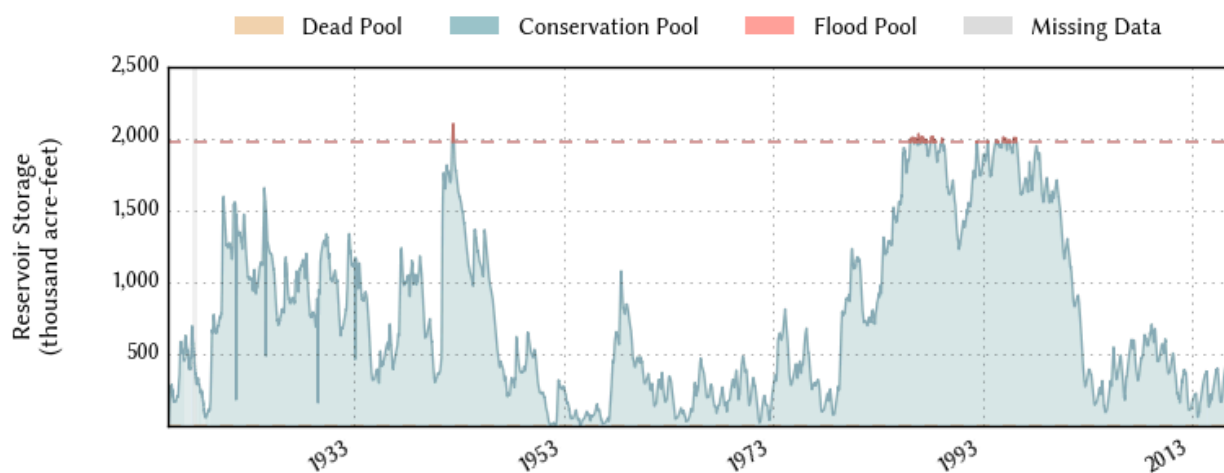


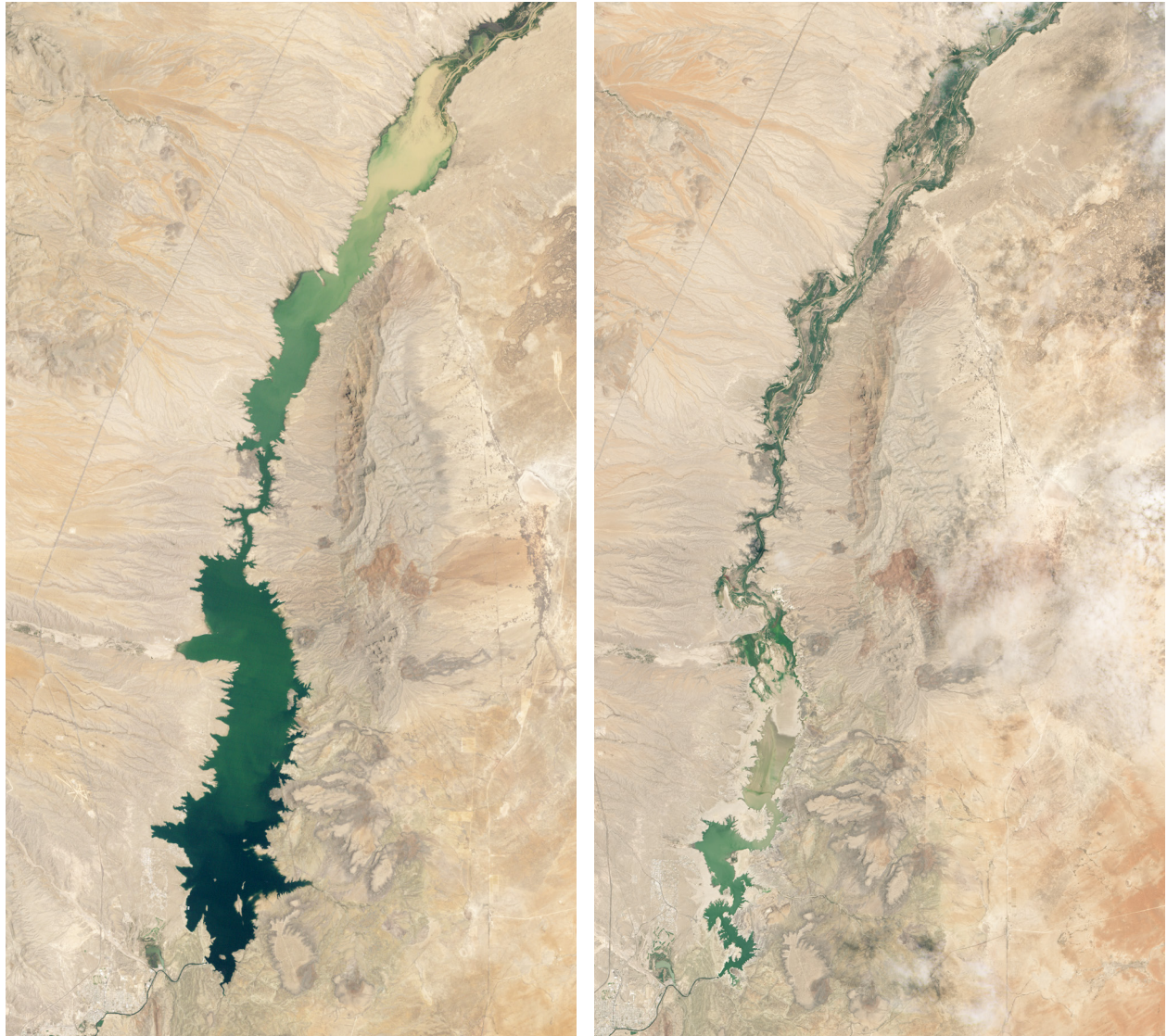
Figure 5.—Reservoir storage in Elephant Butte Reservoir for the past 100 years.<sup>15</sup>

Elephant Butte Reservoir is largely responsible for this variation due to its incredible fluctuations in storage and associated surface area.

From 1916 to 2016, Elephant Butte filled to its capacity of 2.2 million acre-feet only three times: in the 1940s, mid-1980s, and mid-1990s. It remained near its capacity from 1985 to 2000. However,



after nearly a decade of hovering around 500,000 acre-feet, the reservoir hit its lowest level in the past forty years in the summer of 2013, when the reservoir fell to 65,057 acre-feet (3 percent of capacity). Figures 6 and 7 show Elephant Butte Reservoir on June 2, 1994, when the reservoir was full, and on July 8, 2013, when it was virtually empty.

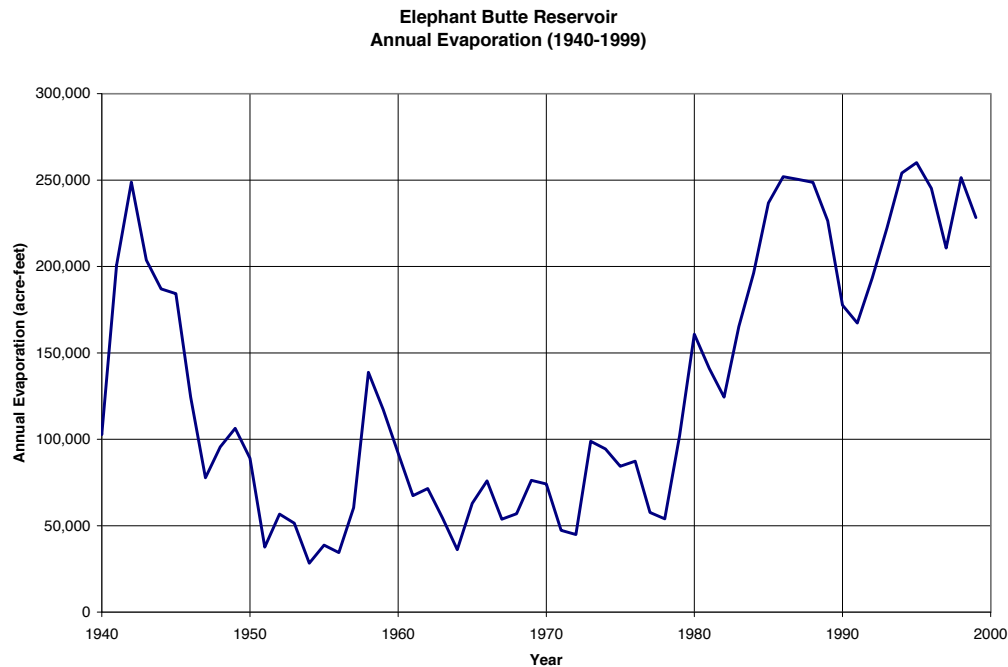


*Figures 6 and 7.—Elephant Butte Reservoir on June 2, 1994, as compared to July 8, 2013.<sup>16</sup>*

The surface area of Elephant Butte when full is 36,000 acres (57 square miles); however, in July 2013, the surface area of the reservoir was merely 4,171 acres (6.5 square miles).

Similar to and influenced by the vast range of reservoir levels, Elephant Butte Reservoir's evaporation has "ranged from less than 50,000 acre-feet per year to over 250,000 acre-feet per year during the past 50 years."<sup>17</sup> The annual evaporation from Elephant Butte Reservoir from 1940 to 1999 is shown in Figure 8.





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*Figure 8.—Annual evaporation loss from Elephant Butte Reservoir 1940-1999.<sup>18</sup>*

The unique problem of Elephant Butte Reservoir—beyond its size and location in a very arid region of New Mexico—is that evaporation “increases at a greater rate than incremental storage.”<sup>19</sup> Thus, as the reservoir holds more water, the amount of water that evaporates dramatically increases. This is a significant factor in determining the future utility of this reservoir, given the challenges of climate change in the 21st century.

## 21st-Century Population Growth and Climate Change

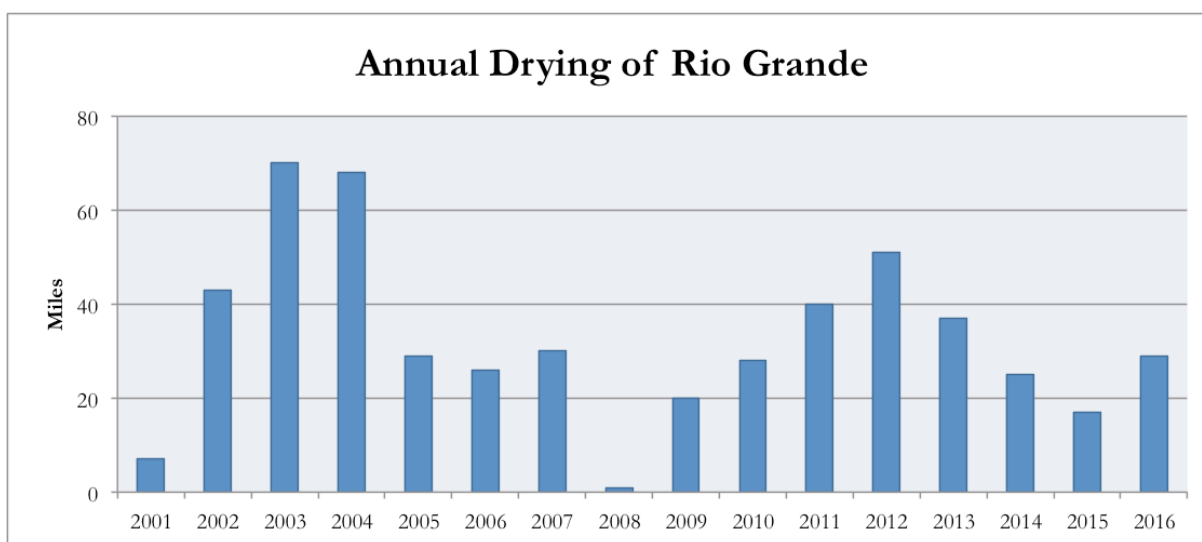
In addition to the already significant challenges facing the Rio Grande prior to the 21st century, this century compounds those burdens with the pressures of population growth, increasing consumption, and climate change. The Rio Grande currently supplies water to municipal and irrigation uses for more than six million people and two million acres of land in the United States and Mexico.<sup>20</sup> Earlier this year, Reclamation concluded that “[t]he river’s flows are often insufficient to meet the basin’s water demands” and that “[t]he magnitude and frequency of water supply shortages within the Rio Grande Basin are severe, even without the effects of climate change.”<sup>21</sup>

The stress placed on the Rio Grande is felt most acutely in its river ecosystems. The warning signs of this problem are river drying and the inability of native species of fish and wildlife to survive given the current challenging conditions. The drying of the Rio Grande in the middle valley in central New Mexico now occurs annually due to water mismanagement in the region. This drying, when



combined with segmentation of habitat caused by gigantic flood control dams, like Cochiti Dam, has led to a significant decline of native species of plants and animals. In 2003, seventy miles of the river dried. Such annual drying is detrimental to the native fish and wildlife and has resulted in a huge uptick in listing of endangered and threatened species on the Rio Grande since the mid-1990s, including the Rio Grande silvery minnow, Southwestern willow flycatcher, Pecos sunflower, yellow-billed cuckoo, and New Mexico meadow jumping mouse, among others.

As the climate warms, these stresses on riverine and riparian environments will become even more pronounced. The West-Wide Climate Risk Assessment for the Upper Rio Grande Basin, conducted by Reclamation in 2013, found that average annual temperatures in the Basin increased by 2.5 degrees Fahrenheit (°F) from 1971 to 2012 (0.7°F per decade), a rate nearly double the global rate



*Figure 9.—River drying along the Rio Grande in central New Mexico 2001-2016.*

of temperature rise.<sup>22</sup> “The greatest temperature increases were measured at sites in the Middle Rio Grande” with an increase of 0.88°F per decade from 1971 to 2012.<sup>23</sup>

Reclamation’s 2013 study also predicted that future mean annual temperatures in the Upper Rio Grande Basin would increase by an additional 5°F to 7°F and precipitation would gradually decrease by the end of this century.<sup>24</sup> As a result, flows in the Rio Grande are projected to decrease by an average of one-third.<sup>25</sup>

These flow reductions, however, will not be distributed evenly throughout the Basin. The climate assessment predicts that by 2100 flows in the Rio Grande will decline in Colorado by 25 percent, in central New Mexico by 35 percent, and in southern New Mexico and Texas by 50 percent.<sup>26</sup> This disparity by region is largely due to the way the 1938 Rio Grande Compact artificially and unevenly distributes water between the states. “These declines are Reclamation’s worst modeled flow outcomes from climate change in the entire United States.”<sup>27</sup>



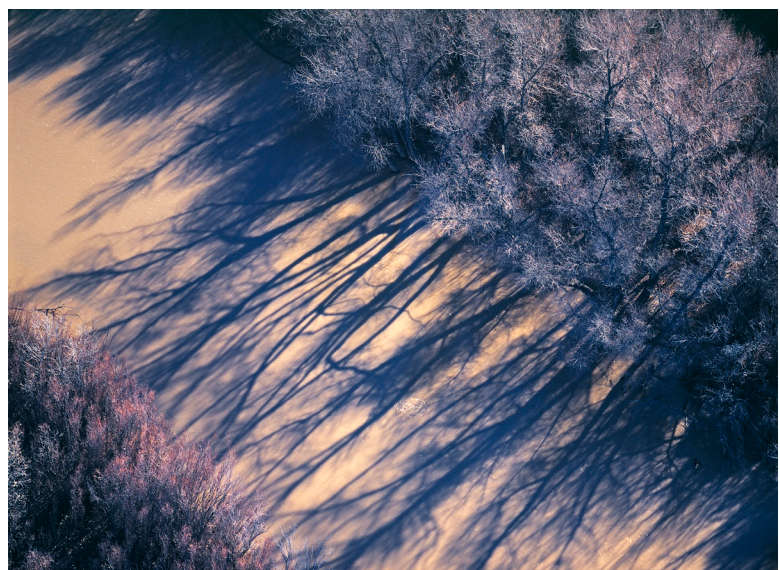


## III. Opportunity

The challenges facing the Rio Grande are great. To move beyond the archaic system of water allocation, the outdated and excessive infrastructure, and the anticipated flow reductions due to our warming climate, we need not only a bold vision but also a willingness to make significant legal and institutional changes. One opportunity—to move beyond the status quo and address the evaporation losses that are creating a significant drain on the Rio Grande system—is to evaluate moving water storage from low- to high-elevation reservoirs<sup>28</sup> to conserve water.

The 2000 Middle Rio Grande Water Supply Study first identified the stress of evaporation losses from Elephant Butte Reservoir and recommended a further assessment of the costs and benefits of continuing to store water there.<sup>29</sup> The Water Acquisition and Management Subcommittee (WAMS) built on this study by preparing a report for the Middle Rio Grande Endangered Species Collaborative Program in 2005. The report emphasized that “evaluating water saving potentials under alternative reservoir operation scenarios during wet and dry water years using realistic allocations of water storage volumes and surface areas” is a high priority and set the objective for its study “to define appropriate water operation alternatives to minimize reservoir evaporation losses and to maximize the conservation of water available to meet Program goals.”<sup>30</sup>

Based on these goals, the subcommittee produced a short background paper evaluating the reservoir free-water surface evaporation rates for the seven Rio Grande reservoirs (Heron, El Vado, Abiquiu, Cochiti, Jemez Canyon, Elephant Butte, and Caballo).<sup>31</sup> The





following Table 1, reproduced from the WAMS study, represents the maximum evaporation losses from these reservoirs and shows the disproportionate amount of water evaporating from the low-elevation reservoirs compared to their counterparts upstream.

Table 1

Reservoir	Spillway Crest Elevation (feet AMSL)	Surface Area at Spillway Elevation (acres)*	Capacity at Spillway (AF)*	Estimated Annual Pan Evaporation (inches/year)	Estimated Annual Free-Water Surface Evaporation (inches/year)	Estimated Percent Surface-Unit Evaporation Relative to EBR	Estimated Maximum Annual Free-Water Surface Evaporation at Area of Spillway Elevation (acre-feet/year)*
Heron	7,186	5,950	401,320	53.2	36.0	46%	17,850
El Vado	6,879	2,452	196,500	60.3	40.8	52%	8,337
Abiquiu	6,350	12,430	119,280*	76.5	52.1	67%	53,967
Cochiti	5,461	9,307	582,019	91.2	61.9	79%	48,009
Jemez Canyon	5,232	2,943	97,425	103.1	71.5	92%	17,535
Elephant Butte (EBR)	4,450	35,984	2,023,400	111.3	77.9	100%	233,596
Caballo	4,182	11,532	326,670	104.3	73.0	94%	70,153

\* These areas, capacities, and maximum evaporation rates are theoretical and used to provide standardized comparisons. For example, although the spillway is higher, the USACE is authorized to store only up to the 6,283.5 foot elevation in Abiquiu Reservoir, with a maximum capacity of 545,784 acre feet.

Table 1.—Comparison of maximum evaporation losses from seven Rio Grande reservoirs.<sup>32</sup>

The estimated annual evaporation losses by reservoir (as reported in the WAMS study) are represented in Figure 10.

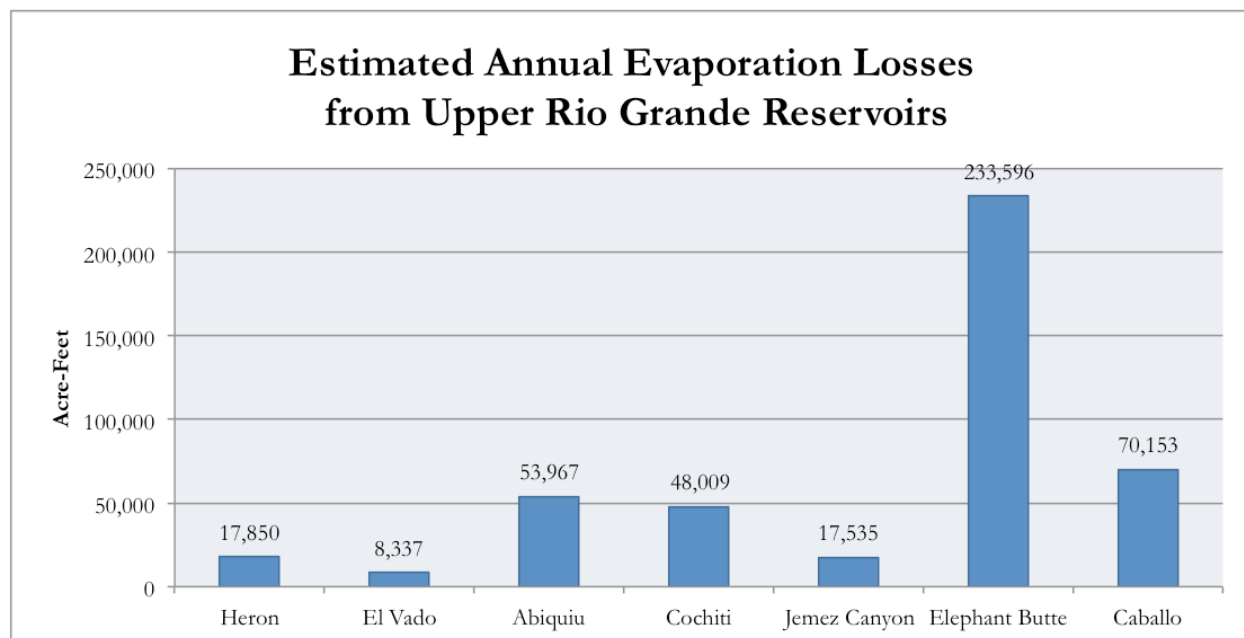


Figure 10.—Evaporation losses from seven Rio Grande reservoirs as reported by WAMS in Table 1.

The reason for the dramatic difference in evaporation is that evaporation rates vary significantly based on the location, elevation, surface area, and environmental conditions of the reservoir. All of

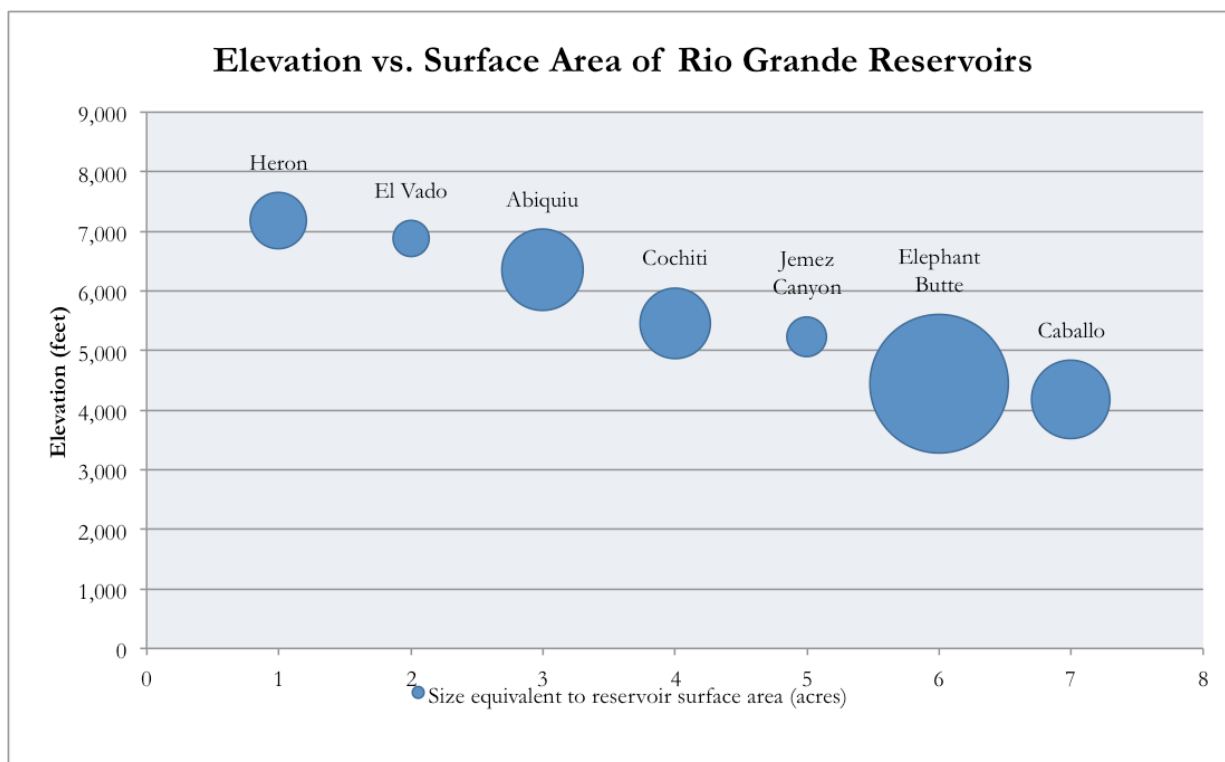


Figure 11.—Relative elevation and surface area associated with seven Rio Grande reservoirs.

these factors influence evaporation rates in the Middle Rio Grande. Figure 11 shows the elevation and surface area of seven reservoirs located on the Rio Chama and Rio Grande in New Mexico.

The size of each circle represents the relative surface area of that reservoir and the height of each circle shows its elevation. There is a 3,000-foot difference between the highest elevation reservoir (Heron) at 7,186 feet and the lowest elevation reservoir (Caballo) at 4,182 feet. Even more stark is the contrast between the reservoir with the smallest surface area (El Vado) at 2,452 acres and the largest (Elephant Butte) at 35,984 acres.

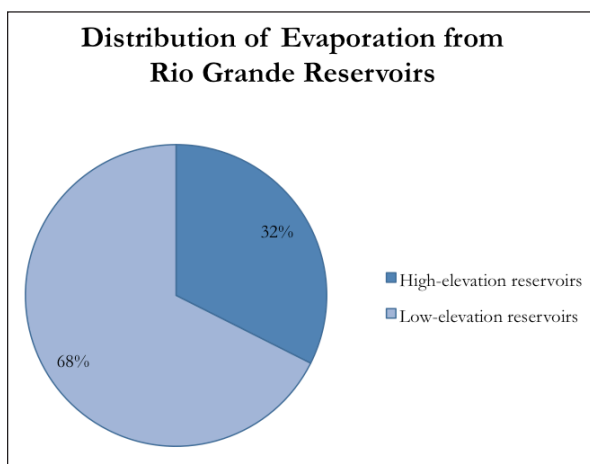
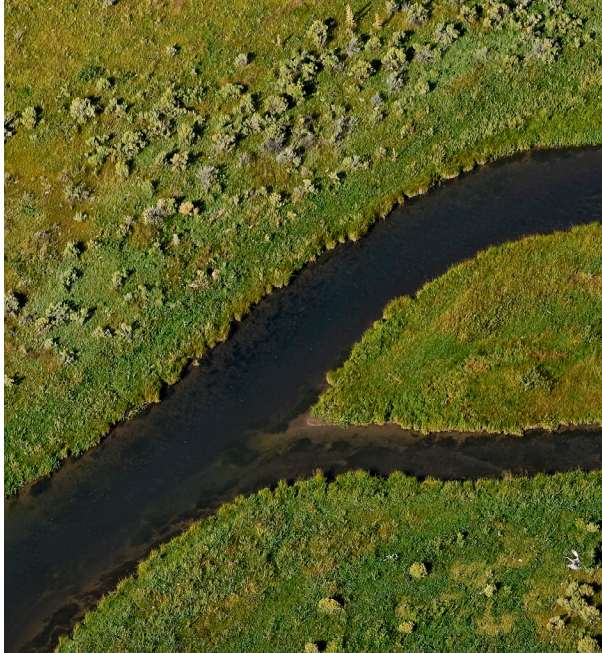


Figure 12.—Comparison of evaporation losses between high- and low-elevation reservoirs.

Despite the fact that nearly five million acre-feet of storage is divided almost equally between high-elevation (2,470,065 acre-feet) and low-elevation (2,350,070 acre-feet) reservoirs, the distribution of evaporative losses is not. The large, low-elevation reservoirs (Elephant Butte and Caballo)—which average 4,316 feet in elevation—make up over 68 percent (303,749 acre-feet) of the evaporation losses in the Rio Grande Basin in New Mexico. The other five reservoirs (Heron, El Vado, Abiquiu, Cochiti, Jemez Canyon)—which average 6,222 feet in elevation—account for 32 percent (145,698 acre-feet) of evaporation losses.





“...significant savings of water could be possible if greater proportions of New Mexico’s Rio Grande water were stored upstream of Elephant Butte Reservoir at locations of increased elevation.”

Based on the drastic difference between high- and low-elevation reservoir evaporation, the WAMS report ultimately concluded that “[s]ignificant savings of water could be possible if greater proportions of New Mexico’s Rio Grande water were stored upstream of Elephant Butte Reservoir at locations of increased elevation.”<sup>33</sup> Importantly, the subcommittee recommended that “[t]he information here should be further developed through a subsequent study to evaluate water saving potentials under alternative reservoir operation scenarios using realistic allocations of water storage volumes and surface areas among these reservoirs for a selection of wet to dry years.”<sup>34</sup> Despite these calls for a comprehensive study and modeling of evaporation for these seven reservoirs, stakeholders have made no progress over the past decade in evaluating alternative storage scenarios. Instead they have actually thwarted the development of this solution, based on their own unwillingness to veer from the status quo.<sup>35</sup>

The need for such a study is only getting more urgent based upon conditions in the Basin. Over the past decade, flows in the Rio Grande have been below average in eight years. From 2011 to 2014, the flow forecasts were below 50 percent of average—reaching a low of 23 percent in 2013—and only returning to hover around 50 percent during the past two years. Further, years when reservoir storage is not at capacity provide an opportunity to move storage upstream to fill unused reservoir space with little threat of limiting future storage.

The effects of climate change will only grow more severe in the coming decades. Reclamation found in its 2016 SECURE Water Report that evaporation from Elephant Butte “is projected to increase by up to 10 percent.”<sup>36</sup> This forecast should place a renewed urgency on completing an independent, comprehensive study that models evaporation from these seven reservoirs and that provides recommendations for a new, integrated approach to reservoir management for the 21st century.



An aerial photograph showing a dark blue river meandering through a vast, vibrant green landscape. The river forms several large, rounded loops and curves. The surrounding land appears to be a mix of grass and low-lying vegetation. The lighting is bright, suggesting a sunny day.

## IV. The Solution

To demonstrate the potential water savings of transferring storage to upstream reservoirs, we conducted an analysis of the monthly storage and evaporation during two years over the past decade, representing average and dry conditions. Appendix A contains a detailed look at the method used in this analysis and the alternatives selected. We chose the year 2010 (April 1 forecast was 102 percent of average) to show a year where average conditions of water availability and storage existed. By contrast, 2013 (April 1 forecast was 23 percent of average) was selected to show water availability and storage conditions in a dry year. 2013 is the driest year on record since the drought of the 1950s and 1960s.

We understand that this analysis is simplistic and that a more comprehensive analysis is needed to explore a full range of alternatives. A future study (conducted by a third party that does not have a stake in the outcome of the effort) that models evaporation and carriage losses associated with different storage and release scenarios is essential to explore all opportunities for water savings and environmental benefits. We, however, provide this investigation as a snapshot of what moving low-elevation storage upstream could produce in water savings and environmental benefits to incentivize further commitment and funding to undertake this more comprehensive study.

Section A identifies the water savings and quantifies the benefits of reallocating that water back to the river to support peak and perennial flows.





## A. WATER SAVINGS

### 2010 Water Savings

In 2010, the estimated evaporation loss from the six Rio Grande reservoirs (Heron, El Vado, Abiquiu, Cochiti, Elephant Butte, and Caballo) was calculated at 157,406 acre-feet.<sup>37</sup> Most of that evaporation (73 percent or 113,874 acre-feet) was the result of storing water in the low-elevation reservoirs of Elephant Butte and Caballo. Moving the low-elevation storage upstream in a wholesale fashion—as shown in scenario 1 (Figure 13)—would save nearly 100,000 acre-feet of water (96,164 acre-feet) from evaporating.

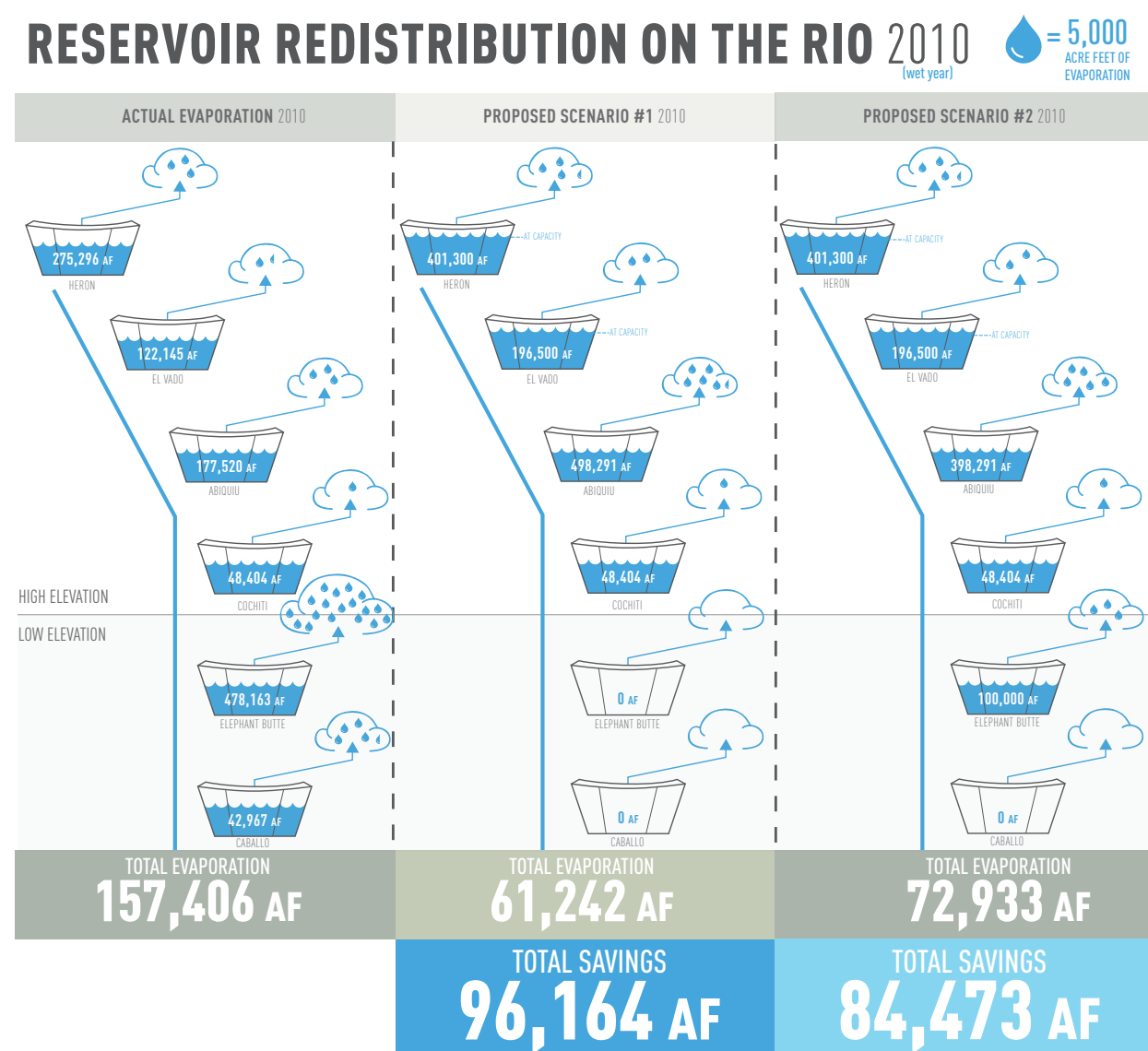


Figure 13.—Possible scenarios based on 2010 data for redistributing reservoir storage on the Rio Grande.



Moving the low-elevation storage upstream in a wholesale fashion would save nearly 100,000 acre-feet of water (96,164 acre-feet) from evaporating.

While scenario 1 seems attractive based on its result, the scenario would not practically accommodate the delivery of Rio Grande Project water to downstream users and could threaten New Mexico's ability to meet its delivery obligation to Texas under the Rio Grande Compact. This alternative simply shows that significant water savings can be achieved by moving storage upstream and sets the upper limit of such savings based on the existing conditions.

A more practical alternative (of which there could be many iterations) involves ensuring at least some minimal necessary storage in Elephant Butte Reservoir or Caballo Reservoir to ensure downstream deliveries. The second alternative developed does just that. Scenario 2 (Figure 13) assumes that all low-elevation storage will be kept in high-altitude reservoirs, except to require a 100,000 acre-foot pool remain in Elephant Butte Reservoir each month. Elephant Butte was chosen as the storage location based on the lower evaporative losses of that water compared with storing it in Caballo Reservoir.

Storage scenario 2 reduces the overall savings identified in scenario 1 by 10,000 acre-feet, but still conserves 84,473 acre-feet of water that would have otherwise evaporated.

## 2013 Water Savings

In 2013, the total evaporation estimated from the six Rio Grande reservoirs (Heron, El Vado, Abiquiu, Cochiti, Elephant Butte, and Caballo) was calculated at 93,934 acre-feet. Sixty-five percent of the water that evaporated (61,172 acre-feet) was the result of storage in low-elevation reservoirs.

As shown in scenario 1 (Figure 14), the wholesale relocation of the low-elevation storage upstream would save over 50,000 acre-feet of water (55,619 acre-feet) from evaporating. While this option does not provide a practical solution for delivery to downstream users, it sets the maximum of attainable savings under the conditions.



Scenario 2 (Figure 14) was developed to move a significant portion of the low-elevation storage upstream, but still provide for 50,000 acre-feet of storage in Elephant Butte Reservoir to meet deliveries downstream. Storage scenario 2 still realizes a water savings of 38,401 acre-feet.

While evaporation in dry years is much less than in wet or average years (when reservoirs are typically full), dry years are when water savings and retiming of deliveries could help make up shortages in the system and provide environmental benefits to already critically stressed ecosystems.

## RESERVOIR REDISTRIBUTION ON THE RIO 2013 (dry year)

 = 5,000  
ACRE FEET OF  
EVAPORATION

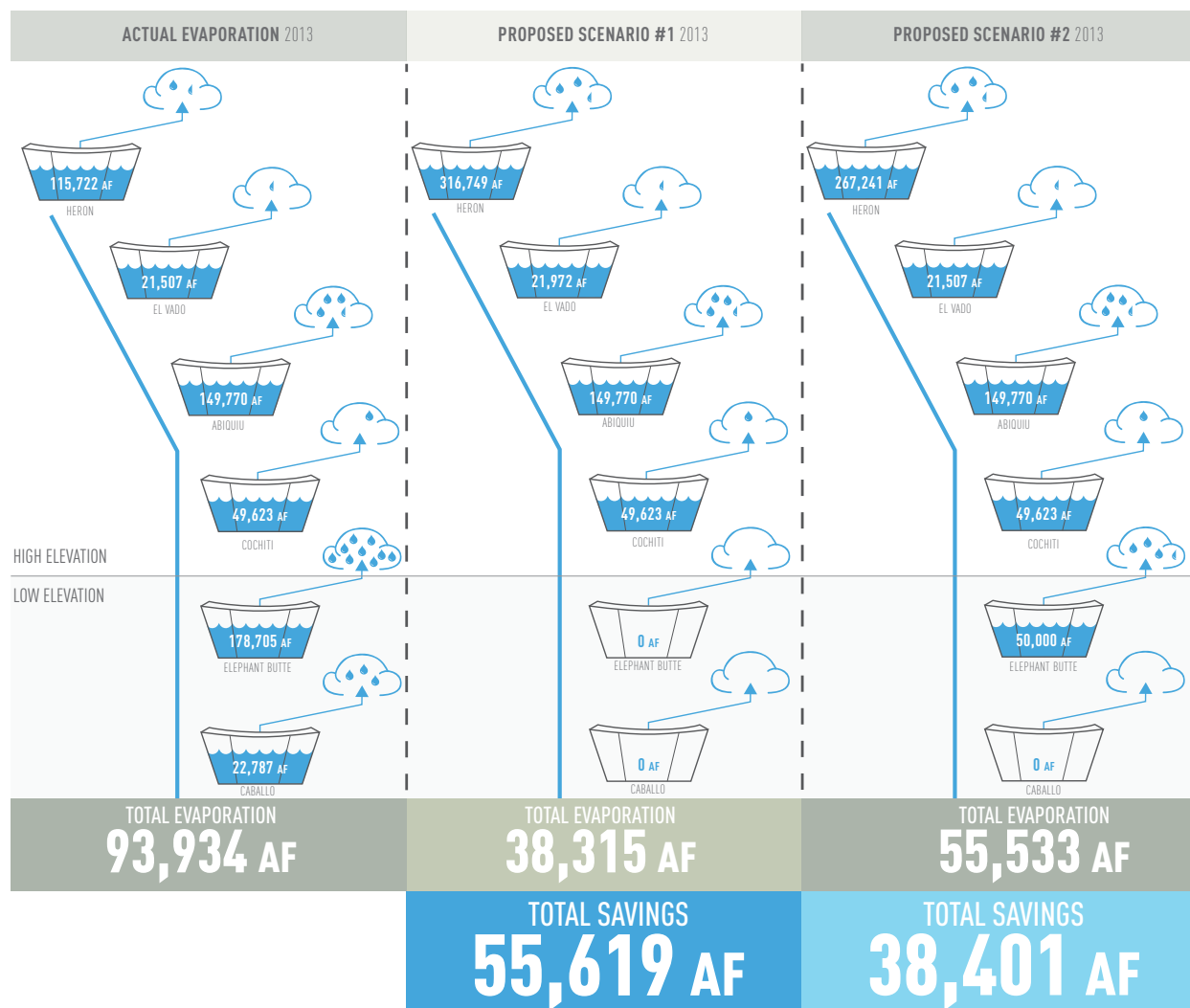


Figure 14.—Possible scenarios based on 2013 data for redistributing reservoir storage on the Rio Grande.

## B. BENEFITS

The imperiled Rio Grande could benefit significantly from relocating storage upstream and the associated water savings that would result. In addition, these changes in storage and re-timing of releases of water in the Basin may create additional efficiencies and benefits for water users, communities, groundwater storage, fish and wildlife, and the Bosque, among other interests.

Possible benefits include:

- Increased base flows in the river during the irrigation season from the transport of Rio Grande Project water downstream for delivery to water users;
- Continuous river flows on the Rio Chama and the Rio Grande due to increase in base flows as well as the availability of water to release with the intention of keeping river flows connected;
- Spring peak flows generated by release of upstream storage (even in dry years when peak flows would not normally occur due to water diversion demands);
- Incentive to measure and ensure water deliveries from upstream storage to downstream location through Middle Rio Grande for greater accountability in the Basin;
- Availability of water to offset water deliveries when the river needs flows the most, even if the conditions on the river will create additional depletions to the system (e.g., evaporation, seepage, use by riparian vegetation, etc.);
- Greater flexibility to operate reservoirs in an integrated manner;
- Opportunity to address the predicted climate-induced flow declines in the Basin;
- Protection and recovery of endangered fish and wildlife;
- Natural recharge of underground storage due to increased and continuous base flows in the river, providing a safety net for water users; and
- Healthy aquatic and riparian ecosystems on the Rio Chama and Rio Grande.

In order to ground these general benefits in specific examples, we provide two instances of how to utilize the upstream storage and associated water savings in 2010 and 2013 to combat two perpetual environmental problems facing the Rio Grande: the annual river drying and the inability to create a spring peak flow. The following map (Figure 15) shows the extent of river drying from Cochiti Dam to Elephant Butte Reservoir in 2010 compared to 2013.

First, as mentioned earlier, river drying in the Rio Grande in central New Mexico is a continual problem based on the high demand and limited supply of water available each year. Even in an average year—such as 2010 where there appears to be a good deal of water based on river flows and storage—28 miles of the river dried (8.5 miles in the Isleta reach, south of Albuquerque, and 19.7 miles in the San Acacia reach, between Socorro and the south boundary of Bosque del Apache National Wildlife Refuge). This is only 10 miles short of the drying during 2013, one of the driest years on record.



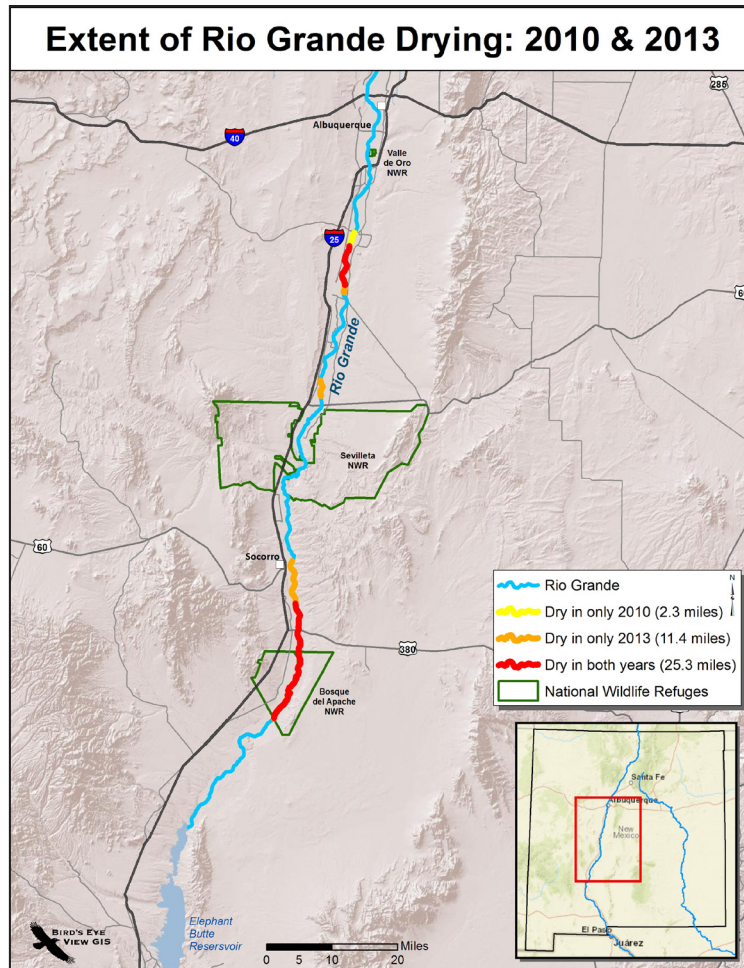


Figure 15.—Extent of Rio Grande drying from Albuquerque to Elephant Butte Reservoir in 2010 and 2013.

The change in operations necessitated by storing Rio Grande Project water in upstream reservoirs may help alleviate this problem. Under the proposed scenario 2 (Figure 13), it is assumed that to meet downstream obligations water must be released from high-elevation reservoirs and carried downstream to maintain the 100,000 acre-feet of storage in Elephant Butte as its contents are evacuated to downstream users.

This release of water downstream would serve the dual purpose of water delivery and creation of environmental flows in hundreds of miles of the Rio Chama and Rio Grande from the location of the upstream storage (in Heron, El Vado, or Abiquiu reservoir) to Elephant Butte Reservoir. The depletions that will certainly occur as some of this water evaporates and seeps into the channel while flowing downstream could be offset by a portion of the 85,000 acre-feet of water savings created by implementation of this alternative storage scenario.

If these deliveries of Rio Grande Project water are still not sufficient to alleviate the drying in the river, a portion of the water saved could be intentionally released downstream at certain times of the year to ensure the river remains connected and that flows are sufficient to support the health

of fish, wildlife, and plants in and along the river. For example, if 40,000 of the 85,000 acre-feet were dedicated to maintaining river flows during four summer months and released continuously over that period, an additional flow of about 150 cubic feet per second (cfs) could be maintained in the river on top of the existing base flow. In 2010, such additional flow would have been enough to ensure that the dwindling river flows at Bosque, NM (hovering below 100 cfs) in the Isleta Reach (Figure 16) would be bolstered above this critical level and reach a more stable flow of around 250 cfs.

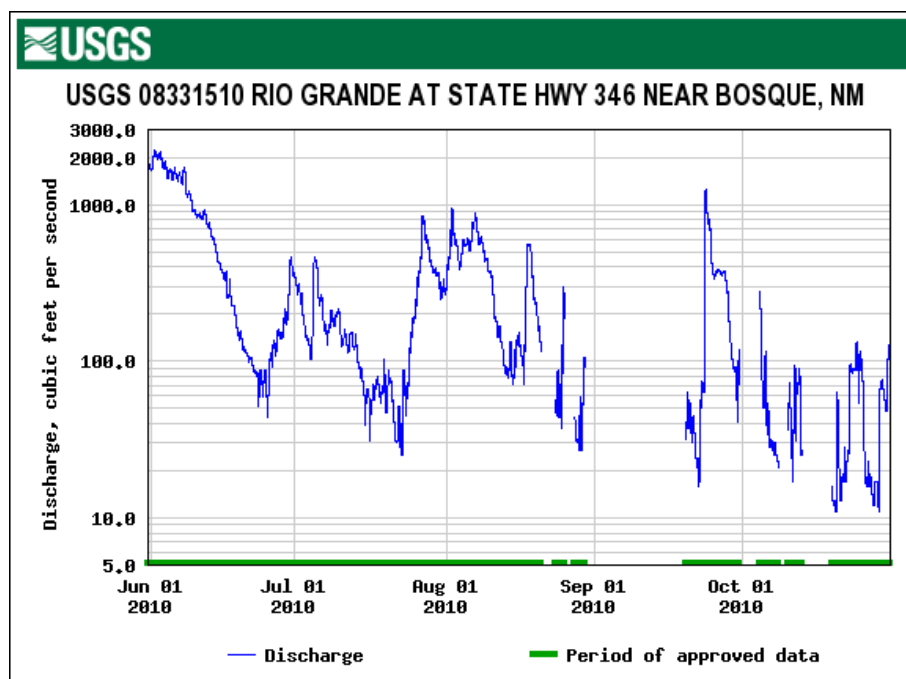


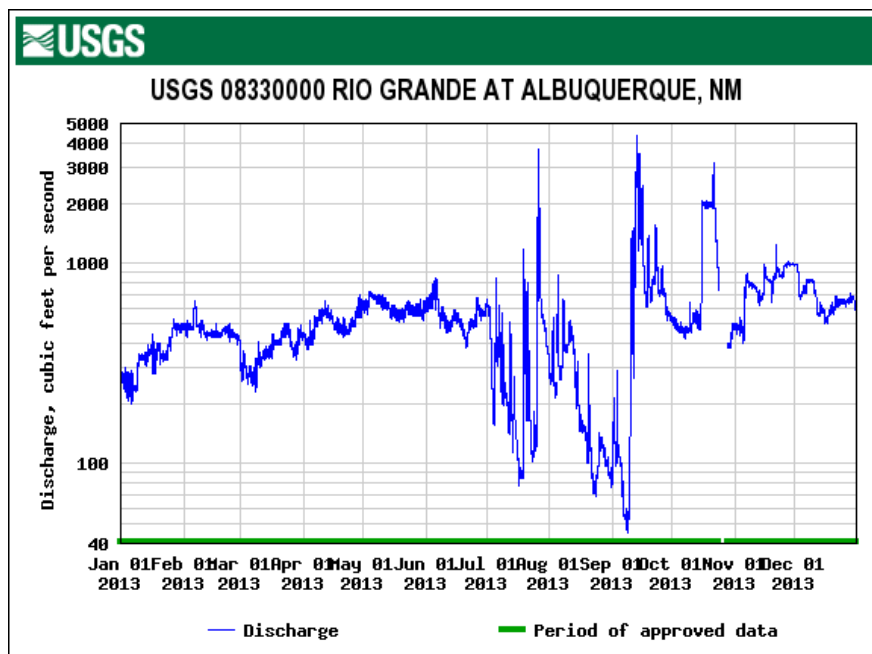
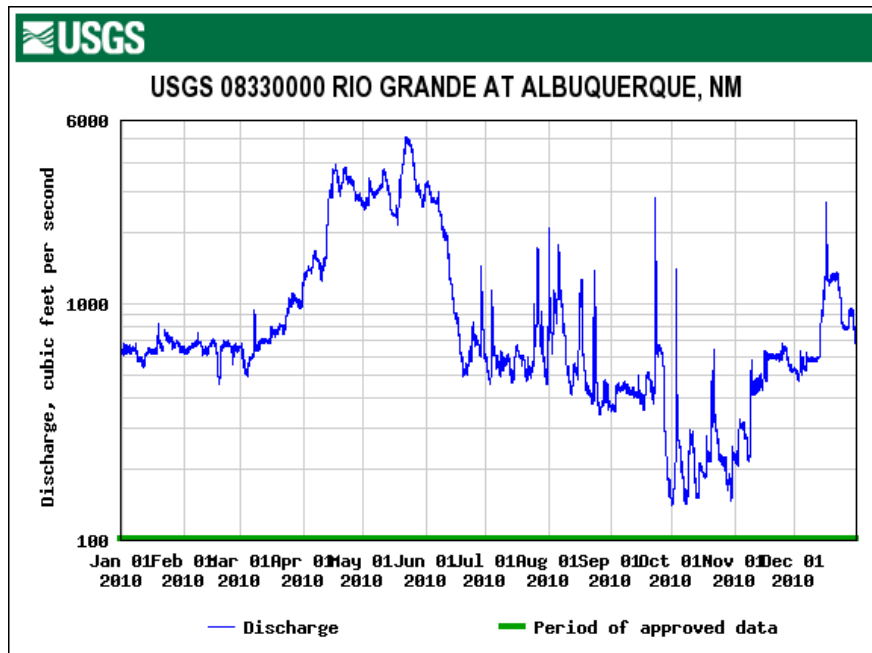
Figure 16.—Rio Grande flows during 2010 irrigation season at near Bosque, NM.

Second, in dry years like 2013, it is difficult to generate a spring peak in the hydrograph (as typically occurred historically) due to the demands placed upon the limited supply of water in the Rio Grande. The lack of spring peak flow in 2013 is apparent when comparing the hydrographs from 2010 and 2013.

In 2013, instead of flows increasing in April, May, and June, creating a significant dynamic rise in the hydrograph, the river's flows remained low and steady. Such conditions fail to transport sediment downstream, cue spawning in native fish, or create aquatic or riparian habitat for fish, wildlife, and nesting migratory birds.

Storing more water upstream provides the opportunity to move storage at opportune times ecologically to generate conditions that might not otherwise be possible. For example, based on the alternate storage scenario 2, storing more water upstream from January to May would save an estimated 18,000 acre-feet of water. In addition to that water, there is at least an additional 100,000 acre-feet of Rio Grande Project storage upstream that could be transported downstream. The timing of such a large-scale release of water would provide deliveries to downstream water users as well as create a critically timed environmental benefit.





Figures 17 and 18.—Comparison of Rio Grande peak flows at Albuquerque, NM, in 2010 and 2013.

If 118,000 acre-feet of water were released over a 20-day period in late May, that water would provide an additional flow of 2,974 acre-feet to whatever base flows already exist in the river. It appears that based on the 350 cfs already in the Rio Grande around that time, a peak flow of 3,300 cfs could be achieved. Due to the channel capacity limitation on the Rio Chama of 1,800 cfs, other integrated reservoir management tools—such as the temporary detention of water in Cochiti Reservoir for a bulk release—may be necessary to achieve the greatest benefits possible. This generated peak flow would only be possible in a year like 2013 given the opportunities afforded by storing more water upstream in any given year.



# V. Institutional Hurdles

Implementing our vision of conserving water in the 21st century by moving reservoir storage upstream and managing our reservoirs in an integrated fashion will require navigating both institutional and legal challenges. Each of the six Rio Grande reservoirs mentioned was authorized individually and has very specific congressional rules associated with its historic purpose and function. This section will discuss the congressional reauthorizations necessary to change how and where water is stored and released. Further, other institutional approvals will be needed from entities like the Rio Grande Compact Commission to implement this new system of water storage and conservation.

In addition to the institutional hurdles described above, the politics and stakeholder interest in the Middle Rio Grande have for years stymied progress toward implementation of this solution. For



In addition to the institutional hurdles, the politics and stakeholder interest in the Middle Rio Grande have for years stymied progress toward implementation of this solution.



Reservoir	Limitations	Authorization/ Approval Required	Benefits
Heron	<ul style="list-style-type: none"> <li>San Juan-Chama Project storage ONLY</li> <li>Storage only for San Juan-Chama contractors</li> <li>NO carryover storage by San Juan-Chama contractors</li> <li>Subject to Article VII of the Rio Grande Compact</li> </ul>	<ul style="list-style-type: none"> <li>Native Rio Grande water storage</li> <li>Renegotiation of contracts to allow carryover storage in Heron</li> <li>Rio Grande Compact Commission approval of native water storage</li> <li>Rio Grande Compact Commission approval of exception to Article VII storage limitation</li> </ul>	<ul style="list-style-type: none"> <li>15,000 acre-feet per year high-elevation native storage</li> <li>Less evaporation of native and San Juan-Chama water</li> <li>Flexibility in Basin-wide reservoir management</li> <li>More water upstream to create environmental benefits</li> </ul>
El Vado	<ul style="list-style-type: none"> <li>Subject to Article VII of the Rio Grande Compact</li> <li>Must ensure space to store “prior and paramount” water for the six Middle Rio Grande Pueblos</li> </ul>	<ul style="list-style-type: none"> <li>Rio Grande Compact Commission approval of exception to Article VII storage limitation</li> </ul>	<ul style="list-style-type: none"> <li>Less evaporation of native and San Juan-Chama water</li> <li>Flexibility in basin-wide reservoir management</li> <li>More water upstream to create environmental benefits</li> </ul>
Abiquiu	<ul style="list-style-type: none"> <li>Permanent storage pool of San Juan-Chama water is currently limited to 200,000 acre-feet</li> <li>Storage easements only acquired up to an elevation of 6,220 feet (allowing 200,000 acre-feet)</li> <li>Subject to Article VII of the Rio Grande Compact if storing native water</li> <li>Channel capacity of Rio Chama is 1,800 cfs</li> </ul>	<ul style="list-style-type: none"> <li>Amendment of contract between Corps and Water Utility Authority</li> <li>Acquisition of permanent flowage easements to cover increase in elevation from 6,220 feet to 6,305 feet</li> <li>Rio Grande Compact Commission approval of storing native Rio Grande Project water upstream</li> <li>Confirmation by Corps that adding up to 467,000 acre-feet of storage would not impact flood control mandate</li> <li>Environmental review of proposed changes</li> <li>Rio Grande Compact Commission approval of exception to Article VII storage limitation</li> </ul>	<ul style="list-style-type: none"> <li>467,000 acre-feet of additional high altitude storage</li> <li>Less evaporation than downstream reservoirs</li> <li>Flexibility in Basin-wide reservoir management</li> </ul>
Cochiti	<ul style="list-style-type: none"> <li>Infrastructure located on Pueblo of Cochiti lands</li> <li>Authorized for flood control purposes</li> <li>Subject to Article VII of the Rio Grande Compact if storing native water</li> </ul>	<ul style="list-style-type: none"> <li>Reauthorization to allow permanent and temporary storage or reregulation of native Rio Grande water</li> </ul>	<ul style="list-style-type: none"> <li>ONLY reservoir on main stem of Rio Grande</li> <li>Provides opportunity for reregulation of Rio Grande flows</li> <li>Serves as alternative for channel capacity limitation of 1,800 cfs on Rio Chama</li> </ul>
Elephant Butte	<ul style="list-style-type: none"> <li>Extremely high evaporation losses that increase at a greater rate than incremental storage</li> </ul>	<ul style="list-style-type: none"> <li>Rio Grande Compact Commission approval of storing Rio Grande Project water upstream of Elephant Butte</li> </ul>	<ul style="list-style-type: none"> <li>Facilitates delivery of Rio Grande Project water to downstream users</li> </ul>
Caballo	<ul style="list-style-type: none"> <li>Significant evaporation losses</li> </ul>	<ul style="list-style-type: none"> <li>Rio Grande Compact Commission approval of storing Rio Grande Project water upstream of Caballo</li> </ul>	<ul style="list-style-type: none"> <li>Facilities power generation and delivery of water downstream</li> </ul>

*Table 2.—Institutional and legal hurdles for reallocation of reservoir storage and integrated management.*



example, the 2005 WAMS report was going to include much more than the three-page appendix providing an overview and recommendation regarding the water savings of moving Elephant Butte storage upstream and planned to include actual modeling of a variety of alternatives using the Corps' URGWOM model.<sup>38</sup> However, operating by consensus, individual stakeholders in the basin killed further exploration of each of the alternatives one-by-one as follows:

- *Alternative No. 1—Reauthorization or Reregulation of Cochiti Lake.* Eliminated from the study because the Pueblo of Cochiti was not ready to discuss.
- *Alternative No. 2—Alternative Storage Strategies for Rio Grande Project Water.* Killed by the New Mexico Interstate Stream Commission due to Rio Grande Compact-related concerns.
- *Alternative No. 3—Evaluation of Timing and Delivery of Closed Basin water from Colorado.* Shut down because of a “commitment” by New Mexico to not seek any contributions from Colorado to aid in delivering water to endangered species.
- *Alternative No. 4—Voluntary Agricultural Forbearance.* Opposed by the Middle Rio Grande Conservancy District based on a litany of reasons, including that the District did not want to act on forbearance without a completed feasibility study.
- *Alternative No. 5—Retention of Water in Abiquiu Reservoir in lieu of release to Elephant Butte.* Resisted by the City of Albuquerque due to potential change in operations at Abiquiu without evaluating other options.
- *Alternative No. 6—Storing program-acquired supplemental water in Heron Reservoir saving evaporation losses.* Overruled by the City of Albuquerque because contract amendment to service contracts would be required, and because of possible implications to authorizing legislation of the San Juan-Chama Project and compacts on the Colorado River.
- *Alternative No. 7—Change in storage and operation of El Vado Reservoir.* Not fully developed, but determined “fruitless” because of elimination of other alternatives.

This model run was merely an exercise to determine what water savings might exist and examine the challenges that the subcommittee would face in implementation, but it in no way changed the status quo other than providing information on alternatives. The fact that even this cursory analysis was eliminated without serious consideration shows the uphill political battle that such an analysis will face even if it is merely a hypothetical investigation.





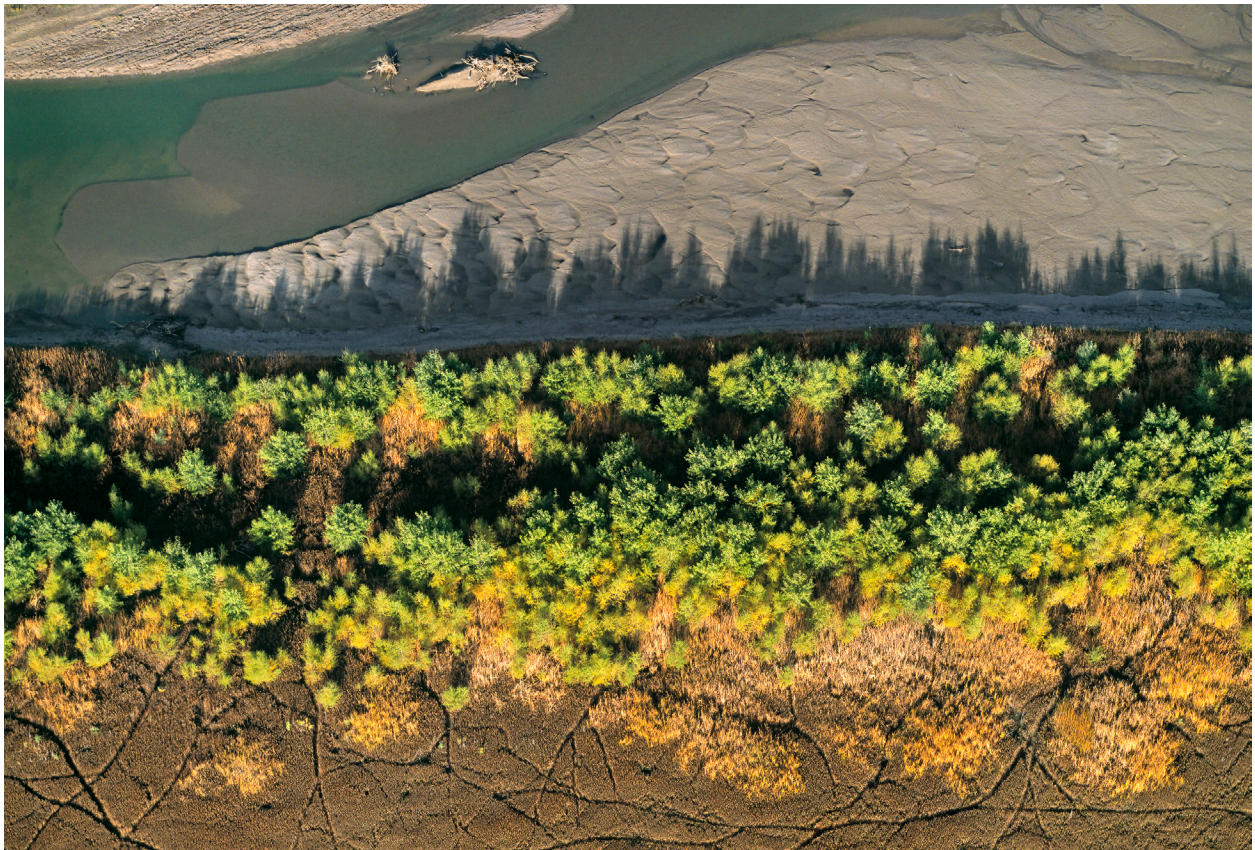
# VI. Conclusion

To save an iconic river and to spark the fundamental changes necessary to create a more flexible, resilient system of water storage and management, we recommend the following next steps:

1. Congress must direct and fund the National Academy of Sciences to review all existing data and identify all existing resources (models, studies, climate data, etc.) in order to conduct a comprehensive evaluation of all alternatives associated with relocating low-elevation storage in high-elevation reservoirs in the Rio Grande Basin in New Mexico. A draft scope of work is included as Appendix B to this report.
2. As water savings are evaluated, Congress needs to obtain a commitment from Basin stakeholders, or it needs to legislate such a commitment that water saved through integrated reservoir management will serve to right the historic injustices to the river and its associated ecosystems and be dedicated to protecting and restoring the river's health.
3. The Rio Grande Compact Commission and its three commissioners should identify the policy and legal reforms necessary to modernize the Compact and ensure that all three states can adapt to the water scarcity that is the reality of our times. The Compact must essentially be rewritten or administered to include flexibilities, or it will be a tool that drives crisis instead of a tool that resolves conflict.
4. The San Juan-Chama Project contractors, led by the Albuquerque-Bernalillo Water Utility Authority, which is already using reservoirs in an integrated fashion, should support federal reoperation and reauthorization of reservoirs.
5. The U.S. Bureau of Reclamation and U.S. Army Corps of Engineers should proactively evaluate what current legal authorities exist to operate all Upper Basin reservoirs in a more integrated fashion.
6. The Elephant Butte Irrigation District (EBID) and El Paso County Water Improvement District #1 (EPW#1) should support the comprehensive study to evaluate reservoir reallocation to conserve water. EBID and EPW#1 should determine the assurances (e.g., policies or agreements) necessary for them to support such operational changes to the system.



7. The EBID and EPW#1 need to determine and consent to a modified delivery schedule for Rio Grande Project water that conserves the most water by storing it upstream while still meeting its obligations to its stakeholders.
8. The Middle Rio Grande Conservancy District needs to provide assurances to Reclamation, EBID, EPW#1, the State of New Mexico, and Mexico (through the International Boundary and Water Commission)—in the form of efficiency improvements, proposed metering and monitoring, or other measures—that any Rio Grande Project or other Compact water transported downstream is not diverted and/or consumed by the District.



To save an iconic river and spark fundamental changes necessary to create a more flexible, resilient system of water storage and management, the very way of thinking about water must evolve into 21st century solutions.





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# VIII. Appendices

## APPENDIX A.

### Calculating Actual Evaporation 2010 and 2013:

To quantify the impact of the location of storage on evaporation in the Rio Grande Basin, Guardians conducted an analysis of the monthly reservoir storage and evaporation in 2010 and 2013.

Guardians used the Rio Grande Compact Commission's annual reports as the source of the actual monthly reservoir volumes (acre-feet), reservoir elevation (feet), and monthly reservoir evaporation (inches). Area-capacity tables for each reservoir were used to determine the estimated surface area. We routinely used elevation as the basis for determining the surface area.

A few exceptions to this data and method of estimating surface area were made due to inconsistencies in the data. First, instead of using the elevation listed for Cochiti Reservoir in 2010 (where the elevation appears to have been misreported), we used the reservoir volume in the area capacity table to estimate the elevation for each month that year. Second, in 2013, the annual reports did not provide any monthly evaporation data for Caballo Reservoir. We used the monthly evaporation data for January through November 2012 and the data for December 2011 to fill this void. No data existed for December 2012.

To calculate the estimated monthly evaporation for each reservoir in acre-feet, the following method was used:

1. The monthly pan evaporation (measured in inches) found in the Rio Grande Compact Commission Reports was converted to feet by dividing the evaporation number by 12. This resulted in the pan evaporation in feet per month.
2. The pan evaporation data (measured in feet) was then converted to open water evaporation. Open water evaporation is considered 70 percent of PAN evaporation. Thus, we multiplied the

pan evaporation data (measured in feet) for each month by 0.7 to get open water evaporation. This resulted in the open water evaporation in feet per month.

3. Evaporation in acre-feet was then calculated by multiplying the open water evaporation in feet by the surface area of the specific reservoir at the given elevation indicated by the volume. We consulted area-capacity curves for each of the six reservoirs to determine the elevation and surface area associated with the specific volume.

These calculations were made using the actual monthly data in 2010 and in 2013 and are located in Appendix A, Tables 1A to 1F (2010) and 2A to 2F (2013). A summary of the actual monthly storage data in 2010 and 2013 is located in Appendix A, Table 1G (2010) and Table 2G (2013). The monthly evaporation calculated for each reservoir and the annual totals are located in Appendix A, Table 1H (2010) and Table 2H (2013).

## Calculating Evaporation for Alternate Scenarios #1 and #2 for 2010 and 2013:

The same method was used to calculate the evaporation losses in the alternate scenarios. In these scenarios, the quantity of water stored in low-elevation reservoirs (Elephant Butte and Caballo) each month was redistributed upstream to the high-elevation reservoirs. Once the redistribution was determined, then the formula detailed above was used to determine the given evaporation based on the new storage volumes in each of the reservoirs.

The quantity of water determined for storage in upstream reservoirs was distributed based on one simple assumption—the highest-elevation reservoirs should be filled to capacity before any water is stored at a lower elevation—in order to conserve the most water due to evaporation loss. Thus, low-elevation storage was used to fill Heron first (the highest-elevation reservoir) to its capacity of 401,300 acre-feet. Thereafter, any remaining low-elevation storage was redistributed to El Vado to its capacity of 196,500 acre-feet, followed by Abiquiu. In 2010, we assumed that it could be possible to acquire additional storage in Abiquiu beyond the 200,000 acre-feet, up to the additional 520,000 acre-feet identified in the U.S. Army Corps of Engineers 1980 Study (a maximum storage of 720,000 acre-feet). For simplicity, none of the scenarios required additional storage in Cochiti Reservoir, but the same method could be used to allocate storage to Cochiti Reservoir and calculate the evaporation losses therefrom if desired.

Appendix A, Tables 1I to 1L (2010 Scenario #1), Tables 1M to 1R (2010 Scenario #2), Tables 2I to 2K (2013 Scenario #1), and Tables 2L to 2N (2013 Scenario #2) show the redistribution and calculation of evaporative losses for two alternative scenarios for 2010 and 2013. The data from the Rio Grande Compact Commission Reports and the area-capacity curves used to calculate these amounts are included as references to the report.



TABLE 1A.--2010 Actual Monthly Storage and Evaporation at Heron Reservoir								
	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	252,562	7,157.55	4,672	0	0.00	0.00	0	63%
Feb	252,974	7,157.64	4,672	0	0.00	0.00	0	63%
Mar	254,021	7,157.87	4,672	0	0.00	0.00	0	63%
Apr	274,527	7,162.27	4,672	5.17	0.43	0.30	1,409	68%
May	308,648	7,169.21	5,110	8.09	0.67	0.47	2,411	77%
Jun	333,712	7,174.04	5,110	9.91	0.83	0.58	2,954	83%
Jul	334,614	7,174.21	5,110	8.57	0.71	0.50	2,555	83%
Aug	303,349	7,168.16	5,110	6.98	0.58	0.41	2,081	76%
Sep	258,093	7,158.76	4,672	6.6	0.55	0.39	1,799	64%
Oct	257,312	7,158.59	4,672	4.42	0.37	0.26	1,205	64%
Nov	247,058	7,156.33	4,672	0	0.00	0.00	0	62%
Dec	226,680	7,151.67	4,184	0	0.00	0.00	0	56%
Maximum	401,300					Annual Evap	14,413	
Annual Avg	275,296							69%

TABLE 1B.--2010 Actual Monthly Storage and Evaporation at El Vado Reservoir								
	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	111,992	6,874.06	2,329	0	0.00	0.00	0	57%
Feb	111,480	6,873.84	2,329	0	0.00	0.00	0	57%
Mar	114,083	6,874.95	2,369	0	0.00	0.00	0	58%
Apr	119,969	6,877.38	2,456	5.62	0.47	0.33	805	61%
May	176,879	6,897.57	3,103	8.87	0.74	0.52	1,606	90%
Jun	172,165	6,896.04	3,068	10.35	0.86	0.60	1,852	88%
Jul	129,847	6,881.27	2,598	8.7	0.73	0.51	1,318	66%
Aug	115,896	6,875.71	2,419	7.33	0.61	0.43	1,034	59%
Sep	111,736	6,873.95	2,329	6.63	0.55	0.39	901	57%
Oct	94,541	6,866.03	2,032	4.22	0.35	0.25	500	48%
Nov	98,544	6,867.97	2,095	0	0.00	0.00	0	50%
Dec	108,611	6,872.59	2,287	0	0.00	0.00	0	55%
Maximum	196,500					Annual Evap	8,017	
Annual Avg	122,145							62%

TABLE 1C.--2010 Actual Monthly Storage and Evaporation at Abiquiu Reservoir								
	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	183,359	6,219.87	4,168	0	0.00	0.00	0	15%
Feb	182,275	6,219.60	4,150	0	0.00	0.00	0	15%
Mar	179,883	6,219.00	4,114	0	0.00	0.00	0	15%
Apr	196,419	6,223.04	4,349	8.19	0.68	0.48	2,078	16%
May	169,903	6,216.45	3,972	10.78	0.90	0.63	2,498	14%
Jun	156,639	6,212.93	3,768	12.26	1.02	0.72	2,695	13%
Jul	157,601	6,213.19	3,785	10.61	0.88	0.62	2,343	13%
Aug	173,978	6,217.50	4,029	9.24	0.77	0.54	2,172	15%
Sep	181,875	6,219.50	4,144	8.67	0.72	0.51	2,096	15%
Oct	181,314	6,219.36	4,138	6.16	0.51	0.36	1,487	15%
Nov	183,037	6,219.79	4,168	0	0.00	0.00	0	15%
Dec	183,962	6,220.02	4,171	0	0.00	0.00	0	15%
Maximum	1,192,800					Annual Evap	15,367	
Annual Avg	177,520							15%

TABLE 1D.--2010 Actual Monthly Storage and Evaporation at Cochiti Reservoir								
	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	48,297	5,344.70	1,284	0	0.00	0.00	0	10%
Feb	48,158	5,344.60	1,277	0	0.00	0.00	0	10%
Mar	47,856	5,344.40	1,264	0	0.00	0.00	0	10%
Apr	47,405	5,344.00	1,235	8.65	0.72	0.50	623	10%
May	46,817	5,343.60	1,201	12.51	1.04	0.73	876	10%
Jun	47,968	5,344.50	1,270	14.98	1.25	0.87	1,110	10%
Jul	49,480	5,345.60	1,355	11.76	0.98	0.69	930	10%
Aug	48,453	5,344.90	1,298	11.54	0.96	0.67	874	10%
Sep	48,505	5,344.90	1,298	10.26	0.86	0.60	777	10%
Oct	49,264	5,345.50	1,346	6.95	0.58	0.41	546	10%
Nov	49,255	5,345.50	1,346	0	0.00	0.00	0	10%
Dec	49,386	5,345.60	1,355	0	0.00	0.00	0	10%
Maximum	491,259					Annual Evap	5,735	
Annual Avg	48,404							10%

TABLE 1E.--2010 Actual Monthly Storage and Evaporation at Elephant Butte Reservoir								
	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	561,481	4,345.20	14,784	3.29	0.27	0.19	2,837	28%
Feb	567,088	4,345.60	14,784	4.47	0.37	0.26	3,855	28%
Mar	540,575	4,343.69	13,046	8.93	0.74	0.52	6,796	27%
Apr	542,497	4,343.83	13,046	12.69	1.06	0.74	9,657	27%
May	600,081	4,347.91	14,784	17.28	1.44	1.01	14,902	30%
Jun	530,354	4,342.94	13,046	15.16	1.26	0.88	11,537	26%
Jul	444,331	4,336.27	13,046	12.23	1.02	0.71	9,307	22%
Aug	383,105	4,331.01	11,169	12.65	1.05	0.74	8,242	19%
Sep	365,864	4,329.43	11,169	11.66	0.97	0.68	7,597	18%
Oct	372,462	4,330.04	11,169	9.33	0.78	0.54	6,079	18%
Nov	392,941	4,331.89	11,169	7.88	0.66	0.46	5,134	18%
Dec	437,172	4,335.68	13,046	5.86	0.49	0.34	4,460	22%
Maximum	2,023,400					Annual Evap	90,403	
Annual Avg	478,163							24%

TABLE 1F.--2010 Actual Monthly Storage and Evaporation at Caballo Reservoir								
	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	31,650	4,141.01	2,719	0	0.00	0.00	0	10%
Feb	61,820	4,149.20	4,854	4.35	0.36	0.25	1,232	19%
Mar	57,380	4,148.21	4,854	7.53	0.63	0.44	2,132	18%
Apr	71,550	4,151.21	4,854	10.88	0.91	0.63	3,081	22%
May	58,260	4,148.41	4,854	14.54	1.21	0.85	4,117	18%
Jun	52,920	4,147.16	3,733	15.75	1.31	0.92	3,430	16%
Jul	60,810	4,148.98	4,854	12.73	1.06	0.74	3,604	19%
Aug	39,380	4,143.51	3,733	11.46	0.96	0.67	2,496	12%
Sep	21,370	4,136.94	2,038	10.15	0.85	0.59	1,207	7%
Oct	18,380	4,135.55	2,038	7.91	0.66	0.46	940	6%
Nov	20,030	4,136.33	2,038	6.01	0.50	0.35	714	6%
Dec	22,050	4,137.24	2,038	4.36	0.36	0.25	518	7%
Maximum	326,700					Annual Evap	23,471	
Annual Avg	42,967							13%



TABLE 1G.--2010 Monthly Storage (Acre-Feet)--ACTUAL							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	252,562	111,992	183,359	48,297	561,481	31,650	1,189,341
Feb	252,974	111,480	182,275	48,158	567,088	61,820	1,223,795
Mar	254,021	114,083	179,883	47,856	540,575	57,380	1,193,798
Apr	274,527	119,969	196,419	47,405	542,497	71,550	1,252,367
May	308,648	176,879	169,903	46,817	600,081	58,260	1,360,588
Jun	333,712	172,165	156,639	47,968	530,354	52,920	1,293,758
Jul	334,614	129,847	157,601	49,480	444,331	60,810	1,176,683
Aug	303,349	115,896	173,978	48,453	383,105	39,380	1,064,161
Sep	258,093	111,736	181,875	48,505	365,864	21,370	987,443
Oct	257,312	94,541	181,314	49,264	372,462	18,380	973,273
Nov	247,058	98,544	183,037	49,255	392,941	20,030	990,865
Dec	226,680	108,611	183,962	49,386	437,172	22,050	1,027,861
Annual Avg	275,296	122,145	177,520	48,404	478,163	42,967	
		Annual Avg	High-Elev	623,365	Low-Elev	521,129	

TABLE 1.H--2010 Monthly Evaporation (Acre-Feet)--ACTUAL							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	0	0	0	0	2,837	0	2,837
Feb	0	0	0	0	3,855	1,232	5,087
Mar	0	0	0	0	6,796	2,132	8,928
Apr	1,409	805	2,078	623	9,657	3,081	17,653
May	2,411	1,606	2,498	876	14,902	4,117	26,410
Jun	2,954	1,852	2,695	1,110	11,537	3,430	23,578
Jul	2,555	1,318	2,343	930	9,307	3,604	20,057
Aug	2,081	1,034	2,172	874	8,242	2,496	16,899
Sep	1,799	901	2,096	777	7,597	1,207	14,377
Oct	1,205	500	1,487	546	6,079	940	10,757
Nov	0	0	0	0	5,134	714	5,848
Dec	0	0	0	0	4,460	518	4,978
Annual	14,413	8,016	15,367	5,735	90,403	23,471	157,405
			High-Elev	43,531	Low-Elev	113,874	

TABLE 11.--Scenario #1: 2010 Monthly Storage and Evaporation at Heron Reservoir

	Heron Actual Capacity (acre-feet)	Proposed Additional RGP Storage in Heron	Total Proposed Storage Heron (acre-feet)	Elevation Actual Storage (feet)	Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	252,562	148,738	401,300	7,157.55	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Feb	252,974	148,326	401,300	7,157.64	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Mar	254,021	147,279	401,300	7,157.87	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Apr	274,527	126,773	401,300	7,162.27	7,186.10	4,672	5,905	5.17	0.43	0.30	1,409	1,781
May	308,648	92,652	401,300	7,169.21	7,186.10	5,110	5,905	8.09	0.67	0.47	2,411	2,787
Jun	333,712	67,588	401,300	7,174.04	7,186.10	5,110	5,905	9.91	0.83	0.58	2,954	3,414
Jul	334,614	66,686	401,300	7,174.21	7,186.10	5,110	5,905	8.57	0.71	0.50	2,555	2,952
Aug	303,349	97,951	401,300	7,168.16	7,186.10	5,110	5,905	6.98	0.58	0.41	2,081	2,404
Sep	258,093	143,207	401,300	7,158.76	7,186.10	4,672	5,905	6.6	0.55	0.39	1,799	2,273
Oct	257,312	143,988	401,300	7,158.59	7,186.10	4,672	5,905	4.42	0.37	0.26	1,205	1,523
Nov	247,058	154,242	401,300	7,156.33	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Dec	226,680	174,620	401,300	7,151.67	7,186.10	4,184	5,905	0	0.00	0.00	0	0
AVG			401,300									
Sum of Evap											14,413	17,133
											RGP Evap	2,730

TABLE 11.--Scenario #1: 2010 Monthly Storage and Evaporation at El Vado Reservoir

	El Vado Actual Capacity (acre-feet)	Proposed Additional RGP Storage El Vado (acre-feet)	Total Proposed Storage (acre-feet)	Elevation Actual Storage (feet)	Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	111,992	84,508	196,500	6,874.06	6,904.00	2,329	3,318	0	0.00	0.00	0	0
Feb	111,480	85,020	196,500	6,873.84	6,904.00	2,329	3,318	0	0.00	0.00	0	0
Mar	114,083	82,417	196,500	6,874.95	6,904.00	2,369	3,318	0	0.00	0.00	0	0
Apr	119,969	76,531	196,500	6,877.38	6,904.00	2,456	3,318	5.62	0.47	0.33	805	1,088
May	176,879	19,621	196,500	6,897.57	6,904.00	3,103	3,318	8.87	0.74	0.52	1,606	1,717
Jun	172,165	24,335	196,500	6,896.04	6,904.00	3,068	3,318	10.35	0.86	0.60	1,852	2,003
Jul	129,847	66,653	196,500	6,881.27	6,904.00	2,598	3,318	8.7	0.73	0.51	1,318	1,684
Aug	115,896	80,604	196,500	6,875.71	6,904.00	2,419	3,318	7.33	0.61	0.43	1,034	1,419
Sep	111,736	84,764	196,500	6,873.95	6,904.00	2,329	3,318	6.63	0.55	0.39	901	1,283
Oct	94,541	101,959	196,500	6,866.03	6,904.00	2,032	3,318	4.22	0.35	0.25	500	817
Nov	98,544	97,956	196,500	6,867.97	6,904.00	2,095	3,318	0	0.00	0.00	0	0
Dec	108,611	87,889	196,500	6,872.59	6,904.00	2,287	3,318	0	0.00	0.00	0	0
AVG			196,500									
Sum of Evap											8,017	10,010
											RGP Evap	2,057



TABLE 1K.--Scenario #1: 2010 Monthly Storage and Evaporation at Abiquiu Reservoir												
	Abiquiu Actual Capacity (acre feet)	Proposed Additional RGP Storage Abiquiu (acre-feet)	Total Proposed Storage (acre- feet)	Elevation Actual Storage (feet)	Est. Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	183,359	359,885	543,244	6,219.87	6,281.50	4,168	7,545	0	0.00	0.00	0	0
Feb	182,275	395,562	577,837	6,219.60	6,286.00	4,150	7,821	0	0.00	0.00	0	0
Mar	179,883	368,259	548,142	6,219.00	6,282.10	4,114	7,582	0	0.00	0.00	0	0
Apr	196,419	410,743	607,162	6,223.04	6,289.70	4,349	8,043	8.19	0.68	0.48	2,078	3,843
May	169,903	546,068	715,971	6,216.45	6,302.60	3,972	8,827	10.78	0.90	0.63	2,498	5,551
Jun	156,639	491,351	647,990	6,212.93	6,294.70	3,768	8,331	12.26	1.02	0.72	2,695	5,958
Jul	157,601	371,802	529,403	6,213.19	6,279.60	3,785	7,427	10.61	0.88	0.62	2,343	4,597
Aug	173,978	243,930	417,908	6,217.50	6,263.60	4,029	6,457	9.24	0.77	0.54	2,172	3,480
Sep	181,875	159,263	341,138	6,219.50	6,251.00	4,144	5,762	8.67	0.72	0.51	2,096	2,914
Oct	181,314	144,895	326,209	6,219.36	6,248.40	4,138	5,626	6.16	0.51	0.36	1,487	2,022
Nov	183,037	160,773	343,810	6,219.79	6,251.50	4,168	5,788	0	0.00	0.00	0	0
Dec	183,962	196,713	380,675	6,220.02	6,257.70	4,171	6,120	0	0.00	0.00	0	0
AVG			498,291									
Sum of Evap											15,367	28,364
RGIP Evap											12,763	
Heron												
Sum Evap	14,413											
	RGIP Evap											
El Vado												
Sum Evap	7,953											
	RGIP Evap											
Abiquiu												
Sum Evap	15,185											
	RGIP Evap											
Total Moved Storage Evap												
EBR/Caballo Evap											17,550	113,874

TABLE 1L--2010 Monthly Evaporation (Acre-Feet)--SCENARIO #1							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0
Apr	1,781	1,088	3843	623	0	0	7,335
May	2,787	1,717	5551	876	0	0	10,931
Jun	3,414	2,003	5958	1,110	0	0	12,485
Jul	2,952	1,684	4597	930	0	0	10,163
Aug	2,404	1,419	3480	874	0	0	8,177
Sep	2,273	1,283	2914	777	0	0	7,247
Oct	1,523	817	2022	546	0	0	4,908
Nov	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0
Annual	17,133	10,010	28,364	5,735	0	0	61,242
			High-Elev	61,242	Low-Elev	0	
							Savings =
							96,164



	Heron Actual Capacity (acre-feet)	Proposed Additional Storage in Heron	Total Proposed Storage Heron (acre-feet)	Elevation Actual Storage (feet)	Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	252,562	148,738	401,300	7,157.55	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Feb	252,974	148,326	401,300	7,157.64	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Mar	254,021	147,279	401,300	7,157.87	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Apr	274,527	126,773	401,300	7,162.27	7,186.10	4,672	5,905	5.17	0.43	0.30	1,409	1,781
May	308,648	92,652	401,300	7,169.21	7,186.10	5,110	5,905	8.09	0.67	0.47	2,411	2,787
Jun	333,712	67,588	401,300	7,174.04	7,186.10	5,110	5,905	9.91	0.83	0.58	2,954	3,414
Jul	334,614	66,686	401,300	7,174.21	7,186.10	5,110	5,905	8.57	0.71	0.50	2,555	2,952
Aug	303,349	97,951	401,300	7,168.16	7,186.10	5,110	5,905	6.98	0.58	0.41	2,081	2,404
Sep	258,093	143,207	401,300	7,158.76	7,186.10	4,672	5,905	6.6	0.55	0.39	1,799	2,273
Oct	257,312	143,988	401,300	7,158.59	7,186.10	4,672	5,905	4.42	0.37	0.26	1,205	1,523
Nov	247,058	154,242	401,300	7,156.33	7,186.10	4,672	5,905	0	0.00	0.00	0	0
Dec	226,680	174,620	401,300	7,151.67	7,186.10	4,184	5,905	0	0.00	0.00	0	0
AVG			401,300									
Sum of Evap											14,413	17,133
											RGP Evap	2,730

	El Vado Actual Capacity (acre-feet)	Proposed Additional Storage El Vado (acre-feet)	Total Proposed Storage (acre-feet)	Elevation Actual Storage (feet)	Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	111,992	84,508	196,500	6,874.06	6,904.00	2,329	3,318	0	0.00	0.00	0	0
Feb	111,480	85,020	196,500	6,873.84	6,904.00	2,329	3,318	0	0.00	0.00	0	0
Mar	114,083	82,417	196,500	6,874.95	6,904.00	2,369	3,318	0	0.00	0.00	0	0
Apr	119,969	76,531	196,500	6,877.38	6,904.00	2,456	3,318	5.62	0.47	0.33	805	1,088
May	176,879	19,621	196,500	6,897.57	6,904.00	3,103	3,318	8.87	0.74	0.52	1,606	1,717
Jun	172,165	24,335	196,500	6,896.04	6,904.00	3,068	3,318	10.35	0.86	0.60	1,852	2,003
Jul	129,847	66,653	196,500	6,881.27	6,904.00	2,598	3,318	8.7	0.73	0.51	1,318	1,684
Aug	115,896	80,604	196,500	6,875.71	6,904.00	2,419	3,318	7.33	0.61	0.43	1,034	1,419
Sep	111,736	84,764	196,500	6,873.95	6,904.00	2,329	3,318	6.63	0.55	0.39	901	1,283
Oct	94,541	101,959	196,500	6,866.03	6,904.00	2,032	3,318	4.22	0.35	0.25	500	817
Nov	98,544	97,956	196,500	6,867.97	6,904.00	2,095	3,318	0	0.00	0.00	0	0
Dec	108,611	87,889	196,500	6,872.59	6,904.00	2,287	3,318	0	0.00	0.00	0	0
AVG			196,500									
Sum of Evap											8,017	10,010
											RGP Evap	2,057

TABLE 10.--Scenario #2: 2010 Monthly Storage and Evaporation at Abiquiu Reservoir

	Abiquiu Actual Capacity (acre- feet)	Proposed Additional RGP Storage Abiquiu (acre-feet)	Total Proposed Storage (acre- feet)	Elevation Actual Storage (feet)	Est. Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	183,359	259,885	443,244	6,219.87	6,267.40	4,168	6,687	0	0.00	0.00	0	0
Feb	182,275	295,562	477,837	6,219.60	6,272.50	4,150	6,993	0	0.00	0.00	0	0
Mar	179,883	268,259	448,142	6,219.00	6,268.20	4,114	6,736	0	0.00	0.00	0	0
Apr	196,419	310,743	507,162	6,223.04	6,276.60	4,349	7,238	8.19	0.68	0.48	2,078	3,458
May	169,903	446,068	615,971	6,216.45	6,290.80	3,972	8,105	10.78	0.90	0.63	2,498	5,097
Jun	156,639	391,351	547,990	6,212.93	6,282.10	3,768	7,582	12.26	1.02	0.72	2,695	5,422
Jul	157,601	271,802	429,403	6,213.19	6,265.30	3,785	6,558	10.61	0.88	0.62	2,343	4,059
Aug	173,978	143,930	317,908	6,217.50	6,246.90	4,029	5,552	9.24	0.77	0.54	2,172	2,993
Sep	181,875	59,263	241,138	6,219.50	6,232.00	4,144	4,806	8.67	0.72	0.51	2,096	2,431
Oct	181,314	44,895	226,209	6,219.36	6,228.90	4,138	4,650	6.16	0.51	0.36	1,487	1,671
Nov	183,037	60,773	243,810	6,219.79	6,232.60	4,168	4,837	0	0.00	0.00	0	0
Dec	183,962	96,713	280,675	6,220.02	6,240.00	4,171	5,207	0	0.00	0.00	0	0
AVG			398,291									
<b>Heron</b>												
Sum Evap	14,413	17,133										
	RGP Evap	2,730										
<b>El Vado</b>												
Sum Evap	7,953	10,010										
	RGP Evap	2,057										
<b>Elephant Butte</b>												
Sum Evap	15,185	25,130										
	RGP Evap	9,763										
<b>Total Moved Storage Evap</b>												
EBR/Caballo Evap		14,550										
		113,874										
<b>Sum of Evap</b>											15,367	25,130
											RGP Evap	9,763
<b>Heron</b>												
Sum Evap	14,413	17,133										
	RGP Evap	2,730										
<b>El Vado</b>												
Sum Evap	7,953	10,010										
	RGP Evap	2,057										
<b>Elephant Butte</b>												
Sum Evap	15,185	25,130										
	RGP Evap	9,763										
<b>Total Moved Storage Evap</b>												
EBR/Caballo Evap		14,550										
		113,874										
<b>Heron</b>												
Sum Evap	14,413	17,133										
	RGP Evap	2,730										
<b>El Vado</b>												
Sum Evap	7,953	10,010										
	RGP Evap	2,057										
<b>Elephant Butte</b>												
Sum Evap	15,185	25,130										
	RGP Evap	9,763										
<b>Total Moved Storage Evap</b>												
EBR/Caballo Evap		14,550										
		113,874										
<b>Heron</b>												
Sum Evap	14,413	17,133										
	RGP Evap	2,730										
<b>El Vado</b>												
Sum Evap	7,953	10,010										
	RGP Evap	2,057										
<b>Elephant Butte</b>												
Sum Evap	15,185	25,130										
	RGP Evap	9,763										
<b>Total Moved Storage Evap</b>												
EBR/Caballo Evap		14,550										
		113,874										
<b>Heron</b>												
Sum Evap	14,413	17,133										
	RGP Evap	2,730										
<b>El Vado</b>												
Sum Evap	7,953	10,010										
	RGP Evap	2,057										
<b>Elephant Butte</b>												
Sum Evap	15,185	25,130										
	RGP Evap	9,763										
<b>Total Moved Storage Evap</b>												
EBR/Caballo Evap		14,550										
		113,874										

	100%	100,000AF
EBR 100k	90,403	14,925
Caballo 100k	23,471	36,300



	EBR Actual Capacity (acre-feet)	Proposed RGP Storage Moved Upstream (acre-feet)	Total Remaining Storage (acre-feet)	Elevation (feet)	Est. Elevation Proposed Storage (feet)	Est. Surface Area (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	561,481	461,481	100,000	4,345.20	4,270	14,784	2,107	3.29	0.27	0.19	2,837	404
Feb	567,088	467,088	100,000	4,345.60	4,270	14,784	2,107	4.47	0.37	0.26	3,855	549
Mar	540,575	440,575	100,000	4,343.69	4,270	13,046	2,107	8.93	0.74	0.52	6,796	1,098
Apr	542,497	442,497	100,000	4,343.83	4,270	13,046	2,107	12.69	1.06	0.74	9,657	1,560
May	600,081	500,081	100,000	4,347.91	4,270	14,784	2,107	17.28	1.44	1.01	14,902	2,124
Jun	530,354	430,354	100,000	4,342.94	4,270	13,046	2,107	15.16	1.26	0.88	11,537	1,863
Jul	444,331	344,331	100,000	4,336.27	4,270	13,046	2,107	12.23	1.02	0.71	9,307	1,503
Aug	383,105	283,105	100,000	4,331.01	4,270	11,169	2,107	12.65	1.05	0.74	8,242	1,555
Sep	365,864	265,864	100,000	4,329.43	4,270	11,169	2,107	11.66	0.97	0.68	7,597	1,433
Oct	372,462	272,462	100,000	4,330.04	4,270	11,169	2,107	9.33	0.78	0.54	6,079	1,147
Nov	392,941	292,941	100,000	4,331.89	4,270	11,169	2,107	7.88	0.66	0.46	5,134	969
Dec	437,172	337,172	100,000	4,335.68	4,270	13,046	2,107	5.86	0.49	0.34	4,460	720
AVG			100,000							Sum of Evap	90,403	14,925
											RGP Evap	14,925

	Capacity (acre-feet)	Proposed RGP Storage Moved Upstream (acre-feet)	Total Remaining Storage (acre-feet)	Elevation (feet)	Est. Elevation Proposed Storage (feet)	Est. Surface Area (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	31,650	0	100,000	4,141.01	4,155	2,719	5,889	0	0.00	0.00	0	0
Feb	61,820	0	100,000	4,149.20	4,155	4,854	5,889	4.35	0.36	0.25	1,232	1,494
Mar	57,380	0	100,000	4,148.21	4,155	4,854	5,889	7.53	0.63	0.44	2,132	2,587
Apr	71,550	0	100,000	4,151.21	4,155	4,854	5,889	10.88	0.91	0.63	3,081	3,738
May	58,260	0	100,000	4,148.41	4,155	4,854	5,889	14.54	1.21	0.85	4,117	4,995
Jun	52,920	0	100,000	4,147.16	4,155	3,733	5,889	15.75	1.31	0.92	3,430	5,411
Jul	60,810	0	100,000	4,148.98	4,155	4,854	5,889	12.73	1.06	0.74	3,604	4,373
Aug	39,380	0	100,000	4,143.51	4,155	3,733	5,889	11.46	0.96	0.67	2,496	3,937
Sep	21,370	0	100,000	4,136.94	4,155	2,038	5,889	10.15	0.85	0.59	1,207	3,487
Oct	18,380	0	100,000	4,135.55	4,155	2,038	5,889	7.91	0.66	0.46	940	2,717
Nov	20,030	0	100,000	4,136.33	4,155	2,038	5,889	6.01	0.50	0.35	714	2,065
Dec	22,050	0	100,000	4,137.24	4,155	2,038	5,889	4.36	0.36	0.25	518	1,498
AVG			100,000							Sum of Evap	23,471	36,300
											RGP Evap	36,300

TABLE 1R.--2010 Monthly Evaporation (Acre-Feet)--SCENARIO #2							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	0	0	0	0	404	0	404
Feb	0	0	0	0	549	0	549
Mar	0	0	0	0	1098	0	1,098
Apr	1,781	1,088	3458	623	1560	0	8,510
May	2,787	1,717	5097	876	2124	0	12,601
Jun	3,414	2,003	5422	1,110	1863	0	13,812
Jul	2,952	1,684	4059	930	1503	0	11,128
Aug	2,404	1,419	2993	874	1555	0	9,245
Sep	2,273	1,283	2431	777	1433	0	8,197
Oct	1,523	817	1671	546	1147	0	5,704
Nov	0	0	0	0	969	0	969
Dec	0	0	0	0	720	0	720
Annual	17,133	10,010	25,130	5,735	14,925	0	72,933
			High-Elev	58,008	Low-Elev	14,925	
							Savings =
							84,473



**TABLE 2A.--2013 Actual Monthly Storage and Evaporation at Heron Reservoir**

	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	156,604	7,133.76	3,190	0	0.00	0.00	0	39%
Feb	145,812	7,130.49	3,190	0	0.00	0.00	0	36%
Mar	136,146	7,127.41	3,190	0	0.00	0.00	0	34%
Apr	136,023	7,127.37	3,190	5.88	0.49	0.34	1,094	34%
May	134,348	7,126.82	3,190	8.03	0.67	0.47	1,494	33%
Jun	124,522	7,123.49	2,690	10.77	0.90	0.63	1,690	31%
Jul	105,594	7,116.45	2,690	7.98	0.67	0.47	1,252	26%
Aug	86,029	7,107.90	2,179	6.86	0.57	0.40	872	21%
Sep	90,345	7,109.93	2,179	5.25	0.44	0.31	667	23%
Oct	92,768	7,111.03	2,179	3.94	0.33	0.23	501	23%
Nov	92,390	7,110.86	2,179	0	0.00	0.00	0	23%
Dec	88,087	7,108.88	2,179	0	0.00	0.00	0	22%
Maximum	401,300					Annual Evap	7,571	
Annual Avg	115,722							29%

**TABLE 2B.--2013 Actual Monthly Storage and Evaporation at El Vado Reservoir**

	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	14,372	6,806.02	733	0	0.00	0.00	0	7%
Feb	18,840	6,811.70	841	0	0.00	0.00	0	10%
Mar	28,562	6,822.11	1,020	0	0.00	0.00	0	15%
Apr	34,461	6,827.57	1,148	6.74	0.56	0.39	451	18%
May	42,509	6,834.19	1,280	9.04	0.75	0.53	675	22%
Jun	20,305	6,813.41	873	11.54	0.96	0.67	588	10%
Jul	17,893	6,810.56	820	8.29	0.69	0.48	397	9%
Aug	23,579	6,817.02	938	7.44	0.62	0.43	407	12%
Sep	19,135	6,812.05	849	5.7	0.48	0.33	282	10%
Oct	18,132	6,810.85	826	4.14	0.35	0.24	199	9%
Nov	14,949	6,806.80	747	0	0.00	0.00	0	8%
Dec	5,345	6,791.34	514	0	0.00	0.00	0	3%
Maximum	196,500					Annual Evap	2,999	
Annual Avg	21,507							11%

**TABLE 2C.--2013 Actual Monthly Storage and Evaporation at Abiquiu Reservoir**

	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	161,736	6,214.30	3,846	2.47	0.21	0.14	554	14%
Feb	167,864	6,215.92	3,938	3.59	0.30	0.21	825	14%
Mar	169,246	6,216.28	3,961	6.13	0.51	0.36	1,416	14%
Apr	154,308	6,212.30	3,735	7.92	0.66	0.46	1,726	13%
May	141,957	6,208.90	3,475	9.47	0.79	0.55	1,920	12%
Jun	125,440	6,204.17	3,292	13.44	1.12	0.78	2,581	11%
Jul	138,759	6,208.00	3,416	9.98	0.83	0.58	1,989	12%
Aug	145,258	6,209.82	3,540	8.92	0.74	0.52	1,842	12%
Sep	151,367	6,211.50	3,694	6.56	0.55	0.38	1,414	13%
Oct	143,031	6,209.20	3,495	5.79	0.48	0.34	1,180	12%
Nov	143,675	6,209.38	3,509	3.63	0.30	0.21	743	12%
Dec	154,603	6,212.38	3,740	2.22	0.19	0.13	484	13%
Maximum	1,192,800					Annual Evap	16,673	
Annual Avg	149,770							13%

**TABLE 2D.--2013 Actual Monthly Storage and Evaporation at Cochiti Reservoir**

	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	48,998	5,345.28	1,329	2.79	0.23	0.16	216	10%
Feb	48,060	5,344.56	1,277	4.14	0.35	0.24	308	10%
Mar	47,933	5,344.46	1,270	7.05	0.59	0.41	522	10%
Apr	48,394	5,344.82	1,290	6.74	0.56	0.39	507	10%
May	48,124	5,344.61	1,277	9.33	0.78	0.54	695	10%
Jun	47,285	5,343.94	1,227	11.79	0.98	0.69	844	10%
Jul	47,114	5,343.80	1,219	7.66	0.64	0.45	545	10%
Aug	47,114	5,343.80	1,219	6.83	0.57	0.40	486	10%
Sep	72,194	5,358.56	2,213	5.33	0.44	0.31	688	15%
Oct	47,089	5,343.78	1,219	4.02	0.34	0.23	286	10%
Nov	46,562	5,343.34	1,176	3.3	0.28	0.19	226	9%
Dec	46,610	5,343.38	1,184	2.83	0.24	0.17	195	9%
Maximum	491,259					Annual Evap	5,519	
Annual Avg	49,623							10%

**TABLE 2E.--2013 Actual Monthly Storage and Evaporation at Elephant Butte Reservoir**

	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	183,064	4,309.10	7,434	3.46	0.29	0.20	1,500	9%
Feb	207,139	4,312.41	7,434	5.84	0.49	0.34	2,533	10%
Mar	220,176	4,314.08	7,434	9.93	0.83	0.58	4,306	11%
Apr	223,067	4,314.44	7,434	14.44	1.20	0.84	6,262	11%
May	193,841	4,310.62	7,434	17.38	1.45	1.01	7,537	10%
Jun	80,576	4,291.30	4,171	21.3	1.78	1.24	5,182	4%
Jul	74,456	4,289.88	4,171	13.09	1.09	0.76	3,185	4%
Aug	90,872	4,293.54	4,171	11.96	1.00	0.70	2,910	4%
Sep	163,572	4,306.23	7,434	9.38	0.78	0.55	4,068	8%
Oct	192,471	4,310.43	7,434	10.03	0.84	0.59	4,350	10%
Nov	236,171	4,316.03	9,563	4.66	0.39	0.27	2,600	10%
Dec	279,060	4,320.83	9,563	2.99	0.25	0.17	1,668	14%
Maximum	2,023,400					Annual Evap	46,100	
Annual Avg	178,705							9%

**TABLE 2F.--2013 Actual Monthly Storage and Evaporation at Caballo Reservoir**

	Capacity (acre-feet)	Elevation (feet)	Est. Surface Area (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Evaporation (acre-feet)	% of Capacity
Jan	8,400	4,129.98	1,546	4.48	0.37	0.26	404	3%
Feb	9,700	4,130.80	1,546	5.04	0.42	0.29	455	3%
Mar	10,570	4,131.33	1,546	9.22	0.77	0.54	831	3%
Apr	10,210	4,131.11	1,546	11.77	0.98	0.69	1,061	3%
May	36,080	4,142.49	2,719	12.3	1.03	0.72	1,951	11%
Jun	21,240	4,136.88	2,038	17.67	1.47	1.03	2,101	7%
Jul	8,600	4,130.11	1,546	14.3	1.19	0.83	1,290	3%
Aug	11,760	4,132.03	1,546	14.35	1.20	0.84	1,294	4%
Sep	39,580	4,143.57	3,733	9.7	0.81	0.57	2,112	12%
Oct	38,580	4,143.27	3,733	9.05	0.75	0.53	1,971	12%
Nov	38,980	4,143.39	3,733	5.69	0.47	0.33	1,239	12%
Dec	39,740	4,143.62	3,733	1.67	0.14	0.10	364	12%
Maximum	326,700					Annual Evap	15,072	
Annual Avg	22,787							7%



TABLE 2G.--2013 Monthly Storage (Acre-Feet)--ACTUAL							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	156,604	14,372	161,736	48,998	183,064	8,400	573,174
Feb	145,812	18,840	167,864	48,060	207,139	9,700	597,415
Mar	136,146	28,562	169,246	47,933	220,176	10,570	612,633
Apr	136,023	34,461	154,308	48,394	223,067	10,210	606,463
May	134,348	42,509	141,957	48,124	193,841	36,080	596,859
Jun	124,522	20,305	125,440	47,285	80,576	21,240	419,368
Jul	105,594	17,893	138,759	47,114	74,456	8,600	392,416
Aug	86,029	23,579	145,258	47,114	90,872	11,760	404,612
Sep	90,345	19,135	151,367	72,194	163,572	39,580	536,193
Oct	92,768	18,132	143,031	47,089	192,471	38,580	532,071
Nov	92,390	14,949	143,675	46,562	236,171	38,980	572,727
Dec	88,087	5,345	154,603	46,610	279,060	39,740	613,445
Annual Avg	115,722	21,507	149,770	49,623	178,705	22,787	
			High-Elev	336,623	Low-Elev	201,492	

TABLE 2H.--2013 Monthly Evaporation (Acre-Feet)--ACTUAL							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	0	0	554	216	1,500	404	2,674
Feb	0	0	825	308	2,533	455	4,121
Mar	0	0	1,416	522	4,306	831	7,075
Apr	1,094	451	1,726	507	6,262	1,061	11,101
May	1,494	675	1,920	695	7,537	1,951	14,272
Jun	1,690	588	2,581	844	5,182	2,101	12,986
Jul	1,252	397	1,989	545	3,185	1,290	8,658
Aug	872	407	1,842	486	2,910	1,294	7,811
Sep	667	282	1,414	688	4,068	2,112	9,231
Oct	501	199	1,180	286	4,350	1,971	8,487
Nov	0	0	743	226	2,600	1,239	4,808
Dec	0	0	484	195	1,668	364	2,711
Annual Avg							
Annual	7,570	2,999	16,674	5,518	46,101	15,073	93,934
			High-Elev	32,761	Low-Elev	61,174	

TABLE 21.--Scenario #1: 2013 Monthly Storage and Evaporation at Heron Reservoir

	Heron Actual Capacity (acre-feet)	Proposed Additional Storage in Heron	Total Proposed Storage (acre-feet)	Elevation Actual Storage (feet)	Est. Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	156,604	191,464	348,068	7,133.76	7,180.00	3,190	5,604	0	0.00	0.00	0	0
Feb	145,812	216,839	362,651	7,130.49	7,180.00	3,190	5,604	0	0.00	0.00	0	0
Mar	136,146	230,746	366,892	7,127.41	7,180.00	3,190	5,604	0	0.00	0.00	0	0
Apr	136,023	233,277	369,300	7,127.37	7,180.00	3,190	5,604	5.88	0.49	0.34	1,094	1,922
May	134,348	229,921	364,269	7,126.82	7,180.00	3,190	5,604	8.03	0.67	0.47	1,494	2,625
Jun	124,522	101,816	226,338	7,123.49	7,150.00	2,690	4,184	10.77	0.90	0.63	1,690	2,629
Jul	105,594	83,056	188,650	7,116.45	7,140.00	2,690	3,707	7.98	0.67	0.47	1,252	1,726
Aug	86,029	102,632	188,661	7,107.90	7,140.00	2,179	3,707	6.86	0.57	0.40	872	1,483
Sep	90,345	203,152	293,497	7,109.93	7,170.00	2,179	5,110	5.25	0.44	0.31	667	1,565
Oct	92,768	231,051	323,819	7,111.03	7,170.00	2,179	5,110	3.94	0.33	0.23	501	1,174
Nov	92,390	275,151	367,541	7,110.86	7,180.00	2,179	5,604	0	0.00	0.00	0	0
Dec	88,087	313,213	401,300	7,108.88	7,186.10	2,179	5,905	0	0.00	0.00	0	0
AVG			316,749							Sum of Evap	RGP Evap	5,553

TABLE 21.--Scenario #1: 2013 Monthly Storage and Evaporation at El Vado Reservoir

	El Vado Actual Capacity (acre-feet)	Proposed Additional Storage El Vado (acre-feet)	Total Proposed Storage (acre-feet)	Elevation Actual Storage (feet)	Est. Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	14,372	0	14,372	6,806.02	6,806.02	733	733	0	0.00	0.00	0	0
Feb	18,840	0	18,840	6,811.70	6,811.70	841	841	0	0.00	0.00	0	0
Mar	28,562	0	28,562	6,822.11	6,822.11	1,020	1,020	0	0.00	0.00	0	0
Apr	34,461	0	34,461	6,827.57	6,827.57	1,148	1,148	6.74	0.56	0.39	451	451
May	42,509	0	42,509	6,834.19	6,834.19	1,280	1,280	9.04	0.75	0.53	675	675
Jun	20,305	0	20,305	6,813.41	6,813.41	873	873	11.54	0.96	0.67	588	588
Jul	17,893	0	17,893	6,810.56	6,810.56	820	820	8.29	0.69	0.48	397	397
Aug	23,579	0	23,579	6,817.02	6,817.02	938	938	7.44	0.62	0.43	407	407
Sep	19,135	0	19,135	6,812.05	6,812.05	849	849	5.7	0.48	0.33	282	282
Oct	18,132	0	18,132	6,810.85	6,810.85	826	826	4.14	0.35	0.24	199	199
Nov	14,949	0	14,949	6,806.80	6,806.80	747	747	0	0.00	0.00	0	0
Dec	5,345	5,587	10,932	6,791.34	6,801.00	514	647	0	0.00	0.00	0	0
AVG			21,972							Sum of Evap	RGP Evap	2,999

<b>Heron</b>	
Sum Evap	13,124
RGP Evap	5,553
<b>El Vado</b>	
Sum Evap	2,999
RGP Evap	0

<b>Total Moved Storage Evap</b>	
EBR/Caballo Actual Evap	61,172
	5,553

TABLE 2K.--2013 Monthly Evaporation (Acre-Feet)--Scenario #1 (ALL IN HERON)							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	0	0	554	216	0	0	770
Feb	0	0	825	308	0	0	1,133
Mar	0	0	1,416	522	0	0	1,938
Apr	1,922	451	1,726	507	0	0	4,606
May	2,625	675	1,920	695	0	0	5,915
Jun	2,629	588	2,581	844	0	0	6,642
Jul	1,726	397	1,989	545	0	0	4,657
Aug	1,483	407	1,842	486	0	0	4,218
Sep	1,565	282	1,414	688	0	0	3,949
Oct	1,174	199	1,180	286	0	0	2,839
Nov	0	0	743	226	0	0	969
Dec	0	0	484	195	0	0	679
Annual	13,124	2,999	16,673	5,519	0	0	38,315
			High-Elev	38,315	Low-Elev	0	
							Savings =
							55,619



TABLE 2L.--Scenario #2: 2013 Monthly Storage and Evaporation at Heron Reservoir

	Heron Actual Capacity (acre-feet)	Proposed Additional RGP Storage in Heron	Total Proposed Storage (acre-feet)	Elevation Actual Storage (feet)	Est. Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	156,604	141,464	298,068	7,133.76	7,170.00	3,190	5,110	0	0.00	0.00	0	0
Feb	145,812	166,839	312,651	7,130.49	7,170.00	3,190	5,110	0	0.00	0.00	0	0
Mar	136,146	180,746	316,892	7,127.41	7,170.00	3,190	5,110	0	0.00	0.00	0	0
Apr	136,023	183,277	319,300	7,127.37	7,170.00	3,190	5,110	5.88	0.49	0.34	1,094	1,753
May	134,348	179,921	314,269	7,126.82	7,170.00	3,190	5,110	8.03	0.67	0.47	1,494	2,394
Jun	124,522	51,816	176,338	7,123.49	7,140.00	2,690	3,707	10.77	0.90	0.63	1,690	2,329
Jul	105,594	33,056	138,650	7,116.45	7,130.00	2,690	3,190	7.98	0.67	0.47	1,252	1,485
Aug	86,029	52,632	138,661	7,107.90	7,130.00	2,179	3,190	6.86	0.57	0.40	872	1,277
Sep	90,345	153,152	243,497	7,109.93	7,160.00	2,179	4,672	5.25	0.44	0.31	667	1,431
Oct	92,768	181,051	273,819	7,111.03	7,160.00	2,179	4,672	3.94	0.33	0.23	501	1,074
Nov	92,390	225,151	317,541	7,110.86	7,170.00	2,179	5,110	0	0.00	0.00	0	0
Dec	88,087	268,800	356,887	7,108.88	7,180.00	2,179	5,604	0	0.00	0.00	0	0
AVG			267,214							Sum of Evap	RGP Evap	11,741
												5,553

TABLE 2M.--Scenario #2: 2013 Monthly Storage and Evaporation at Elephant Butte Reservoir

	EBR Actual Capacity (acre-feet)	Proposed RGP Storage Moved Upstream (acre-feet)	Total Remaining Storage (acre-feet)	Elevation (feet)	Est. Elevation Proposed Storage (feet)	Est. Surface Area Actual Storage (acres)	Est. Surface Area Proposed Storage (acres)	Evaporation (inches)	Evap / 12 (feet)	Evap (feet) x 0.7	Est. Actual Evaporation (acre-feet)	Est. Proposed Storage Evaporation (acre-feet)
Jan	183,064	133,064	50,000	4,309.10	4,280	7,434	2,562	3.46	0.29	0.20	1,500	517
Feb	207,139	157,139	50,000	4,312.41	4,280	7,434	2,562	5.84	0.49	0.34	2,533	873
Mar	220,176	170,176	50,000	4,314.08	4,280	7,434	2,562	9.93	0.83	0.58	4,306	1,484
Apr	223,067	173,067	50,000	4,314.44	4,280	7,434	2,562	14.44	1.20	0.84	6,262	2,158
May	193,841	143,841	50,000	4,310.62	4,280	7,434	2,562	17.38	1.45	1.01	7,537	2,597
Jun	80,576	30,576	50,000	4,291.30	4,280	4,171	2,562	21.3	1.78	1.24	5,182	3,183
Jul	74,456	24,456	50,000	4,289.88	4,280	4,171	2,562	13.09	1.09	0.76	3,185	1,956
Aug	90,872	40,872	50,000	4,293.54	4,280	4,171	2,562	11.96	1.00	0.70	2,910	1,787
Sep	163,572	113,572	50,000	4,306.23	4,280	7,434	2,562	9.38	0.78	0.55	4,068	1,402
Oct	192,471	142,471	50,000	4,310.43	4,280	7,434	2,562	10.03	0.84	0.59	4,350	1,499
Nov	236,171	186,171	50,000	4,316.03	4,280	9,563	2,562	4.66	0.39	0.27	2,600	696
Dec	279,060	229,060	50,000	4,320.83	4,280	9,563	2,562	2.99	0.25	0.17	1,668	447
AVG			50,000							Sum of Evap	RGP Evap	18,601
												18,601

<b>Heron</b>	
Sum Evap	11,741
RGP Evap	5,553
<b>Elephant Butte</b>	
Sum Evap	18,601
RGP Evap	18,601

<b>Total Moved Storage Evap</b>	
EBR/Caballo Evap	30,342
	61,172

TABLE 2N.--2013 Monthly Evaporation (Acre-Feet)--Scenario #2 (50k in EBR)							
	Heron	El Vado	Abiquiu	Cochiti	Elephant Butte	Caballo	Total/Mo.
Jan	0	0	554	216	517	0	1,287
Feb	0	0	825	308	873	0	2,006
Mar	0	0	1,416	522	1,484	0	3,422
Apr	1,753	451	1,726	507	2,158	0	6,595
May	2,394	675	1,920	695	2,597	0	8,281
Jun	2,329	588	2,581	844	3,183	0	9,525
Jul	1,485	397	1,989	545	1,956	0	6,372
Aug	1,277	407	1,842	486	1,787	0	5,799
Sep	1,431	282	1,414	688	1,402	0	5,217
Oct	1,074	199	1,180	286	1,499	0	4,238
Nov	0	0	743	226	696	0	1,665
Dec	0	0	484	195	447	0	1,126
Annual	11,741	2,999	16,673	5,519	18,601	0	55,533
			High-Elev	36,932	Low-Elev	18,599	
							Savings =
							38,401

## APPENDIX B.

### National Academy of Sciences Reservoir Reoperations Study Draft Scope of Work

#### **Goal 1: Identify how much storage physically and legally exists in high-elevation (Heron, El Vado, Abiquiu, Cochiti, Jemez Canyon, Galisteo) and low-elevation reservoirs (Elephant Butte and Caballo).**

##### Tasks:

- Identify existing storage and break down each by purpose (flood control, sediment, storage for irrigation, municipal, or other uses).
- Identify possible additional storage in each reservoir (e.g., Corps 1987 review of Abiquiu Reservoir identifies an additional 467, 000 acre-feet of storage, above flood and sediment control and San Juan-Chama Project storage, that could be utilized given additional hurdles like easement acquisition and legal constraints).
- Identify legal constraints on use of each reservoir (e.g., congressional authorizations, Rio Grande Compact, channel capacities, etc.).

#### **Goal 2: Determine the surface area versus stage and volume for each reservoir.**

##### Task:

- Find and review the most recent sedimentation or other study that contains surface area-capacity curves for each reservoir.

#### **Goal 3: Determine the evaporation losses from each of the high-elevation (Heron, El Vado, Abiquiu, Cochiti, Jemez Canyon, Galisteo) and low-elevation reservoirs (Elephant Butte and Caballo).**

##### Tasks:

- Find the monthly PAN evaporation data for each reservoir.
- Determine the monthly evaporation rates at each storage site.
- Determine if models already exist to estimate reservoir evaporation losses in a given year or series of years.



**Goal 4: Determine the amount of water savings that could occur if more water is stored upstream. Develop examples of where, how, and when water can be stored and released, creating several alternative scenarios representing dry, wet, and average streamflow years.**

Tasks:

- Determine how refined our period of analysis needs to be to establish benefit of the proposed movement of storage. Is it one year, three years, five years, ten years, etc.?
- Can the post-1974 period of record be used without grossly overestimating the amount of water in storage looking forward, based on climate-change predictions?
- Identify three periods of record that represent the wet-, dry-, and average-year scenarios on the Rio Grande. For example, 2011–2013 might represent the dry-year scenario. What is the shortest period that would give us the full picture?
- Identify or develop method/model/procedure for evaluating the savings by moving storage upstream.

**Goal 5: Determine the amount of existing carriage losses of status quo water management, based on typical water delivery/movement patterns.**

Tasks:

- Model or use another method to determine how much water is lost in transport.
- Determine modifications needed to existing flow patterns to facilitate additional upstream storage and calculate the additional carriage losses between reservoirs and delivery points.
- Determine net water savings of a new proposed water storage plan, factoring in carriage losses.

**Goal 6: Develop a reservoir release plan that allows for the transport and delivery of water downstream while prioritizing river health and securing flows for native species in the Rio Chama and Rio Grande.**

Tasks:

- Determine what the ideal flow pattern (timing/amount) is from U.S. Fish and Wildlife Service for native species, including but not limited to the Rio Grande silvery minnow, Southwestern willow flycatcher, and yellow-billed cuckoo.
- Determine the ideal flow pattern to facilitate natural river processes now lacking in the Middle Rio Grande ecosystem (e.g., sediment transport, overbank flooding, cottonwood/willow regeneration, etc.).
- Determine channel capacity limitations.



# IX. End Notes

<sup>1</sup> Dettinger et al. 2015 at 2088.

<sup>2</sup> Dettinger et al. 2015 at 2088.

<sup>3</sup> Llewellyn et al. 2013 at Appendix A-5.

<sup>4</sup> Reproduced from Llewellyn et al. 2013 at Appendix A-6.

<sup>5</sup> *The fishes of Illinois Forbes*, Stephen Alfred, 1844-1930; Richardson, Robert Earl, b. 1877. Available at: [https://commons.wikimedia.org/wiki/File:Scaphirhynchus\\_platorynchus.jpg](https://commons.wikimedia.org/wiki/File:Scaphirhynchus_platorynchus.jpg)

<sup>6</sup> Tarlock at 770.

<sup>7</sup> Skelton 2015.

<sup>8</sup> Reclamation Act, Section 2 (June 17, 1902).

<sup>9</sup> Kelly et al. 2007 at 526-613.

<sup>10</sup> Kelly et al. 2007 at 539.

<sup>11</sup> Llewellyn et al. 2013 at 18.

<sup>12</sup> A study published in *Bioscience* found that manmade reservoirs are releasing methane into the atmosphere, contributing 1.3 percent of the global total of annual carbon emissions. See Mooney 2016.

<sup>13</sup> Papadopoulos 2000, ES at 1.

<sup>14</sup> Papadopoulos 2000 at 25, 63.

<sup>15</sup> <https://waterdatafortexas.org/reservoirs/individual/elephant-butte>

<sup>16</sup> See <http://earthobservatory.nasa.gov/IOTD/view.php?id=81714>

<sup>17</sup> Papadopoulos 2000 at 25.

<sup>18</sup> This graph is reproduced from Figure C-4.1 of Papadopoulos 2000 at Appendix C.

<sup>19</sup> Papadopoulos 2000 at 67.

<sup>20</sup> Reclamation 2016 at 7-1.

<sup>21</sup> Reclamation 2016 at 7-1.

<sup>22</sup> Llewellyn et al. 2013 at 37.

<sup>23</sup> Llewellyn et al. 2013 at 38.

<sup>24</sup> Llewellyn et al. 2013 at 39.

<sup>25</sup> Llewellyn et al. 2013 at 40.

<sup>26</sup> Dettinger et al. 2015 at 2083.



<sup>27</sup> Dettinger et al. at 2083.

<sup>28</sup> Kelly 2011 at 16-4 to 16-10.

<sup>29</sup> Papadopoulos 2000 at 67.

<sup>30</sup> WAMS 2000 at 20.

<sup>31</sup> WAMS 2000 at E-70.

<sup>32</sup> Reproduced from WAMS 2000 at E-70.

<sup>33</sup> WAMS 2000 at E-71.

<sup>34</sup> WAMS 2000 at E-72.

<sup>35</sup> Kelly 2007.

<sup>36</sup> Reclamation 2016 at 7-7.

<sup>37</sup> See Appendix A for an explanation of how this data was calculated.

<sup>38</sup> Kelly 2007.







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