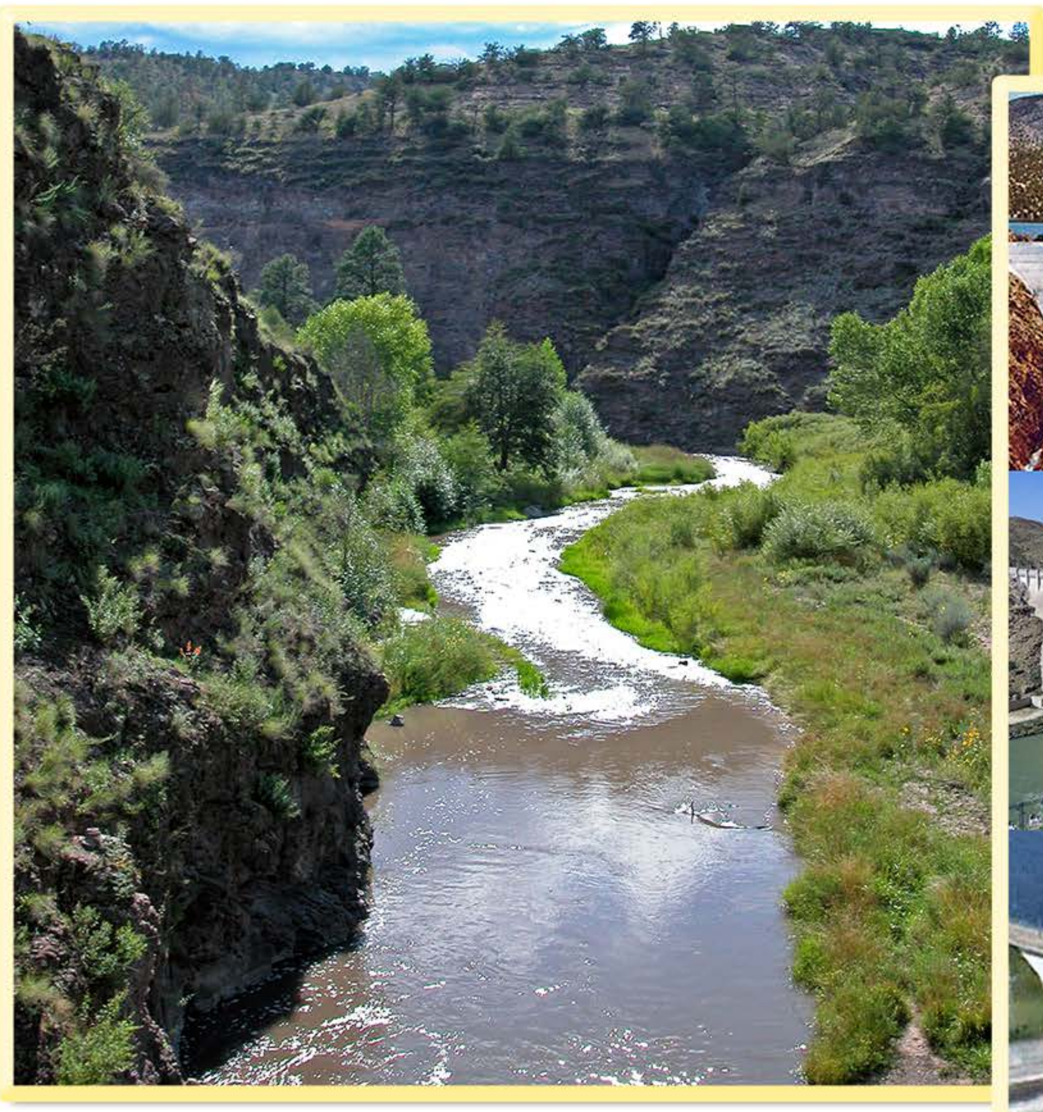
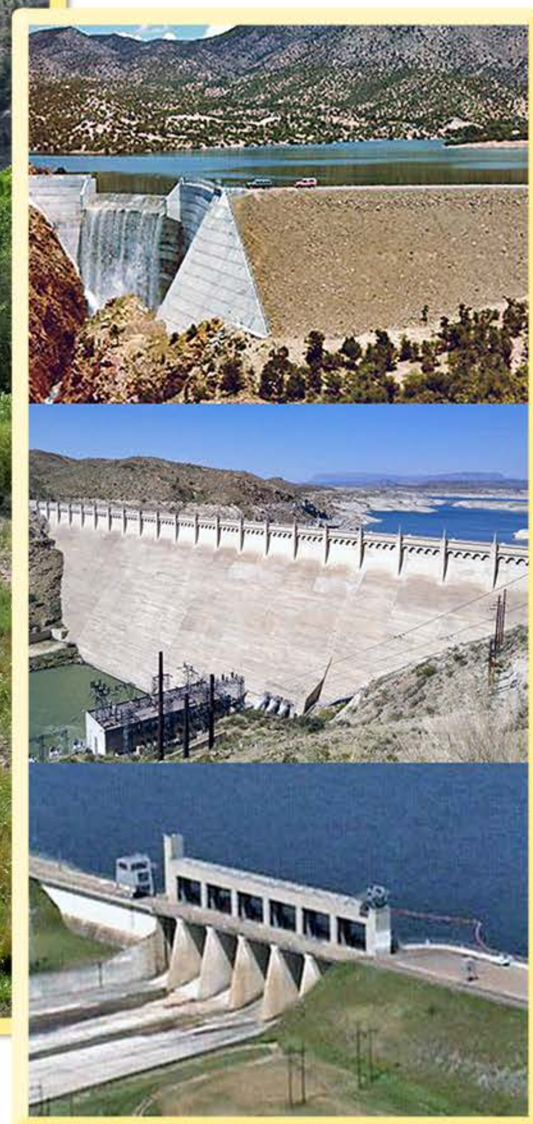
RECLAMATION
Managing Water in the West

SECURE Water Act Section 9503(c)—Reclamation Climate Change and Water 2016

Chapter 7: Rio Grande Basin





U.S. Department of the Interior
Bureau of Reclamation

March 2016

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

SECURE Water Act Section 9503(c) Report to Congress

Chapter 7: Rio Grande Basin

Prepared for

United States Congress

Prepared by

U.S. Department of the Interior
Bureau of Reclamation

U.S. Department of the Interior
Bureau of Reclamation
Policy and Administration
Denver, Colorado

March 2016

Acronyms and Abbreviations

°F	degrees Fahrenheit
AFY	acre-feet per year
Compact	Rio Grande Compact
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
GNEB	Good Neighbor Environmental Board
IBWC	International Boundary Water Commission
Reclamation	Bureau of Reclamation
RGRWA	Rio Grande Regional Water Authority
TWDB	Texas Water Development Board
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
WaterSMART	Sustain and Manage America's Resources for Tomorrow

About this Chapter

This summary chapter is part of the 2016 SECURE Water Act Report to Congress prepared by the Bureau of Reclamation (Reclamation) in accordance with section (§) 9503 of the SECURE Water Act. The 2016 SECURE Water Act Report follows and builds on the first SECURE Water Act Report, submitted to Congress in 2011,[1] which characterized the impacts of warmer temperatures, changes to precipitation and snowpack, and changes to the timing and quantity of streamflow runoff across the West.

This chapter provides a basin-specific summary for the Rio Grande Basin. This chapter is organized as follows:

- **Section 1**: River basin setting,
- **Section 2**: Impacts to water and environmental resources,
- **Section 3**: Potential adaptation strategies to address basin water supply and demand imbalances, and
- **Section 4**: Coordination activities to build climate resilience.

This chapter provides updated information from Reclamation studies completed or initiated in the basin over the past five years. The key studies referenced in this chapter include the Upper Rio Grande Impact Assessment, Lower Rio Grande Basin Study, Santa Fe Basin Study, and the Pecos Basin Study. Additional information relevant to the Rio Grande Basin, including the latest climate and hydrology projections for the basin, is included in Chapter 2: Hydrology and Climate Assessment.

Rio Grande Basin Setting

States: Colorado, New Mexico, and Texas in the US; four states in Mexico

Major Cities: Santa Fe, Albuquerque, and Las Cruces, New Mexico; El Paso, Del Rio, Laredo, and Brownsville, Texas, and Ciudad Juarez, Mexico.

International: Mexico

River Length: 1,900 miles

River Basin Area: 180,000 square miles

Major River Uses: Municipal, Agricultural (2,000,000 acres of land in U.S. and Mexico), Hydropower (15 megawatts), Recreation, Flood Control, Navigation, and Fish and Wildlife

Notable Reclamation Facilities: San Juan-Chama Project, Heron Dam , El Vado Dam, Nambe Falls Dam, Elephant Butte Dam and Powerplant, and Caballo Dam.

Other Notable Facilities: Amistad and Falcon Dams (International Boundary and Water Commission

[1] The first SECURE Water Act Report, submitted to Congress in 2011 is available on the Reclamation website: www.usbr.gov/climate/secure/docs/2011secure/2011SECUREreport.pdf .

Contents

Page

Figures

Page

Tables

Page

1 Basin Setting

Today, the Rio Grande supplies water for municipal and irrigation uses for more than 6 million people and 2 million acres of land in the United States (U.S.) and Mexico. The headwaters in the San Juan Mountains of southern Colorado drain approximately 182,200 square miles from both Texas and Mexico. The Rio Grande serves as a source of water for agricultural irrigation, municipal and industrial supplies, as well as domestic, environmental, and recreational uses in Colorado, New Mexico, Texas, and Mexico. Seventy-five percent of Rio Grande Basin water is currently allocated for agriculture. Significant agricultural production occurs in Colorado's San Luis Valley and New Mexico's acequias, Indian Pueblos, and irrigation districts upstream of the bi-national boundary between Mexico and the U.S. Surface water supplements groundwater pumping for the New Mexico cities of Albuquerque and Santa Fe; however, it is significantly less than the 50 percent reliance on surface water for municipal uses by the City of El Paso.

The river's flows are often insufficient to meet the basin's water demands. The magnitude and frequency of water supply shortages within the Rio Grande Basin are severe, even without the effects of climate change. In recent years, intermittent and low flows have occurred throughout the Rio Grande system, and in many years, river flows do not reach the Gulf of Mexico. The river also supports unique fisheries and riparian ecosystems along much of its length, and significant efforts are underway to protect migratory bird habitat in a number of wildlife refuges, as well as threatened and endangered riverine and riparian species in the basin. In addition, the low flows are often associated with elevated river temperatures and water quality concerns, especially along the United States-Mexico border region.

The Rio Grande Basin is located in the southwestern United States and northern Mexico (Figure 7–1). The river's headwaters are in the San Juan Mountains of southern Colorado. The river flows southward through Colorado's San Luis Valley, then through central New Mexico, where it picks up flows from the Rio Chama, and then southeastward as it forms the international boundary between Texas and four states in Mexico. The Rio Grande picks up flows from the Pecos River within Texas and from the Rio Conchos within Mexico, before ultimately flowing into the Gulf of Mexico. The total river length is 1,896 miles, and it flows through the cities of Alamosa, Colorado; Albuquerque and Las Cruces, New Mexico; El Paso, Laredo, and Brownsville, Texas; and through several large sister cities in Mexico along the United States/Mexico border. Basin topography varies, from the mountains and gorges of the headwaters to the Rio Grande Bosque (riverside forest) and high desert of central New Mexico, to deserts and subtropical terrain along the boundary between Texas and Mexico.

Figure 7–1. The Rio Grande Basin of Colorado, New Mexico, Texas, and Mexico.

The Reclamation projects in or serving the Upper Rio Grande Basin include the Closed Basin Project in Colorado, the San Juan-Chama trans-mountain diversion project between Colorado and New Mexico, the Middle Rio Grande Project in central New Mexico, and the Rio Grande Project in southern New Mexico and far-west Texas. These projects support approximately 200,000 acres of irrigated agriculture, which produces alfalfa, cotton, vegetables, pecans, and grain; they also provide water to municipalities, tribes, and industry. Reclamation's facilities provide critical water and power for industry and communities including Albuquerque and Las Cruces in New Mexico; El Paso, Texas; and Ciudad Juarez in Chihuahua, Mexico.

The waters of the Rio Grande are heavily utilized, and due to the highly variable and limited supply, as well as this heavy usage, the river is subject to regular intermittency, especially in the central to southern New Mexico and West Texas reaches. The Rio Grande Basin supports critical habitat for the Rio Grande silvery minnow and the southwestern willow flycatcher, both designated as endangered under the Endangered Species Act (ESA). To protect these critical resources, Reclamation must continually evaluate and report on compliance with the ESA, including the risks and impacts from a changing climate, and identify appropriate adaptation and mitigation strategies in conjunction with stakeholders, utilizing the best available science.

Along the Pecos River, Reclamation operates Sumner Dam, which serves the Fort Sumner Irrigation District, and Avalon and Brantley Dams, which serve about 25,000 acres of agricultural land in the Carlsbad Irrigation District. In the Lower Rio Grande Basin, Amistad and Falcon Reservoirs are operated by the International Boundary and Water Commission (IBWC) for flood control and water supply purposes, and have been designated as a special water resource by the Texas Water Development Board (TWDB). Seventy-eight percent of the watershed that feeds these international reservoirs is in Mexico. Historically, Mexico has not always been able to meet its obligations under the governing Treaty due to drought and its own competing needs for, and uses of, tributary waters.

This section along the United States/Mexico border is subject to additional water supply and water quality challenges. As Hurd stated (2012), decreasing runoff and streamflow in Mexico's arid north bordering the Rio Grande threaten not only Mexican irrigation and food production but also Treaty-obligated deliveries to the Rio Grande. The Good Neighbor Environmental Board (GNEB) identified numerous challenges of working in international watersheds. As noted by the GNEB, "an arid climate, the presence of poverty, rapid population growth, aging infrastructure, an international border, and laws in both countries that were put into place in earlier times under different circumstances are just a few of the potential roadblocks" to effective water management in the U.S.-Mexico border region (GNEB, 2005).

1.1 Rio Grande Basin Studies

Climate change is affecting water supply, infrastructure, and management practices of the Rio Grande Basin to meet basin resource needs[2] reliably. Since 2011, Reclamation has funded and conducted four studies in the Rio Grande Basin through the Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program. These studies were used to define current and future imbalances in water supply and demand in the basin and sub-basins over a long-term planning horizon (i.e., more than 50 years), and to develop and analyze adaptation and mitigation strategies to resolve those imbalances.

Upper Rio Grande Impact Assessment: Reclamation conducted the Upper Rio Grande Impact Assessment to determine baseline risks to water supplies and demands, establishing a foundation for more in-depth analyses and the development of adaptation strategies. The study was conducted by Reclamation in partnership with Sandia National Laboratories and the U.S. Army Corps of Engineers (USACE) and was completed in 2013.

Lower Rio Grande Basin Study: Reclamation collaborated with the Rio Grande Regional Water Authority (RGRWA), which includes 53 member entities, to fund the study. The study area encompasses 166,000 square miles along the United States-Mexico border from Fort Quitman, Texas, to the Gulf of Mexico. The study was completed in 2013.

Santa Fe Basin Study: Reclamation collaborated with the City of Santa Fe and Santa Fe County on a basin study focused on the Santa Fe River Basin in northern New Mexico. This study also evaluated water sources in New Mexico and southern Colorado that provide water supply to the City of Santa Fe and Santa Fe County, including the Upper Rio Grande, Reclamation's San Juan-Chama Project, and local groundwater supplies. The study was released in 2015.

Pecos River Basin Study: Reclamation is collaborating with the New Mexico Interstate Stream Commission to fund this study. The basin study will focus on the Fort Sumner Underground Water Basin (Fort Sumner Basin), within the Pecos River Basin, New Mexico, and includes a general assessment of climate change impacts and potential adaptation strategies in the entire Pecos River Basin of New Mexico. The study is scheduled to be completed in 2016.

These Basin Studies are conducted in coordination with stakeholders in the Rio Grande Basin. The purposes of the Basin Studies are to define current and future imbalances in water supply and demand in the basin and sub-basins over a long-term planning horizon, and to develop and analyze adaptation and mitigation strategies to address those imbalances.

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[2] Resource needs include water allocations and deliveries for municipal, industrial, and agricultural use; hydroelectric power generation; recreation; fish, wildlife, and their habitats (including candidate, threatened, and endangered species); water quality including salinity; flow- and water-dependent ecological systems; and flood control.

2 Analysis of Impacts to Water Resources

The Rio Grande passes through a number of climatic zones. The high-mountain headwater areas in the San Juan and Sangre de Cristo Mountains of Colorado and New Mexico receive an average of 40 inches of precipitation per year, mostly in the form of snow. Snowmelt from these headwater regions forms the majority of total annual flow in the Upper Rio Grande Basin, from the headwaters to Elephant Butte Reservoir. These flows peak in the late spring and early summer and diminish rapidly by mid-summer in the arid and semi-arid basin, but are supplemented by summer rains that are components of the North American Monsoon.

In the reach between Elephant Butte Dam and Fort Quitman, Texas, the supply comes primarily from storage reservoirs. Farther downstream, in the Lower Rio Grande Basin, flows are generated from local rainfall, inflows from Mexico, (especially the Rio Conchos, a major tributary for which Mexico has a delivery obligation to the United States), and reservoir releases. The climate of the Lower Rio Grande region in Texas ranges from arid subtropical where the river enters the state at El Paso to humid subtropical in the eastern portion of the region. Prevailing winds are southeasterly throughout the year, and the warm tropical air from the Gulf of Mexico produces hot, humid summers and mild, dry winters.

Key findings related to projected changes in temperature, precipitation, snowpack, and runoff in the Rio Grande Basin from the Chapter 2: Climate and Hydrology Assessment as well as completed Basin Studies and Impact Assessments are presented below.

- **Temperature** is projected to increase with the range of annual possibility widening through time. Climate projections suggest that temperatures throughout the Rio Grande are projected to increase by roughly 5 to 6 degrees Fahrenheit (°F) during the 21^{st} century. Projected changes in climate and hydrology in the Rio Grande Basin have geographic and temporal variation, and the progression of change through time varies among the climate models used to develop the projections.
- **Precipitation** projections show that mean-annual precipitation is projected to decrease gradually during the 21^{st} century. Climate projections suggest that annual precipitation in the Rio Grande Basin will remain quite variable over the next century, with a decrease of from 2.3 to 2.5 percent by 2050. Temperature and precipitation changes are expected to affect hydrology in various ways, including snowpack development.
- **Snowpack** is expected to diminish due to warming impacting the accumulation of snow during the cool season (late autumn through early spring) and the availability of snowmelt to sustain runoff to the Rio Grande during the warm season (late spring through early autumn). Snowpack

decreases are expected to be more substantial over the portions of the basin where baseline cool-season temperatures are generally closer to freezing thresholds and more sensitive to projected warming. This is particularly the case for the lower-lying areas of the basin.

- **Annual runoff**, at all locations, is projected to steadily decline through the 21st century, responding to slight decreases in precipitation in combination with warming across the region.
- **Seasonality of runoff** is also projected to change in the Upper Rio Grande. Warming would be expected to lead to more rainfall and runoff, rather than snowpack accumulation, during the winter. Projections show this seasonality change to be more pronounced in the portions of the basin currently with lower-elevation snowpack, and therefore to be larger in the Rio Chama than in the mainstem of the Rio Grande.
- **Changes in the magnitude of flood peaks** also are expected in the Upper Rio Grande, although there is less certainty in the analysis of these types of acute events than there is for changes in annual or seasonal runoff. These changes have implications for flood control and ecosystem management. However, there is a high degree of variability among model simulations, suggesting there is a high degree of uncertainty in this flood metric.
- **Low-flow periods** in the Rio Grande are projected to become more frequent due to climate change. Decreasing annual minimum runoff would be associated with reduced water availability to support diversions for agricultural, municipal, and industrial uses and adversely affects aquatic habitats through reduced wetted stream perimeters and availability of aquatic habitat and through increased water temperatures detrimental to temperature-sensitive aquatic organisms.
- **Availability of water supplies** will be impacted by changes in climate and precipitation within the Rio Grande Basin. Mean annual runoff is projected to decrease. Warmer conditions are expected to transition from snowfall to rainfall, producing more December-March runoff and less April-July runoff.

Changes in water supply and reservoir operations because of climate change may have subsequent effects to water allocations from year to year, which in turn could trigger changes in water use (e.g., crop types, cropping dates, or transfers among different uses). Key findings related to projected changes in demand are summarized below.

- The atmosphere's moisture-holding capacity increases when air temperature increases. Therefore, plant water consumption and surface water evaporation associated with agriculture, riparian consumption, and other outdoor water uses will increase in a warming climate. Net irrigation water demand is expected to increase by up to 19 percent in 2080 (Reclamation, 2015 [Irrigation]).

- Additionally, agricultural water demand could be locally affected by crop failures caused by changes in pests and diseases. Furthermore, these natural-system changes must be considered in combination with socioeconomic changes, including population growth, infrastructure, land use, technology changes, and human behavior.
- Agricultural irrigation is the predominant water use in the Rio Grande Basin and the western United States as a whole. The seasonal volume of agricultural water demand could increase if growing seasons become longer.
- In addition, reservoir evaporation at Elephant Butte Reservoir, the reservoir with the highest evaporative losses in the Upper Rio Grande Basin, is projected to increase by up to 10 percent (Reclamation, 2015 [Irrigation]) (Reclamation, 2015 [Santa Fe]). Changes in factors other than temperature, such as net radiation and wind speed, can also affect reservoir evaporation rates.
- Climate change also could result in increased demand for in-stream flow or reservoir releases to satisfy other system objectives, including ecosystem support, the needs of Threatened and Endangered species, hydropower generation, municipal and industrial water deliveries, river and reservoir navigation, and recreational uses.
- Diversions and consumptive use by industrial cooling facilities are predicted to increase, since these processes will function less efficiently with warmer air and water temperatures. The timing of these diversions and timing of diversions needed for the production of hydropower also could be a factor in ecosystem demands and navigation and recreational water uses. New or expanded industries, such as oil and gas development, are also expected to result in increased demands.
- In the Lower Rio Grande, the storage capacity of the system is expected to decrease gradually due to future sedimentation of the reservoirs. Prolonged drought and higher intensity rainfall events may result in increased sediment loading. The U.S. share of the firm annual yield of the Amistad-Falcon Reservoir System is expected to decrease from 1.01 million acre-feet per year (AFY) in the year 2010 to 979,200 AFY in the year 2060, a reduction of about 6 percent.

Climate projections indicate changing hydrology for the Rio Grande Basin, with potential effects on water management, human infrastructure, and ecosystems. Although there are uncertainties in the details, some general patterns are clear. The impacts of climate change on Reclamation's ability to satisfy these key management objectives are described in the following sections.

2.1 Water Delivery

The projected water supply imbalances will greatly reduce the reliability of deliveries to all users who depend on Rio Grande water. In the Upper Rio

Grande, supplies over the course of the 21st century are projected to decrease by about one-fourth in the Colorado portion of the basin, and by about one-third in the New Mexico portion. In the Lower Rio Grande, in addition to the projected supply imbalance of approximately 592,000 AFY due to population growth, there is projected be another approximately 86,000 AFY of supply imbalance due to climate change. The reliability of the Rio Grande to meet future needs in the study area is severely compromised by a growing gap between demand and availability and the potential for diminishing supplies due to climate change and competing uses in the Texas Rio Grande Regional Water Planning Area (also known as Region M).

The usable, manageable water supply is projected to decline. There will be a loss of winter snowpack, which will result in a decrease in water supply, as well as a decrease in the ability throughout the basin to store water for use during the summer irrigation season. There will also be an increase in all outside demands (including agricultural, riparian, and urban landscaping) due solely to the projected increases in temperature. The decrease in water supply will be exacerbated by the increase in demand; the gap between supply and demand will grow even if there are no decreases in average annual precipitation.

The growing imbalance between supply and demand is expected to lead to a greater reliance on non-renewable groundwater resources. Increased reliance on groundwater resources will lead to greater losses from the river into the groundwater system. Additionally, projections suggest a somewhat more reliable supply from the imported San Juan-Chama Project water than from native Rio Grande water. A greater reliability of the imported water supply than the native water supply, which has the most aboriginal and senior water rights holders and users, could have significant socio-economic implications. Finally, all of the changes in water supply that are projected to result from climate change would be compounded by the numerous other changes made to the landscape and to the water supply.

2.2 Hydropower

Climate changes that result in decreased reservoir inflow or disrupt traditional timing of inflows could adversely affect hydropower generation. Lower flows and lower reservoir levels associated with climate change are projected to lead to decreases in opportunities for hydropower generation. The projected decrease is substantial, from an initial generation within the Upper Rio Grande system of around 15 megawatts, the projected rate drops almost 50 percent to around 8 megawatts by the end of the 21st century, with most of the decrease coming during the months of May through September. Hydropower is generated in the Upper Rio Grande Basin at El Vado, Abiquiú, and Elephant Butte Dams. Hydropower generation at these facilities fluctuates both seasonally and annually. Because reservoirs in the Upper Rio Grande Basin typically generate power incidental to other reservoir releases, hydropower generation is vulnerable to both changes in annual runoff and seasonal runoff patterns.

2.3 Recreation at Reclamation and Other Federal Facilities

The Upper Rio Grande Impact Assessment identified a number of water-dependent recreational activities that are expected to be negatively affected by climatic changes that reduce water supply in the basin for recreational uses. These activities include:

- Fishing along the Conejos River and Rio Grande in Colorado, along the Rio Grande between Taos Junction Bridge and Embudo in New Mexico, and in Heron, El Vado, Abiquiú (USACE), Cochiti (USACE) Elephant Butte, and Caballo Reservoirs
- Camping along the Rio Grande in Colorado and New Mexico, including below Taos Junction Bridge, along the Rio Chama above Abiquiú Reservoir, and at Heron, El Vado, Abiquiú, Cochiti, and Elephant Butte Reservoirs
- White-water rafting along the Rio Grande above Embudo, and between El Vado and Abiquiú Reservoirs on the Rio Chama
- Flat-water boating in Heron, El Vado, Abiquiú, Cochiti, Elephant Butte and Caballo Reservoirs

Although decreases in available water many decrease the opportunities for water-related recreation at these facilities, demand for water-related recreation is anticipated to increase as the climate warms (Reclamation, 2013 [URGIA]).

The Texas Department of Tourism notes that in 2013, the total destination spending for tourism for Cameron, Hidalgo, Willacy, Webb, and Starr Counties was more than $28.8 billion (Texas Economic Development & Tourism, 2014). In addition, water-related recreational activities such as boating, sport fishing, birdwatching, and commercial fishing in the lower Laguna Madre and adjacent waters also influence the regional economy. Increased summer and winter temperatures may increase the popularity of these water-based activities. Moreover, reduced supplies, altered timing of flows, and increased variability will change the availability and nature of these recreational opportunities.

2.4 Flood Control Management

Floods are projected to grow in magnitude with climate change; thus, flood control operations are projected to be needed more often in the future, even as overall supplies decrease. In the Upper Rio Grande Impact Assessment, all climate simulations projected an increase in the month-to-month and inter-annual variability of flows over the course of the century. Abiquiú, Cochiti, and Jemez Reservoirs are the main flood control reservoirs on the system managed and operated by USACE. Table 7–1 indicates how often these primarily flood control reservoirs fill to within 99 percent of capacity, under both past and projected future conditions. The frequency, intensity, and duration of both droughts and floods are projected to increase.

Table 7–1. Instances of insufficient flood control capacity in the USACE Abiquiu, Cochiti, and Jemez reservoirs by major period—Upper Rio Grande Basin

Source: Reclamation 2013 (URGIA)

Reservoir	Simulation period (years)	Months with insufficient flood control capacity	Years with insufficient flood control capacity
Abiquiu	1950 – 1999 (49)	0 (0%)	0 (0%)
Cochiti		0 (0%)	0 (0%)
Jemez		0 (0%)	0 (0%)
Abiquiu	2000 – 2049 (50)	4 (0.7%)	4 (8 %)
Cochiti		172 (29%)	47 (94 %)
Jemez		6 (1%)	6 (12%)
Abiquiu	2050 – 2099 (50)	5 (0.8 %)	3 (6%)
Cochiti		110 (18%)	26 (52%)
Jemez		4 (0.7%)	4 (8 %)

2.5 Fish and Wildlife Habitat

Climate change is projected to reduce available water in the Upper Rio Grande system. This reduction in water is expected to make environmental flows in the river more difficult to maintain and reduce the shallow groundwater available to riparian vegetation. Both of these impacts have implications for the habitat of fish and wildlife in the Upper Rio Grande Basin riparian ecosystems.

Projected decreases in minimum runoff are projected to affect aquatic habitats adversely through reduced wetted stream perimeters and availability of aquatic habitat, and through increased water temperatures that are detrimental to temperature-sensitive aquatic organisms. However, there is a high degree of variability among model simulations, suggesting there is a high degree of uncertainty in this low-flow metric.

Figure 7–2. Along the Rio Grande, restoration of riverine habitat is commencing. Projects, such as the one shown here, near Santo Domingo Pueblo, NM, include removing invasive species like saltcedar and replanting native trees like cottonwood and willows.

In the Middle Rio Grande Valley Basin area, the U.S. Fish and Wildlife Service (USFWS) administers three national wildlife refuges, including the Valle de Oro National Wildlife Refuge, Sevilleta National Wildlife Refuse and Bosque del Apache National Wildlife Refuge. In addition, within the wildlife corridor of the Lower Rio Grande Valley Basin area, the U.S. Fish and Wildlife Service administers two individually unique national wildlife refuges, including Lower Rio Grande Valley National Wildlife Refuge and Santa Ana National Wildlife Refuge, and the Texas Parks and Wildlife Department administers multiple other wildlife management areas. The Lower Rio Grande Valley National Wildlife Refuge covers 91,000 acres in the region, with plans to expand to 132,000 acres. The Santa Ana National Wildlife Refuge covers 2,088 acres in the region. Two flyways for migratory birds and waterfowl converge in the Lower Rio Grande Basin in Texas, which is also home to the World Birding Center, a top worldwide destination for bird watching. According to a study by Texas A&M University, the economic contribution from wildlife watchers in the Rio Grande Valley is estimated to be approximately $463 million per year (Texas A&M University, 2012).

2.6 Endangered, Threatened, or Candidate Species

A delicate balance in water management in the basin is required to meet species and habitat needs, manage flows in the highly variable flow regime of the Rio Grande, and satisfy competing human water demands. In the mid-1990s, the Rio Grande silvery minnow and the southwestern willow flycatcher were designated as endangered under the ESA. Portions of the Rio Grande Basin are proposed to be designated as critical habitat for the western distinct population segment of the yellow-billed cuckoo (western yellow-billed cuckoo). Climate plays a key role in determining the distribution and biophysical characteristics of habitats and ecosystems that provide the ecological resources needed for life. In-stream flows and riparian systems that support endangered species and other fish and wildlife will be negatively affected by decreases in water supply and changes in the timing of flows. This will result in increases in demand due to open water evaporation and water use by plants (transpiration).

In the Lower Rio Grande Basin, imbalances have and will continue to have adverse impacts on the sensitive ecological communities that depend on the Rio Grande and associated riparian habitat. The Lower Rio Grande Valley National Wildlife Refuge and Wildlife Corridor support 69 rare, threatened, or endangered species. All of these sensitive resources will be subject to increased stressors in the future as water supplies become more constrained by increased demand and climate change.

2.7 Water Quality

More intense droughts and higher temperatures lead to a greater moisture deficit in the region’s forests. Trees that are not getting enough water are more susceptible to beetle infestations, and infected weakened and dead trees are more susceptible to catastrophic wildfires. Thunderstorms tend to build over fire scars because heat builds up over the blackened ground, and intense thunderstorms on the fire scars lead to the washing of ash into rivers and reservoirs, and often to large debris and sediment flows. Ash in the rivers and reservoirs can lead to decreased oxygen in the water and cause fish kills. Fire-scar runoff can lead to debris and sediment accumulation in reservoirs and this accumulation can lead to less reservoir storage and flood protection for downstream human infrastructure, and so on.

A recent Environmental Protection Agency (EPA) study considered climate change impacts to water quality in the Rio Grande Basin above the confluence with the Rio Puerco (EPA, 2013). In the EPA analyses, absolute reductions in total nitrogen, phosphorous, and suspended solids loads reflect reductions in total flow volumes. However, projected reductions do not reflect how the concentration of these pollutants may change under future climate scenarios. Concentrations of these and other pollutants, and of salt, are expected to increase in the future under projected warming scenarios in response to increased evaporation rates for surface water and increased precipitation intensity that could wash a greater volume of pollutants from the land surface into the river (Reclamation, 2013 [URGIA]).

2.8 Flow- and Water-Dependent Ecological Resiliency

In the Upper Rio Grande Basin, the available water supply is low relative to the demand for water. Ecological and human systems within the basin already operate close to thresholds (points at which small changes could have larger-scale repercussions) related to available water supply. In the future, if projected water supplies decrease and demands increase, water availability thresholds may be crossed, and key systems may undergo regime shifts. It has been suggested (Williams et al., 2010) that forests in some parts of New Mexico, such as in the Jemez Mountains, may have crossed such a threshold. Moisture stress in the trees has led to bark beetle infestations and wildfire, and the forest may be undergoing a transition even now to a new ecosystem, with new structures, processes, and species (Benson et al., 2014).

Many parts of the Upper Rio Grande system are also near thresholds with respect to snowpack temperatures. In areas where the winter snowpack temperatures are already close to the freezing point, a small increase in temperature could lead quickly to a large decrease in the region’s ability to store winter moisture in snow for use during the summer. It is possible that some systems in the basin have already crossed ecological thresholds.

3 Potential Adaptation Strategies to Address Vulnerabilities

Reclamation administers programs that include long-term planning focused on options to provide water management assistance to address complex water issues on local, regional, and statewide levels, as well as water conservation-related projects under WaterSMART (Sustain and Manage America's Resources for Tomorrow). Recent and on-going Reclamation studies with partners in the Rio Grande Basin include:

Santa Fe Basin Study: This small sub-watershed of the Upper Rio Grande completed a basin study focused on options to provide water management assistance to address complex water issues. Adaptation strategies identified for further development for the municipal supplies within this watershed include combinations of water conservation (decreases in the water used per person in the basin), direct reclaimed water reuse, aquifer storage and recovery through direct injection and indirect seepage through the bed of the Santa Fe River, and acquisition of additional water rights (Table 7–2).

Table 7–2. Adaptations to Projected Changes in Water Supply and Demand

Source: Reclamation, 2015 (Santa Fe)

Adaptation Strategy	Description	Infrastructure Components
Direct/Indirect Reclaimed Water Reuse	Use reclaimed water from the City of Santa Fe wastewater treatment plant to meet contract obligations; remaining reclaimed water for potable reuse or return flow credits for pumping	New conveyance for reclaimed water from wastewater treatment plant to existing Buckman Regional Water Treatment Facility and distribution system or new conveyance to the Rio Grande for return flow credits
Water Conservation	Reduce water use on a per person per day basis	None
Direct Injection for Aquifer Storage and Recovery	Inject treated water into the aquifer in wet and normal years for use in dry years	Construction and operation of injection well(s); withdrawal using existing wells and distribution system
Infiltration for Aquifer Storage and Recovery in the Santa Fe River	Maintain flow in the Santa Fe River to induce infiltration into the aquifer for use in dry years	Withdrawal using existing wells and distribution system.
Additional Surface Water Rights	Additional surface water would be diverted at the Buckman Direct Diversion and treated at the Buckman Regional Water Treatment Facility.	Existing diversion, conveyance, treatment, and distribution systems

The City and County of Santa Fe have received a Water SMART Title XVI Grant to begin development of their water reuse strategy. This project is currently scheduled for completion in May 2016. The water reuse feasibility study will evaluate alternatives for both potable and non-potable applications of reclaimed water to augment water supplies. The feasibility study will evaluate ways to use reclaimed wastewater in a more cost-effective and efficient manner and will consider both potable and non-potable alternatives to meet water demand while better balancing environmental conditions in the watershed.

The Santa Fe Basin Study also included a general assessment of adaptation strategies that could be pursued within the basin, or which are already underway within the basin, to provide adaptations related to energy, transportation, land use, watershed wildlife and ecology, food security, and quality of life (Reclamation, 2015 [Santa Fe]). Adaptation strategies reviewed in this process include:

- Incorporate urban agriculture in water and land-use planning
- Cultivate climate-appropriate crops
- Provide incentives and programs to reduce water use, especially during drought
- Increase solar panel installation to reflect heat and produce energy
- Encourage limited-term urban lease of agricultural water rights during drought
- Expand rainwater harvesting techniques
- Adjudicate Santa Fe Basin water rights
- Augment potable supplies with reclaimed wastewater
- Increase above- and below-ground water storage capacity
- Require pervious pavement where appropriate
- Improve soils and watershed resiliency
- Design or modify bridges and culverts to handle higher-intensity runoff events
- Manage and plan restoration holistically
- Improve ecosystem biodiversity
- Decentralize energy infrastructure
- Establish a climate change-targeted monitoring system to observe changes in key resources, such as snowpack or ecological indicators

Lower Rio Grande Basin Study: The Lower Rio Grande Basin Study evaluated four adaptation strategies to the projected gap between water supply and demand, which were analyzed at the 2060 levels of water supply/demand. The potential adaptation strategies identified in the study include:

- seawater desalination,
- brackish groundwater desalination,
- reuse, and
- fresh groundwater development.

Brackish groundwater desalination was identified as the strategy most suitable for preliminary engineering and affordability analysis. In the Lower Rio Grande Basin, brackish groundwater supplies are four times more plentiful than fresh groundwater supplies and have much fewer competing demands. To address expected shortages in the area, potential adaption strategies include the continued development of the range of strategies recommended by State of Texas Water Planning Region M (i.e., Lower Rio Grande Basin planning area) and adapted by the Texas State Water Plan. Figure 7–3 depicts the relative proportions of future water strategies contained in the current Region M Plan. Many of these strategies would increase the efficiency of the use of Rio Grande supplies when implemented by the water user groups and government entities at all levels.

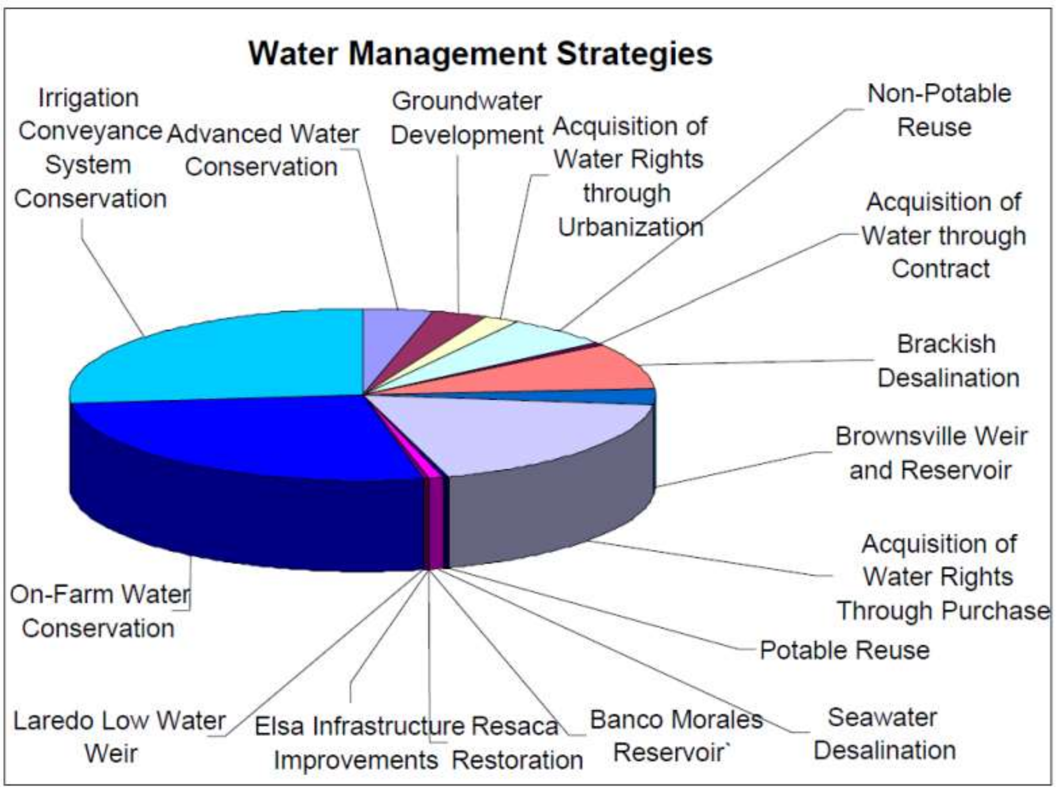

Figure 7–3. Relative portions of future water supply strategies for the Lower Rio Grande from the 2010 Region M Plan.
Source: Reclamation, 2013 (Lower Rio Grande)

4 Coordination Activities

Reclamation participates in coordinated adaptation activities that respond to climate stresses, as well as changes in land use, population growth, invasive species, and other stressors. These activities include managing limited water supplies for multi-purpose beneficial uses, implementing water conservation, optimizing hydropower production, planning for future operations and supporting rural water development. Specific examples of coordination in the Rio Grande Basin include:

- **United States Geological Survey (USGS) National Water Census: Upper Rio Grande Basin Focus Area Study** – Reclamation is participating in the USGS National Water Census Focus Area Study. This study seeks to improve estimates of selected water budget components to assess water availability and use in the Upper Rio Grande Basin of Colorado, New Mexico, and Texas. See below for additional details on this effort (Section 4.1).
- In the central New Mexico reach, Reclamation works closely with the **Middle Rio Grande Endangered Species Collaborative Program**, which includes 16 Federal, state, and local governmental entities, Indian tribes and Pueblos, and non-governmental organizations representing diverse interests, to support the water and habitat needs of Federally listed endangered species in the Middle Rio Grande.
- The **Lower Rio Grande Basin Study** was conducted in partnership with the Rio Grande Regional Water Authority (RGRWA), which includes 53 member entities comprising several irrigation districts and municipalities, along with the Texas Parks and Wildlife, Texas Water Development Board, and International Boundary and Water Commission. Reclamation also attended regularly scheduled stakeholder meetings sponsored by RGRWA and local planning groups. Local sponsors are currently exploring options to better understand aquifer characteristics that would enable them to make more-informed decisions about a specific location for one or more brackish desalination plants.

4.1 U.S. Geological Survey Upper Rio Grande Basin Focus Area Study

The USGS has initiated a series of studies, focused on selected large watersheds, where there is a desire on the part of watershed stakeholders to conduct a comprehensive technical assessment of water availability with the best available tools. These geographic Focus Area Studies contribute toward ongoing assessments of water availability in these watersheds and provide opportunities to test and improve approaches to water availability assessment.

In 2014, the Upper Rio Grande Basin of Colorado, New Mexico, Texas, and northern Mexico was chosen as one of three new focus area studies for the USGS National Water Census, with work to commence in Fiscal Year 2016. The conjunctive use of water in the Upper Rio Grande Basin takes place under a myriad of legal constraints, including the Rio Grande Compact (Compact) and several Federal water projects. The conveyance and use of surface water in the Upper Rio Grande Basin, which serves as the primary source of irrigation water for agriculture throughout the basin, as well as for municipal use by the major municipalities along the river corridor, and environmental and recreational uses, is achieved through an engineered system of reservoirs, diversions, and irrigation canals.

Changes in climate have reduced reservoir water supplies, leading to increased use of groundwater for irrigation, municipal and industrial uses, and for downstream delivery under the Compact. These new demands have significantly altered surface water/groundwater exchange along reaches of the Rio Grande. In particular, reaches that previously had groundwater discharge to the Rio Grande are now losing reaches. In addition, the operation of agricultural drains changes the distribution of surface-water/groundwater exchange, and has implications for river flows and river and riparian ecosystems. The Upper Rio Grande Basin Focus Area Study is being performed in collaboration with Reclamation, USACE, USFWS, and other resource management agencies in the study area to better understand and adapt to these changes. Products will include:

- basin-wide water-use data by category (such as municipal, agricultural, and domestic);
- field-verified evapotranspiration estimates;
- evaluation of streamflow trends and regional calibration of a national-scale watershed model;
- improved snowmelt modeling techniques;
- groundwater availability assessment, development of a basin-scale hydrogeological framework, and water-level surface and change maps; and
- estimates of surface water and groundwater exchange

In addition to work done as part of the National Water Census, and funded through WaterSMART, the USGS has undertaken a series of regional groundwater availability studies in the West to improve the understanding of groundwater availability in major aquifers across the country including work on the One-Water Hydrologic Flow Model to simulate a broad range of conjunctive-suffface and groundwater use issues. The Middle Rio Grande Basin Regional Groundwater Availability Study, a 6-year effort (1995-2001) was conducted to improve the understanding of the hydrology, geology, and land-surface characteristics of the Middle Rio Grande Basin in order to provide the scientific information needed for water resources management. This initial proof-of-concept study was conducted prior to the development of the groundwater availability assessment strategy outlined in Circular 1323 and served as a precursor to current regional groundwater availability studies.

4.2 U.S. Army Corps of Engineers Coordination

Within New Mexico, and in the Rio Grande Basin generally, climate change is anticipated to have profound effects on flood risk, water supply, ecosystem health, land cover, and other areas of national concern. The Upper Rio Grande facilities are operated by Reclamation and USACE, in cooperation with local water management agencies, including state agencies, municipalities, irrigation districts, and Native American tribes. Coordination among Federal partners around these regional issues is a significant need. In 2013, Reclamation released an Impact Assessment within the WaterSMART Basin Study Program West-wide Climate Risk Assessments to support the identification of impacts from climate change on the resources within the basin. This work has provided a basis for basin studies to evaluate potential adaptations to the projected changes in the Pecos and Santa Fe watersheds in New Mexico, and could provide a basis for a multi-stakeholder basin study to evaluate potential adaptation measures throughout the Upper Rio Grande. The USACE Albuquerque District has been working with Reclamation's Albuquerque Area Office on the Pecos Basin Study, currently scheduled for completion in 2016.

In addition, water operations staff from both agencies, as well as the Middle Rio Grande Conservancy District, USFWS, and other interested parties hold frequent, often daily, water-operations conference calls during the irrigation season to discuss what water is being called on, where it is being demanded, how it will move through the system, and how to maintain ESA target flows. On these calls, stakeholders discuss releases by Reclamation from Heron and El Vado Reservoirs in northern New Mexico and releases by USACE at Abiquiú and Cochiti Reservoirs to meet various flow needs in the Middle Rio Grande.

Finally, the USACE Albuquerque District has initiated the New Mexico Watershed Futures meeting series to improve regional coordination among Federal partners to better understand how New Mexico watersheds and water resources are likely to respond to climate change. This regular meeting among regional Federal staff is used to share information pertinent to climate change within New Mexico and adjacent regions, so that Federal agencies can better serve sponsors, stakeholders, and constituents. The meeting draws attendees from the regional offices of almost all Federal agencies to discuss climate modeling, impacts assessment and visualization, adaptation, resilience, and vulnerability. It is anticipated that these meetings will enable Federal agencies to better leverage their individual science and expertise to the benefit of all participants.

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