RECLAMATION

Managing Water in the West

West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment

Executive Summary

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Albuquerque Area Office

December 2013

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.

The U.S. Army Corps of Engineers Mission is to deliver vital public and military engineering services; partnering in peace and war to strengthen our Nation's security, energize the economy and reduce risks from disasters.

Sandia Laboratory Climate Security program works to understand and prepare the nation for the national security implications of climate change.

Participation in this study by USACE, Albuquerque District, was supported by the USACE Institute for Water Resources Response to Climate Change Program, the Middle Rio Grande Endangered Species Collaborative Program (USACE funding authority), the USACE Albuquerque District Flood Risk Management Program and the USACE Albuquerque District Reservoir Operations Branch.

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Note Regarding this West-Wide Climate Risk Assessment – Impact Assessment

The Upper Rio Grande Impact Assessment is a reconnaissance-level assessment of the potential hydrologic impacts of climate change in the Upper Rio Grande Basin. For this study, to isolate the impacts of climate change from other changes that may occur within the basin, Reclamation has assumed that current water operations by all water-management entities acting in the Upper Rio Grande Basin would continue unchanged in the future. This assessment does not consider any operational changes that may or may not be made by basin stakeholders in the future and does not reflect the position of any entity regarding future operational changes. The results should not be interpreted as an indication of actions that Reclamation or other entities may or may not take to maintain compliance with environmental laws such as the Endangered Species Act or National Environmental Policy Act, or with Interstate Water Compacts. Possible adaptation and mitigation strategies to address imbalances in future water supply and demand in the basin may be considered in a subsequent Basin Study, which would include interested stakeholders.

Acronyms and Abbreviations

ABCWUA	Albuquerque – Bernalillo County Water Utility Authority
AF	acre-feet
AMO	Atlantic Multidecadal Oscillation
AOGCM	Atmosphere-Ocean General Circulation Model
BCSD	Bias Corrected Spatially Downscaled
BIA	Bureau of Indian Affairs
CC	Climate Change
CDF	Cumulative Density Function
cfs	cubic feet per second
CMIP3	Coupled Model Intercomparison Project 3
CO_2	Carbon Dioxide
COOP	Cooperative Observer Network
ENSO	El Niño – Southern Oscillation
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ET	Evapotranspiration
GCM	Global Circulation Model
HDe	Hybrid Delta Ensemble
IPCC	Intergovernmental Panel on Climate Change
LFCC	Low Flow Conveyance Channel
LCCs	Landscape Conservation Cooperatives
M&I	municipal and industrial
msl	mean sea level
MRG	Middle Rio Grande
MRGCD	Middle Rio Grande Conservancy District
MW	megawatts
NARCCAP	North American Regional Climate Change Assessment Program
NMISC	New Mexico Interstate Stream Commission
NMOSE	New Mexico Office of the State Engineer
NOAA	National Oceanic and Atmospheric Administration
PDO	Pacific Decadal Oscillation
PDSI	Palmer Drought Severity Index
RCMs	Regional Climate Models
Reclamation	Bureau of Reclamation
Service	U.S. Fish and Wildlife Service
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperature
SWA	SECURE Water Act
SWE	Snow Water Equivalence
URG	Upper Rio Grande
URGIA	Upper Rio Grande Impacts Assessment
URGSiM	Upper Rio Grande Simulation Model
URGWOM	Upper Rio Grande Water Operation Model
USACE	U.S. Army Corps of Engineers
USGCRP	U.S. Global Change Research Program
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VIC	Variable Infiltration Capacity (hydrologic model)
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WCRP	World Climate Research Programme
WWCRA	West-Wide Climate Risk Assessment

Executive Summary

Background and Purpose

In the Upper Rio Grande Basin of Colorado and New Mexico, the water management challenges posed by a highly variable and extremely limited water supply have been exacerbated by prolonged drought. Water managers are asking whether the hot and dry conditions experienced in the Upper Rio Grande Basin in the past several years are related to climate change, and whether, as a result, water management planning should incorporate the possibility of a hotter, drier, and more variable future. The Bureau of Reclamation (Reclamation), with technical assistance from the U.S. Army Corps of Engineers (USACE) and Sandia National Laboratories conducted the Upper Rio Grande Impact Assessment (URGIA) as a way to begin to answer such questions.

The Upper Rio Grande Impact Assessment (URGIA) is an activity of the West-Wide Climate Risk Assessment (WWCRA), which is a component of the Reclamation WaterSMART Basin Study Program. The Basin Study Program is aimed at addressing section 9503 of the SECURE Water Act (SWA) and Secretarial Orders 3289 and 3297, supporting the U.S. Department of the Interior's coordinated response to the hydrologic implications of a changing climate. The SWA designates Reclamation to assess the risks to water supplies and demands posed by climate change, including changes in snowpack, in timing and quantity of runoff, in groundwater recharge and discharge as well as changes in demands and consumptive usage within major Reclamation river basins in the Western United States. Baseline analyses of these conditions are being performed under the WWCRA Impact Assessments and are being expanded, in cooperation with local water-management partners, through Basin Studies.

Objectives, Scope, and Uncertainty

The URGIA includes a detailed evaluation of the climate, hydrology, and water operations of the Upper Rio Grande Basin of Colorado and New Mexico, along with a quantitative evaluation of the potential impacts associated with climate change on streamflow, water demand, and water operations in this basin.

The URGIA focuses on the Upper Rio Grande Basin, defined for this study as the Rio Grande and its tributaries from the headwaters of the Rio Grande and Rio Chama in Colorado to Caballo Reservoir in south central New Mexico (locations are shown in Figure 1 in the main report). In this portion of the Rio Grande Basin, snowmelt runoff is the major contributor to streamflow.

This Impact Assessment presents an overview of the current climate and hydrology of the Upper Rio Grande, an analysis of observed trends in temperature and precipitation over the past decade, and a comparison of these trends against model projections. It also presents hydrologic projections developed from global climate models, which have been used as input to a local operations model to evaluate the ways that the projected climatic and hydrologic changes would impact water availability and management within the Upper Rio Grande. Specific risks to water supplies and demands posed by climate change, and evaluated in this study, include changes in snowpack, timing and quantity of runoff, groundwater recharge and discharge, as well as changes to evaporation, transpiration, and other water demands. These risks are then evaluated in terms of their potential impacts on key water operations and uses within the basin, as required by the SWA, including:

- Water and power infrastructure/operations
- Water delivery
- Flood control operations
- Water quality
- Fish and wildlife habitat
- Endangered Species Act (ESA) listed species and critical habitat
- Flow and water-dependent ecological resiliency
- Recreation

This Impact Assessment purposefully assesses the potential impacts of climate change alone and does not attempt to project what future development or management actions may be, including how population may change, how power generation may evolve, or how land use, including the amount and type of irrigated agriculture, may change. While factors such as these will undoubtedly be affected by climate change, they are also changing due to societal factors that are independent of climate change. It is anticipated that this information will serve as a foundation for future studies focused on developing strategies to adapt to and mitigate climate change impacts.

The projections presented here are based on reasonable assumptions about our future. Since we do not know how humans are going to behave, what energy sources they will be using, or how much carbon dioxide they will emit into the atmosphere, there is uncertainty associated with any projection of future climatic changes. Furthermore, the hydrologic projections presented in the URGIA are built upon a series of analytic steps: starting with Global Circulation Models (GCM) runs at a global scale, with downscaling and bias correction to make the results usable at a local level, followed by land surface modeling (rainfall-runoff) at a basin scale, and finally operations modeling at the river network level. Each of these steps represents a conceptual simplification of a complex physical system that is imperfectly understood. In addition, statistical methods are employed to connect the three different model types—and each statistical transformation of the

output increases the uncertainties associated with the model results. Still, the projections of potential hydrologic impacts of climate change generated under the URGIA are reasonable based on the information available to date, are consistent with other projections developed for this basin, and provide a sound basis for initial conceptualization of adaptation measures.

Observed Climate Trends

To assess the current rate of temperature and precipitation change in the Upper Rio Grande and to evaluate how these rates of change compare to model projections, temperature and precipitation data from 35 climate stations in the U.S. Global Historical Climatology Network database were analyzed. Over the period 1971 through 2011, average temperatures in the Upper Rio Grande Basin rose at a rate of just under 0.7 degrees Fahrenheit (°F) per decade, a rate approximately double the global rate of temperature rise (Rahmstorf et al. 2012). Such rates of warming are unprecedented over the last 11,300 years (Marcott et al. 2013). This rate of warming has the potential to cause significant environmental harm and change the region's hydrology.

Projected Trends in Climate, Hydrology, and Water Demand

In future years, pronounced changes in climate are anticipated for the Upper Rio Grande. The climate modeling used to support this study suggests that average temperatures in the Upper Rio Grande Basin may rise by an additional 4 to 6 °F by the end of the 21st century. These model simulations do not consistently project changes in annual average precipitation in this basin, but they do project changes to the magnitude, timing, and variability of inflows to the system. Such precipitation changes, coupled with temperature-driven increases to evaporative demands within the system, are expected to cause significant changes in the available water supply and demand.

For this study, Reclamation developed projections of the hydrologic impacts of these modeled climate changes for the Upper Rio Grande Basin over the rest of this century. These projections present a picture of changing hydrology for the Upper Rio Grande, with implications for water management, human infrastructure, and ecosystems. Although there are uncertainties in the details, some general patterns are clear. The list below discusses possible implications of those general patterns.

- **Decreases in overall water availability.** Supplies of all native sources to the Rio Grande are projected to decrease on average by about one third, while flows in the tributaries that supply the imported water of the San Juan-Chama Project are projected to decrease on average by about one quarter.

- **Changes in the timing of flows.** The seasonality of flows is projected to change. Anticipated changes include earlier snowmelt runoffs as well as increased variability in the magnitude, timing, and spatial distribution of streamflow and other hydrologic variables. Projections indicate that this basin will experience a decrease in summertime flows and less of a decrease (or potentially even an increase) in wintertime flows.

- **Increases in the variability of flows.** All simulations used in this study project an increase in the month-to-month and inter-annual variability of flows over the course of the century. The frequency, intensity, and duration of both droughts and floods are projected to increase.

Water operations modeling for the Upper Rio Grande Basin using these hydrologic projections as input suggests that increasing water demands within the basin will exacerbate the gap between supply and demand. Such changes would lead to water management challenges for Reclamation and other water managers within the Upper Rio Grande Basin.

Impacts on Water Management

The decreases in supply, changes in magnitude and seasonality of flows, and increases in the availability of water supply projected in this study will present considerable challenges for water management within the Upper Rio Grande Basin. Such challenges are evaluated in this URGIA in terms of the parameters defined in the Secure Water Act (SWA), including:

- **Water Infrastructure and Operations, and Water Delivery.** The reduced surface-water inflows to the Upper Rio Grande Basin, coupled with increases in the demand for irrigated agricultural and riparian vegetation, are projected to result in decreased reservoir storage throughout the system, with commensurate impacts on water delivery.

- **Hydropower Generation.** Lower flows and lower reservoir levels associated with climate change are projected to lead to less hydropower generation. The projected decrease is substantial, from an initial generation within the Upper Rio Grande system of around 15 megawatts,

the 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.

- **Flood Control Operations.** Floods are projected to become more extreme with climate change, and thus flood control operations would be needed more often in the future, even as overall supplies decrease.

- **Water Quality.** Concentrations of nitrogen, phosphorus, suspended solids, and salt may increase in the future in response to increased evaporation rates for surface water and increased precipitation intensity, which would wash a greater volume of pollutants into the river, despite a decreased overall flow volume.

- **Fish and Wildlife Habitat, Including Endangered Species Act (ESA) Listed Species and Critical 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.

- **Flow and Water-Dependent Ecological Resiliency.** Ecological and human systems within the basin already operate close to thresholds (i.e., points at which small changes could have larger-scale repercussions) related to available water supply. It is possible that some systems in the basin have already crossed ecological thresholds. In the future, as projected water supplies decrease and demands increase, water availability thresholds may be crossed—causing additional key systems to undergo regime shifts.

- **Recreation.** The availability of water-based recreation at Reclamation and USACE reservoirs and river-based recreation, including whitewater rafting and fishing, may be negatively impacted by the projected decreases in flows. Moreover, increased temperatures may increase the usage of available water-based recreational opportunities.

- **The Rio Grande Compact.** Analyses presented in this report assume that Colorado would use its ability for priority administration to assure its obligations are met under the Rio Grande Compact. The analyses assume that New Mexico would take additional management actions to meet its obligations under the Rio Grande Compact, although in this study, Reclamation makes no assumptions about what those management actions would be. The irrigation system would be significantly impacted.

Summary of Impacts for Water Management

The projections presented in the Upper Rio Grande Impact Assessment present a picture of changing hydrology for the Upper Rio Grande, with implications for water management, human infrastructure, and ecosystems. Although there are uncertainties in the details, some general patterns are clear. This section summarizes possible implications of those general patterns.

First, our usable, manageable water supply is projected to decline. We anticipate a loss of winter snowpack, which will result in a decrease in water supply, as well as a decrease in our ability to store the water supply that we do have 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 will likely 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.

Further, the water supply to the Upper Rio Grande will be subject to increased variability and uncertainty. We are already experiencing increases in extreme temperatures. Looking ahead, we anticipate greater year-to-year variability in all aspects of our climate and hydrology.

There will also be changes in the geographic distribution and timing of runoff. Although the projections here do not portray it, other studies (e.g., Asmerom et al. 2013) have indicated some potential for strengthening of the summer monsoons, with corresponding increases in the portion of the basin's precipitation that falls downstream of our current water storage infrastructure. The projections suggest a somewhat more reliable supply from the San Juan-Chama Project than for the native Rio Grande supply (as long as there is no across-the-board decrease in available supply in the Upper Colorado River system). A greater reliability of the imported water supply than the native supply, which has the most senior users, could have significant socio-economic implications.

Feedbacks can lead to cascading impacts. For example, more intense droughts and higher temperatures lead to a greater moisture deficit in the region's forests. Trees that aren't 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 to debris flows. Ash in the rivers can lead to decreased

oxygen in the water and cause fish kills. Debris flows can lead to sediment accumulation in our reservoirs, and sediment accumulation in our reservoirs can lead to less flood protection for downstream human infrastructure, and so on.

And finally, all of the changes in our water supply that are projected to result from climate change would be compounded by the numerous other changes we have made to our landscape and our water supply and distribution. The analysis presented in this report attempts to project the impacts of climate change only on the water supply and demand within the Upper Rio Grande Basin, rather than predict what the future would look like in this basin. The future will depend on numerous societal choices.

Next Steps

The projections and analysis presented in this report represent a solid first step in the assessment of potential impacts in the Upper Rio Grande Basin, based on the best science and tools available at the time of initiation of the study. However, methods and tools for projecting the impacts of climate change are constantly being developed and refined. Efforts are currently underway to perform operational modeling of climate projections for the Upper Rio Grande Basin on a daily timestep for information on the ways that the projected impacts would be experienced by humans, fish, and wildlife. We also hope to perform further analyses using more recently developed simulations with models with finer resolutions.

Some WaterSMART Basin Study Program activities are available for stakeholders to pursue next steps, including:

- **Basin studies** to conduct in-depth water supply, demand, and operations analyses that are cost-shared with stakeholders and selected through a competitive process.

- **Landscape Conservation Cooperatives** to partner with other governmental and nongovernmental entities to identify, build capacity for, and implement shared applied science activities to support resource management at the landscape scale.

Reclamation is adding new activities to the Basin Studies Program that will provide stakeholders more opportunities to further refine adaptation strategies developed in Basin Studies.