NASA
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APPLICATIONS
OFFICE

National Aeronautics and
Space Administration

Rio Grande River Basin Needs Assessment Report

Tools for managing a precious resource

July 2022

1. Introduction

The mission of the National Aeronautics and Space Administration (NASA) Western Water Applications Office (WWAO) is to address critical water-resource issues in the western United States (U.S.) by increasing access to and use of NASA's water-related data and capabilities. NASA WWAO staff frequently work with water resource stakeholders to understand their challenges, and provide space- or terrestrial-based remote sensing data to either complement existing data sources or address knowledge gaps.

From August to November 2020, Daniel B. Stephens & Associates, Inc. (DBS&A) worked with WWAO to conduct a survey to characterize the overall water management, stakeholders, and water management challenges in the Rio Grande Basin in Colorado, New Mexico, and Texas. This initial project phase included the review of publicly available data and interviews with basin stakeholders. The basin needs assessment workshop was planned to follow the basin characterization, but was delayed due to the COVID-19 pandemic in the hope that the workshop could be held in person at a later time. The workshop was held virtually in March 2022.

DBS&A worked with the WWAO to plan and facilitate the Rio Grande Basin needs assessment workshop. This report presents an overview of the Rio Grande Basin, identifies the stakeholders who participated in the workshop and their roles within the basin, provides a summary of the workshop and descriptions of the Use Case scenarios developed, presents the most significant water management needs identified, and makes recommendations for aiding in the development of future projects.

1.1 Rio Grande Basin

The Rio Grande flows for approximately 1,900 miles from the mountains of southern Colorado to the Gulf of Mexico (Utton Center, 2013). Its waters are shared by three states (Colorado, New Mexico, and Texas), two countries (the U.S. and Mexico), and numerous tribes and pueblos (Utton Center, 2013) (Figure 1). The Rio Grande is the fifth longest river in the U.S., and forms a 1,255-mile segment of the U.S.-Mexico international border (IBWC, 2020). The watershed area is 335,000 square miles, with approximately half of the area in the U.S. and half in Mexico (IBWC, 2020). Water diverted for agricultural use has long been the primary use of water from the Rio Grande, and approximately 75 percent of the water is currently allotted for agriculture (IBWC, 2020). The Rio Grande water supply is highly variable, and is affected by climatic conditions (NMISC and NMOSE, 2018). Surface water in the Rio Grande Basin in Colorado comes largely from snowmelt, and streamflow is highly variable both seasonally and annually. Annual runoff in high-flow years can be up to 8 times the runoff in drought years (DWR, 2019). The Rio Grande at Del Norte gage measured total annual flow of 1.1 million acre-feet in 1987 and 164,000 acre-feet in 2002 (RGBRT, 2015).

The Rio Grande is divided into two major river reaches that have different legal regimes: (1) the Rio Grande from the headwaters in Colorado to Ft. Quitman, Texas (a distance of approximately 670 miles), which is the subject of the 1906 Rio Grande Convention (Treaty) between the U.S. and Mexico and (2) the lower reach from Ft. Quitman to the Gulf of Mexico (approximately 1,230 miles), which is the subject of the 1944 Rivers Treaty between the U.S. and Mexico. The 1944 treaty also addresses the Colorado and Tijuana Rivers outside of the Rio Grande Basin (Utton Center, 2013). The Rio Conchos is the largest tributary of the Rio Grande; it flows from the Mexican state of Chihuahua into the Rio Grande at the Mexican town of Ojinaga, just upstream of Presidio, Texas. This confluence is below Ft. Quitman and upstream of Amistad and Falcon Reservoirs. In Mexico, the Rio Conchos has several reservoirs, and the water is used for agriculture and hydropower. The northern one-third of the San Luis Valley in Colorado is a closed basin, meaning that runoff in this subbasin does not contribute to the Rio Grande (DWR, 2019).

The Pecos River is a tributary of the Rio Grande. It originates in north-central New Mexico and flows into Texas before entering the Rio Grande. Pecos River flows in Texas are controlled by releases from Red Bluff Reservoir, located near the Texas-New Mexico state line (FWTWPG, 2020). Water released from this reservoir has high salinity; the Pecos River contributes more than 26 percent of the annual salt load to Amistad Reservoir (FWTWPG, 2020).

There are numerous interstate compacts in place, either within the Rio Grande Basin or affecting the imported Colorado River supplies, including the Colorado River, Costilla Creek, Pecos River, Rio Grande, and Upper Colorado River Basin Compacts (Utton Center, 2011). These compacts apportion water between the states, and require that water be administered to ensure compliance with the compact obligations (NMISC and NMOSE, 2018).

Nearly all of the dams and reservoirs on the Rio Grande and its tributaries were constructed by the federal government, and were therefore authorized by the U.S. Congress (Kelly et al., 2007). They also specify the volume of water that may be stored, for what purpose, and when and how the water must be released (Kelly et al., 2007). The authorizations also specify what type of water may be stored (e.g., native Rio Grande or imported San Juan-Chama Project water). The U.S. federal government is also involved in managing surface water where endangered species habitat or other federal interests are affected (e.g., the federal government's trust obligations to tribes and pueblos) (NMISC and NMOSE, 2018). The tribes and pueblos are sovereign governments with authority over their water supply (NMISC and NMOSE, 2018).

Comparing water use among sectors within the Rio Grande Basin in Colorado, the breakdown of total water demand in 2015 is provided in Table 1-1.

Table 1-1. Colorado Rio Grande Basin Water Demand by Sector, 2015

Percentage of Total Water Demand		
Irrigation	Municipal	Self-Supplied Industrial
99%	0.6%	0.4%

A combination of surface and groundwater supplies are used for irrigation of approximately 515,000 acres in the Rio Grande Basin in Colorado. The principal crops grown are potatoes, alfalfa, native hay, barley, wheat, and small vegetables (lettuce, spinach, and carrots) (DWR, 2019). The Colorado Water Plan only presents total water demand values for surface water plus groundwater, and the agricultural diversion demand for the Rio Grande Basin in Colorado (surface water and groundwater) was 1,825,200 acre-feet per year (ac-ft/yr) in 2015 (DWR, 2019).

The NMOSE Water Use and Conservation Bureau publishes water use reports every 5 years; the most recent report presents data from 2015 (Magnuson et al., 2019). For 2015, the NMOSE reports irrigated acreages of 243,728 acres in the Rio Grande Basin and 110,769 acres in the Pecos River Basin in New Mexico (surface water and groundwater) (Magnuson et al., 2019). For irrigation with surface water, the irrigated acreages are reported as 133,181 acres in the Rio Grande Basin and 36,117 acres in the Pecos River Basin (Magnuson et al., 2019), or 169,298 acres total within the Rio Grande and Pecos River Basins. In 2015, water withdrawals totaled 1,439,750 acre-feet in the Rio Grande Basin in New Mexico, including 802,029 acre-feet of surface water (56 percent) and 637,721 acre-feet of groundwater (44 percent) (Magnuson et al., 2019). The proportion of water withdrawals for surface water and groundwater and for various categories of use are shown in Tables 1-2a and 1-2b (Magnuson et al., 2019).

Table 1-2a. New Mexico Rio Grande Basin Withdrawal Volumes, 2015

Category	Withdrawal (acre-feet)		
	Surface Water	Groundwater	Total
Commercial (self-supplied)	903	36,731	37,634
Domestic (self-supplied)	0	17,783	17,783
Industrial (self-supplied)	0	4,839	4,839
Irrigated agriculture	614,794	415,079	1,029,873
Livestock (self-supplied)	820	7,091	7,911
Mining (self-supplied)	1,079	16,662	17,741
Power (self-supplied)	0	6,271	6,271
Public water supply	61,947	133,265	195,212
Reservoir evaporation	122,486	0	122,486
Total	802,029	637,721	1,439,750
% of Total	56	44	100

Table 1-2b. New Mexico Rio Grande Basin Withdrawal Percentages, 2015

Category	Withdrawals (%)	
	Surface water	Groundwater
Commercial (self-supplied)	0.1	5.8
Domestic (self-supplied)	0.0	2.8
Industrial (self-supplied)	0.0	0.8
Irrigated agriculture	76.7	65.1
Livestock (self-supplied)	0.1	1.1
Mining (self-supplied)	0.1	2.6
Power (self-supplied)	0.0	1.0
Public water supply	7.7	20.9
Reservoir evaporation	15.3	0.0
Total	100.0	100.0

Projected 2020 water demand for the Rio Grande Basin in Texas totaled 1,189,493 acre-feet, including 235,283 acre-feet for municipal use (20 percent) and 843,820 acre-feet for irrigation (71 percent) (FWTWPG, 2020; Freese and Nichols, 2020; Plateau WPG, 2020; RGRWPG, 2020). These values do not split out the volumes that are supplied by surface water and groundwater.

The population in the Rio Grande Basin in Colorado was 46,000 in 2015, and is projected to be between 42,300 and 67,300 by 2050 (DWR, 2019). The population in the Rio Grande Basin in New Mexico was 1,532,954 in 2015 (Magnuson et al., 2019). New Mexico projects population by county and regional planning area; the boundaries do not follow river basin boundaries in most cases. In the state's regional water plans, New Mexico presents population projections for low- and high-growth scenarios. Summing the population projections for the Taos, Jemez y Sangre, Middle Rio Grande, Socorro-Sierra, and Lower Rio Grande planning areas, the total population is projected to be between 1,679,962 and 2,103,135 in 2050 (NMISC and NMOSE, 2016a, 2016b, 2016c, 2017a, and 2017b). These projections include areas outside the Rio Grande Basin; however, the majority of this population is within the basin. Approximately 70 percent of this population is within the Middle Rio Grande planning region, which includes Albuquerque and Rio Rancho. The population in the Rio Grande Basin in Texas was projected to be 1,346,406 in 2020 (FWTWPG, 2020; Freese and Nichols, 2020; Plateau WPG, 2020; RGRWPG, 2020), and is projected to be 1,145,779 in 2050. The total Rio Grande Basin population was estimated to be approximately 2.9 million for the portion of the basin within the U.S. in 2015 (this is the sum of the 2015 populations for Colorado and New Mexico and the 2020 projected population for Texas), and is projected to be between 2.9 and 3.3 million in 2050.

There are many stakeholders in the Rio Grande Basin, including federal water management agencies, state water management agencies, irrigation, conservation, and conservancy districts, tribes and pueblos, water suppliers, state water resources research institutes, agricultural service centers and extension services, and environmental groups. As identified during the 2020 needs assessment, key water management challenges in the basin include (1) insufficient water supply, (2) compact compliance and other legal and policy issues, such as interstate compacts, incomplete water rights adjudications, water rights transfers, reservoir operations, Endangered Species Act compliance, and implementation of water rights settlements, (3) a need for a better understanding of water resources, (4) vulnerability to climate and the potential effects of climate change, (5) water quality, and (6) water infrastructure and maintenance needs.

2. Project Background

DBS&A worked with WWAO to conduct a survey that characterized the water management challenges and stakeholders in the Rio Grande Basin in Colorado, New Mexico, and Texas. The survey included two tasks: (1) describing the overall management and use of the Rio Grande Basin's water resources and identifying and cataloging the basin's stakeholders and

(2) conducting interviews of a cross section of the basin stakeholders. DBS&A conducted a total of 19 Rio Grande Basin stakeholder interviews, with 31 individuals representing 23 entities. DBS&A and NASA WWAO continued this work by planning and facilitating a Rio Grande Basin water resource stakeholder needs assessment workshop.

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3. Needs Assessment Workshop

All stakeholder organizations and representatives who were identified during and/or who participated in the Rio Grande Basin characterization study were interested in participating in a future needs assessment workshop. DBS&A contacted these and additional individuals, and invited them to attend the Rio Grande Basin needs assessment workshop. The majority of stakeholders who participated in the characterization study also participated in the follow-on workshop. They were joined at the workshop by a few additional stakeholders who were not able to participate in the prior study. The pre-workshop webinar served to bring everyone up to speed with the WWAO needs assessment goals and processes.

In preparation for the workshop, DBS&A and WWAO held biweekly teleconferences to discuss the workshop plans and progress, and coordinate efforts. The goal of the workshop was to identify, prioritize, and catalog the needs of the Rio Grande Basin water resource stakeholders focusing on data needs, further discuss the Rio Grande Basin information and data gaps, and identify where WWAO may be able to assist.

DBS&A distributed workshop save-the-dates and invitations, providing the workshop dates, location, and goals. DBS&A tracked the workshop RSVPs, and coordinated with WWAO staff regarding the workshop and participants.

As part of this task, a pre-workshop webinar was held on February 16, 2022. WWAO developed and facilitated this webinar, and DBS&A coordinated with stakeholders regarding their participation. During the pre-workshop webinar, NASA WWAO provided an overview of the workshop structure, including the use case development process, and discussed what to expect from the workshop. The Needs Assessment Workshop was held virtually on March 7, 8, and 9,

2022. Attendees of the workshop are listed in Table 3-1. The workshop facilitators, technical experts, and notetakers are listed in Table 3-2.

Table 3-1. Needs Assessment Workshop Attendees

Organization	Name	Position
Albuquerque Bernalillo County Water Utility Authority (Water Authority)	Kelsey Bicknell	Water Resource Scientist
Colorado Division of Water Resources	Ashenafi Madebo	Lead Modeler
Elephant Butte Irrigation District (EBID)	Dennis McCarville	GIS Analyst
Jemez Pueblo	Clarice Madalena	Natural Resources Program Manager
Middle Rio Grande Conservancy District (MRGCD)	Francesca Shirley	Conservation Specialist
	Anne Marken	Water Ops Division Manager
	Casey Ish	Water Resource Specialist
U.S. Bureau of Reclamation (USBR)	Drew Loney	Civil Engineer (Hydrologist)
	Dagmar Llewellyn	Hydrologist
	John Branum	Civil Engineering Technician
	Carolyn Donnelly	Civil Engineer
NASA Applied Sciences Program	Sativa Cruz	
New Mexico Bureau of Geology & Mineral Resources and New Mexico Interstate Stream Commission (ISC)	Stacey Timmons	Associate Director, Hydrology
New Mexico Farm and Livestock Bureau (NMF&LB)	Katelin Spradley	Regional Manager
	Tiffany Rivera	Director of Government Affairs
NOAA	Joel Lisonbee	Regional Drought Information Coordinator
Rio Grande Headwaters	Daniel Boyes	Program Manager
San Luis Valley Water Conservancy District	Heather Dutton	Water Manager and Restoration Specialist
Texas Commission on Environmental Quality (TCEQ)	Anthony Stambaugh	Rio Grande Watermaster
Texas Water Development Board (TWDB)	Nelun Fernando	Manager, Water Availability/Surface Water Division

Table 3-2. Needs Assessment Workshop Facilitators, Technical Experts, and Notetakers

Name	Position
NASA	
Mark Davidson	WWAO Alliance Lead; NASA JPL SBIR
Indrani Graczyk	WWAO Program Manager
Stephanie Granger	WWAO Strategist; NASA JPL Applied Science Systems Engineering Technical Group Supervisor
Christopher Hain	Marshall Space Flight Center Scientist
Amber Jenkins	WWAO Information Architectures Lead; Applied Science Engineer
Christine Lee	Scientist; Water and Ecosystems Group, JPL
Amber McCullum	WWAO Research to Applications Lead; NASA Ames Reserach Center
Forrest Melton	Ames Research Center Program Manager and WWAO Program Scientist
Cassie Nickles	Postdoc; Applied Science Systems Engineering, JPL
Catalina Oaida	WWAO Stakeholder Engagement Lead; NASA Jet Propulsion Laboratory (JPL) Science and Applications Systems Engineer
JT Reager	Scientist; Water and Ecosystems Group, JPL
DBS&A	
Kenny Calhoun	GIS Services Manager
Amy Ewing	Hydrogeologist
Janet Wolfe	Marketing and Communications Manager
Lisa Huey	Marketing and Proposal Coordinator
Sandra West	Marketing and Proposal Coordinator

The workshop agenda included a welcome and overview, introductions, and an overview of NASA WWAO's capabilities and current projects. A needs assessment overview and a summary of the Rio Grande Basin survey followed. The workshop participants began by brainstorming needs for each of the four broad use case categories in their respective breakout groups. The four use case categories included Water Supply Monitoring and Forecasting, Water Use and Management/Agriculture, Climate and Extremes, and Watershed Health and Water Quality, and were developed based on information obtained in the survey.

Three breakout sessions were held for each use case category on day 2 of the workshop. The breakout groups were held concurrently, and each breakout session lasted about an hour.

During the breakout sessions, each group worked together to develop one or more use cases for their use case category, following the modified use case template that is provided in Table 3-3. The use case methodology was designed to enhance attendee participation in the workshop and to develop detailed descriptions of the needs that could potentially lead to new project development to address these needs. Workshop discussions were focused on the most important water management needs in the Basin, as defined by the participating stakeholders.

DBS&A and NASA WWAO facilitated the breakout group discussions, and the NASA notetakers recorded the group discussions. This information was used to complete the use case tables that are provided in Section 4.

Table 3-3. Modified Use Case Template

Use Case Element	Description
Current State	Current decision-making process and the data and models used to support decision making, or the water management challenge where lack of information is precluding progress.
Desired Result	Desired improvements to the decision-making process or the water management challenge.
Need/Gap/Objective	The information needed to achieve the desired result.
Description/Decision Context	The decision to be made, how it is made, and who makes the decision, including information about what data are used to inform the decision-making process and who is currently responsible for producing and/or interpreting the data.
Participants	The primary participants who are impacted by this need.
Workflow	The flow of information from a set of inputs to models to outputs that are used to make the decision.
Priority (MI, VI, I)	Provide a rough estimate of the priority of the need as MI (most important), VI (very important), or I (important). Include the rationale for prioritization, if possible.
Obstacles to address the need?	Obstacles to addressing the need (participation, administrative boundaries, funding, etc.)
Data Sources	Describe potential sources of information that are aligned with the data characteristics defined above.
Data Characteristics	Describe the required characteristics of the data needed to improve the decision. Include necessary modifications to existing models.
Partner Potential?	Identify the primary organization that would partner with WWAO to develop/implement a potential project to address the need, including name(s) and contact information.

On day 3 of the workshop, the full group of workshop attendees participated in a group report-out, where a representative from each use case category presented what they had developed and discussed the day before. This was also an opportunity for those who may not have had the chance to sit in a concurrent breakout session to provide additional input to synergistic use cases. The group report-out was followed by a discussion of the project's next steps by WWAO.

4. Use Cases

This section provides descriptions of the use cases that were developed during the Rio Grande Basin needs assessment workshop. A total of 12 use cases were developed during breakout sessions (Table 4-1). Of these use cases, 5 were developed for the Water Supply Monitoring and Forecasting category (A), 3 were developed for the Water Use and Management/Agriculture (B) and Climate and Extremes (C) categories, and 1 was developed for the Watershed Health and Water Quality (D) category.

Table 4-1. Use Cases by Category

A: Water Supply Monitoring and Forecasting
A-1: Improving Streamflow Forecasting
A-2: Integrated Data/Information System and Modeling
A-3: Groundwater-Surface Water Interaction and Groundwater Level Monitoring
A-4: Vegetation Changes and Impacts to Water Supply/Quality
A-5: Channel Geomorphology and Sedimentation
B: Water Use and Management/Agriculture
B-1: Fallow-Field Monitoring to Support Water Conservation
B-2: Quantification of Conveyance Losses
B-3: Improved Water Supply Forecasts to Support Basinwide Planning and Farm Management
C: Climate and Extremes
C-1: Identifying the Strongest Influences on Streamflow
C-2: Identifying the Impact of Soil Moisture Deficits
C-3: Identifying Tipping Points for Irreversible Change
D: Watershed Health and Water Quality
D-1: Impacts of Wildfire Events

The final 12 Rio Grande Basin use cases are discussed in the following subsections, which include a completed use case table for each use case.

4.1 Category A: Water Supply Monitoring and Forecasting Use Cases

4.1.1 Use Case A-1: Improving Streamflow Forecasting

Water is a limited resource in the Rio Grande Basin, and basin water managers are basing their management decisions on incomplete snow and runoff data. This makes it difficult to accurately predict streamflow and make the management decisions necessary for meeting Rio Grande Compact deliveries. This issue is expected to be exacerbated by the impacts of climate change in the future.

There is a need to better understand and predict impacts to runoff and streamflow, including (1) better quantifying snowpack, particularly at the mid-elevations and rain on snow transition zones in the Rio Grande Basin headwaters, (2) better constraining and predicting dust on snow processes, including dust source vegetation and soil moisture conditions, winds, (3) more observations of soil moisture conditions between the snowpack/headwaters regions and downstream to constrain runoff infiltration and therefore better predict streamflow downstream, (4) better understanding of changes in vegetation conditions, particularly in the headwaters regions, where forest health is being impacted by wildfires and beetle infestations and the interactions with snowmelt-driven streamflow, and (5) quantifying and predicting impacts to streamflow timing and volume due to vegetation-snowpack interactions.

Rio Grande Basin water managers would benefit from having better forecasting of streamflow—both timing and volume—to support water supply management decisions. Having more accurate data to use as input to models would allow for better predictions of streamflow and better management of water resources. Table 4-2 summarizes Use Case A-1 developed during the workshop.

Table 4-2. Use Case A-1: Improving Streamflow Forecasting

Use Case Element	Description
Current State	Water is a scarce resource in the Rio Grande Basin, and basin water managers are basing their decisions on incomplete snow and runoff data. This makes it difficult to accurately predict streamflow and make the management decisions necessary for meeting Rio Grande Compact deliveries. The current streamflow predictions are a moving target, and this makes it difficult to plan. This issue is expected to be exacerbated by the impacts of climate change in the future.
Desired Result	Better forecasting of streamflow, both timing and volume, to support water supply management decisions. Having more accurate data to input into models will allow for better predictions of streamflow and better management of the resource.
Need/Gap/Objective	Water managers need better spatial distribution of snow measurements, especially additional measurement stations/density in the mid-elevations of the Rio Grande Basin headwaters and high elevations in the Conejos watershed, as well as soil moisture data. The projections of the timing and magnitude of summer monsoons also need improvement.
Description/Decision Context	There are sparse in situ observations at mid-elevations in the Rio Grande Basin headwaters where rain-snow transition bands are located. It would be helpful to have more spatially distributed snowpack information. There is increasing understanding that antecedent soil moisture conditions also impact partitioning of runoff, so understanding soil moisture conditions in the regions between the snowpack and downstream streamflow could help improve streamflow forecasts. Information from remote sensing is needed to better understand the interplay between forest health/vegetation cover changes (e.g., from wildfires, insect infestations) and streamflow/runoff output in the headwaters and downstream regions. Dust on snow impacts to runoff also need to be better quantified and predicted, including dust source regions (winds, soil moisture and vegetation conditions) and impacts to runoff timing and magnitude.
Participants	TCEQ, Rio Grande Headwaters Restoration Project, Ohkay Owingeh, and NASA Ames Research Center. Supplemental input from USBR and the Water Authority.
Workflow	(needs input)
Priority	Most important
Obstacles to Address the Need	(needs input)
Data Sources	USBR is currently working to develop a snow monitoring program using remote sensed technology (in year 1 of 5)
Data Characteristics	(needs input)
Partner Potential	USBR, USGS, NRCS, San Luis Valley Conservancy District/CO entities installing SnoLite stations, National Center for Atmospheric Research (NCAR), Colorado Division of Water Resources (manages CO stream gages), U.S. Fish and Wildlife Service (especially for near Bosque del Apache in New Mexico)

4.1.2 Use Case A-2: Integrated Data/Information System and Modeling

A headwater hydrologic model for the Rio Grande Basin that refines hydrologic rainfall runoff predictions and can process future climate scenarios does not exist. Basin water managers would like to have access to computational modeling (or its outputs) that captures the interaction of different physical processes and translates measurements into water management metrics. More broadly, it would be useful to have a central location that makes federal data available to end users. The New Mexico Water Data Act is making data more available on the state level, but the workshop participants agree that this effort needs to be expanded. The New Mexico Water Data Initiative was brought up as a helpful solution to hosting or integrating such data. This initiative has come out of the New Mexico Water Data Act, and is spearheading a collaborative effort to share and integrate New Mexico's water data for effective water management and planning. Table 4-3 summarizes Use Case A-2 developed during the workshop.

4.1.3 Use Case A-3: Groundwater-Surface Water Interaction and Groundwater Level Monitoring

Groundwater-surface water interactions are not well understood in the Rio Grande Basin, and groundwater level measurement data are lacking. The basin water managers would benefit from more and better data that can be input to models to better understand current groundwater levels and trends and predict future conditions, allowing for better management decisions, especially with current and future impacts due to climate change. Specifically, more groundwater level and water quality data are needed, in addition to more and better evapotranspiration (ET) data, at decision-making spatial scales. In addition, participants said that recharge from snowpack is decreasing and depletions are increasing due to increased pumping and decreased recharge in the basin. There was interest in knowing whether recharge from monsoons is increasing as a result of climate change.

Several ideas were discussed to leverage existing well data, aerial or remote sensing monitoring techniques, and/or modeling tools. For example, one idea could be to build an artificial network, and bring in what exists from in situ observations, and then go back to compare with remote sensing data and iterate. Another idea was to use airborne electromagnetic (AEM) observation platforms, which may be good at bridging the data spatial coverage gaps and increase well data value. To understand where the loss of connectivity happens between surface water and groundwater, ET data from remote sensing derived data products could potentially be used as proxy. This method could also potentially help predict where the disconnect might happen next. Table 4-4 summarizes Use Case A-3 developed during the workshop.

4.1.4 Use Case A-4: Vegetation Changes and Impacts to Water Supply/ Quality

Changes in vegetation cover can alter runoff timing and volume, erosion/dust sources, evapotranspiration, water supply, and water quality; however, these changes are not well documented in the Rio Grande Basin. Workshop participants felt that it would be useful to document historical changes in vegetation cover (e.g., vegetation type and percent coverage) for the complete watershed, in addition to tracking future changes that result from wildfire, insect infestation, and land use changes, assessing impacts on water supply and water quality. Table 4-5 summarizes Use Case A-4 developed during the workshop. This use case overlaps with Use Case A-1, but specifically focuses on impacts of vegetation cover changes on streamflow, as well as with Use Case C-1.

4.1.5 Use Case A-5: Channel Geomorphology and Sedimentation

Sediment inputs to the Rio Grande are not well defined, and management activities tend to be reactive rather than predictive. An evaluation of past changes in river morphology and major sedimentation inputs could be used to help predict when and where future sedimentation will occur, allowing management activities to be more targeted in the future. Table 4-6 summarizes Use Case A-5 developed during the workshop.

Table 4-3. Use Case A-2: Integrated Data/Information System and Modeling Page 1 of 2

Use Case Element	Description
Current State	The Upper Rio Grande Water Operations Model (URGWOM) is an interagency effort (e.g., USBR, USACE, OSE), but it is an operations model and is not hydrologic. More broadly, data are often not available or are difficult to find.
Desired Result	The basin would benefit from having a headwater hydrologic model that refines hydrologic rainfall runoff predictions and can process future climate scenarios. The basin managers would like to have access to computational modeling (or its outputs) that captures the interaction of different physical processes and translates measurements into water management metrics. More broadly, it would be useful to have a central location that makes federal data available to end users (e.g., agencies, basin water managers, and the public). The New Mexico Water Data Act is making data more available on the state level, but this needs to be expanded.
Need/Gap/Objective	Improved computational modeling for the Rio Grande Basin, through improved access/integration of remote sensing data, that gives a better picture of the physical processes going on (e.g., how much water goes to groundwater, into streamflow, or evaporates to understand how much water is left to manage; summer monsoonal rain intensity). Physically based models in particular would be preferred to better predict under changing climate and capture extremes. Model output at spatial resolutions that match the processes on the ground.
Description/Decision Context	NASA projects are generally mission specific, but other agencies and basin managers do not think this way. The group would like to see data available by subject (e.g., drought) instead. Model output at spatial resolutions that match the processes on the ground are needed. Can these be supplemented/improved by remote sensing data? Can the New Mexico Water Data Act and subsequent water hub initiative host or connect the disparate datasets of interest?
Participants	USBR, Water Authority. Supplemental input from the New Mexico Bureau of Geology & Mineral Resources and New Mexico ISC.
Workflow	Funding; staffing; basinwide collaboration
Priority	Very important
Obstacles to Address the Need	Issues with where federal data may be hosted and accessed by other partners (e.g., sometimes IT security issues with data exchanges/tech transfer). Could NASA start hosting tools and processed images? Also, extra steps are required to process remote sensing data. Who will be responsible for data processing to create and host these value-added data products?

Table 4-3. Use Case A-2: Integrated Data/Information System and Modeling Page 2 of 2

Use Case Element	Description
Data Sources	SUMMA (NCAR) could be used as an integrated hydrologic modeling system. USGS PRMS (rainfall-runoff) is used on an annual timescale, but cannot be used for monthly/seasonal evaluations. Integration of NASA remote sensing data (e.g., forest/vegetation, snow, soil moisture) into such models might improve modeling outputs. NM Water Data Initiative as potentially the hub to share and integrate the data.
Data Characteristics	For modeling input: ?? For model validation: ?? (this is likely process dependent) For summer monsoonal rainfall, even categorical (good, average, poor rainfall) would be helpful.
Partner Potential	USBR, ACOE, USGS, NCAR, NOAA NIDIS

Table 4-4. Use Case A-3: Groundwater-Surface Water Interaction and Groundwater Level Monitoring Page 1 of 3

Use Case Element	Description
Current State	Groundwater-surface water interactions are not well understood in the Rio Grande Basin, and groundwater level measurement data are lacking. In Colorado, MODFLOW is used (4-5 layers), and they integrate CU software crop consumptive use data. In New Mexico, RiverWare and Hydrus models are being used, and also MODFLOW (using RiverWare for surface water components).
Desired Result	The participants are interested in having more/better quality data that can be inputted into models to better understand current groundwater levels and trends, and predict future conditions, of groundwater levels, and to understand recharge rates. This would allow for better management decisions, especially with current and future impacts due to climate change. It would also be helpful to identify areas where gains and losses in groundwater happen, from headwaters to downstream. It would be especially helpful to have more data in areas where there is disconnection between the river and groundwater aquifers. Participants said that recharge from snowpack is decreasing, and depletions are increasing due to increased pumping and decreased recharge in the basin. There was interest in knowing whether recharge from monsoons is increasing as a result of climate change. In addition to more available water level data, the participants would like to have access to more water quality data. Water age and chemical data could be used for mixing analyses to better understand interactions. It would be especially helpful to have more data in areas where there is disconnection between the river and groundwater aquifers. Better/more evapotranspiration (ET) data would be useful, and this information could be used as a proxy (look at decreases in ET and see if they correlate to dry years, assess connectivity, make predictions).
Need/Gap/Objective	Identify and bring together existing data. Develop methods to leverage in situ data with modeling and/or aerial observations platforms to close the spatial discrepancy between in-situ and remotely sensed data. Explore and develop a process to use ET data as a proxy to help understand whether groundwater-surface water disconnect takes place. Identify and bring together existing data. Develop methods to leverage in-situ (e.g. well) data with modeling, and/or aerial observations platforms to close the spatial discrepancy between in-situ and remotely sensed data. Explore and develop a process to use ET data as a proxy to help understand whether groundwater-surface water disconnect takes place. In New Mexico, the ISC has an open modeling position that they are having trouble filling, so they are currently subcontracting out modeling work. The OSE does have groundwater modelers, but their capacity is limited. The states/existing stakeholders have limited funding for improving the basin data, and would benefit from federal support/involvement/partnering/collaboration.

Table 4-4. Use Case A-3: Groundwater-Surface Water Interaction and Groundwater Level Monitoring Page 2 of 3

Use Case Element	Description
Description/Decision Context	In Colorado, snowmelt has decreased over the last 20 years, which has reduced the amount of recharge, made less water available for irrigation, and decreased return flow from irrigation. In New Mexico, surface water availability is decreasing, and this will present obstacles, as there will be decreased recharge and increased groundwater production (with some irrigating with groundwater instead of surface water). What will the effect on groundwater levels be? It is important to understand the interplay between changes in surface water availability, changes in recharge rates of aquifers, groundwater pumping and climate change, as well as where the surface and groundwater disconnect may happen. This would help with planning for meeting the various compact agreements and decision making for water resources in general. Partnerships with USGS and OSE would be helpful. This use case was identified during the initial workshop/Session A breakout sessions, and was developed in a follow-up meeting held on March 18, 2022.
Participants	NMBGMR, Colorado Division of Water Resources. While not part of this particular discussion, partnerships with entities like USGS and OSE would be helpful.
Workflow	Several ideas were discussed to leverage existing well data, aerial or remote sensing monitoring techniques and/or modeling tools. For example, one idea could be to build an artificial network, and bring in what exists from in-situ observations, then go back to compare with remote sensing data and iterate. Another was to use airborne electromagnetic (AEM) observation platforms, which may be good at bridging the data spatial coverage gaps and increase well data value. To understand where the loss of connectivity happens between surface water and groundwater, ET from remote sensing derived data products could potentially be used as proxy. This method could also potentially help predict where the disconnect might happen next.
Priority	Important
Obstacles to Address the Need	In New Mexico, the OSE has established ways of doing things, and it is difficult to change current practices (the group recommends involving the OSE with this initiative). There are not a lot of in situ measurements currently being taken. There is a general lack of recent data; therefore, maps are often made from outdated data. Funding has been cut (e.g., USGS), decreasing the number of measurements that are collected. Entities like NMBGMR do not have hydrologic modeling capabilities in-house, been outsourcing (Hydros modeling). How best to resolve the spatial resolution needed over the narrow area of interest (along the river)? Current remote sensing data like GRACE has too coarse spatial resolution.

Table 4-4. Use Case A-3: Groundwater-Surface Water Interaction and Groundwater Level Monitoring Page 3 of 3

Use Case Element	Description
Data Sources	Recharge simulated by land surface models (LSMs), in situ groundwater, and recharge. GRACE terrestrial water storage, aerial electromagnetic (AEM) method to collect groundwater data and combine with in-situ well data. ET as proxy to assess areas of disconnectivity between surface water and groundwater.
Data Characteristics	The New Mexico Water Data Initiative is moving towards OGC's SensorThings API format, and the NMBGMR suggests this data format. Having a time component for recharge would be interesting. It would be useful to be able to see how changes in precipitation/monsoon impact recharge, understand trends and assess changes over time (at seasonal scales, relative to a baseline). To understand the data trends, we will need more than just annual measurements. The possibility of running airborne electromagnetic (AEM) surveys to identify depth to groundwater/the water table was discussed, and the participants said little of this has been done in the basin, and the data would be useful. Areas of interest could include river compact delivery points (Otowi gage in northern New Mexico [CO-NM], Elephant Butte Reservoir [NM-TX]), as well as areas where the Rio Grande is gaining/losing. Spatially, participants identified the need for good coverage down the length of the river + vegetated areas on either side, and of irrigated areas. There was discussion about the need for depths to the bottom of aquifers, although some of this information is known.
	Having more annual data measurements would be great, but seasonal data would be even better (there are large seasonal differences, especially due to the irrigation season). If annual, January-February was given as a recommended timeframe (when water production is at a minimum). This would likely be a good time for Airborne and remote sensing, although the best time may differ by river segment.
Partner Potential	USGS, Colorado Division of Water Resources, New Mexico Water Data Initiative/NMBGMR, New Mexico Office of the State Engineer/ISC, TWDB, TCEQ, MRGCD, EBID, USBR (a two year Water Smart project will kick off this fall that will make datasets available/more accessible through New Mexico's Water Data Initiative. The NMBGMR would be interested in hosting the information on newmexicowaterdata.org, or linking people to it from there.

Table 4-5. Use Case A-4: Vegetation Changes and Impacts to Water Supply/Quality

Use Case Element	Description
Current State	Changes in vegetation cover are not well tracked in the watershed, and can alter runoff, erosion/dust sources, evapotranspiration, water supply, and water quality.
Desired Result	Document historical changes in vegetation cover (e.g., vegetation type and percent coverage) in the watershed (both in the headwaters/forests and further downstream/at lower elevations), and track future changes due to fire, insect infestation, land use changes, etc., to assess impacts on water supply.
Need/Gap/Objective	Map/evaluate changes in vegetation over time, allowing for improved predictions of the impact future changes in vegetation may have on water supply and water quality.
Description/Decision Context	Changes/degradation in vegetation and soil properties in the Four Corners area can lead to the region being a dust-source, which during wind events supplies dust that deposits on mountain snowpack, altering runoff timing and volume. Forest fires and beetle infestations lead to forest degradation in mountainous headwaters regions of the basin, potentially impacting snowmelt and runoff output. Vegetation changes and fires can also lead to increased sedimentation, so monitoring areas of changing vegetation can help inform higher risk areas for erosion and sedimentation.
Participants	USBR, Water Authority
Workflow	(needs input)
Priority	Important
Obstacles to Address the Need	(needs input)
Data Sources	(needs input)
Data Characteristics	Annual surveys?
Partner Potential	NRCS, USFWS

Table 4-6. Use Case A-5: Channel Geomorphology and Sedimentation

Use Case Element	Description
Current State	Sediment inputs to the Rio Grande are not well defined; management is reactive rather than predictive.
Desired Result	Understand past changes in the river channel and sediment inputs, and predict where future sedimentation will occur.
Need/Gap/Objective	Map/evaluate channel geomorphology over time, and predict future sedimentation events.
Description/Decision Context	An evaluation of past changes in river morphology and major sedimentation inputs could be used to help predict when and where future sedimentation will occur, allowing management activities to be targeted (e.g., when and where to dredge). Understanding river dynamics also helps inform restoration projects (e.g., which areas to inundate; which to protect from inundation).
Participants	USBR, Water Authority
Workflow	(needs input)
Priority	Important. This use case is seen as important, especially with climate change and the potential for precipitation to be more concentrated and intense (with an increase in the frequency and severity of flooding).
Obstacles to Address the Need	Do NASA tools have the capability to address this need?
Data Sources	SWOT will be launching in fall 2022, and will have a 21 day repeat time. It will be measuring rivers (greater than 50-100-meter width) and lakes (greater than 250 x 250 square meter area), and should show river changes, especially in non-vegetated areas. These data should yield channel width and location, river bed slope, and streamflow. Other potential data sources could include satellite imagery, such as Landsat, which would offer the historical perspective, having a long record length.
Data Characteristics	Annual surveys would be useful (e.g., after spring runoff each year)
Partner Potential	USBR, Water Authority

4.2 Category B: Water Use and Management/Agriculture Use Cases

4.2.1 Use Case B-1: Fallow-Field Monitoring to Support Water Conservation

The Rio Grande Basin pilot fallowing program financially incentivizes farmers to temporarily fallow their fields to conserve water. This program makes it possible to keep land in production long-term, while also conserving water in the shorter term. This program is seen as a key strategy toward developing a broader solution for monitoring and protecting agricultural water supplies in the Rio Grande Basin. There is significant opportunity for expanding the program; however, data are needed to (1) verify which fields are fallow, (2) assess field conditions, and (3) quantify changes in ET and consumptive use. Table 4-7 summarizes Use Case B-1 developed during the workshop.

4.2.2 Use Case B-2: Quantification of Conveyance Losses

Water managers need an accurate understanding of how much water is lost during conveyance in channels. With a better quantification of losses, they could more effectively identify high-priority canal regions or sections to potentially line. Water managers and users would benefit from understanding how much water is going to irrigation (consumptive use) vs. conveyance losses. These data could be used to target funding for canal lining projects, as well as provide information to assist in improving irrigation scheduling to reduce water loss. Existing unlined canals may support habitat and contribute to groundwater recharge, so potential canal lining projects will need to be evaluated on a case-by-case basis. Table 4-8 summarizes Use Case B-2 developed during the workshop.

4.2.3 Use Case B-3: Improved Water Supply Forecasts to Support Basinwide Planning and Farm Management

As discussed in earlier use case descriptions (e.g., Use Case A-1), Rio Grande Basin water managers are basing their management decisions on incomplete snow and runoff data. In addition to promoting Rio Grande Compact compliance, better water supply forecasts would lead to more informed agricultural management decisions, such as (1) whether or not to plant or fallow in a given year, (2) what to plant (creating the possibility of planting higher-value crops), and (3) reducing operational costs by moving away from fertilizer-intensive crops. Improved monthly forecasts of runoff and seasonal precipitation would give producers the data they need to make better management decisions. Table 4-9 summarizes Use Case B-3 developed during the workshop.

Table 4-7. Use Case B-1: Fallow Field Monitoring to Support Water Conservation Page 1 of 2

Use Case Element	Description
Current State	The Rio Grande Basin pilot fallowing program financially incentivizes farmers to temporarily fallow their fields to conserve water or make water rights available for use by other users in dry years.
Desired Result	Expanding the fallowing program is key to keeping land in production long-term while also conserving water. More data are needed to support the program expansion, as well as to assess the long-term impacts of fallowing (e.g., aridification). Need independent, quantifiable information on where land is fallow, and ability to monitor field changes during fallowing. For long-term planning, it would be nice to be able to quantify the volume of water conserved due to the fallowing program each year; quantify total water conserved over time; and visualize water savings spatially.
Need/Gap/Objective	Data are needed to (1) verify which fields are fallow, (2) assess field conditions (e.g., cover crops, weeds, changes in soil moisture), and (3) quantify changes in evapotranspiration (ET) and consumptive use.
Description/Decision Context	Fallowing fields is increasingly important for conserving water as supplies dwindle. A key goal is to improve, grow, and manage the fallowing program over the long term, which will require independent, reliable information for fallowed land.
Participants	Water conservation programs: program managers, conservation committees, boards of directors, GIS mapping departments. Irrigation districts. Producers/farmers whose land is enrolled in the fallowing program.
Workflow	Records of enrollment in the fallow program are currently used. Some ground truthing is done by supervisors/producers, but it is not completely reliable and data entry lacks consistency.
Priority	Most important/very important. This program will be a key piece toward developing a broader solution to monitor and protect water supplies for agriculture in the Rio Grande Basin.
Obstacles to Address the Need	Potential for confusion between cover crops and other pasture crops (e.g., hay, alfalfa) when using remotely sensed data. Frequent cloud cover during key parts of the year (which impacts use of Landsat data). Small field size – many fields are long and narrow, rather than square. Potential requirement to integrate with Truepoint Solutions utility billing software. Potential concerns of producers about private property rights and surveillance.

Table 4-7. Use Case B-1: Fallow Field Monitoring to Support Water Conservation
Page 2 of 2

Use Case Element	Description
Data Sources	Spatial maps of remotely-sensed ET, soil moisture, and vegetation conditions on fields. Verifiable remote-sensing data. No requirement for on-ground instrumentation at this time, though this may change in the future.
Data Characteristics	*Spatial resolution:* Field-scale. Minimum 1-2 acres. *Temporal resolution:* Monthly (can start at beginning of calendar month). Other uses beyond fallowing might need to have a weekly timeframe, for purposes of irrigation deliveries. *Geographic extent:* Across a given irrigation/water conservation district, using shapefiles of enrolled areas. *Data latency:* Within 6 months from the end of each month. Would most likely analyze on per-season basis, so within a month at the end of the season. *Data accuracy:* Known accuracy for both classification of fallow/non-fallow and expected accuracy of ET/soil moisture/vegetation condition. (For vegetation condition, fractional cover might be helpful as an indicator of crop cover/ weeds). Remote-sensing data need to be verifiable. *Data delivery:* Info needs to be accessible to users/agricultural producers across the Rio Grande Basin. An online portal would be best, and it should not require large bandwidth or long load times. Rural communities can have spotty mobile coverage/slow internet (<1 Mbps DL speed). Solution must be viewable on mobile phone. Having reports delivered by email would be helpful. *Data formats:* Interactive maps of fallowed fields. Any format compatible with ArcGIS (e.g., vector, raster, shapefile, GeoTIFF).
Partner Potential	MRGCD, Elephant Butte Irrigation District, Irrigation districts along Rio Grande (Elephant Butte; El Paso County Water Improvement District), New Mexico Farm & Livestock Bureau (NMF&LB) – could help with outreach to Ag producers to build awareness of data, training to use the data (both important for uptake / trust). The NM ISC is also managing a fallowing pilot program in the Lower Rio Grande (similar to MRGCD and EBID).

**Table 4-8. Use Case B-2: Quantification of Conveyance Losses
Page 1 of 2**

Use Case Element	Description
Current State	Water managers need an accurate understanding of how much water is lost during conveyance in channels. With a better understanding of losses, they could more effectively identify high-priority canal regions or sections that should be lined and allocate funding more efficiently.
Desired Result	Quantify how much water is going to irrigation (consumptive use) vs. conveyance losses (e.g., seepage, depercolation, infiltration into canal). Inform the timing of water deliveries (basing them on soil moisture instead of rotation) by integrating scheduling data with inflow/outflow information for specific gages or canals. Because canals support unique and diminishing habitats for animals and plants, such as the bosque (cottonwood forest bordering the Rio Grande), users would ideally have the ability to perform high-resolution mapping of riparian ecosystems around canals.
Need/Gap/Objective	Collecting remotely sensed ET data over agricultural areas would help to define the regional water losses. A more consistent, homogeneous measure of ET would act as an indicator of sufficient water supply and identify areas of crop stress. Digitized information on irrigation deliveries would make it easier to access, sort and filter, and verify the accuracy of the information. Ability to monitor ET in riparian ecosystems along canals.
Description/Decision Context	There is currently an extensive network of gages/meters throughout the MRGCD, but it is difficult to tease out consumptive use via irrigation vs. conveyance losses. Irrigation deliveries are currently written down in hard copy logs. Gaging data in MRGCD currently provided by MRGCD hydrology team, who maintain and install gages. USBR posts these data to its website, though this will change within the next year.
Participants	Channel-lining decisions currently made by conservancy district engineering staff, with approval from boards of directors, and input from other technical staff on impact and operations. Accounting departments are involved in funding discussions and decisions.
Workflow	(needs input)
Priority	Very important/most important. Addressing this issue could help accelerate or justify increased funding for canal lining, offering an important route to conserving agricultural water supplies and saving water in critical U.S. reservoirs.
Obstacles to Address the Need	Many districts do not have geographic information system (GIS) technician(s) or use GIS, so any solution needs to be web-based and compatible with Google Earth or other free tools. Very small spatial resolution needed to map vegetation communities along canals (50 feet by 50 feet).

**Table 4-8. Use Case B-2: Quantification of Conveyance Losses
Page 2 of 2**

Use Case Element	Description
Data Sources	Satellite-based ET. NISAR soil moisture data for wetland area mapping. 6-m Single Look data may be able to identify smaller seepage areas around canals.
Data Characteristics	*Spatial resolution:* Field-scale ET data. Also potentially ET data within 50 feet of either side of canals. *Temporal resolution:* Weekly at a minimum; daily ideal. *Geographic extent:* Basin-wide for all canal locations and irrigated lands, within benefitted area of each district. *Data latency:* In-season (when irrigation occurs, Mar 1-Oct 31 in normal year): weekly data with latency of ≤7 days. Off-season: More cloud cover changes latency. Monthly data with latency of ≤30 days. *Data accuracy:* A known, well-established accuracy is more important than a specific accuracy. In-season: need higher accuracy for water deliveries. Riparian ecosystems around channels: lower accuracy OK. *Data delivery:* Final format not critical; prefer RESTful application programming interface (API). *Data formats:* Web-based, compatible with Google Earth map interface or other free tools. Most technical staff at irrigation/conservation/tribal entities do not have GIS expertise. Data formats that are compatible with RiverWare could be helpful. Potential need for input into MODFLOW for USBR groundwater modeling. Data formats that are simple and easy to share are important. The state of New Mexico Water Data Initiative is moving toward OGC's SensorThings API format, and that could be a potential data standard here as well.
Partner Potential	MRGCD, USBR (technical services could help with measurement and verification, provide guidance on whether or not there would be a benefit in lining a particular canal), New Mexico ISC, Bureau of Indian Affairs, U.S. Fish and Wildlife Service

Table 4-9. Use Case B-3: Improved Water Supply Forecasts to Support Basinwide Planning and Farm Management Page 1 of 2

Use Case Element	Description
Current State	In the Middle Rio Grande (MRG) of New Mexico, unreliable water supply means that 98% of crops are alfalfa or pasture (low-value crops for a high-value-water region). Producers need to know they have enough water to get through the season. Springtime decisions are particularly critical, as they determine whether states (e.g., New Mexico) store water or release it, governing how much water will be available for consumption.
Desired Result	Better water supply forecasts would lead to more informed agricultural management decisions. Examples include (1) whether or not to plant or fallow in a given year, (2) creating the possibility of planting higher-value crops in the MRG, and (3) reducing operational costs by moving away from fertilizer-intensive crops.
Need/Gap/Objective	Improved forecasts of runoff and seasonal precipitation on a monthly basis. Reliable forecasts of monsoonal precipitation during snowmelt runoff season (holy grail). Tercile quantification of monsoonal forecasts (good, medium, poor). Closing of the water budget.
Description/Decision Context	In the upper/middle Rio Grande (Colorado, New Mexico), seasonal forecasts come primarily from a best estimate of total water volume—a single volumetric forecast for the year from NRCS, which does not offer timing of flows or streamflow forecasts. There is also the opportunity to use ensemble-based streamflow forecasts from Colorado Basin River Forecast Center working with USBR. Additional research on how to implement this operationally is ongoing with NCAR (Structure for Unified Modeling model). Incorporating weather patterns into forecasts is currently under evaluation and ongoing testing in the Rio Grande Basin. National Water Model not yet being used, due to limitation on local-scale information for the Rio Grande Basin. Information also supports decisions made about water releases to meet compact agreements.
Participants	USBR, Colorado Basin River Forecast Center, West Gulf River Forecast Center, National Weather Service, NCAR
Workflow	(needs input)
Priority	Important to very important, depending on user community.
Obstacles to Address the Need	Technical (expand details).
Data Sources	Need SWE and soil moisture (root-zone) data to improve accuracy of runoff and total water-supply forecasts.

Table 4-9. Use Case B-3: Improved Water Supply Forecasts to Support Basinwide Planning and Farm Management Page 2 of 2

Use Case Element	Description
Data Characteristics	*Spatial resolution:* For streamflow water supply: HUC 10 Watersheds or finer scale if possible (headwater most important). *Temporal resolution:* For seasonal prediction forecasts: First forecast needs to be available by Jan 1, Feb 1, Mar 1, Apr 1, with outlooks extending until the end of snowmelt runoff. ▪ During monsoon season: Ideally monthly precipitation measures (including monsoon in summer, hurricanes in fall), to be provided throughout the year. ▪ 5-days for precipitation within season (currently obtained from National Weather Service). *Geographic extent:* Entire Rio Grande Basin. Regarding monsoonal precipitation forecasts, we would also like to know where it provides direct water to fields. *Data latency:* Monthly updates available on first of each month either going through full snowmelt season, or Oct 31 for monsoonal precipitation forecasts. At bare minimum, producers need information with 30 to 60 days of notice to make planting decisions. Forecasts on Jan 1 or Feb 1 would give enough lead time to producers to make planting decisions, which are made around April 1 in the Upper Rio Grande, and other times in other parts of Rio Grande Basin. *Data accuracy:* Tercile-type quantification levels would be a big step up from current state, but finer quantification would be better. Known quantitative accuracy alongside forecasts would be brilliant. Forecasts for above-average precipitation need to be more accurate than for below-average and medium-level precipitation. Monthly runoff forecasts should have accuracy estimate for each HUC 10 Watershed. *Data delivery:* Maps and descriptions of seasonal outlooks that summarize findings. Gridded data products (possibly served through NASA Distributed Active Archive Centers (DAACs)). *Data formats:* Forecasts are used as inputs for USBR Upper Rio Grande Basin operations model developed in RiverWare. Gridded format could be ingested by potential future modeling efforts (e.g. TWDB's nascent capability).
Partner Potential	West Gulf River Forecast Center, USBR, TWDB, NCAR, U.S. Army Corps of Engineers, International Boundary and Water Commission, Irrigation districts (MRGCD, EBID, El Paso, others), Texas Department of Emergency Management, New Mexico Farm & Livestock Bureau – for reported accuracies and ingestion of/feedback on maps, Texas Department of Agriculture, Texas A&M Agrilife Extension, NRCS

4.3 Category C: Climate Change and Extremes Use Cases

4.3.1 Use Case C-1: Identifying the Strongest Influences on Streamflow

Rio Grande Basin needs assessment workshop participants were interested in identifying which of the influences on streamflow is the strongest, and which has changed the most over time. In order to assess this, more accurate, detailed, higher resolution data will be needed. Data needs that were identified include improved snow and runoff, soil moisture, spatial ET, reservoir evaporation, groundwater level, and forest and riparian system health data. Management practices were also discussed as having significant influences on streamflow. Table 4-10 summarizes Use Case C-1 developed during the workshop.

4.3.2 Use Case C-2: Identifying the Impact of Soil Moisture Deficits

Basin water managers would like to be able to input soil moisture data into models on a large scale in order to identify the impact of increasing soil moisture deficits on runoff, infiltration, vegetation health, and biodiversity. There is interest in defining how infiltration and runoff are impacted by soil type, and higher-resolution data are needed to support this assessment. Table 4-11 summarizes Use Case C-2 developed during the workshop. This use case has some overlap with Use Cases A-1 and B-3.

4.3.3 Use Case C-3: Identifying Tipping Points for Irreversible Change

Basin water managers discussed the importance of identifying where the physical system may fail as a result of the impacts due to climate change. There was discussion of how threatened and endangered species and land management decisions are made based on historical conditions and ranges, although these may not be the dominant factors for future decision making. There was interest in obtaining a better understanding of what minimum flow is needed to maintain the natural system, and in understanding the increased risk of drought. Table 4-12 summarizes Use Case C-3 developed during the workshop. Note that the group was not able to fully develop this use case; further exploration of this topic is needed.

4.4 Category D: Watershed Health and Water Quality Use Cases

4.4.1 Use Case D-1: Impacts of Wildfire Events

Basin water managers discussed the importance of collecting data that can be used to evaluate the impacts of wildfire events on the timing and volume of streamflow and water quality. There

Table 4-10. Use Case C-1: Identifying the Strongest Influences on Streamflow

Use Case Element	Description
Current State	Use model outputs from consultants/researchers and the USBR to inform short- and long-term decisions/planning.
Desired Result	More accurate/detailed/higher resolution data (on water availability–current and future–and use) to inform decisions/planning. Run models at a higher temporal frequency and with more accurate inputs to assess forecasting scenarios.
Need/Gap/Objective	(Forecasting) Trend analysis to help water managers better evaluate which management scenario they should follow Spatial data on ET, reservoir evaporation, snowfall/snowmelt, groundwater elevations, forest and riparian system health (chlorophyll) Further discussion/evaluation to identify needs and how WWAO can support decision makers
Description/Decision Context	Decide on allocations to various users (domestic, riparian/riverine, etc.) based on water availability each year. The water utility decides based on consultant and USBR models/estimates of water availability.
Participants	Water management agencies across the Rio Grande Basin (federal), USBR, USFS, state forestry departments, private water agencies, tribes, municipalities
Workflow	(needs input)
Priority	Important
Obstacles to Address the Need	(needs input)
Data Sources	ET, reservoir evaporation, snowfall/melt, groundwater elevations, forest and riparian system health (chlorophyll)
Data Characteristics	*Spatial data:* Currently have point data (on the ground), could be improved by spatial data across the basin *Temporal resolution:* Spring through October decisions (need more high-frequency data), less frequent in fall and winter *Predictive ability:* health of ecosystems (vulnerability to fire for example, perhaps NDVI as a measure of vegetation health), soil moisture (thermal bands) *Data calibration* of spatial/aerial data to ground measurements *Data access:* Needs to be user friendly, approachable for decision makers
Partner Potential	USBR, ACOE, Colorado Division of Water Resources, UNM

Table 4-11. Use Case C-2: Identifying the Impact of Soil Moisture Deficits Page 1 of 2

Use Case Element	Description
Current State	Streamflow forecasts are being used for water rights, reservoir storage. digital elevation models (DEMs) and land cover data are being used for identification of treatment regions to assist with infiltration/decrease in runoff and sedimentation into reservoirs. WRF-Hydro (NCAR) is currently the most helpful model that provides streamflow information.
Desired Result	Data for large and small watershed scales for snow pack, soil moisture Higher resolution data for root zone soil moisture (currently limited to top few centimeters of soil) Trend analysis
Need/Gap/Objective	The ability to incorporate additional/new data into the model. Soil moisture at a large scale. Spatially distributed snowpack data Vegetation health and how it is changing, more focus needed in desert regions Infiltration/runoff and how it is impacted by biodiversity in the soil (e.g., how soil structure/biodiversity changes after a fire) Infiltration/runoff and how it is impacted by soil type (need higher resolution data) Limited broadband access in rural areas—especially important for agricultural applications. Perhaps make the data cell-phone compatible, easy to access/view/interpret. Budget constraints that limit the ability to interpret data in-house–more agencies need pre-packaged results (e.g., limited budgets with state agencies and newer/small staff groups).
Description/Decision Context	Water allocation decisions made in advance (e.g., 30 to 60 days in advance) for agricultural applications.
Participants	Possible participants from southern New Mexico: WRRI and Doña Ana Soil Conservation District (may want pre-packaged data)
Workflow	WRF-Hydro (NCAR) model for streamflow Current soil moisture models Consultants providing information/model outputs (not done in-house with the decision-makers)
Priority	Important: Not used directly by EBID
Obstacles to Address the Need	Funding Data analysis (not done in-house). Limited bandwidth for analytics. Broadband access (limited internet connectivity). Need changes depending on where you are in the watershed (e.g., mountains, valleys, desert).

Table 4-11. Use Case C-2: Identifying the Impact of Soil Moisture Deficits Page 2 of 2

Use Case Element	Description
Data Sources	Soil moisture (thermal bands, radar/passive microwave) Snowpack Turbidity (sedimentation during runoff events) Optical sensors for geomorphology?
Data Characteristics	Data Access: ▪ Easily accessible/pre-packaged/mobile-compatible ▪ Clear data distribution pathway/plan to stakeholders, ability to modify the pathway to meet stakeholder needs ▪ Available offline *Temporal resolution:* Monthly data during the spring/late winter for agriculture, as well as summer and winter for cover crops; watershed planning, quarterly data; summer/monsoon (July/August) season for runoff assessments; year-round for fire season. *Historical data:* Used to identify trends and highly vulnerable/changing areas
Partner Potential	BLM, soil and water conservation districts, USFS, Water Resources Research Institutes, Doña Ana Soil Conservation District

Table 4-12. Use Case C-3: Identifying Tipping Points for Irreversible Change

Use Case Element	Description
Current State	Threatened and endangered species management is generally based on preserving/restoring historical ranges and habitat regions, though it is changing to incorporate future ideal habitat regions Land management decisions-based on historical data and forecasting (e.g., current climate trajectory models and scenarios) Water managers use models and ground point data taken locally Balancing recreation and species management interests (e.g., USFWS)
Desired Result	Resource managers would like to be able to assess valuable and vulnerable areas/species to inform and prioritize treatments and allocation of funding. Understanding our current state: drought vs. aridification; understanding the changing propensity toward drought (e.g., how much does historical information represent our future trajectory)
Need/Gap/Objective	Phenology, vegetation health, species trajectory maps, total water available per year (percent of average?) Trend analysis (only as good as the data) Limited historical climatological data
Description/Decision Context	What is the minimum river flow to maintain the system? Reservoir releases to maintain flows. Restoration/mitigation activities, water diversions? Where should water resources management organizations have canals? What are the ecological implications of river modifications? Allocation decisions with conflicting needs of humans/ecosystems.
Participants	(possible participants are provided below under potential partners)
Workflow	(needs input)
Priority	(because this is so broad and we were missing some experts, we did not set a priority)
Obstacles to Address the Need	Data availability (limited to at most the past 30 years with RS data, the satellite era is relatively short) Current data are uncertain (paleo records), difficult to augment/address this obstacle
Data Sources	Changes in green-up (NDVI time series), land cover mapping (grasslands, forested, bare-ground)
Data Characteristics	(needs input)
Partner Potential	UNM (including the Sustainability Studies Program), USFS and Valles Caldera National Preserve, NMSU's State Climate Office, USFWS and the USFWS Civilian Climate Corp (including at Bosque del Apache National Wildlife Refuge in New Mexico), New Mexico Energy Minerals and Natural Resources Department (EMNRD), National Park Service/Big Bend National Park, TWDB, TCEQ, coastal groups in Mexico, tribes

are a number of forest thinning projects underway in the upper portions of the Rio Grande Basin, including projects funded by The Nature Conservancy's Rio Grande Water Fund, though none of these projects are operating at large scales. These projects are being implemented in an effort to reduce the risk of catastrophic wildfire and its impacts to the physical/surface water system, including erosion and sedimentation. There is a need to better define the potential impacts due to wildfire in order to target ongoing and future forest restoration efforts and mitigate these impacts. Table 4-13 summarizes Use Case D-1 developed during the workshop.

Table 4-13. Use Case D-1: Impacts of Wildfire Events Page 1 of 2

Use Case Element	Description
Current State	The Water Authority is using the Rio Grande Water Fund to monitor forest health and plan for treatment to minimize the impacts of wildfire. The Nature Conservancy (TNC) has been leading efforts to implement forest treatments with funding from the Rio Grande Water Fund since approximately 2014. The Water Authority helps to fund the program. We do not know if they are currently using satellite data. Follow up with The Nature Conservancy is needed to find out more about the forest treatments. They have a comprehensive plan on their website. [Need to assess TNC's approach to modeling and evaluating scenarios for forest treatment; F-SIM for modeling and model inputs and outputs unknown.] Background: Following the Las Conchas Fire in 2011, a sediment plug shut down the Water Authority's drinking (surface) water treatment plant. The intensity of storms after the fire directly led to the problem. This was a severe fire that destroyed orchards, etc., in the area and distributed heavy metals and reinforced the need to take care of headwater forest for downstream water quality.
Desired Result	The Water Authority and other entities need to be able to project impacts of wildfire on streamflow. Near term, there is potential to do a better job with forest treatment. Better snowmelt data could have an impact on how resource managers approach this challenge—ideally, using a more comprehensive model with snow melt, soil, forest health rolled into one. More broadly, it would be helpful to be able to decide where to put money for forest treatments in the West in general. EBID also expressed the need to give more attention to desert ecosystems in southern or other parts of New Mexico; while mountain areas are more important from a water supply perspective, basic information on health, vegetation, and changes in soil moisture are also important in desert areas. Keeping sediment out of irrigation canals and reservoirs is important; otherwise, EBID and other irrigation districts or irrigators have to pay to remove it.
Need/Gap/Objective	Collect data to use in models that are used to evaluate the potential impacts of wildfire on the timing and volume of streamflow, as well as water quality. TNC is using F-SIM for modeling, and to evaluate model inputs and outputs. It would be useful to assess how well the impacts on streamflow can be tied to forest treatments. This would allow for an evaluation of the benefits resulting from treatments.
Description/Decision Context	TNC is collaborating with UNM researchers regarding these data and information, and TNC is the keeper of the Rio Grande Water Fund. The Water Authority contributes to the Rio Grande Water Fund, in an effort to support the long-term planning for water quality and supply, with the goal of protecting source water. Contributors do not participate in defining how things are done and what the funds are used for.

Table 4-13. Use Case D-1: Impacts of Wildfire Events
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Use Case Element	Description
Participants	TNC, Rio Grande Water Fund, Water Authority (Albuquerque), New Mexico Energy, Minerals and Natural Resources Department (EMNRD) Forestry Division, USDA Forest Service, UNM, Southwest Conservation Corps (may be doing some of the forest treatments)
Workflow	See above for funding, modeling, forest treatments. The objective would be to assess the TNC and UNM modeling approach; seek opportunities to assist and improve data, and ability to achieve the desired results defined above. Satellite data would be useful in support of the existing modeling, and NASA could also assist with improving modeling tools or developing new tools.
Priority	Very important. These activities have a direct impact that the public can see. NASA may be able to help improve the current efforts, potentially increasing efficiency.
Obstacles to Address the Need	Not aware of specific obstacles, other than lack of funding as an obstacle.
Data Sources	Unknown
Data Characteristics	On-the-ground monitoring and drone surveys; satellite data (Contact Shawn Penman at EDAC for more information).
Partner Potential	With TNC, UNM, and others

5. Summary and Conclusions

The Rio Grande Basin needs assessment workshop was held virtually in March 2022, and this report presents an overview of basin stakeholders, provides a summary of the workshop and descriptions of the use case scenarios developed, presents the most significant water management needs identified, and makes recommendations for aiding in the development of future projects.

The Rio Grande flows for approximately 1,900 miles, and is shared by three states, two countries, and numerous tribes and pueblos. The basin water supply is highly variable, and the watershed area is vast, covering approximately 335,000 square miles. The basin's most significant water management needs include the need for a better understanding of water resources and physical processes, and addressing vulnerability to climate and the potential effects of climate change.

Basin stakeholders would benefit from more data collection, monitoring, modeling, and analysis to be used to better inform water resource management decisions. Water managers are currently basing their management decisions on incomplete snow and runoff data, and need better forecasting of streamflow—both timing and volume—to support water supply management decisions. Having more accurate data to use as input for models would allow for better predictions of streamflow and better management of water resources.

A headwater hydrologic model for the Rio Grande Basin that refines hydrologic runoff predictions and can process future climate scenarios does not exist. Basin water managers would like to have access to computational modeling (or its outputs) that captures the interaction of different physical processes and translates measurements into water management metrics. More broadly, the basin stakeholders would like to have a central location that makes federal data available to end users.

The most significant obstacles to meeting the identified needs in the basin include funding and staffing limitations, and infrequent basinwide collaboration. There are also issues with where federal data may be hosted and accessed by other partners. Basin stakeholders would like to see a central location set up for hosting data, making it available for use by agencies, basin water managers, and the public.

Rio Grande Basin water resources managers rarely collaborate on a basinwide scale. The current NASA needs assessment project provided the opportunity for various stakeholders in this region to start those conversations, which may spur ongoing collaboration among basin stakeholders. Continued basinwide collaboration, combined with technical support from NASA, will aid in the development and success of future projects, and therefore more informed, data-based decision making for water resources management in the Rio Grande Basin.

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Figure

Explanation

Rio Grande Basin

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RIO GRANDE BASIN STUDY

Rio Grande Basin

Figure 1

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