APPENDIX 7

REPORT ON URGWOM DEVELOPTMENT SIMULATIONS AND FINAL RESULTS FOR PREPARATION OF BIOLOGICAL ASSESSMENT ON WATER MANAGEMENT ACTIONS ON THE MIDDLE RIO GRANDE, FEBRUARY 2012

Report on

URGWOM Development, Simulations, and Final Results for Preparation of a Biological Assessment on Water Management Actions on the Middle Rio Grande

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Numerous individuals and representatives from different agencies and organizations must be acknowledged for contributing toward the completion of all aspects of the work documented in this report for preparation of a Biological Assessment (BA) of Water Management Actions on Middle Rio Grande. Enhancements and development of the Upper Rio Grande Water Operations Model (URGWOM) for meeting specific needs for this study were completed through coordination with the interagency Population and Habitat Viability Assessment/Hydrology ad hoc Work Group (PHVA Work Group) of the Middle Rio Grande Endangered Species Collaborative Program with model runs completed throughout the process leading to the final simulations and results presented in this report. Several agency representatives were involved with the PHVA work group efforts since the inception of the work group in December of 2007 and the subsequent work on the BA write-up.

Leann Towne with the U.S. Bureau of Reclamation (Reclamation) was instrumental in overseeing and assuring all aspects of the analyses and modeling were completed as co-leader of the PHVA work group along with the support from April Fitzner and Stephen Kissock as co-leaders from the U.S. Army Corps of Engineers (Corps). The significant support from the following other agency representatives throughout the entire process was also essential for successful completion of all work: Dagmar Llewellyn, Jim Wilber, Josh Mann, Valda Terauds, and Jeanne Dye-Porto with Reclamation; Rolf Schmidt Peterson with the Interstate Stream Commission (ISC); David Gensler with the Middle Rio Grande Conservancy District (MRGCD); John Stomp and Andrew Lieuwen with the Albuquerque Bernalillo County Water Utility Authority (ABCWUA); Randy Shaw (previously with the Bureau of Indian Affairs (BIA)) and Chris Banet from BIA; Paul Tashjian, Lori Robertson, and Jennifer Bachus with the U.S. Fish and Wildlife Service (Service); and Tim Ward (previously with the University of New Mexico). Collaborative Program Management Team (PMT) liaisons Terina Perez and Kathy Dickinson were also imperative to the overall effort along with the oversight from Collaborative Program Managers, Yvette McKenna and Lisa Croft.

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Executive Summary

The Upper Rio Grande Water Operations Model (URGWOM) was selected as the tool for completing model runs for providing needed hydrologic information for the U.S. Bureau of Reclamation (Reclamation) and U.S. Army Corps of Engineers (Corps) to prepare water operations Biological Assessments (BAs) for use in consultation with the U.S. Fish and Wildlife Service (Service). The model was used by the Population and Habitat Viability Assessment/Hydrology ad hoc work group (PHVA work group) of the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) for analyzing scenarios for managing reservoirs and diversions in the Rio Grande basin. Numerous model enhancements and updates were completed throughout the modeling process to meet the needs for the PHVA work group analyses and BA preparation that included the following:

- adjusting the physical layout of the Middle Rio Grande in the model, incorporating groundwater-surface water interaction, and updating the URGWOM database and data management interface (DMIs) accordingly;
- completing a review of the calibration with a low flow calibration enhancement to improve model performance at simulating low flows and the timing and extent of river drying;
- enhancing the representation of the calibration and inflows for the reach from San Marcial to Elephant Butte Reservoir – important for accurately representing Compact deliveries;
- setting up policy for flow tools including Cochiti deviations and pumping from the Low Flow Conveyance Channel;
- updating model policy for Prior and Paramount (P&P) storage for the six Middle Rio Grande Pueblos to occur at El Vado Reservoir up to the minimum starting on January 5th and with calls for P&P releases from El Vado Reservoir computed with reference to URGWOM loss rates and usable flow factors of 1.0,
- updating policy for Albuquerque Bernalillo County Water Utility Authority (ABCWUA) diversions, and representing increased diversions at Angostura during shortage operations;
- updating policy for the use of Reclamation's leased San Juan-Chama Project water including step downs in target flows for representing Reclamation's discretionary operations to use supplemental water to manage the recession after the runoff, but
  - with no use of supplemental water to control the rate of drying after any river rewetting in final model runs;
- incorporating the Buckman Direct Diversion;
- updating calculations for usable storage available at Elephant Butte Reservoir,
- updating assumed initial conditions throughout the modeling process with estimated values for December 31, 2011 used in final model runs; and
- representing deep aquifer heads accurately for scenarios including different heads for modeling with no Heron Dam operations for the San Juan-Chama Project where ABCWUA would rely on groundwater pumping to meet needs.

This report provides additional background information on the items listed above as completed to meet the needs for the PHVA work group analyses for BA preparation, specific details about flow tools defined by the PHVA work group, and scenarios evaluated throughout the modeling process. Results from final simulations are also presented. Notes on the communication and coordination of the analyses with the PVA work group of the Collaborative Program are also included.

Model runs were set up as part of a process that ultimately led to a defined Proposed Action for Reclamation's BA and other final scenarios to be modeled. The Proposed Action entails meeting the 2003 Biological Opinion (2003 BO) flow requirements as possible utilizing an initial supply of supplemental water and assumed future Reclamation leases of San Juan-Chama Project water (12,000 acre-ft/year for the first five years and 8000 acre-ft/year for the following five years). Pumping from the Low Flow Conveyance Channel (LFCC) is also included to manage the recession after the continuous flow requirement (or after the runoff). It was determined that flow requirements under the 2003 BO cannot be fully met under the Proposed Action. Flow targets cannot always be met with the projected available supply of supplemental water, and more river drying would occur. Results from the modeling indicate the total annual amount of supplemental water needed to meet the 2003 BO flow requirements over the next ten years may average from 32,000 acre-ft/year to 49,000 acre-ft/year depending on the hydrology for the next ten years. The additional supplemental water needed beyond the amount provided under the Proposed Action may average from 17,800 acre-ft/year to 35,900 acre-ft/year.

A review was also completed of the impact of Reclamation's actions including Heron Dam operations for the San Juan-Chama Project and El Vado Dam operations along with the Supplemental Water Program included under the Proposed Action. It was determined that Heron Dam operations help to augment flows in the Middle Rio Grande as a result of providing San Juan-Chama Project water to the Middle Rio Grande Conservancy District (MRGCD) and ABCWUA. El Vado Dam operations also help to augment flows in the Middle Rio Grande. Water stored at El Vado Reservoir during the runoff as not needed to meet the daily irrigation demand, and when storage restrictions per Article VII of the Compact are not in effect, is released to meet irrigation needs later in the summer and helps to provide additional flows in the Middle Rio Grande. Reclamation's Supplemental Water Program consisting of leases of San Juan-Chama water and pumping from the Low Flow Conveyance Channel (LFCC) to the river further helps to augment flows in the Middle Rio Grande. It was also determined that Middle Rio Grande Conservancy District (MRGCD) diversions adversely impact flows as river flows are diverted.

1.0. Introduction

In April 2008, the Upper Rio Grande Water Operations Model (URGWOM) was selected by the Population and Habitat Viability Assessment/Hydrology ad hoc work group (PHVA work group) of the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) to use as the primary tool for analyzing scenarios for managing reservoirs and diversions in the Rio Grande basin and evaluate impacts of potential operational scenarios on the long-term viability of the Rio Grande silvery minnow (*Hybognathus amarus*) and the southwestern willow flycatcher (*Empidonax trailii extimus*). Results from the model runs were referenced for providing needed hydrologic information for the U.S. Bureau of Reclamation (Reclamation) and U.S. Army Corps of Engineers (Corps) to prepare water operations Biological Assessments (BAs) for use in consultation with the U.S. Fish and Wildlife Service (Service).

This report provides background information on all the model development and preparatory work since the inception of the PHVA work group in December 2007. Numerous enhancements and updates to URGWOM were completed to meet the needs for the PHVA work group analyses that included incorporating a representation of the groundwater-surface water interaction in the

Middle Rio Grande, completing a detailed review of the model calibration and a low flow calibration enhancement, and reviewing the model policy and incorporating numerous rule changes and updates to meet the needs for the study. Several flow tools as defined by the PHVA work group were set up in URGWOM for analysis as potential solutions for meeting flow needs that included Cochiti deviations, relinquished Compact credits/storage of Emergency Drought Water, Reclamation leases of contractor San Juan-Chama Project water, Low Flow Conveyance Channel (LFCC) pumping, and alternate letter water delivery schedules.

The process for ultimately defining the final water management scenarios for modeling is discussed which started with an initial screening of water management scenarios and eventually led to a single defined scenario for the Proposed Action in Reclamation's BA. A detailed analysis of the Proposed Action was completed, and all simulation results as referenced for preparation of Reclamation's BA are presented. Results are also presented for a scenario that includes all the flow tools defined by the PHVA work group. This documentation serves as the last three deliverables under the PHVA work group charter (2010) and documentation of all model development, completed simulations, and final results for BA preparation. Work was completed through the PHVA work group and with contributions from the URGWOM Technical Team (Tech Team).

1.1. URGWOM

Operations of facilities in the Rio Grande basin from the Colorado-New Mexico state-line to below Elephant Butte Reservoir including the Rio Chama are modeled with URGWOM. URGWOM is a daily timestep computational model developed through an interagency effort and is used to simulate processes and operations of facilities and complete accounting calculations for tracking the delivery of water allocated to specific users. Policy for setting dam releases along with diversions and other demands are represented in coded rules in an URGWOM ruleset. Various methods are included to represent physical processes such as floodwave travel times; reservoir evaporation and seepage; conveyance losses to deep percolation, open water evaporation, and evapotranspiration (ET); surface water-groundwater interaction; and irrigation return flows.

URGWOM was developed using the RiverWare software application developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado at Boulder. RiverWare is a generalized river basin modeling environment that can be used to develop an operations model for any configuration and to simulate operations to meet needs for flood control, water supply, recreation, etc. Numerous methods are available for representing the key physical processes in a basin. RiverWare is designed to provide river basin managers with a tool for scheduling, forecasting, and planning reservoir operations and includes extensive capabilities for rulebased simulations and water accounting. A key benefit of RiverWare is that software development is ongoing and new methods and capabilities can be added to RiverWare by the software developers to meet evolving needs. The rule policy language (RPL) editor in RiverWare is used to code various aspects of policy for operations for flood control, ecological benefits, recreation, and deliveries to irrigation districts, municipalities, and other water users.

Separate modules of URGWOM are used by agencies involved with Rio Grande operations in New Mexico. The Accounting Model is used to track the status of accounts under actual

operations. A Forecast Model is used to develop forecasted inputs for Water Operations Model runs which simulate operations under a provided forecast for preparing Annual Operating Plans (AOP). All the work for the PHVA work group was completed with the planning module of URGWOM (Boroughs, 2010a). The Planning Model uses the same single URGWOM ruleset used with the Water Operations Model but the Planning Model uses a Combined account to represent water for all contractors for San Juan-Chama Project water other than the Albuquerque Bernalillo County Water Utility Authority (ABCWUA), Middle Rio Grande Conservancy District (MRGCD), and water for the Cochiti Recreation Pool. Using a Combined account allows for longer model runs to be completed more efficiently.

Several other aspects of URGWOM that are key for the analyses are discussed in this document, but more information can be obtained at the URGWOM website: (http://www.spa.usace.army.mil/urgwom/default.asp). The set up for URGWOM simulations includes initial conditions, an assumed hydrology, and details on operational policy for setting demands and releases from reservoirs in the system as represented in the URGWOM ruleset, and the related assumptions for the model runs for the PHVA work group are discussed further in this report. Slight adjustments to model parameters or the rules are implemented to represent proposed changes to operations. Resulting flows are analyzed to identify the timing of river drying and the occurrence of recruitment and overbank flows where a comparison of the results between two model runs indicates the impact of a change on the river flows.

2.0. Model and Ruleset Changes

To assure the needs for the PHVA work group analyses could be met, several adjustments were made to different aspects of URGWOM and the ruleset used to represent policy for operations. Changes included overseeing work by the URGWOM Technical Team to incorporate a new configuration for representing groundwater-surface water interaction in the Middle Rio Grande. Following this work, a detailed review of the model calibration was completed with specific focus on the model performance at simulating lower flows and predicting the timing and extent of river drying. Model policy for standard operations was reviewed, and several aspects of the URGWOM rules were edited to assure policy is represented accurately as needed for the PHVA work group analyses. Work on the rules included changes for representing ABCWUA diversions and deliveries of ABCWUA's San Juan-Chama Project water from Abiquiu Reservoir to the diversion, policy for increased diversions at Angostura Dam when MRGCD is in a shortage situation, and El Vado Dam releases that may be set per Article VIII of the Compact. The model and ruleset were adjusted to incorporate or make changes for flow tools analyzed as potential solutions for meeting water needs for Endangered Species Act (ESA) needs including Cochiti deviations, relinquished Compact credits/storage of Emergency Drought Water, Reclamation leases of contractor San Juan-Chama Project water, LFCC pumping, and alternate letter water delivery schedules. The model approach for representing the use of supplemental water to meet flow requirements was also reviewed.

2.1. Middle Valley Rework

Work included an update to the representation of the physical system and processes in the Middle Rio Grande for including groundwater-surface water interaction between the shallow aquifer and the river, drains, and canals (URGWOM Technical Team, 2010). The shallow groundwater system throughout the Middle Rio Grande is set up as a grid of 57 groundwater areas. The groundwater areas are established in a 3 x 19 grid with three columns of groundwater areas for the area under the river and on each side of the river for 19 separate subreaches between Cochiti Dam and San Marcial. Seepage between the surface water and shallow aquifer is head based and computed daily. The subreaches represent river lengths of 5 to 15 miles with the boundaries defined by gage locations or other key benchmarks along the river. Modeled inflows to each of these subreaches are referenced for identifying modeled river drying.

Crop consumption is computed based on irrigated areas and crop evapotranspiration (ET) rates, and canal seepage is included. Open water evaporation from the river and riparian ET losses are also represented. Deep percolation is computed daily as a head based loss, and wasteway returns are simulated. Refer to Figure 2.1 for a screen capture of the workspace from URGWOM for the top portion of the Middle Rio Grande system.

Numerous new model inputs are needed as a result of the Middle Valley Rework, so incorporating the changes required significant work by the Tech Team to the data management interface (DMIs) and URGWOM database as maintained in files that have the format of the Corps' Hydrologic Engineering Center Data Storage System (DSS).

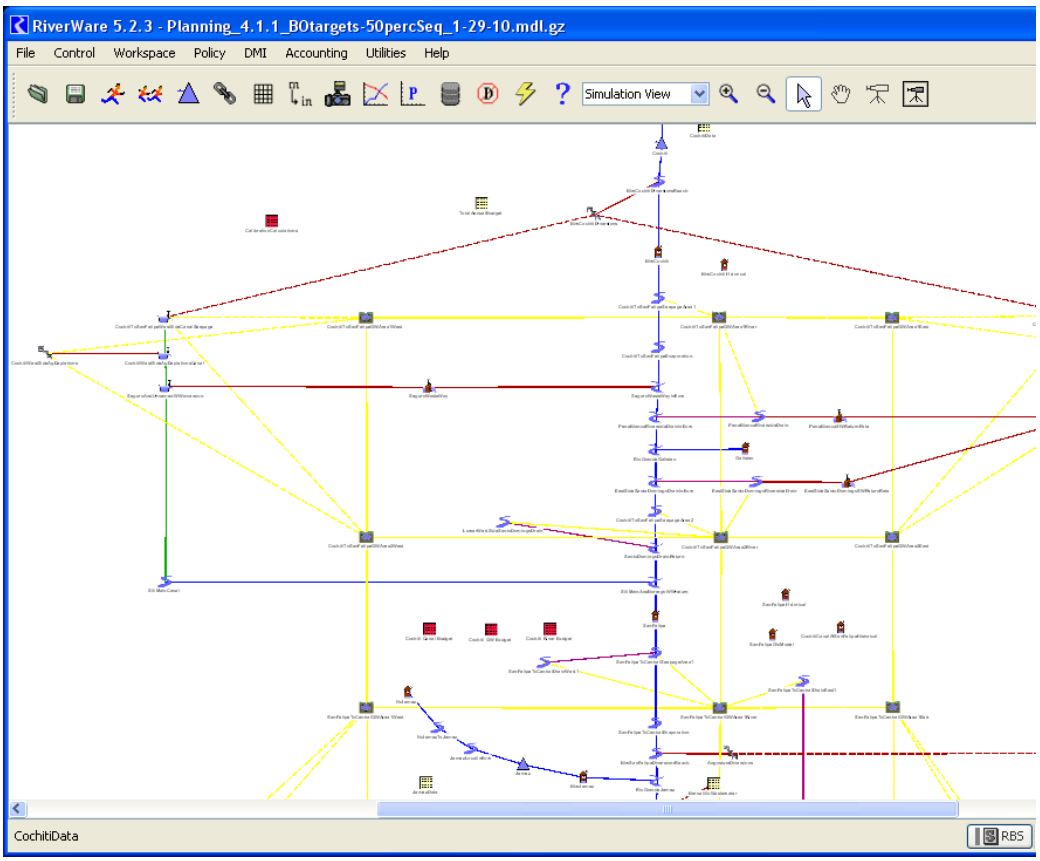

Figure 2.1. Screen Capture of the Representation of the Top Portion of the Middle Rio Grande System in URGWOM

2.2. Calibration Review

After the Middle Valley Rework was implemented in the Planning Model, an updated review of the model calibration was completed with specific focus on the model results at low flows and simulated river drying, of specific interest to the PHVA work group and for BA preparation. Adjustments were incorporated for a few model parameters used for setting canal seepage, return flows at wasteways, and stream seepage. The model calibration entailed reviewing model results with the historical hydrology and historical operations from 1990 through 2007 versus historical gaged flows at key gage location along the Middle Rio Grande for the same period. The difference in the model flows and historical gage flows represent model residuals which were evaluated to assure the model is simulating river flows accurately and there are no trends toward over-predicting or under-predicting flows. The distribution of the residuals was reviewed at the key gage locations. Refer to Figure 2.2 for a sample plot of the distribution of the daily residuals at the location of the USGS gage Rio Grande at Albuquerque, NM (ID#08330000) (herein after referred to as Central).

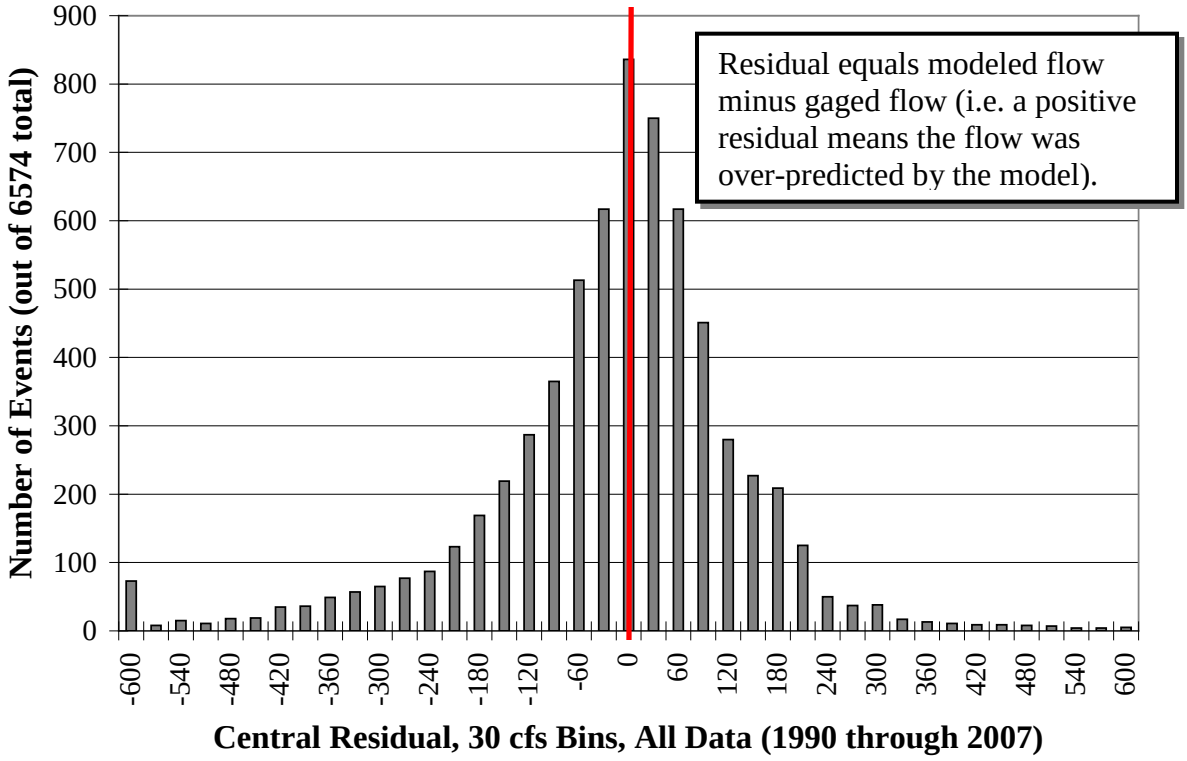

Figure 2.2. Sample Plot of Distribution of Residuals – Central

The review of the model calibration also included a check of the timing for simulated river drying under historical operations versus available RiverEyes data for when river drying actually occurred based on field observations. Refer to Figure 2.3 for a sample plot of the modeled flow at a model node below the Isleta diversion using the 2007 hydrology and operations versus the historical data for when river drying occurred at the corresponding location based on the RiverEyes data. In preparation for post-processing model output from URGWOM runs and providing key information on simulated river drying, trigger flows were defined for each subreach in URGWOM for when river drying would be expected.

As a separate side exercise to update the model calibration, the approach for representing inflows to the reach between the location of the USGS gage Rio Grande Floodway at San Marcial, NM (ID# 08358400) (herein after referred to as San Marcial) and Elephant Butte Reservoir was refined to assure simulated inflows to the reservoir are accurate and computed Compact credits are correct in the model simulations. The new approach was calibrated such that the modeled inflows to Elephant Butte Reservoir match actual inflows computed using a mass balance on the reservoir with recent historical data.

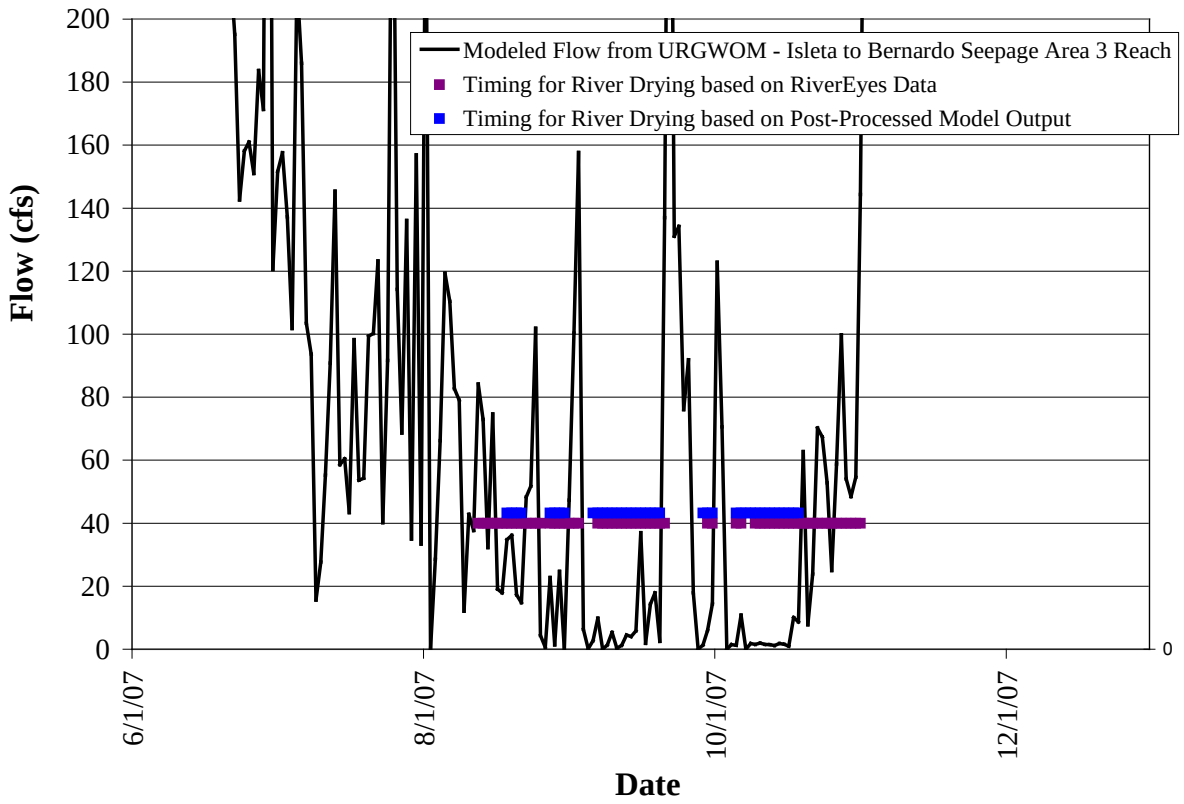

Figure 2.3. Sample Plot of Simulation Results for River Drying versus RiverEyes Data

2.3. Model Policy for Standard Operations

The URGWOM rules for representing standard operations have been refined over years of model development. In addition to the policy for flood control operations, the URGWOM rules include policy for moving San Juan-Chama Project allocated to contractors, deliveries to meet water uses in the Middle Rio Grande, and standard policy for potential storage, releases, or bypasses of native Rio Grande water at dams in the basin in New Mexico. A summary of policy for standard operations as represented in URGWOM is presented in section 2.3.1 below. Further review of the policy was completed by the PHVA work group as a result of the work group's review of several iterations of test model runs before final simulations were completed, and a few additional enhancements were incorporated to assure the needs for BA preparation are met as discussed in section 2.3.2.

2.3.1. Summary of Standard Operations

San Juan water is diverted from the San Juan basin to Heron Reservoir to allow for New Mexico to use its portion of San Juan water under the Upper Colorado River Compact. Diversions occur up to the capacity of the San Juan-Chama Project infrastructure and to assure minimum bypass flows are maintained on the San Juan river tributaries and such that the total diversion volume does not exceed 270,000 acre-ft/year or 1,350,000 acre-ft over any 10-year period. Diversions are also curtailed as needed based on lack of space at Heron Reservoir below the maximum pool elevation.

San Juan-Chama Project water at Heron Reservoir is allocated to contractors each year up to the total firm yield of 96,200 acre-ft. A Cochiti recreation pool is maintained with San Juan-Chama Project water where this water is generally delivered from Heron Reservoir to Cochiti Lake in the late fall and winter to enhance fish and wildlife habitat at the upper end of Cochiti Lake. Allocated San Juan-Chama Project water may be kept in storage at Heron Reservoir until the end of the calendar year. Any remaining contractor water is reverted back to the Project pool on December 31st; although, Reclamation may issue waivers to allow contractors to continue storing allocated water until September 30th of the year following the year the water was allocated if there is a benefit to Reclamation. MRGCD has allocated storage space for San Juan-Chama Project water at El Vado Reservoir where the water will remain in storage until needed to meet the demand for their diversions in the Middle Rio Grande after native water supplies are exhausted. ABCWUA and other contractors have allocated storage space at Abiquiu Reservoir.

ABCWUA San Juan-Chama Project water is delivered to their surface water diversion in Albuquerque and will also be released as letter water deliveries to payback MRGCD or the Compact deliveries for depletions to the surface water supplies caused by groundwater pumping. These deliveries are set based on schedules provided by the Office of the State Engineer. Actual paybacks are determined by the Office of the State Engineer and the deliveries are requested as letters from the State to Reclamation, hence the name "letter water deliveries. Other contractors for San Juan-Chama Project water may also cause depletions in the basin and then use allocated San Juan-Chama Project water to payback the river.

Native Rio Grande water is bypassed at Heron Dam, and Rio Grande water is stored at El Vado Reservoir if Article VII of the Rio Grande Compact is not in effect as defined by usable storage at Elephant Butte and Caballo reservoirs that exceeds 400,000 acre-ft (States of New Mexico, Colorado, and Texas, 1938). Computed usable storage does not include any Compact credit water, based on the status as of the end of the previous year, or San Juan-Chama Project water in storage at Elephant Butte Reservoir. If Article VII is not in effect, El Vado Reservoir is filled with native Rio Grande inflows not needed to meet the daily irrigation demand in the Middle Rio Grande and in a manner to assure downstream channel capacities are not exceeded. If Article VII is in effect, native Rio Grande water is bypassed at El Vado Reservoir as not needed for storage to meet the Prior and Paramount (P&P) needs of the six Middle Rio Grande pueblos. Native Rio Grande water is bypassed at Abiquiu Reservoir and Cochiti Lake unless storage is needed to maintain flows below downstream channel capacities. Any potential storage at Abiquiu or Cochiti Lake is evacuated as possible but may be retained as carryover storage until after the irrigation season if inflows decrease and conditions are satisfied to lock in storage until the non-irrigation season.

Water is delivered from El Vado Reservoir to meet the MRGCD demand at Cochiti Dam using available native Rio Grande water in storage, if needed, and with MRGCD's San Juan-Chama Project water used when native supplies are exhausted. Deliveries to meet the full demand at Cochiti include P&P water released for the six Middle Rio Grande pueblos if needed to meet their demand. Diversions occur at Cochiti and the Angostura, Isleta, and San Acacia diversions.

Water is released from Elephant Butte and Caballo Dams to meet a standard demand schedule for the lower valley below Caballo Dam with curtailments to the full demand schedule implemented if needed based on the available usable storage at Elephant Butte and Caballo Reservoirs.

2.3.2. Edits to Rules for Standard Operations

Several changes were implemented into the model and ruleset as needed to better represent the latest policy for different aspect of operations and make key needed adjustments for the analyses completed by the PHVA work group and for BA preparation. These changes include several smaller changes such as setting up the model to only allow storage at El Vado Reservoir for MRGCD, to assure the Cochiti Rec Pool is maintained a priority even when there are shortages to contractor allocations, and to not include San Juan-Chama Project water at Elephant Butte Reservoir and also reference the Compact credit water in storage as of the end-of the previous year for the computation of usable storage. Other more significant changes were reviewed which pertained to model policy for diversions of Santa Fe City and County water at the Buckman Direct Diversion, ABCWUA diversions, shorting MRGCD diversions to assure supplemental water for meeting flow targets is not diverted, increased Angostura diversions when MRGCD is in a shortage situation, reregulation at El Vado Reservoir for P&P needs, and releases from El Vado Dam per Article VIII of the Compact.

2.3.2.1. Buckman Direct Diversion

URGWOM was updated to represent diversions at the Buckman Direct Diversion for Santa Fe City and County San Juan-Chama Project water and native Rio Grande water per acquired water rights. The physical layout of the model was edited to include the diversions from the river below the USGS gage Rio Grande at Otowi Bridge, NM (ID# 08313000) (herein after referred to as Otowi). Accounts were established in URGWOM for the delivery of Santa Fe City and County water as included in the Combined account in the planning module of URGWOM. Policy was coded in the URGWOM ruleset for setting daily diversion amounts based on assumed average diversion daily rates for native Rio Grande water (1.50 cfs), along with native water used for mixing operations at the diversion that is immediately discharged back to the river (1.00 cfs), and for Santa Fe City and County use of their annual allocations of San Juan-Chama Project water (7.75 cfs). Policy is also included to represent the curtailment and cutoff of diversions of native Rio Grande water based on threshold flows at Otowi of 325 and 200 cfs, respectively. Deliveries of Santa Fe City and County San Juan-Chama Project water are made to meet diversion needs which may be cutoff if Abiquiu Dam is in flood control operations to maintain downstream flows below channel capacities. With this change to the model, Santa Fe City and County's use of their annual allocation of San Juan-Chama Project water is represented and thus reflected in all the final model run results.

2.3.2.2. ABCWUA Diversions

Policy for representing deliveries of ABCWUA water to their surface water diversion was refined for the modeling for the PHVA work group and for BA preparation. URGWOM is set up to model full diversions with a check against an input year for the startup of the diversions and against established preemptive cutoff criteria where a preemptive cutoff is implemented before actual permit restrictions would result in curtailed diversions or when diversions would be cut off due to high river flows. The preemptive cutoff represents the assumption that Albuquerque would switch to groundwater supplies 1) during low flows before curtailments would occur per the permit, 2) during high flows when it may be unsafe or impractical to operate the diversion dam, or 3) when flood control operations at Abiquiu or Cochiti might prevent Albuquerque from receiving a delivery of their allocated San Juan-Chama Project water. The high flow thresholds

for a preemptive diversion cutoff are 1800 cfs out of Abiquiu Dam or 4500 cfs out of Cochiti Dam. The threshold low flow for a preemptive cutoff is 200 cfs and diversions will not restart until at least two weeks after any preemptive cutoff criterion is not satisfied and the flow at Central is greater than 250 cfs.

Full Albuquerque diversions are set to 130 cfs where 65 cfs is provided by delivered San Juan Chama Project water and the other 65 cfs is native Rio Grande water that will be returned. Releases of Albuquerque's San Juan-Chama Project water are set to provide the 65 cfs with loss rates applied. The loss rate is based on the San Juan-Chama loss rate of 1.23 percent from Abiquiu Dam to Cochiti Lake and monthly loss rates from Cochiti Dam to the diversion. While the current preemptive cutoff criteria would prevent diversions from being curtailed or cutoff per permit restrictions, the permit restrictions are still checked with the rules.

Wastewater returns from Albuquerque are set as an input based on historical data and are not affected by a cutoff to the surface water diversions as actual wastewater returns are not dependent on whether surface water or groundwater is being used to provide drinking water. Assumed returns range from approximately 77.5 cfs to 83.4 cfs (slightly more than half the diversion).

2.3.2.3. Shorted Diversions

If MRGCD is in a shortage situation and the supply is inadequate to meet the demand for all Middle Rio Grande Project diversions, it is possible that full requested diversions would not be met. Under these circumstances (i.e. there is no water in storage for meeting irrigation demands and the river flow is less than the full demand at Cochiti Dam), "requested diversions" at the Middle Rio Grande Project diversions are set to the lower amounts that would be received. Shorting the diversions is a modeling approach needed to prevent supplemental water from being diverted that is specifically designated for meeting target flows for ESA. Key changes for the modeling for the PHVA work group included adjustments to the model policy where diversions are only shorted if there are no downstream targets. That is, during shortage situations, supplemental water could then be diverted if needed to meet the full requested diversion and there are no downstream targets. Edits also included adjustments needed with the Middle Valley Rework implemented to appropriately consider contributions from the Unit 7 Drain to the Socorro Main Canal when setting the potential shorted diversion at the San Acacia diversion.

2.3.2.4. Increased Angostura Diversions

Policy for setting diversions at the Angostura diversion were adjusted such that diversions are increased when MRGCD is in a shortage situation as indicated by no water in storage and river flow at Cochiti that is less than the full demand for the Middle Rio Grande Project diversions. Diversions are set higher at the Angostura Diversion to assure the six Middle Rio Grande Pueblos receive their water and allow for MRGCD to utilize the limited supply as efficiently as possible. At these times, diversions at Angostura are increased from the regular input diversion requested values to the total capacity of the canals of 400 cfs. The rule for setting shorted diversions was adjusted to appropriately consider times when diversions at Angostura might be increased. Also, model policy for setting the flow returned to the river at the Central wasteway versus the flow delivered down the Albuquerque drain was adjusted for when Angostura diversions are increased to assure all the flow is delivered down the Albuquerque drain at these

times (i.e. no flow is returned to the river via the Central wasteway during such shortage operations).

2.3.2.5. Reregulation for P&P at El Vado Reservoir

Policy for reregulation at El Vado Reservoir for P&P was reviewed. Edits were incorporated such that model policy matched actual implemented policy. Details of the needed model changes were documented by a consultant for the Bureau of Indian Affairs, Brian Westfall (2009), and all those documented changes were incorporated for the modeling for the PHVA work group and for BA preparation, except monthly demand values from 2003 were maintained in URGWOM per a PHVA work group decision at the work group meeting held on October 26, 2010 (PHVA work group, 2010).

Note that changes included additional adjustments made after Reclamation's DRAFT BA was distributed in 2011. Changes for the final model runs included adjustments to the approach for computing calls for releases from P&P storage to reference loss coefficients in URGWOM and usable flow factors equal to 1.0 (Different usable flow factors are used to compute the P&P storage requirement). In addition, storage at El Vado Reservoir to meet P&P storage requirements, regardless of the status of the stipulations of Article VII of the Compact, begins on January 5th up to a computed minimum P&P storage requirement. Storage for the P&P storage requirement continues as needed after the storage requirements are then computed beginning on March 1st with reference to a forecasted runoff volume. These last changes for the final model runs were implemented based on communication with the BIA and representatives from the six Middle Rio Grande Pueblos after the DRAFT BA was distributed. The monthly demand values from 2003 were still maintained for the final model runs for computing the storage requirement.

2.3.2.6. Article VIII of the Compact

For the modeling for the PHVA work group, URGWOM was set up to model El Vado Dam releases that would be made based on a call by Texas per Article VIII of the Compact which essentially states that Texas may call for a release, starting in January, of water in storage from post-Compact reservoirs to the amount of an accrued Compact debt to bring the usable storage up to 600,000 acre-ft (States of New Mexico, Colorado, and Texas, 1938). A threshold debt for when a call would actually be made is included in the model which was set to -20,000 acre-ft based on the assumption that Texas would not actually make a call until the debt accrued to exceed 20,000 acre-ft. El Vado Dam releases are set to a computed average rate to release the volume equal to the Compact debt over an input period defined as the Article VIII release season in the model (January 2nd through February 20th), but no release will be made if there is no Rio Grande water in storage.

2.4. Flow Tools

In preparation for modeling for the PHVA work group, flow tools to be analyzed as potential solutions to meeting flow needs for ESA purposes were defined and set up in URGWOM. Flow tools include actions that have been implemented as temporary actions in the past such as Cochiti deviations, relinquished Compact credits/storage of Emergency Drought water, Reclamation leases of San Juan-Chama Project water, and pumping from the LFCC to the river. Details of potential future operations were defined for modeling these actions. Other modeled flow tools include alternate delivery schedules for letter water deliveries to payback the Compact based on a timing that would benefit ESA needs and defined policy for conserving leased San Juan-Chama Project water during years with a wet runoff. Details of the flow tools as set up in the model and ruleset for the modeling for the PHVA work group are presented below.

2.4.1. Cochiti Deviations

Cochiti deviations are currently authorized through 2013 where the Corps may temporarily store native Rio Grande water to be released at the time of the runoff peak flow to further augment flows sufficiently to provide recruitment flows (or overbank flows) in the Middle Rio Grande (Corps, 2009). Specific criteria are coded in the URGWOM rules for identifying whether the runoff is sufficient to enact Cochiti deviations to provide recruitment flows (or overbank flows) but insufficient to provide the needed hydrograph by just bypassing inflows at Cochiti Reservoir. Operations entail providing overbank flows if conditions support providing the higher flows.

Within URGWOM, deviations are implemented to provide *recruitment* flows if the March through July flow forecast at Otowi is between 50% and 80% of average and the projected peak inflow to Cochiti Reservoir during the recruitment or overbank season is between 1,800 and 5,000 cfs or the March through July forecast is greater than 80% of average but the projected peak inflow is less than 3,500 cfs. The projected peak inflow to Cochiti is estimated during an URGWOM simulation based on input inflows. Deviations are implemented to provide *overbank* flows if the Otowi forecast is between 80% and 120% of average and the projected peak inflow to Cochiti is between 3,500 and 10,000 cfs or the Otowi forecast is between 50% and 80% of average but the projected peak inflow is greater than 5,000 cfs.

If deviations are implemented, model target flows at Central are reset to provide recruitment (or overbank) flows based on input 30-day target hydrographs that include 3,000 cfs for 7 days for recruitment (or 5,800 cfs for 5 days for overbank flows). An appropriate amount of allowable re-regulation at Cochiti Reservoir is then established in the model. Inflows for re-regulation are set daily to the inflow of native Rio Grande water not needed to meet downstream demands and re-regulation begins a set period before the time of the projected peak inflow such that water can stored and subsequently released to augment the peak inflow. Refer to Figure 2.4 for a flowchart that depicts the model policy for implementing Cochiti deviations. Water from re-regulation is released as needed for targets where the needed release at Cochiti Dam reflects the adjusted targets at Central to provide the recruitment (or overbank) flows. No supplemental water is released from Abiquiu Reservoir when Cochiti deviations are implemented.

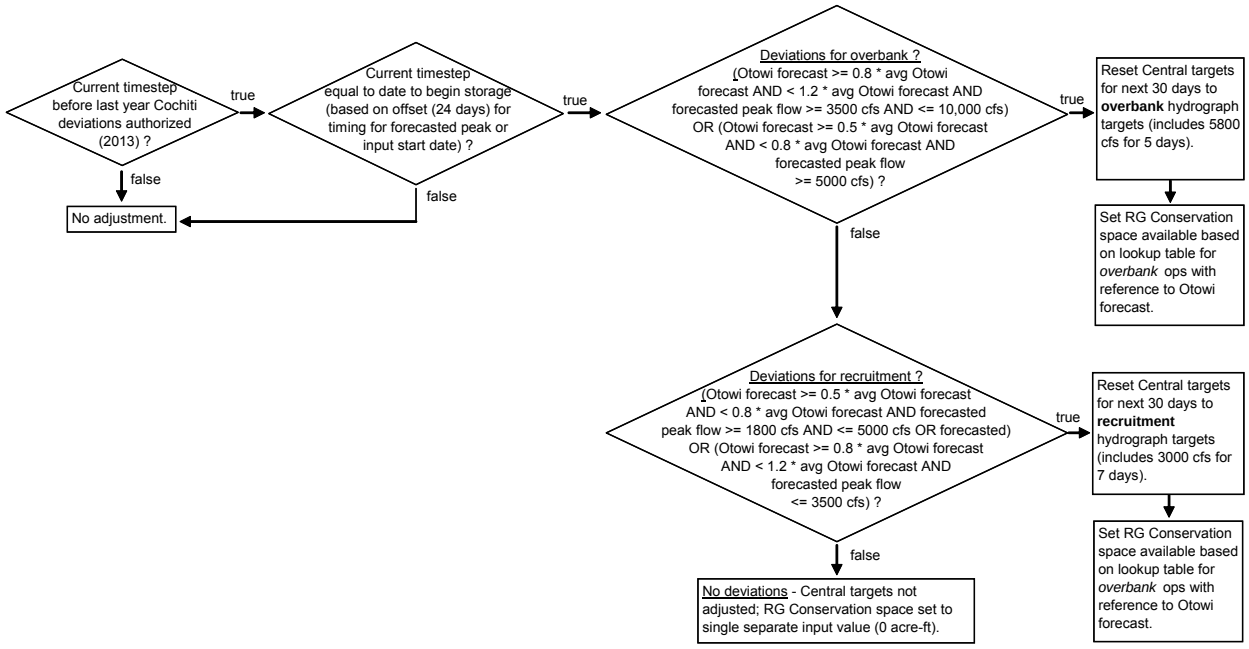

Figure 2.4. Flowchart for Implementing Cochiti Deviations

2.4.2. Relinquished Compact Credits/Storage of Emergency Drought Water

Agreements have been made in the past where Compact credits are relinquished and allocations are made for storage of native Rio Grande water at El Vado Reservoir as Emergency Drought water when stipulations of Article VII of the Compact are in effect. Policy is coded in the URGWOM ruleset to simulate potential future relinquished Compact credits and the subsequent storage of Emergency Drought water. The current model assumption is that Compact credits will be relinquished annually each year if the Compact credit at the beginning of the year exceeds 100,000 acre-ft to reduce the credit to 70,000 acre-ft. Allocations for subsequent storage of Emergency Drought water at El Vado Reservoir are set to 1/3 of the relinquished credit for each of three purposes: MRGCD, ESA, and municipalities. Initial allocations for storage of Emergency Drought water, from past relinquished credits, can also be input. Allocations are tracked for the three separate purposes where any water in storage for the corresponding account contributes to the allocation. When water is released from a storage account established for one of the three purposes, the allocation has been used and is reduced.

Inflows of native Rio Grande water to El Vado Reservoir when Article VII is in effect are stored to separate accounts for Emergency Drought water after any storage requirement for P&P needs is met first. Storage accumulates in the Emergency Drought accounts with the actual inflow of native Rio Grande water. Available inflows of native Rio Grande water for Emergency Drought storage are split between the MRGCDDrought and SupplementalESA accounts based on the ratio of available allocation for the accounts. An allocation for storage of Emergency Drought water for municipalities is tracked but is not used since exact policy for how such water would be used by municipalities has not been defined.

Water for MRGCD is tracked in an MRGCDDrought account at El Vado reservoir and is used to meet the MRGCD demand when native Rio Grande water is no longer available to meet the

MRGCD demand at Cochiti but before any of MRGCD's San Juan-Chama Project water would be used. Emergency Drought water for meeting targets is tracked in the SupplementalESA account at El Vado Reservoir and is used to meet targets before leased San Juan-Chama Project water in the Reclamation account at Abiquiu is used. A specific season for using SupplementalESA water can be defined; however, the entire calendar year was designated for all model runs completed for the PHVA work group.

Within URGWOM, releases from the SupplementalESA account are effectively bypassed through Reclamation's account at Abiquiu (Water is first released from the Reclamation account to meet targets and water in the SupplementalESA account is released to replenish the storage in the Reclamation account if SupplementalESA water is available); thus, Emergency Drought water is effectively used first before available leased San Juan-Chama Project water. Note that Compact calculations are appropriately configured in URGWOM to not count Emergency Drought water that passes through Abiquiu Reservoir as San Juan-Chama Project water.

2.4.3. Reclamation Leases

Supplemental water is defined as water designated to be released to meet target flows in the Middle Rio Grande and may come from two sources: water leased by Reclamation from contractors for San Juan-Chama Project water or native Rio Grande water stored as Emergency Drought water at El Vado specifically to be used for targets (Refer to section 2.4.2 for more details on Emergency Drought water). Leases of San Juan-Chama Project water by Reclamation from contractors are represented in URGWOM as transfers at Heron Reservoir from the account storage for the source contractor to Reclamation's account.

For the final model runs completed for the PHVA work group, leases are represented as 12,000 acre-ft/year for the first five years and 8,000 acre-ft/year for the following five years of simulation from the Combined account which represents all contractors for San Juan-Chama Project water other than MRGCD, ABCWUA, and the Cochiti Rec Pool. These lease volumes reflect estimated future leases where it is anticipated that less water will be available after five years as contractors continue to develop water uses. Leased water transferred at Heron Reservoir is moved to 30,000 acre-ft of allocated space at Abiquiu Reservoir for supplemental water as space becomes available.

2.4.3.1. Conservation of Lease Water at Threshold Year-to-Date Otowi Flow Volume

A related side flow tool defined by the PHVA work group entails conserving leased San Juan-Chama Project water after the year-to-date Otowi flow volume reaches 1,000,000 acre-ft. This approach represents a policy of conserving lease water after a wet runoff to increase the chances of having supplemental water during more potential dire situations in future years. The policy also represents one approach for prioritizing the use of available supplemental water where the represented priority is effectively to use supplemental water earlier in the year and also bank supplemental water during wetter years to have for the early part of subsequent years by not using supplemental water during the summer following wetter runoffs. Note that the policy does not affect the use of Emergency Drought water allocated for ESA purposes. Any available Emergency Drought water for ESA is always used as needed to meet targets.

2.4.4. Low Flow Conveyance Channel Pumping

URGWOM was set up to model pumping of flows from the LFCC to the river to manage recession and ameliorate and/or prevent river drying. Refer to Figure 2.5 for a picture of pumps used to pump from the LFCC. Diversions at the Neil Cupp site, North Boundary of the Bosque del Apache National Wildlife Refuge, and South Boundary are simulated (Pumping at the Fort Craig site was determined by the PHVA work group to be inconsequential to URGWOM simulation results and is not included). Water that seeps into the LFCC is pumped to the river where pumping begins based on different trigger low flows at San Acacia for each site (130, 100, and 80 cfs, respectively), and the rate of pumping varies based on the year classification under the 2003 Biological Opinion (2003 BO). After pumping has initiated at a site, pumping will continue for a minimum of one week and until the flow at San Acacia has exceeded 150 cfs. Pumping will cease for the year at each site after input dates for each site. For the final model runs completed for the PHVA work group, pumping at each site was set to end for the year on July 15th to effectively represent using the pumps to manage the recession after the continuous flow requirement and/or after the runoff but no later. Minimum bypasses in the LFCC are established at each pump site to reflect the actual constraint of only being able to pump the available water above a minimum LFCC flow: 10 cfs at the Neil Cupp and North Boundary sites and 5 cfs at the South Boundary site.

Figure 2.5. Low Flow Conveyance Channel Pumps

2.4.5. Alternate Letter Water Delivery Schedules

A flow tool defined by the PHVA work group entails using alternate schedules for letter water deliveries, if specific conditions are satisfied, for the portion of deliveries to payback the Compact. The alternate delivery schedules represent using the paybacks to augment flows needed for targets, augment flows for recruitment, to prevent river drying, or to help manage the recession after the continuous flow requirement or after the runoff.

The approach coded into URGWOM for the PHVA work group entails using letter water deliveries from ABCWUA to payback the Compact by providing a 7-day spiked release at the timing of the peak (Figure 2.6) if Cochiti deviations are not implemented and the Compact credit is greater than 70,000 acre-ft. As a second but lower priority alternate schedule, ABCWUA letter water deliveries to payback the Compact would occur during September and October as

opposed to November and December if the Compact credit is greater than 70,000 acre-ft and the flow at San Acacia is greater than 150 cfs for the last seven days of August (Figure 2.7). Flows for the first alternate delivery to provide a spiked release is computed in the model. Each year, conditions are evaluated to determine if an alternate delivery schedule should be simulated. The typical delivery schedule for ABCWUA is presented in Figure 2.8

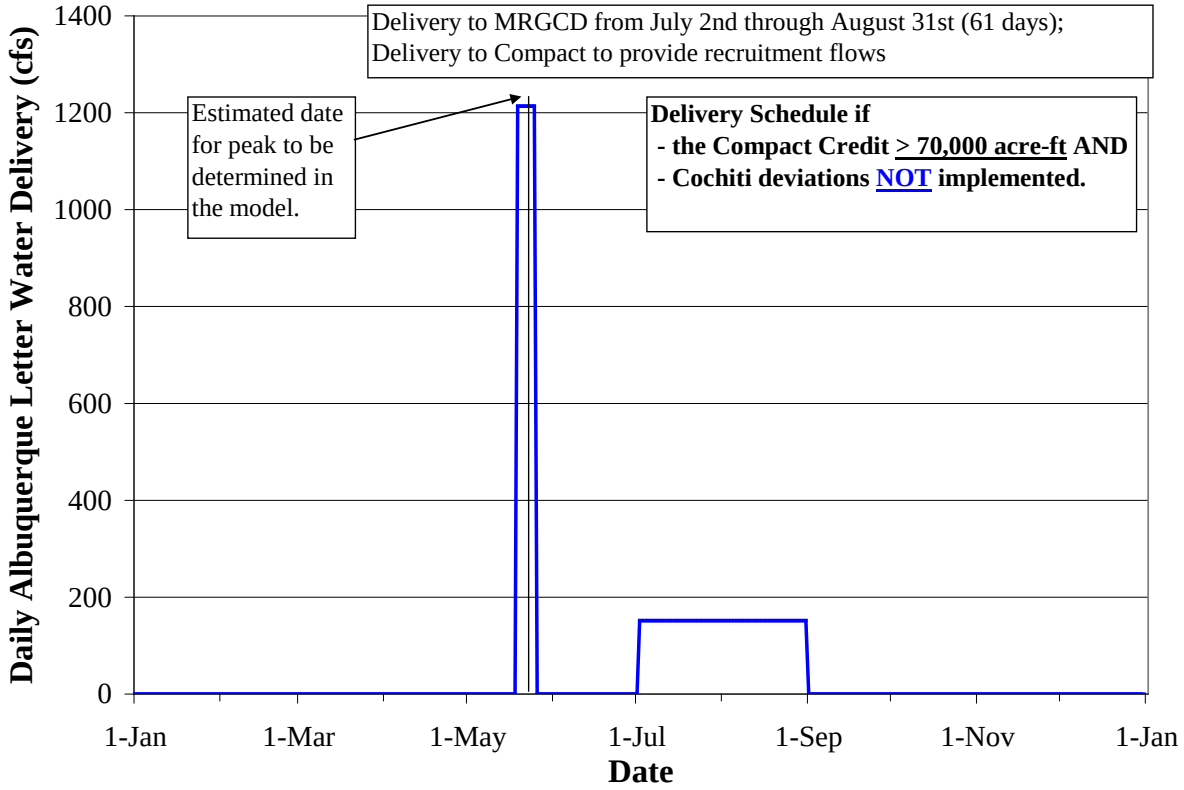

Figure 2.6. Sample *Alternate* Schedule for ABCWUA Letter Water Deliveries to Provide Spiked Release

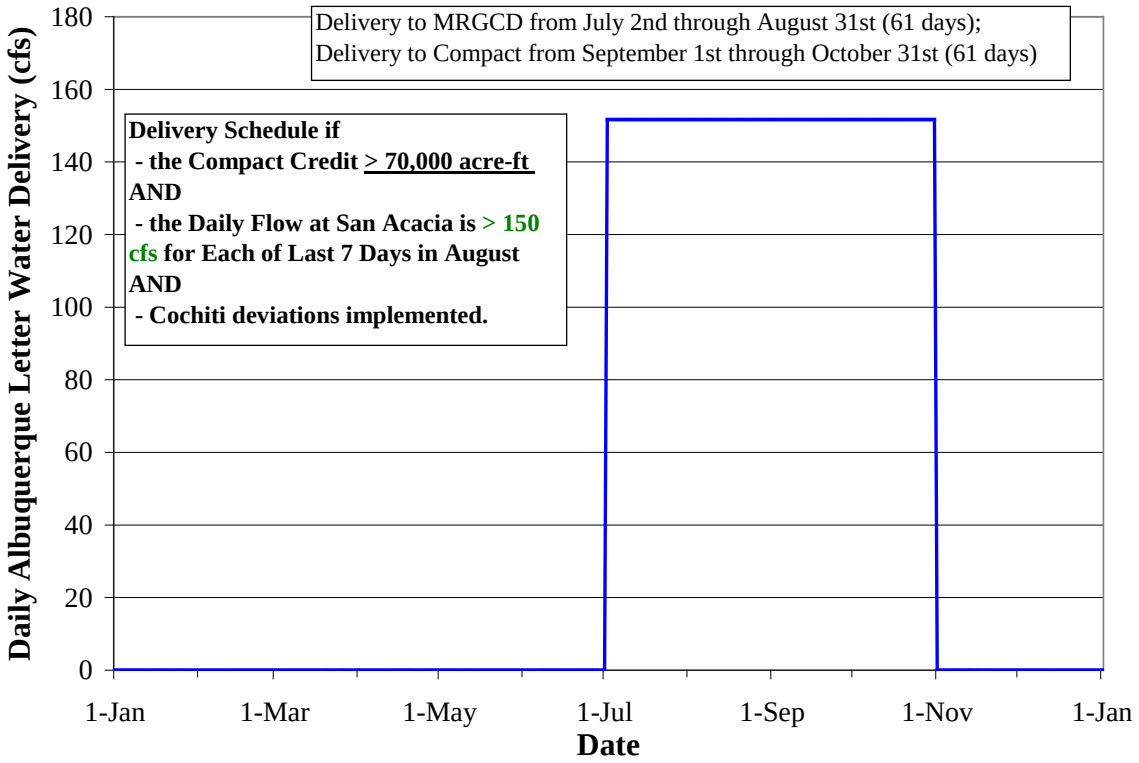

Figure 2.7. Sample *Alternate* Schedule for ABCWUA Letter Water Deliveries

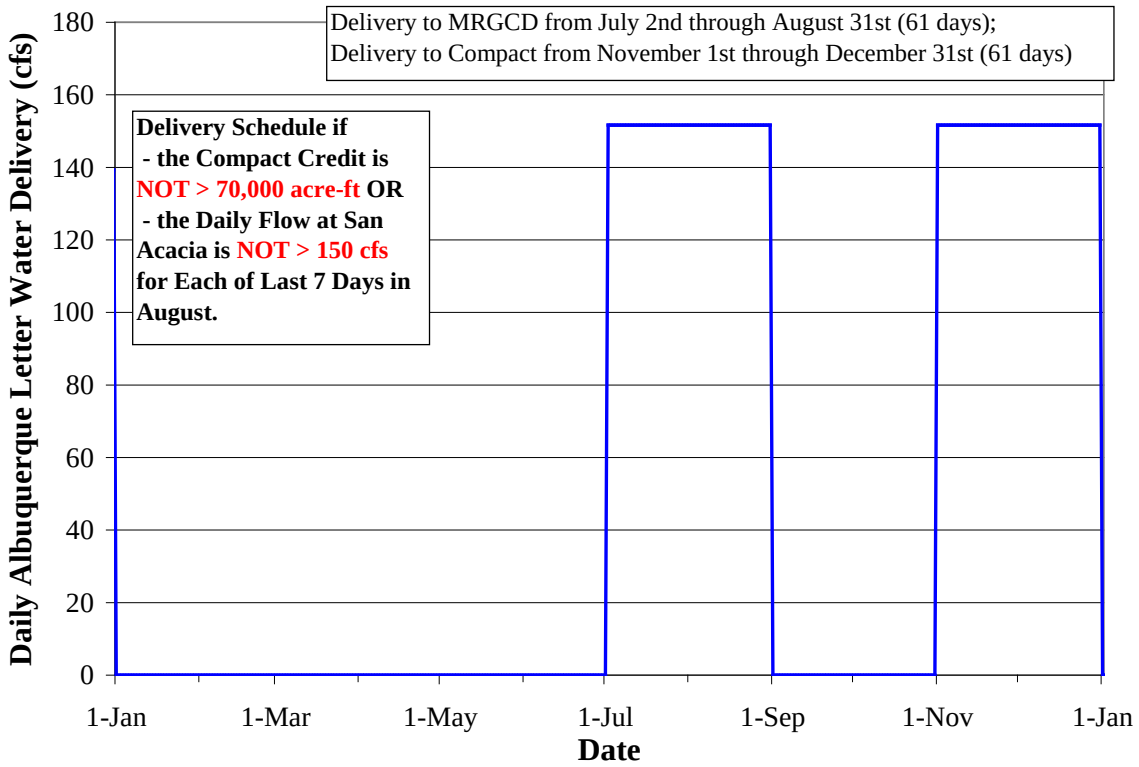

Figure 2.8. Sample Typical Schedule for ABCWUA Letter Water Deliveries

Alternate letter water delivery schedules for the Combined account entail the following. Deliveries for Santa Fe and half of the amount for other contractors not including PVID will be delivered at an alternate time if the Compact credit is greater than 70,000 acre-ft. That portion will be delivered in a 7-day spike around the peak (Figure 2.9) if Cochiti deviations are not implemented or as a constant release from June 15th through June 30th to help manage recession if the Compact credit is greater than 70,000 acre-ft but Cochiti deviations are implemented. The second alternative is presented in Figure 2.10. The typical delivery schedule for the Combined account is presented in Figure 2.11.

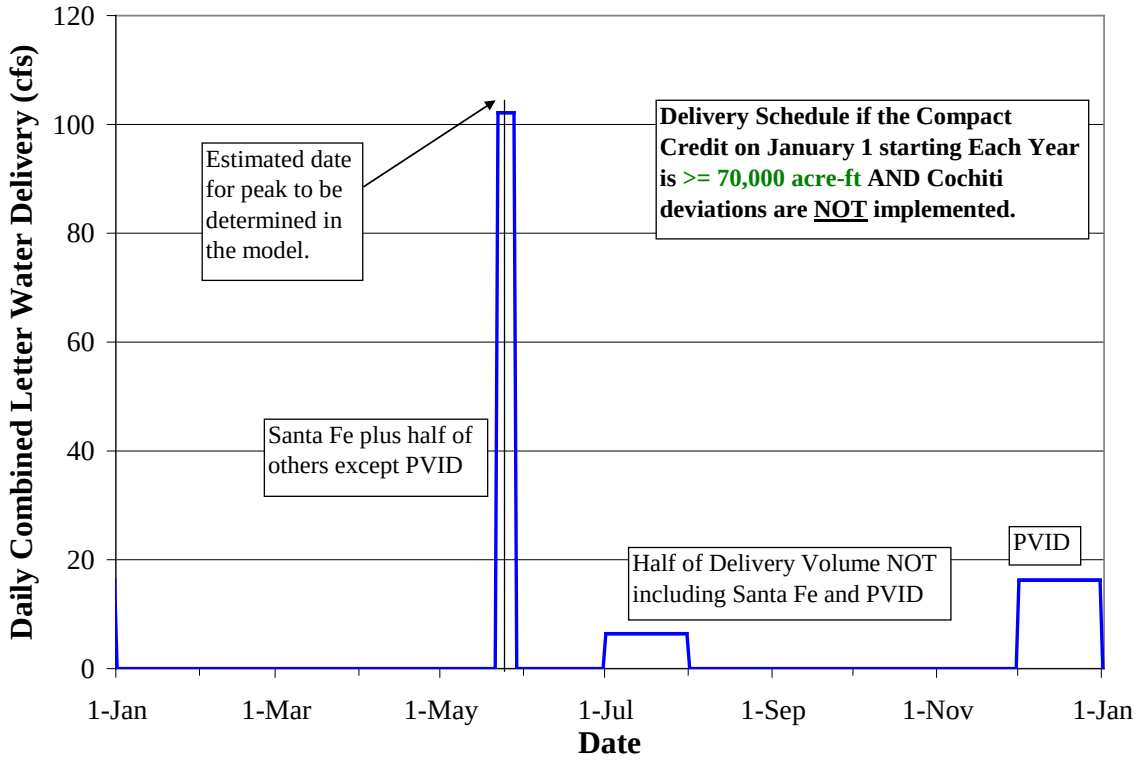

Figure 2.9. Sample *Alternate* Schedule for Combined Account Letter Water Deliveries to Provide Spiked Release

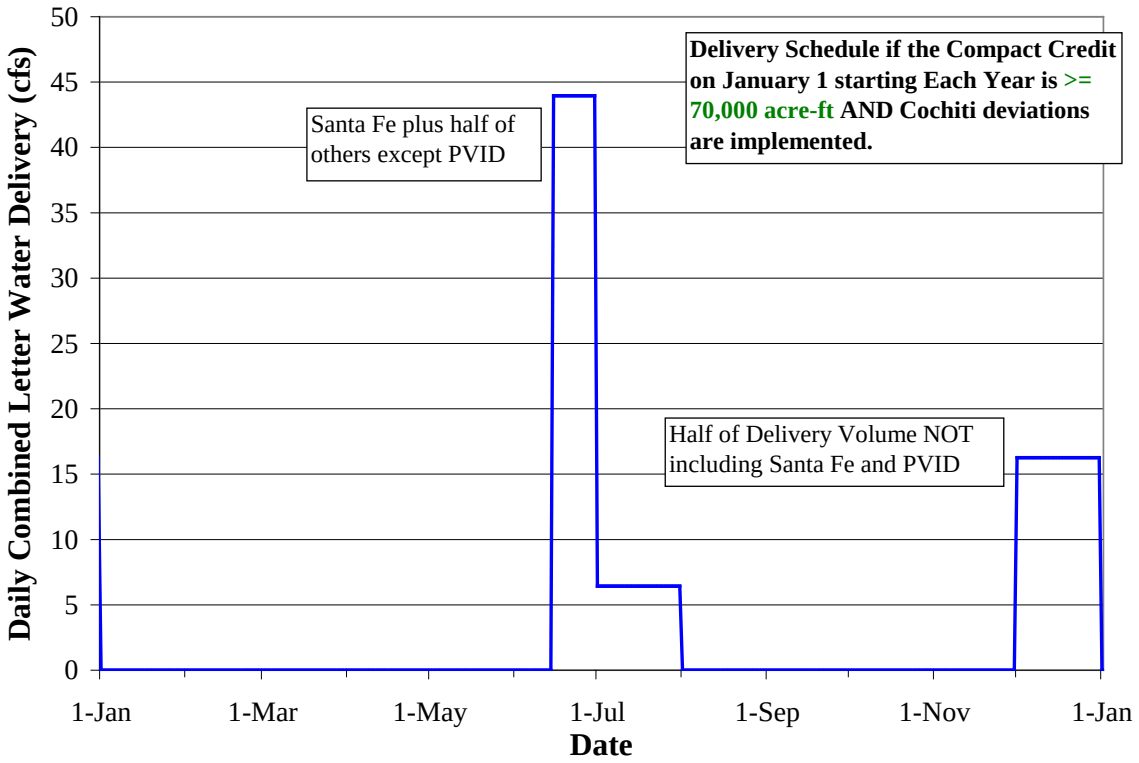

Figure 2.10. Sample *Alternate* Schedule for Combined Account Letter Water Deliveries

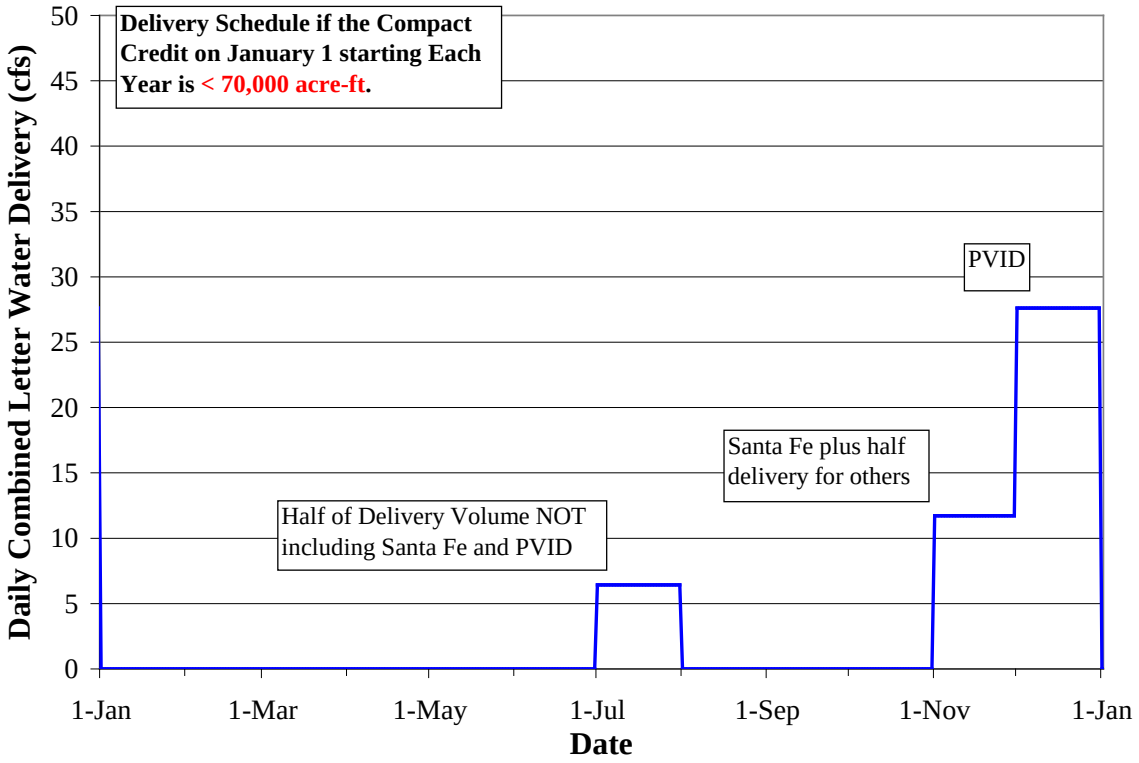

Figure 2.11. Sample Typical Schedule for Combined Account Letter Water Deliveries

2.5. Policy for Use of Supplemental Water

The model approach for representing the release of supplemental water from Abiquiu Dam was reviewed in detail prior to completing the final simulations. Supplemental water consists of Reclamation leases of San Juan-Chama Project water and any Emergency Drought water allocated for ESA purposes. The model is set up to simulate the use of supplemental water to meet flow requirement per the 2003 BO (Service, 2003) which consists of different flow requirements based on the year classification (i.e. wet, average, or dry). Within URGWOM, years are classified as Wet, Average, or Dry based on the forecasted March through July flow volume at Otowi relative to an average flow volume for the same period. A year will automatically be classified as Dry if storage restrictions per Article VII of the Rio Grande Compact are in effect (States of New Mexico, Colorado, and Texas, 1938). The year classification as of May 1st is maintained for the remainder of the year in URGWOM. Needs for supplemental water are represented in the model using target flows at four locations: Central, below the Isleta Diversion Dam (herein after referred to as Isleta), at the location of the USGS gage Rio Grande Floodway at San Acacia, NM (ID# 08354900) (hereinafter referred to as San Acacia), and San Marcial. Refer to Table 2.1 for the 2003 BO targets as represented in URGWOM. A target in the table is maintained until the next date in the table and note that targets are used to represent the continuous flow requirement (the darker shaded cells) and step downs in targets (the lighter shaded cells) are used to represent the use of supplemental water to manage the recession after the continuous flow requirement.

Table 2.1. 2003 BO Targets at Middle Rio Grande Locations for Different Year Classifications

	Central			Isleta			San Acacia			San Marcial		
Date	**Dry**	**Avg**	**Wet**	**Dry**	**Avg**	**Wet**	**Dry**	**Avg**	**Wet**	**Dry**	**Avg**	**Wet**
Jan 1	100	100	100	100	100	150	175	175	175	10	10	100
June 10	100	100	100	50	100	150	100	100	100	10	10	50
June 14	100	100	100	40	100	150	80	90	100	8	8	40
June 18	100	100	100	30	100	150	60	80	100	6	6	30
June 22	100	100	100	20	100	150	40	70	100	4	4	20
June 26	100	100	100	10	100	150	20	60	100	2	2	10
June 30	100	100	100	0	100	150	0	50	100	0	0	0
Nov 15	100	100	100	100	100	150	175	175	175	10	10	100

Values with darker shading represent targets for the continuous flow requirement.
Values with lighter shading represent targets to manage the recession after the continuous flow requirement.

Target flows are used in the model to represent discretionary operations where supplemental water is used to manage the recession after the runoff and to also control the rate of drying after any river rewetting (river drying is restricted to no more than eight additional miles per day per the 2003 BO). A 30-day step down in targets at Isleta, San Acacia, and San Marcial may be implemented at the end of the runoff to manage the recession, and seven-day step downs in target flows may be instituted for the same three locations with the onset of river drying following any river rewetting to represent the use of supplemental water to control the rate of drying. Trigger river flows are used to indicate when step downs need to be established and model inputs are also set up for establishing the step down in target flows and the number of steps.

Refer to Figure 2.12 for a sample plot of flows at San Acacia (zoomed in to a low flow range) and step downs in the San Acacia targets – after the continuous flow requirement – followed by a 30-day step down to manage the recession after the runoff followed by 7-day step downs in targets to drive the use of supplemental water to control the rate of drying after any river rewetting. Target flows may not be met if there is not supplemental water available during the simulation to meet the targets. Within URGWOM, triggers are set up to allow for both the 30-day step downs to manage the recession or the 7-day step downs in targets for controlling the rate of river drying to be turned on or off independently. Note that both policies were modeled for Reclamation's DRAFT BA distributed in 2011, but only the 30-day step down to manage the recession was included as part of the Proposed Action model runs for the final simulations.

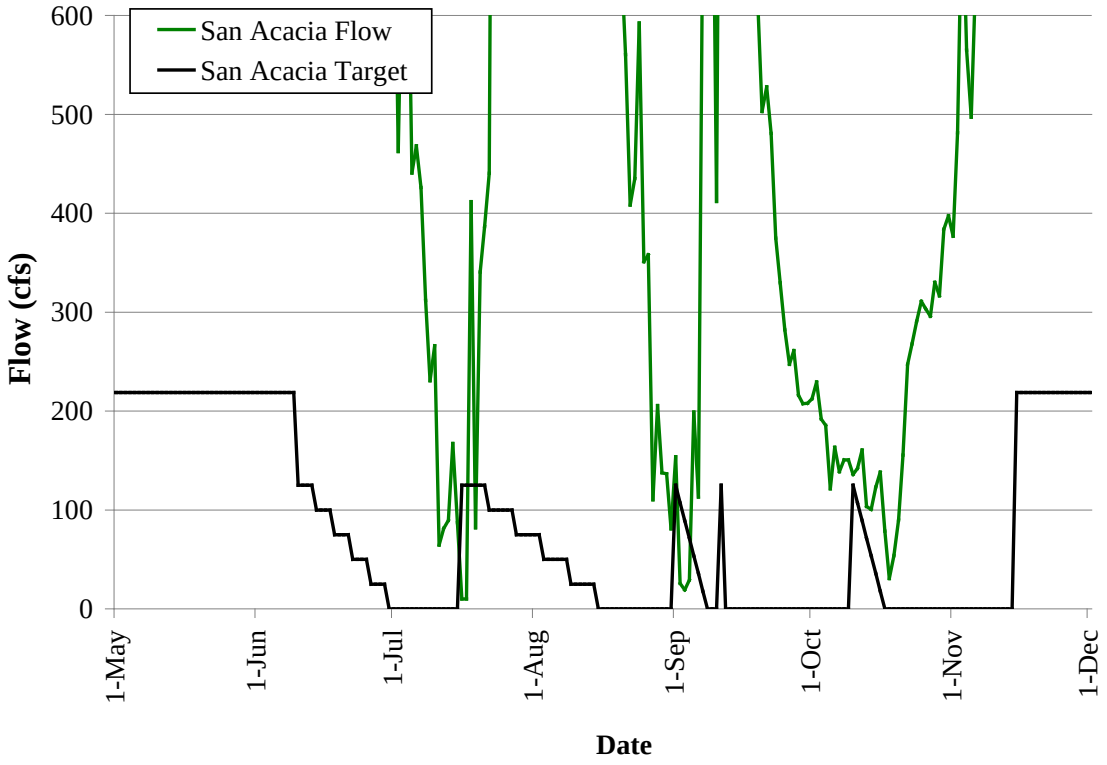

Figure 2.12. Sample Plot of Step Downs in Target Flows at San Acacia

The review of the modeled use of supplemental water included a review of supplemental water used in a rulebased simulation with the 2003 BO targets and the 2003 through 2006 hydrology versus actual supplemental water used during the same historical years. This analysis indicated that the model represents the use of supplemental water at a much higher precision than can be attained in actual operations due to the travel time from Abiquiu Dam to target locations (which may exceed four days to San Marcial), physical operational constraints at the dams, and several uncertainties about conditions in actual operations that can significantly affect river flows such as varying MRGCD wasteway returns, monsoon season tributary inflows, and varying loss rates to evaporation and riparian ET. The review of modeled supplemental water use versus historical supplemental water use for 2003 through 2006 indicated that applying an adjustment factor of 25% yields a more accurate representation of the annual volumes of supplemental water that would be needed under actual operations (i.e. for a defined target of 100 cfs, a target of 125 cfs is

used in the model to reflect the additional supplemental water really needed due to the various actual constraints and uncertainties in actual operations).

The model is used to determine the amount of supplemental water needed to meet targets based on all the conveyance losses and physical processes in the system. Actual historical operations have entailed agreements between Reclamation and MRGCD for providing certain flows below a major diversion in return for releases of supplemental water from Abiquiu Reservoir. While such agreements may be developed with accurate consideration of the physical conveyance losses from Abiquiu Dam to the diversion location, such agreements are not directly modeled in URGWOM.

3.0. Description of Water Management Scenarios

Modeling for the PHVA work group was completed in separate phases as exact needs for modeling evolved. Work to identify an appropriate Proposed Action for BA preparation started with a full list of potential operational scenarios to provide different flow conditions in habitat for listed species. A qualitative review of the scenarios was completed and the list was pared down to 11 scenarios for screening to develop a reasonable list for analysis given the resources required to complete model runs and analyze results. Some initial options were identified as impractical such as operating for target flows at San Acacia without targets at Isleta, and other scenarios were deemed too similar to other scenarios to warrant separate analysis.

After modeling the 11 scenarios, a best scenario was identified but dismissed by the Service during a meeting of the Executive Committee of the Collaborative Program. Focus then shifted to evaluating conditions with no actions taken for listed species to represent a Pre-ESA Management scenario that would be used for a non-front loaded BA but further review led to a final Proposed Action in Reclamation's BA that includes Reclamation's Supplemental Water Program that includes leases of San Juan-Chama Project water and pumping from the LFCC. Details of the different water management scenarios modeled through the PHVA work group activities leading to the final simulations are discussed in more detail below.

3.1. Initial Water Management Scenarios

Initial work by the PHVA work group entailed developing numerous scenarios for analysis that were defined primarily by different target flows at different locations in the Middle Rio Grande where the timing along with the location of targets reflect an area of focus for the scenario in regards to managing for the Albuquerque (Angostura to Isleta), Isleta (Isleta to San Acacia), and/or San Acacia (San Acacia to San Marcial) reaches. The original list of scenarios was pared down to 11 options for screening based on an initial qualitative evaluation completed by Collaborative Program representatives at a PHVA work group meeting. Names for the 11 scenarios and defined targets are noted below:

1. BO Targets,
2. Dry Year Targets,
3. BO Targets with no continuous flow requirement,
4. New Targets A – 2003 BO targets with an adjustment to 100 cfs year round target at Isleta and San Acacia in average and wet years,

5. New Targets B – 2003 BO targets with an adjustment to 100 cfs year round target at Isleta and 50 cfs year round target at San Acacia in average and wet years,
6. New Targets C – 2003 BO targets with an adjustment to 50 cfs year round target at Isleta and San Acacia in average and wet years,
7. Flow Target Management A – 100 cfs year round target at Central, Isleta, and San Acacia – no San Marcial target,
8. Flow Target Management B – 100 cfs year round target at Central and Isleta and 50 cfs year round target at San Acacia – no San Marcial target,
9. Flow Target Management C – 100 cfs year round target at Central and 50 cfs year round target at Isleta and San Acacia – no San Marcial target,
10. Albuquerque-Isleta Management A – 100 cfs year round target at Central and Isleta – no San Acacia or San Marcial targets, and
11. Albuquerque-Isleta Management B – 100 cfs year round target at Central and 50 cfs year round target at Isleta – no San Acacia or San Marcial target.

Modeling was then completed for the 11 potential operational scenarios and results for various key indicators were evaluated. The list was then reduced to five scenarios for further screening based on results for the timing and extent of expected river drying under a scenario and the supplemental water needed to meet the targets given the projected available supply of supplemental water. The ability to bank supplemental water under a scenario to be available for dire situations was also considered. The next round of screening of the five remaining scenarios was completed using an approach where "elements", or issues of concern, were evaluated for each scenario based on the results from the URGWOM runs. Considerations included May-June flow volumes, miles and duration of river drying, supplemental water needed, and deficits at meeting targets with projected available supplemental water. Weightings were given to the importance of different elements, and overall ratings were developed and the scenarios were ranked. The process led to selection of the Albuquerque-Isleta Management B scenario as the best operational scenario which is defined based on using available supplemental water to specifically manage the Albuquerque and Isleta reaches, but this scenario was dismissed by the Service at a meeting of the Executive Committee of the Collaborative Program.

3.2. Pre-ESA Management Scenario

After results from the screening process were dismissed, focus of the PHVA work group's efforts shifted to analyzing a Pre-ESA Management scenario for preparing a non-front loaded BA. The Pre-ESA Management scenario reflects river conditions if operations matched current operations but with no considerations for ESA implemented in regards to flow requirements. URGWOM runs were completed using all the infrastructure and physical aspects of the system modeled as is and with no targets in the Middle Valley. No PHVA flow tools were included, except for Cochiti deviations simulated for the first three years of the simulation per the authorized of the operation through 2013. The PHVA work group worked on a model run for the Pre-ESA Management scenario, but the focus later shifted to the final Proposed Action for Reclamation's BA that includes the 2003 BO Targets met as possible with just Reclamation's flow tools (or Reclamation's Supplemental Water Program).

3.3. Final Water Management Scenario for Proposed Action

Final model runs were completed to represent the Proposed Action in Reclamation's BA that entails meeting the 2003 BO targets as possible with supplemental water available from

Reclamation's Supplemental Water Program that includes the projected leases of San Juan-Chama Project water and LFCC pumping. With recent developments to infrastructure, including the ABCWUA drinking-water diversion project and Santa Fe's Buckman diversion, the availability of San Juan-Chama Project water for lease to Reclamation's Supplemental Water Program is expected to decline. Total lease volumes are anticipated to drop to approximately 12,000 acre-ft/year for the next five years and 8,000 acre-ft/year for the following five years.

The Proposed Action entails using the available supply of supplemental water to meet the 2003 BO targets as possible. Resulting conditions in the river will be based on using the available supply *immediately* as needed to meet the 2003 BO with requirements. There is no established priority in regards to which flow requirements have priority under the conditions of a limited supply of supplemental water. When supplemental water is gone, target flows may not be met. Targets are included with the Proposed Action to represent the use of supplemental water under discretionary operations to manage the recession after the continuous flow requirement (or after the runoff) and also to control the rate of drying after any river rewetting as discussed in section 2.5. These actions support Rio Grande silvery minnow salvage operations.

The Proposed Action includes pumping from the LFCC to the river in the San Acacia reach. Pumps have been installed at sites along the LFCC to pump to the river the water that has accumulated in the LFCC from groundwater seepage. This operation includes pumping at the Neil Cupp, North Boundary, and South Boundary sites at which Reclamation performs pumping to help manage the recession and control the rate of the drying after the continuous flow requirement or after the runoff. Pumping is conducted at all sites to manage the recession after the continuous flow requirement or after the runoff, but no pumping is included later in the summer under the Proposed Action.

3.4. Model Scenarios for Evaluating Impacts of Reclamation Actions and Non-Fed Actions

As needed for BA preparation, URGWOM simulations were completed to evaluate impacts of Reclamation's water operations actions (Heron Dam operations for the San Juan-Chama Project along with the Supplemental Water Program and Middle Rio Grande Project operations) and non-Federal actions (including operations of the Middle Rio Grande Project diversion structures to provide flows to MRGCD and the six Middle Rio Grande Pueblos). Impacts were analyzed by utilizing model runs set up for the Proposed Action and sequentially turning off each action. Each action is described below.

3.4.1. Heron Dam Ops for the San Juan-Chama Project and the Supplemental Water Program

The San Juan-Chama Project involves the trans-mountain diversion to the Rio Grande basin of a portion of New Mexico's allocation under the Upper Colorado River Basin Compact. Water is diverted from tributaries of the San Juan River, and delivered beneath the continental divide by way of the Azotea Tunnel to Willow Creek, then to the Rio Grande via Heron Reservoir and the Rio Chama. Reclamation maintains this water in a Project pool at Heron Reservoir and allocates it to contractors each year.

Water at Heron Reservoir that is allocated to contractors and subsequent deliveries out of Heron Reservoir are tracked with a daily accounting model. All inflows to Heron Reservoir that are native to the basin are bypassed and are not included with San Juan-Chama accounting. Water allocated to MRGCD is released from Heron Dam to El Vado Reservoir each year as space is

available in El Vado Reservoir and is then used as needed to meet MRGCD's daily demand. Water allocated to ABCWUA is released from Heron Dam to Abiquiu Reservoir, depending on available space in Abiquiu, and is delivered to ABCWUA's surface-water diversion structure in Albuquerque or is released as letter water deliveries to offset depletions to surface water supplies caused by groundwater pumping, as assessed by the Office of the State Engineer. Water allocated to other contractors may also be released from Heron Dam to offset depletions or may be released for storage in available storage space at El Vado and/or Abiquiu Reservoir. In the near future, water allocated to Santa Fe will be released from Heron Dam to provide water to Santa Fe's Buckman Direct Diversion. San Juan-Chama Project water used to offset evaporation losses from the recreation pool maintained at Cochiti Lake may be partially released from Heron Dam during the first part of July but is generally released from Heron Dam in the late fall and winter.

Allocated San Juan-Chama Project water to contractors may be maintained in storage at Heron Reservoir until the end of the calendar year. Under normal operations, any contractor water remaining in Heron Reservoir on December 31st is reverted back to the Project pool; although, Reclamation may issue waivers to allow contractors to continue storing allocated water until September 30th of the year following the year that the water was allocated if there is a benefit to Reclamation. Historically, contractors have utilized waivers and leased their allocated water to Reclamation's Supplemental Water Program; however, the supplies available for lease are projected to decline as planned water uses by contractors, including ABCWUA and Santa Fe drinking-water diversions, come on-line.

URGWOM runs were completed to evaluate the impacts of Reclamation's operations to provide water to San Juan-Chama contractors from Heron Dam, which constitute Reclamation's discretionary actions under the San Juan-Chama Project. These model runs specify no trans-basin diversions from the San Juan basin, no new allocations of San Juan-Chama Project water to contractors, and no releases of San Juan-Chama Project Water from Heron Dam. Without these operations, MRGCD would not have additional supplies from annual allocations of San Juan-Chama Project water, and ABCWUA would not have supplies for its drinking-water diversion project. No deliveries would be made to offset losses from a Cochiti Recreation Pool, and there would be no letter water deliveries to offset impacts of groundwater pumping.

For the analysis of the impacts of Heron Dam operations, any San Juan-Chama Project water for MRGCD, ABCWUA, and other contractors already in storage at El Vado and Abiquiu Reservoirs as an initial condition is used to meet standard demands, but no new San Juan-Chama Project water is available once these supplies are depleted. All San Juan-Chama Project water initially in Heron Reservoir is retained and gradually evaporates. Supplemental Water available under initial conditions is used to meet targets for the 2003 BO as long as the supply lasts, but no additional San Juan-Chama Project water is made available for lease to the Supplemental Water Program; therefore, under these model runs, Middle Rio Grande flow targets are not always met after the initial supply is used. A list of aspects of project operations turned off to evaluate the impact of Heron Dam operations for the San Juan-Chama Project is presented in the column labeled "El Vado Ops and MRGCD Divs (no SJC Project Ops or Supplemental Water Program) No SJC Ops" in Table 3.1.

Reclamation maintains a Supplemental Water Program composed of contractor San Juan-Chama Project water leased annually from contractors and LFCC pumping for meeting the 2003 BO flow requirements. Impacts of Reclamation's Supplemental Water Program were evaluated

separately by comparing resulting river flows at Middle Rio Grande locations from simulations completed for the Proposed Action with the Supplemental Water Program to model runs completed for the Proposed Action without the Supplemental Water Program included but all other aspects of operations the same. This approach allowed for the specific impacts of the Supplemental Water Program to be isolated.

3.4.2. El Vado Dam Operations

El Vado Reservoir is used to store water native to the Rio Grande basin for later use to meet Middle Rio Grande Project irrigation demands. Storage in El Vado Reservoir may occur if native flows are available on the Rio Chama and restrictions to storage are not in place per Article VII of the Rio Grande Compact. Under normal reservoir operations, water is typically stored during the descending limb of the spring snowmelt runoff hydrograph to assure that releases can be restricted and do not exceed the downstream channel capacity. A limited amount of water will be stored each year regardless of Article VII restrictions to assure that water can be provided to meet the demand for the six Middle Rio Grande Pueblos, which is tracked separately with a daily accounting model and released as needed to specifically meet the demand for the Pueblos. Other native water in storage is released as needed to meet the MRGCD demand when available flows in the Middle Rio Grande from the mainstem of the river and tributary inflows are insufficient. The extent of Reclamation's discretion in the operation of the Middle Rio Grande Project is the storage and release of water from El Vado Reservoir. Diversion of the released water, as well as San Juan-Chama water or native water from the mainstem of the Rio Grande, is under the control of the MRGCD.

Impacts of El Vado Dam operations were evaluated using URGWOM runs for which the following actions are shut off:

- Heron Dam operations for the San Juan-Chama Project (as discussed in the section 3.4.2), and
- Storage of native Rio Grande water in El Vado Reservoir.

All inflows of native Rio Grande water are bypassed, and there is no storage of San-Juan Chama Project water for use by MRGCD water-right's holders when native Rio Grande flows drop below demand. MRGCD would only have any native and San Juan-Chama Project water present in El Vado Reservoir under initial conditions. Note that Reclamation could not operate El Vado Dam to assure that channel capacities in the reach of the Rio Chama below El Vado Dam are not exceeded; however, operations at Abiquiu Reservoir to prevent exceedence of channel capacities below Abiquiu Dam would still be included in these runs.

Since the Supplemental Water Program is not included and Heron Dam operations under the San Juan-Chama Project are also not included, there are no new Reclamation leases. Also, ABCWUA has no new San Juan-Chama Project water available to use for letter water deliveries or drinking-water project diversions. Impacts of El Vado Dam operations are indicated by a comparison between these model runs and model runs in which the Supplemental Water Program and Heron Dam operations for the San Juan-Chama Project are shut off. A list of aspects of project operations turned off to evaluate the impact of Middle Rio Grande Project operations is presented in the next to the last column in Table 3.1.

3.4.3. Middle Rio Grande Project Diversions

Water is diverted at Cochiti Dam and diversion structures at Angostura, Isleta, and San Acacia for irrigation of lands for MRGCD and the six Middle Rio Grande Pueblos, generally from March 1st through October 31st. Irrigation demand is highest during the months of June and September and may be high in July and August if there are not significant rainfall contributions from monsoon season storm events.

Impacts of Middle Rio Grande Project diversions were evaluated by completing URGWOM runs with no diversions. No native Rio Grande water is stored at El Vado Reservoir and released to meet the irrigation demand. Also, no Heron Dam operations are included for the San Juan-Chama Project; thus, no new MRGCD San Juan-Chama Project water is available in storage at El Vado Reservoir. Refer to the last column in Table 3.1 for a list of aspects of operations that are included for these model runs. Impacts of the diversions are indicated by differences in these model runs versus the model runs with diversions but no El Vado Dam operations, no Heron Dam operations for the San Juan-Chama Project, and no Supplemental Water Program.

Table 3.1. List of Operations Included for "Action by Action" Effects Analysis for Reclamation's BA

#	Operation	Current Ops (*not modeled - actual data referenced*)	Proposed Action (*with actual and unlimited supply of supplemental water*)	Proposed Action (SJC Ops, El Vado Ops, and MRGCD Divs) with No Supplemental Water Program	El Vado Ops and MRGCD Divs (no SJC Project Ops or Supplemental Water Program)	MRGCD Divs only	No Actions
1	Reclamation Leases	X	X				
2	LFCC Pumping	X	X				
3	SJC Project Diversions	X	X	X			
4	Heron Waivers	X	X	X			
5	MRGCD SJC Storage at El Vado	X	X	X			
6	ABCWUA SJC Storage at Abiquiu	X	X	X			
7	ABCWUA Diversions	X	X	X			
8	ABCWUA Letter Water Delivery	X	X	X			
9	SJC Combined Account Storage at Abiquiu	X	X	X			
10	Combined Letter Water Delivery	X	X	X			
11	Refilling of Cochiti Recreation Pool	X	X	X			
12	Maintain Target Flows	X	X	X			
13	P&P Storage at El Vado	X	X	X	X		
14	Releases of P&P Water from El Vado	X	X	X	X		
15	Storage for Initial Unused Allocation of Emergency Drought Water	X	X	X	X		
16	Rio Grande Storage at El Vado	X	X	X	X		
17	RG Releases from El Vado for MRGCD	X	X	X	X		
18	El Vado Storage for Channel Capacity	X	X	X	X		
19	MRGCD Diversions for Non-Indians	X	X	X	X	X	
20	Diversions for Pueblos	X	X	X	X	X	
21	Cochiti Deviations (years 1 and 2)	X	X	X	X	X	X
22	New Relinquished Credits						
23	Alternate Letter Water Deliveries						
24	Conserve Supplemental Water after YTD Otowi Volume exceeds 1,000,000 acre-ft						

Compare with previous scenario to evaluate impact of Reclamation's Supplemental Water Program at offsetting impacts of Reclamation's actions.

Compare with proposed action to evaluate impact of Reclamation's SJC Project operations, including Heron Dam Operation and the Supplemental Water Program.

Compare with previous scenario to evaluate impact of Reclamation's El Vado Dam operations.

Compare with previous scenario to evaluate impact of MRGCD Diversions.

3.5. Model Runs with All PHVA Flow Tools

In addition to the primary model runs for the Proposed Action as discussed in section 3.3, model runs were also completed during the process with *all* PHVA flow tools incorporated, as described in section 2.4, to evaluate impacts of all the identified potential solutions for meeting flow needs. Draft results from those model runs are not discussed in detail in this report but allowed for the impact of flow tools not included with the Proposed Action to be reviewed. The finding was that new allocations for storage of Emergency Drought Water from any new Relinquished Compact credits would significantly augment the supplemental water supply for meeting target flows in the Middle Rio Grande but would also reduced the accrued Compact credit. The additional flow tool to use alternate delivery schedules for letter water to payback the Compact yielded smaller benefits for meeting ESA needs.

3.6. Initial Conditions

Initial conditions are needed for all URGWOM model runs and inputting needed initial values is a step for setting up the model runs. In preparation for all modeling, the PHVA work group developed a template spreadsheet for inputting all needed initial conditions. Values are exported to ASCII files from the Excel spreadsheet with a macro and a RiverWare control file/executable DMI was set up in URGWOM for importing the initial conditions. The same initial conditions were used for all final model runs that represent the best estimate of December 31, 2011 conditions at the time final model files were set up.

All details and assumptions for developing initial conditions were documented by Boroughs (2011). Total storage levels at each reservoir along with the status for each storage account used as initial conditions are presented in Table 3.2. Initial conditions also include unused allocations for storage of Emergency Drought water from previous Relinquished Compact credits. The estimated unused allocations as initial conditions are 50,500 acre-ft for MRGCD and 19,500 acre-ft for ESA. Emergency Drought water is stored during simulation for these initial unused allocations. Initial river flows are also needed for several locations in the model but are inconsequential to the results. Initial shallow aquifer levels were also input as identified by the URGWOM Technical Team based on equilibrium conditions from completed calibration runs.

Table 3.2. Estimated December 31, 2011 Total and Account Storage Levels and Incidental, Carryover, and Sediment Contents used as Initial Conditions for Final Model Runs

Account	Heron	El Vado	Abiquiu	Cochiti	Jemez	Elephant Butte
TOTAL	219,833	98,522	177,294	53,926	0	280,000
San Juan-Chama Project Water:						
Federal Pool	151,032	---	---	---	---	---
Albuquerque	48,200	0	154,196	---	---	29,487
MRGCD	0	79,326	1100	---	---	---
Combined	20601	0	1942	---	---	19,103
Cochiti Rec Pool	0	---	---	48,037	---	---
Reclamation	0	0	16308	---	---	---
NMISC	---	---	0	---	---	---
Jemez Sediment Pool	---	---	---	---	0	---
Native Rio Grande Water:						
Rio Grande	0	0	0	0	-1114	164,410
Indian Storage	---	0	---	---	---	---
MRGCD Drought	---	0	---	---	---	---
Supplemental ESA	---	19,196	---	---	---	---
Rio Grande Conservation	---	---	0	0	0	---
NM Credit	---	---	---	---	---	65,000
CO Credit	---	---	---	---	---	2000
Incidental Content	---	---	0	0	-1114	---
Carryover Content	---	---	0	0	0	---
Sed Deposition	---	---	3748	5889	1114	---
Total storage at Caballo Reservoir is 11,093 acre-ft.						

3.7. Sequences

All simulations were completed using five 10-year synthetic hydrologic sequences developed by the PHVA work group with reference to paleo-data for representing a wide range of potential hydrologic conditions that could occur over the next 10 years. The sequences are comprised of historical years when data are available as needed for URGWOM simulations but years are re-sequenced to represent wet spells and drought spells not evident in the historical data. Refer to the documentation on sequence selection by Roach (2009) for details on the process for developing the sequences. The selected five sequences represent hydrologic conditions, defined by 10-year Otowi flow volumes, that would be exceeded 10, 30, 50, 70, and 90 percent of the time based on the paleo-data. Refer to Figures 3.1 through 3.5 for charts showing the historical years included with each synthetic 10-year hydrologic sequence. In addition to the annual Otowi flow volumes, or Otowi Index Supply (OIS), the charts also include a depiction of a representative monsoon volume (RMV) that is independent of the sequence selection approach, so the RMV would have its own different exceedence probability under each sequence.

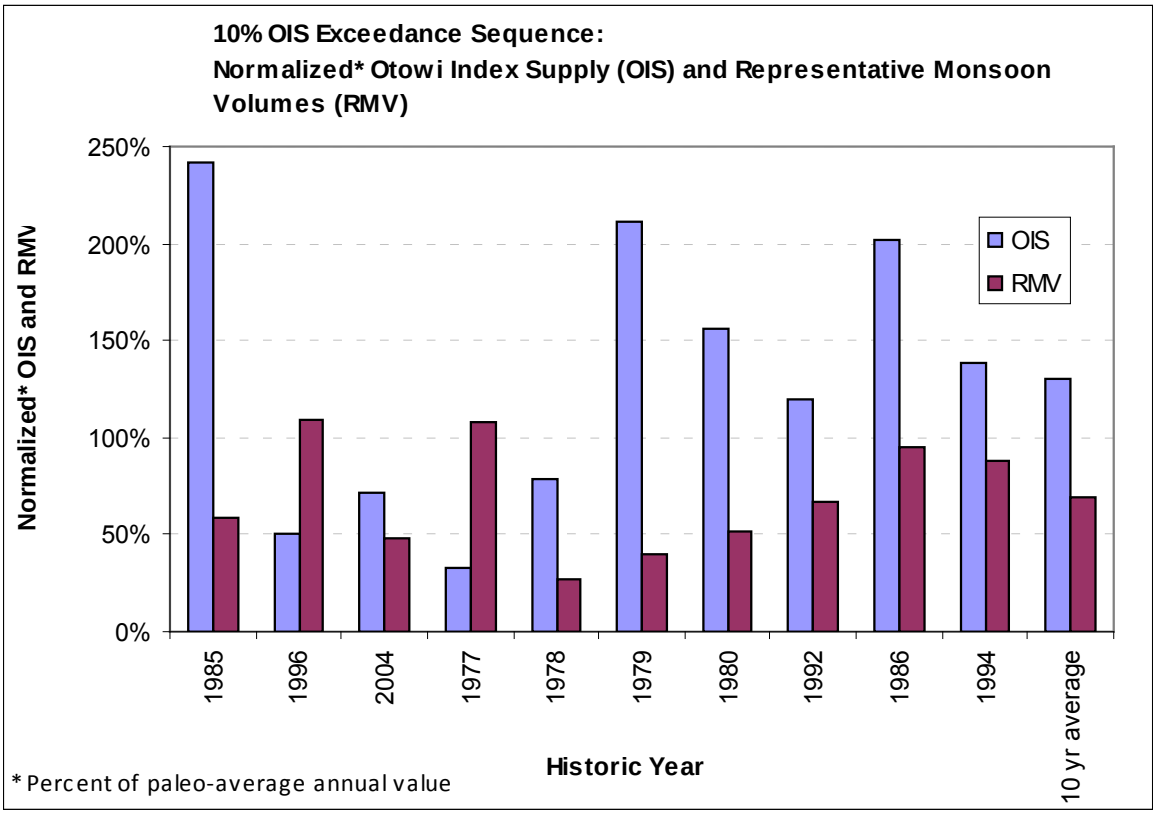

Figure 3.1. Synthetic Hydrologic Sequence with 10 percent Exceedence

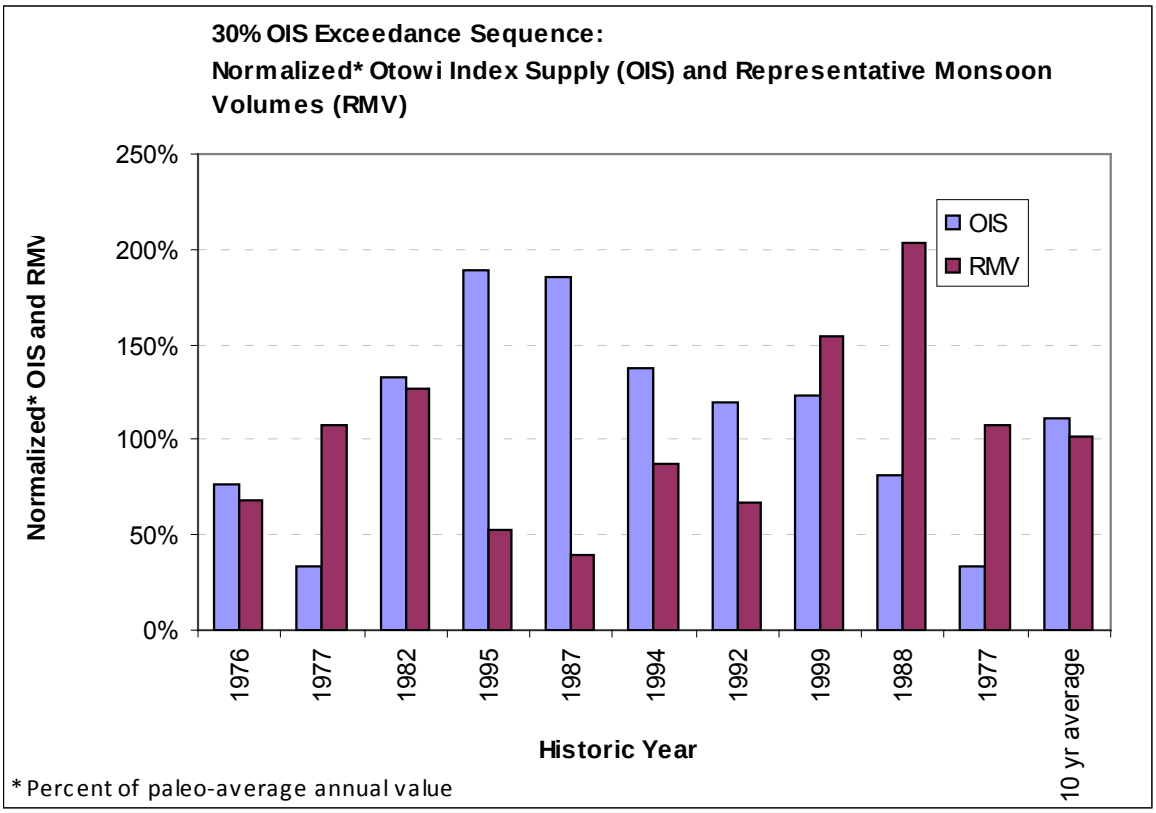

Figure 3.2. Synthetic Hydrologic Sequence with 30 percent Exceedence

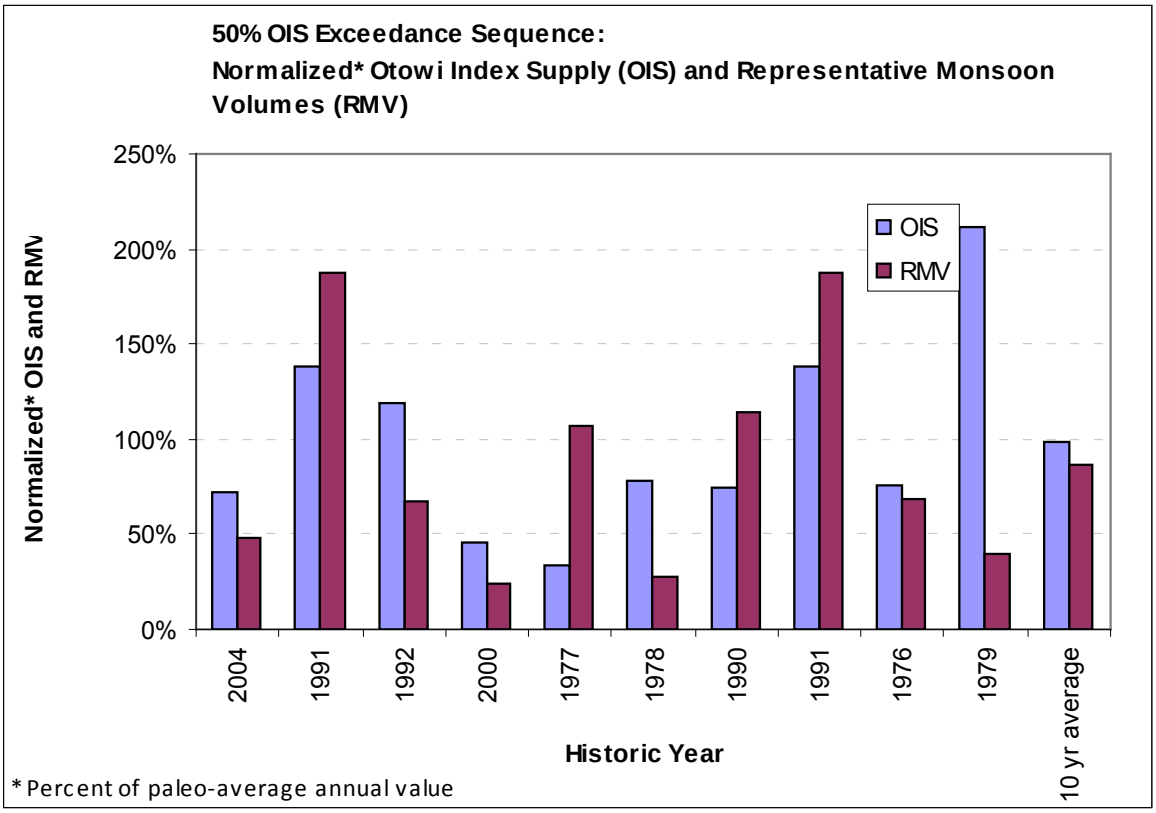

Figure 3.3. Synthetic Hydrologic Sequence with 50 percent Exceedence

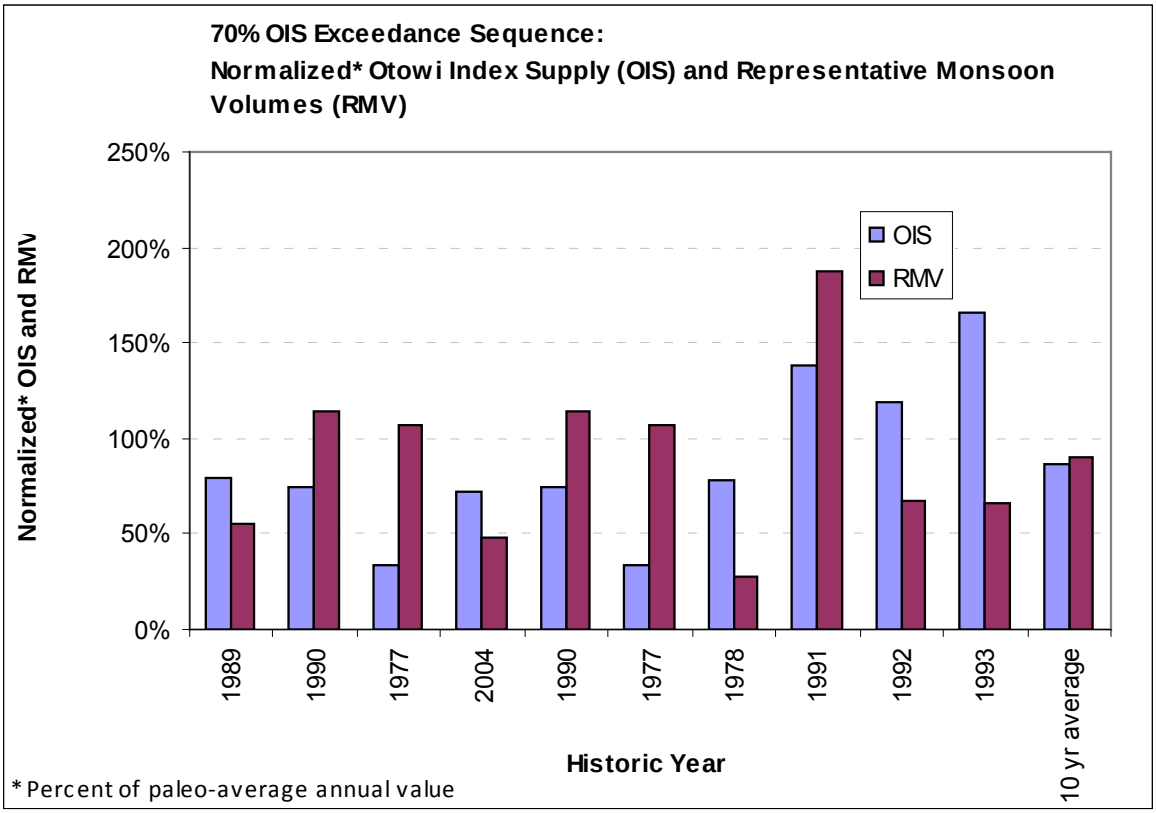

Figure 3.4. Synthetic Hydrologic Sequence with 70 percent Exceedence

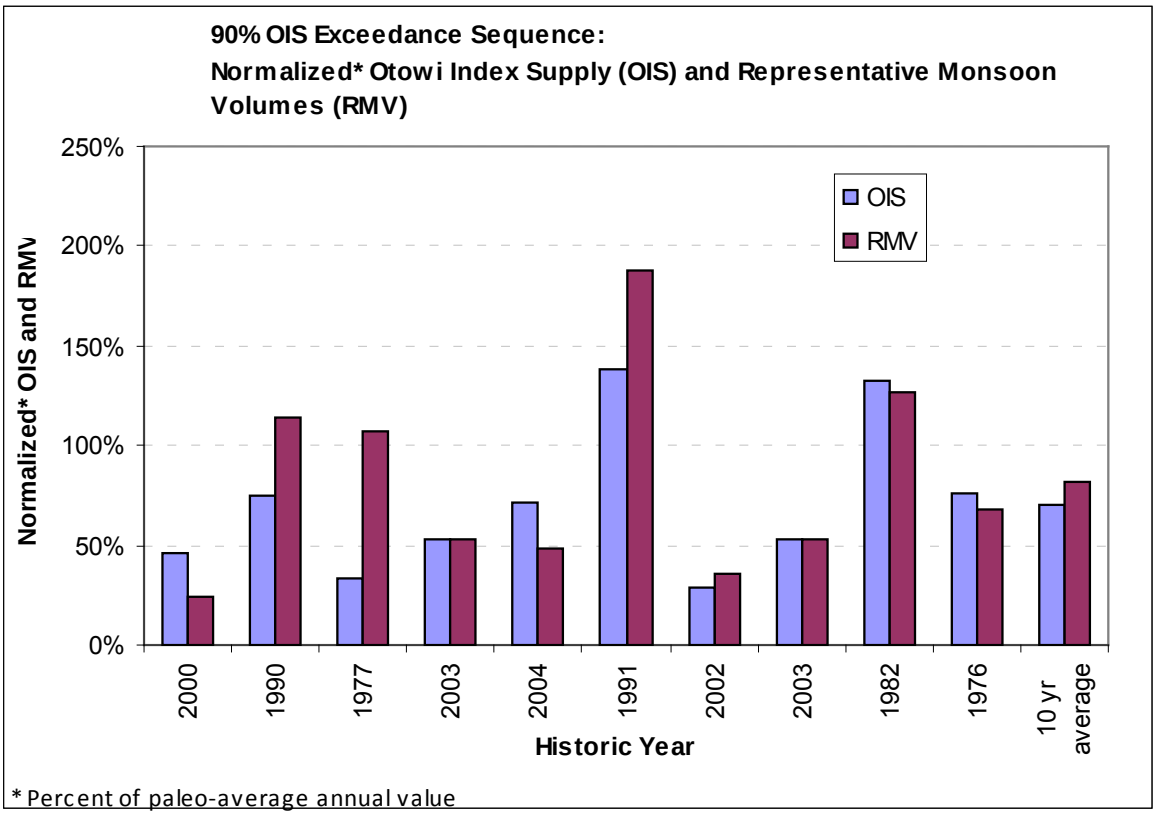

Figure 3.5. Synthetic Hydrologic Sequence with 90 percent Exceedence

4.0. Model Run Results

Five final model runs were completed for the Proposed Action as described in section 3.3 with the five synthetic hydrologic sequences presented in section 3.7 and the initial conditions discussed in section 3.6. Results were analyzed to determine impacts of operations as defined for the Proposed Action on numerous identified indicators. Five additional companion model runs were completed with a hypothetical unlimited supply of supplemental water that were used solely to evaluate the total amount of supplemental water needed to meet the 2003 BO targets and resulting river flows if the targets could always be met. Additional model runs were completed to evaluate the impacts of Reclamation's actions and non-Federal actions as described in section 3.4. The analysis of these model runs was completed with focus on resulting river flows with actions removed.

4.1. Proposed Action

Results for the Proposed Action run were evaluated for resulting river flows, the timing and extent of river drying, the resulting supply for MRGCD, ABCWUA supply, the cumulative Compact credit, and Article VII status. In addition, results from the companion model runs with an unlimited supply included were reviewed to evaluate the total amount of supplemental water needed to meet the 2003 BO targets and the additional supplemental water needed above that available under the Proposed Action.

4.1.1. River Flows

Exceedence curves were developed that represent the amount of time over the entire 50-years of analysis from the five 10-year model runs that flows are exceeded. The curves indicate the amount of time that the flow at a site would be exceeded under the given hydrology and modeled operations. Separate curves were developed for each key target location with reference to the model runs for the Proposed Action versus the model runs with the hypothetical unlimited supply included. Refer to Figure 4.1 for the exceedence curves developed with modeled flows at Central where the focus is zoomed in on lower flows. Lower flows are exceeded more often with the unlimited supply of supplemental water available to always meet the 2003 BO flow requirements during the simulation. Curves are presented in Figures 4.2 and 4.3 for the same location that were developed with focus on model results for the irrigation seasons (March through October) and the non-irrigation seasons (November through February), respectively. These curves clearly indicate that the benefit from having an unlimited supply of supplemental water is evident primarily during the irrigation season. Targets can mostly be met during the non-irrigation season, even with the limited supply of supplemental water represented by the Proposed Action.

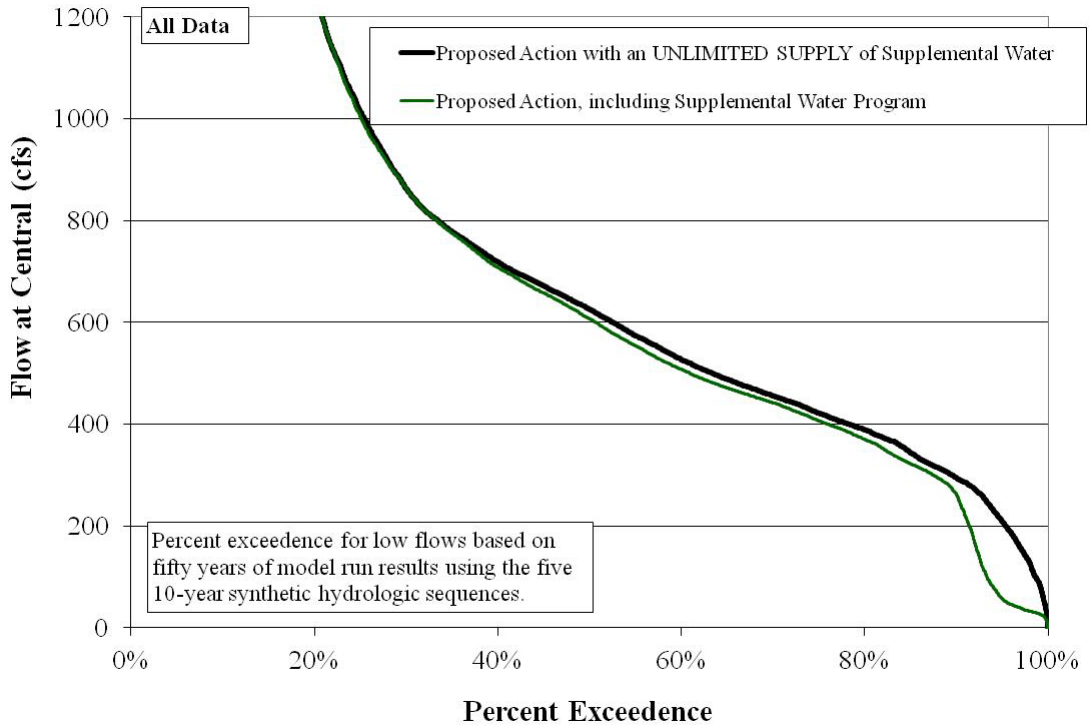

Figure 4.1. Exceedence Curves for Modeled Flows at Central – All Data

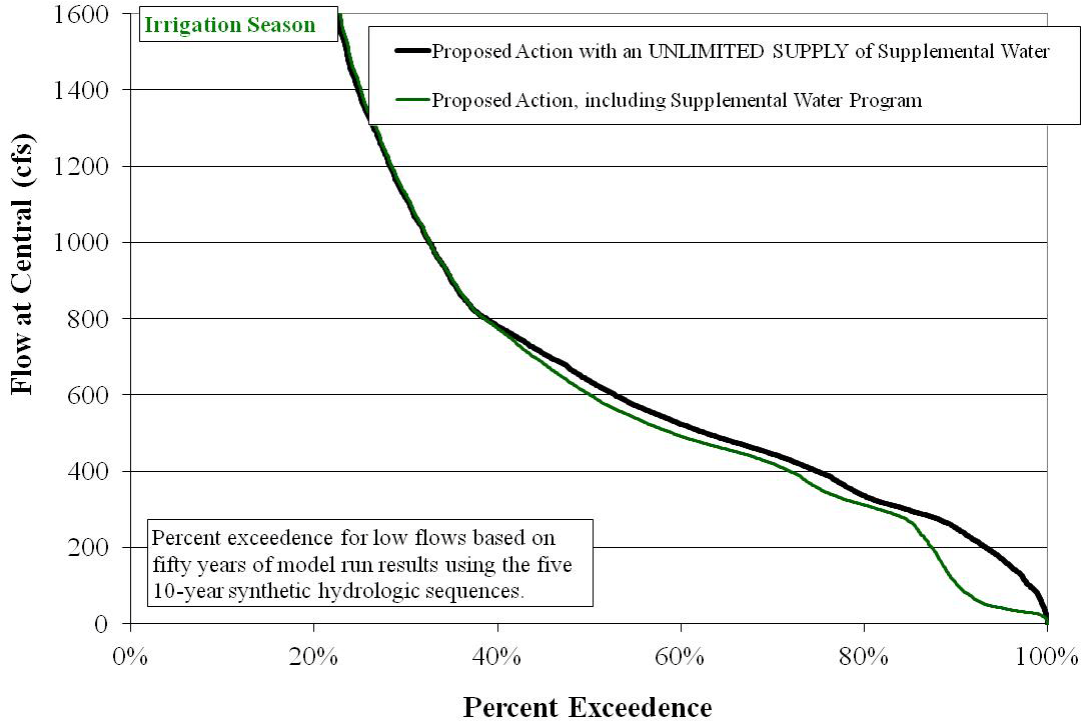

Figure 4.2. Exceedence Curves for Modeled Flows at Central – Irrigation Season

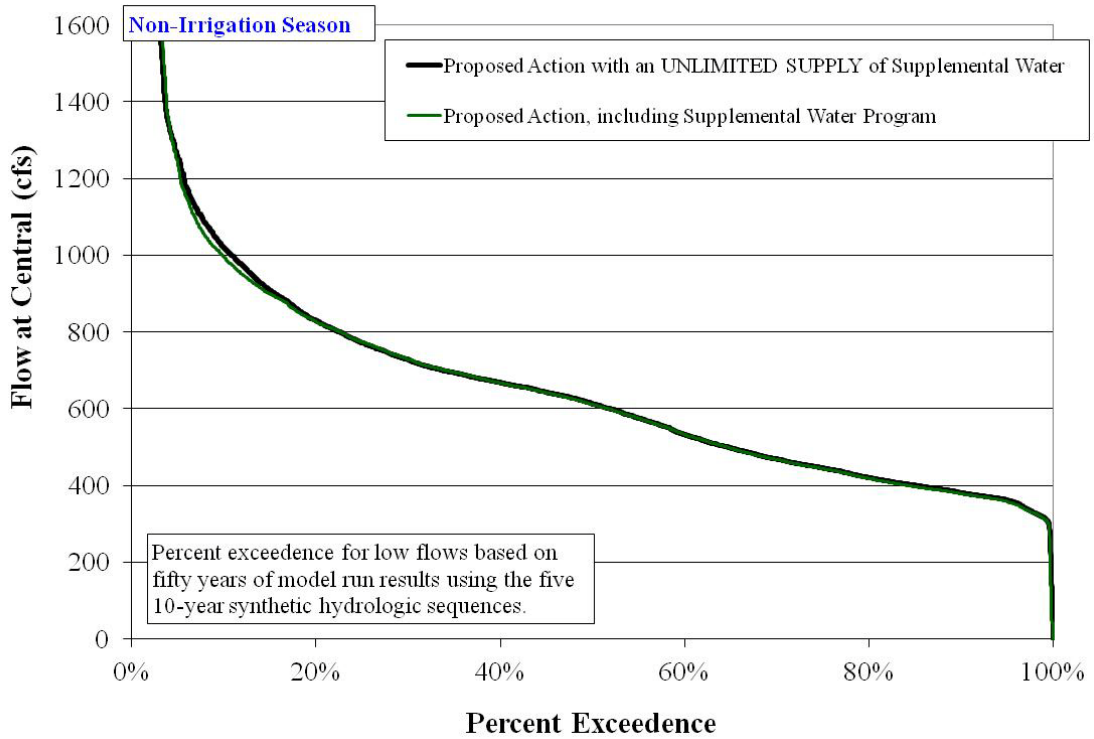

Figure 4.3. Exceedence Curves for Modeled Flows at Central – Non-Irrigation Season

Flow exceedence curves are presented in Figure 4.4 and 4.5 for the resulting flows at Isleta during the irrigation season and non-irrigation season, respectively. Each chart includes curves for the resulting flows under the Proposed Action and with an unlimited supply of supplemental water included. The x-axes on these charts are labeled based on the number of days that a flow is not exceeded during the irrigation season (or non-irrigation season) on average. This alternate x-axis format allows for the average number of days of drying at the location to be identified. Based on the curves in Figure 4.4, an additional 15 days per year of river drying could be expected under the Proposed Action versus if the 2003 BO targets were always met as occurs in the model runs with an unlimited supply of supplemental water. Note that river drying is allowed under the 2003 BO, so river drying is still indicated when an unlimited supply of supplemental water is used. Curves are presented for the irrigation season results at San Acacia and San Marcial in Figures 4.6 and 4.7.

Based on work with all the PHVA flow tools during the study, results would be similar if all PHVA flow tools were modeled with low flows exceeded slightly more often and flow targets achieved a bit more often, primarily due to additional Emergency Drought water with new modeled relinquished Compact credits, but flows would still not match the results with an unlimited supply of supplemental water as there would still be a shortage in the amount of supplemental water needed to always meet the 2003 BO flow requirements with all PHVA flow tools included.

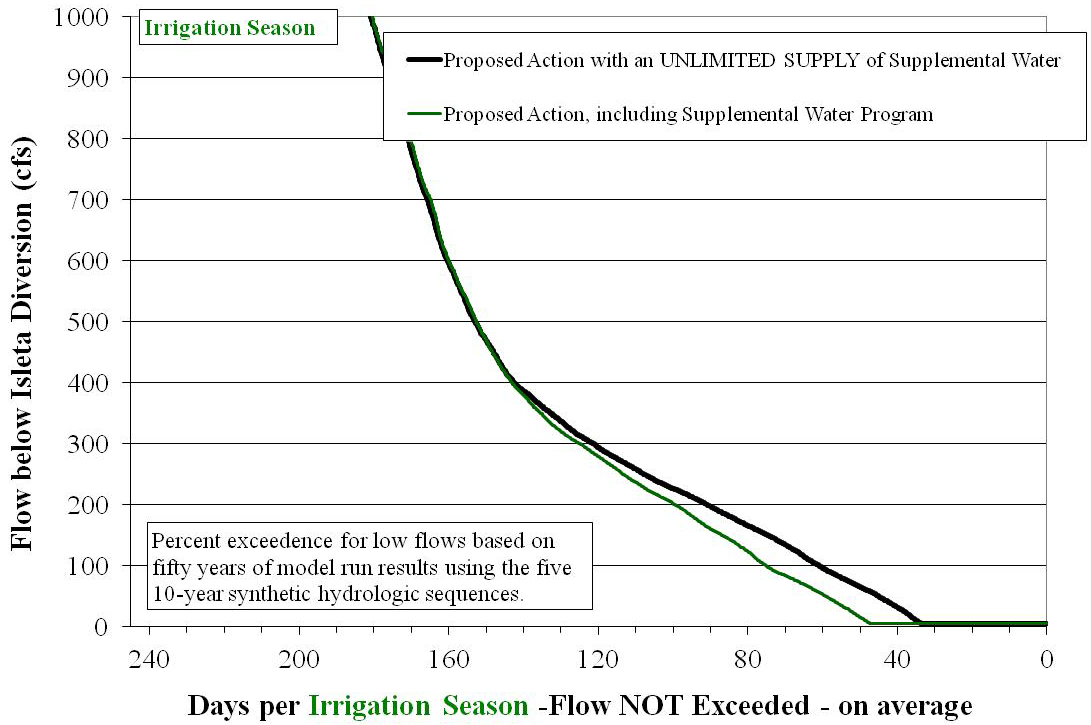

Figure 4.4. Exceedence Curves for Modeled Flows at Isleta – Irrigation Season

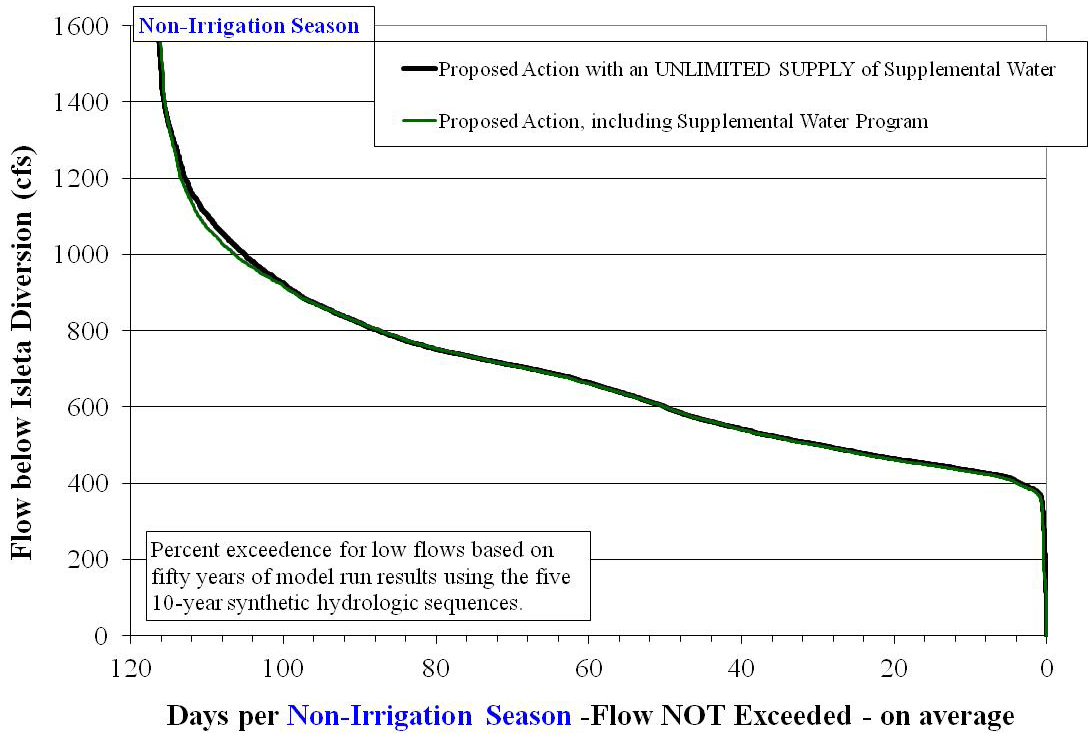

Figure 4.5. Exceedence Curves for Modeled Flows at Isleta – Non-Irrigation Season

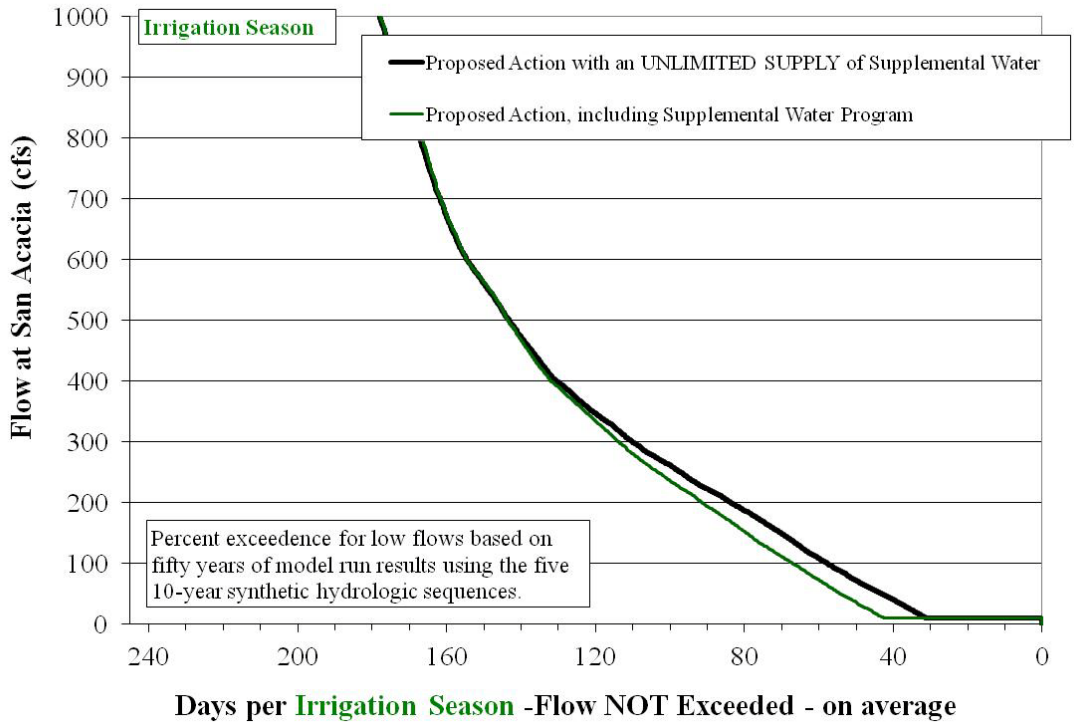

Figure 4.6. Exceedence Curves for Modeled Flows at San Acacia – Irrigation Season

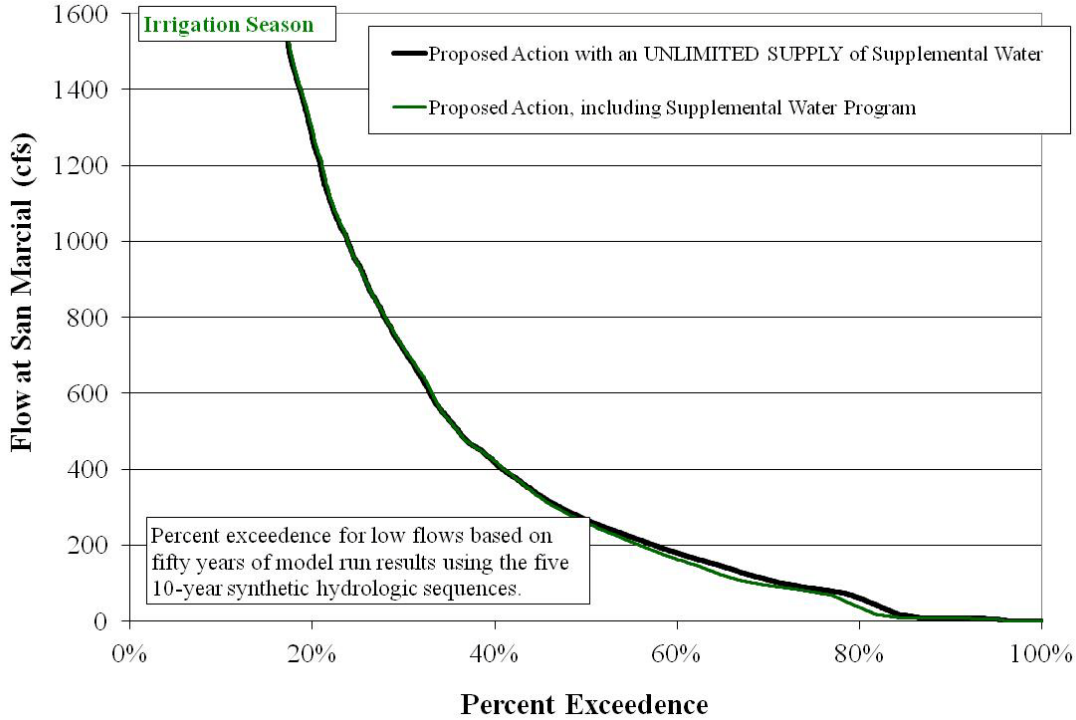

Figure 4.7 Exceedence Curves for Modeled Flows at San Marcial – Irrigation Season

4.1.2. River Drying and Recruitment or Overbank Flows

The exceedence curves presented in the figures in section 4.1.1 provide an indication as to when river drying would be expected based on the flow at the target locations, but more resolution on the timing and extent of river drying can be determined based on the modeled flows at individual subreaches in URGWOM. Separate charts were developed to depict when river drying would be expected for a particular subreach or anywhere within the main reaches (e.g. Angostura to Isleta, Isleta to San Acacia, or San Acacia to San Marcial). These charts were then created for each model run with each sequence with additional separate charts for the model runs with an unlimited supply of supplemental water included.

Two sample charts are presented in Figures 4.8 and 4.9. The timing for expected river drying is depicted by the date within the calendar year, as designated for the x-axis, for each year of a run, as designated on the y-axis (Years 2010 through 2019 are used on the presented charts but any years could be noted for a 10-year analysis period). The orange bars represent the timing for when river drying is indicated under the Proposed Action. In addition, recruitment flows are depicted to allow for impacts between the timing for recruitment flows and the timing of river drying to be evaluated. The red bars in the chart represent times when recruitment flows (at least 3000 cfs for 7 days at Central) are provided under the Proposed Action. The timing for when Cochiti Deviations are implemented is depicted by blue bars.

General conclusions from the review of all the produced river drying charts from the analysis include the following: More river drying is evident under the proposed action versus with an unlimited supply of supplemental water because the amount of supplemental water under the Proposed Action is insufficient for always meeting the flow requirements under the 2003 BO. Note that with an unlimited supply of supplemental water included, some river drying still occurs as allowed under the 2003 BO. For the final model runs, the 7-day step downs in target flows to represent the use of supplemental water for controlling the rate of river drying after any river rewetting are turned off (as discussed in section 2.5); thus, more river drying is apparent without this operation and additional use of supplemental water. Also note that based on the review of all the PHVA flow tools throughout the modeling process, less river drying would be expected with any new relinquished Compact credits and the resulting additional Emergency Drought water.

The occurrence of recruitment (and overbank) flows is a function of the hydrology and not impacted by the flow requirements under the 2003 BO, but it could be emphasized that Cochiti deviations do help with providing additional recruitment (or overbank) flows in years when defined recruitment or overbank flows would not otherwise be achieved. Deviations prevent extended periods without recruitment or overbank flows during drought periods. Cochiti deviations were only modeled for years 1 and 2 based on the current authorization for the operation, but the benefit can still be seen from this limited range of application.

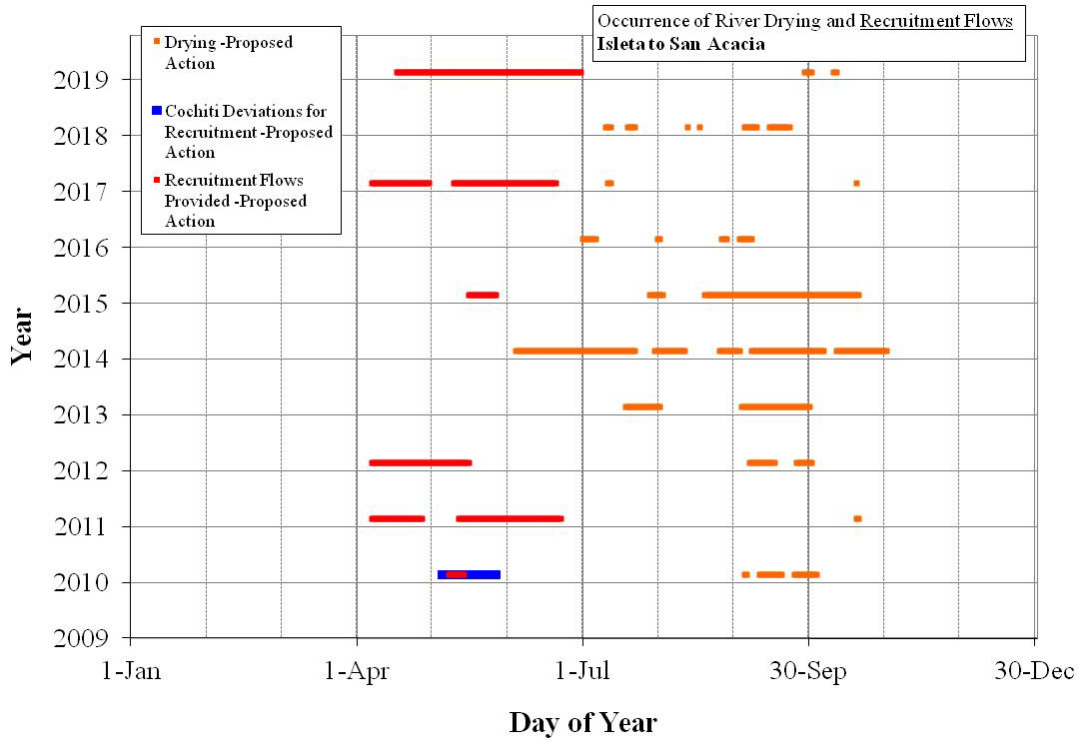

Figure 4.8. Depiction of Timing of River Drying and Recruitment Flows (and Cochiti Deviations for Recruitment) for Proposed Action – 50 percent Exceedence Sequence

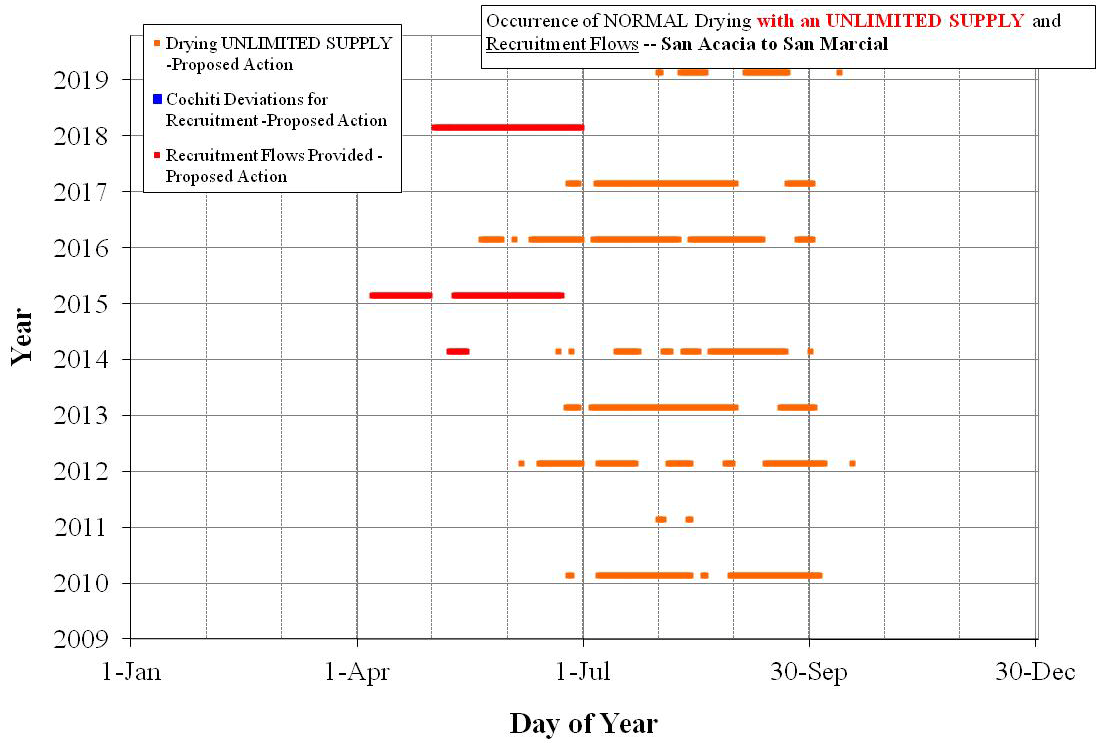

Figure 4.9. Depiction of Timing of River Drying and Recruitment Flows (and Cochiti Deviations for Recruitment) for Proposed Action *with an Unlimited Supply* – 90 percent Exceedence Sequence

4.1.3. Supplemental Water Needed for the 2003 BO Flow Requirements

Model results from the simulations with a hypothetical unlimited supply of supplemental water included were reviewed to evaluate the total amount of supplemental water needed at Abiquiu Reservoir to meet the 2003 BO flow requirements under each hydrologic sequence. Refer to Figure 4.10 for a plot of the 10-year total volumes needed. The fifty values for the annual total supplemental water needed to meet the 2003 BO flow requirements from the five 10-year runs were also used to develop an exceedence chart (Figure 4.11). The chart can be used to identify the chance that an annual volume of supplemental water would be needed based on the model runs with the five sequences. The exceedence chart could also be used to identify how often an identified available amount of water would be sufficient. Note that the volumes of supplemental water used in actual operations for the historical period from 2001 through 2011 are noted on the chart to provide some perspective of where these recent historical years fall relative to what could occur based on the model runs with the hydrologic sequences.

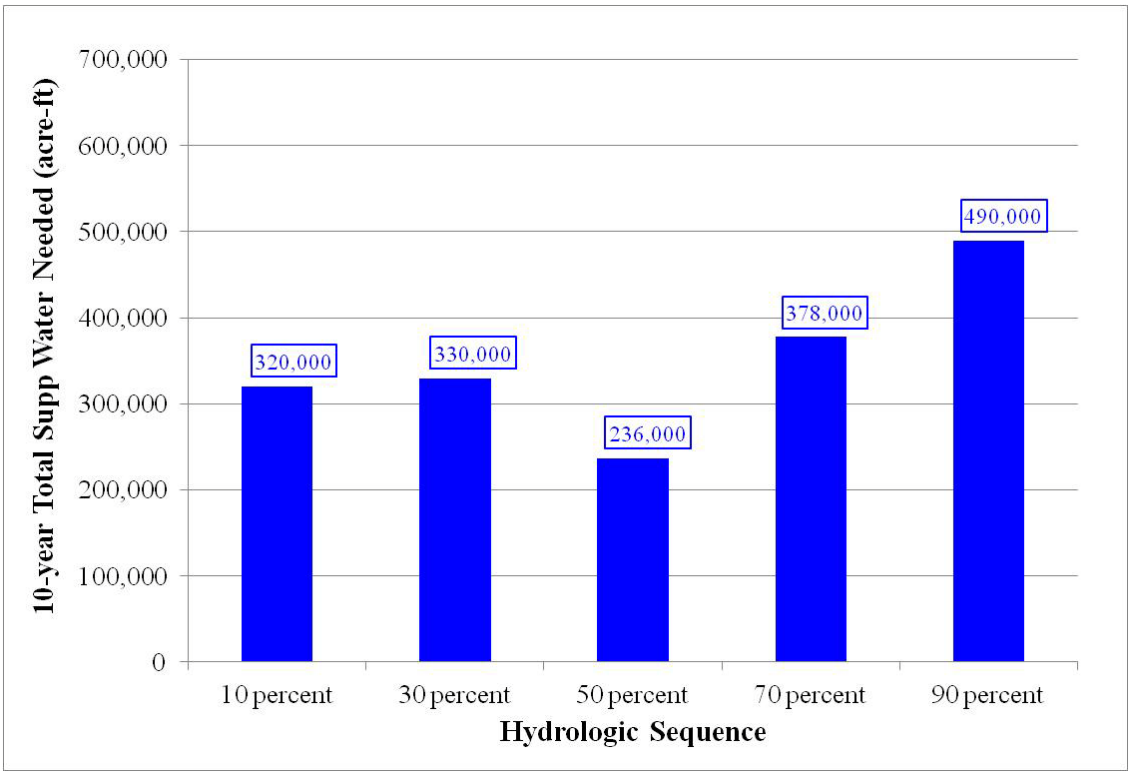

Figure 4.10. 10-year Total Supplemental Water Needed to Meet 2003 BO Flow Requirements

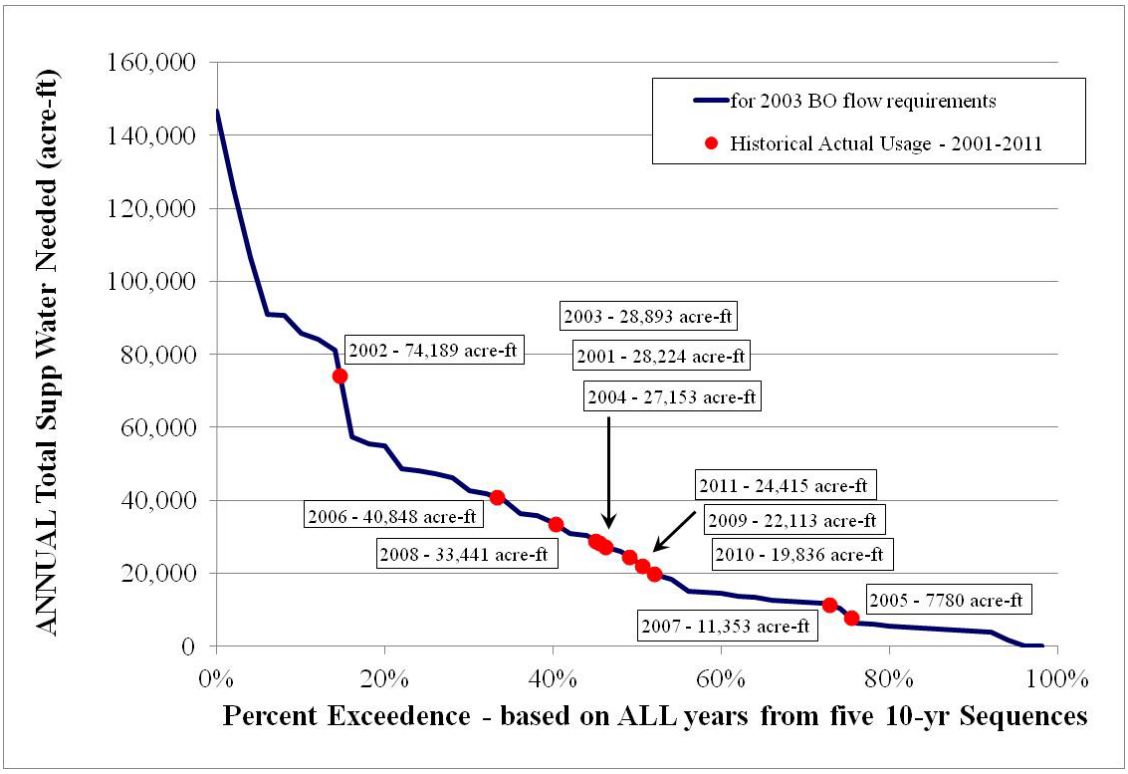

Figure 4.11. Exceedence Chart for Annual Total Supplemental Water Needed to Meet 2003 BO Flow Requirements

Model results for the Proposed Action were compared to the companion model results with an unlimited supply of supplemental water included to identify the additional supplemental water that would be needed above that provided under the Proposed Action to meet the 2003 BO flow requirements. Refer to Figure 4.12 for a plot of the supplemental water needed split between the amount provided under the Proposed Action and the additional supplemental water needed to always meet the 2003 BO flow requirements. Values are evaluated as a volume needed at Abiquiu Reservoir. The amount of supplemental water provided at the source is depicted by the additional line in the chart which is higher due to losses to Abiquiu Reservoir from the source for the supplemental water (e.g. Reclamation leases of San Juan-Chama Project water at Heron Reservoir). Simply divide the values by 10 to obtain corresponding annual values.

Based on the review of all PHVA flow tools during the modeling process, the additional amount of supplemental water needed would be less if supplemental water was provided due to new Relinquished Compact credits; although, the new allocations for storage of Emergency Drought water with any new Relinquished Compact credits would not completely cover the additional supplemental water needed beyond that provided under the Proposed Action.

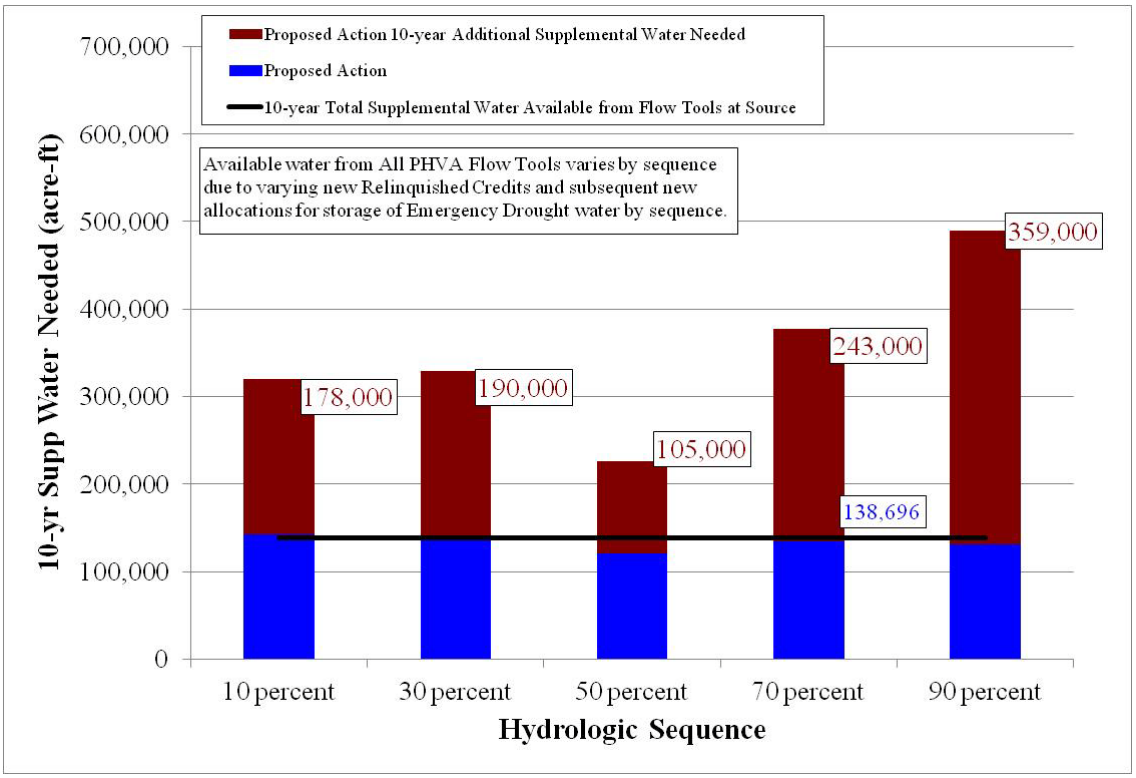

Figure 4.12. 10-year Additional Supplemental Water Needed under the Proposed Action

4.1.3.1. Water Needs by Individual Flow Requirement

Results for the total supplemental water needed to meet the 2003 BO flow requirements as modeled with a hypothetical unlimited supply of supplemental water were reviewed to break down the contribution of supplemental water needed 1) for the continuous flow requirement through June 15th, 2) to manage the recession after the continuous flow requirement (or after the runoff), and 3) to control the rate of drying after any river rewetting. The total average need based on all five model runs with each sequence is just over 35,000 acre-ft/year where the water needs for the three particular aforementioned individual flow requirements average approximately 11,000 acre-ft/year, 9,600 acre-ft/year, and 0 acre-ft/year, respectively; although, it should be emphasized that supplemental water was not used to control the rate of river drying after any river rewetting in the final model runs. These are average values, so the actual amount needed in a given year for a particular flow requirement could be much higher or as low as zero. It should also be emphasized that the hydrologic sequences are comprised of historical years since 1975, but the runoff ends earlier for some previous years (e.g. 1950 and 1951) where the needs for supplemental water to meet the continuous flow requirement would begin very early and be very high in volume to maintain continuous flow through June 15th (Llewellyn, 2011). Water needs to meet the continuous flow requirement for these particular earlier years would not be indicated in the model results based on the simulations completed with hydrologic year from 1975 and later included in the hydrologic sequences.

A separate analysis was completed to identify that over 13,000 acre-ft/year, on average, would be needed solely for the 100 cfs year round target at Central. Results are presented in Figure 4.13 as average annual water needs based on the results using all hydrologic sequences. Other individual flow requirements also contribute to the total amount of supplemental water needed

for the 2003 BO flow requirements such as targets at Isleta and different target flows used during average and wet years.

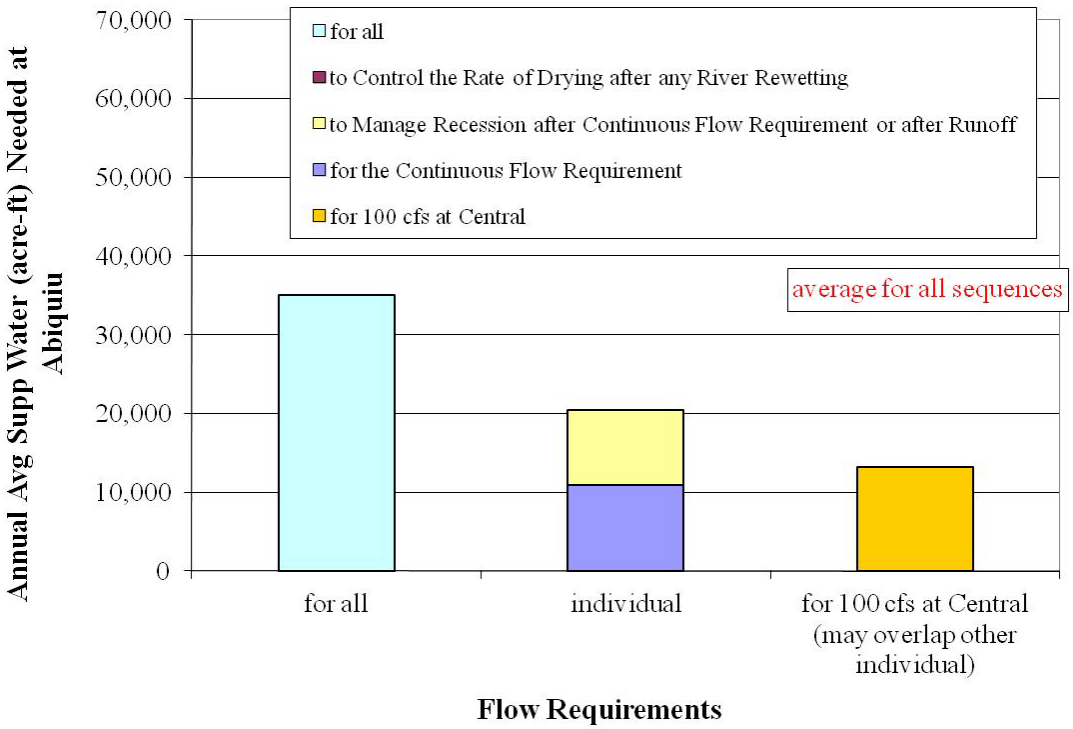

Figure 4.13. 10-year Additional Supplemental Water Needed with All PHVA Flow Tools

4.1.4. Compact Credit and Article VII Status

The simulated cumulative Compact credit under the Proposed Action for each sequence is plotted in Figure 4.14. The charts reflect the annual adjustment to the Compact credit at the end of each year based on the delivery for the year and Compact calculations. A gradual reduction in the Compact credit is evident, when it is positive, due to evaporation losses to the additional water in storage at Elephant Butte Reservoir. The model results indicate a Compact credit that would never go negative under the Proposed Action except with the wettest 10 percent exceedence sequence, and there would be a slight gain to the cumulative Credit over the 10-year analysis period under all the hydrologic sequences. Note that Compact delivery obligations are more difficult to attain during wet periods when all flows as measured at Otowi above a constant allowable depletion amount (used for higher flow years) must be delivered to Elephant Butte Reservoir. The implemented approach for the Compact calculations allows for an annual credit to be more likely achieved during drier years.

Based on all the work during the modeling process with all the PHVA flow tools, it should be conveyed that the cumulative Compact credit would indeed be lower with any new relinquished Compact credits and the Compact credit would be more susceptible to going negative or even decrease below a critical threshold of 200,000 acre-ft of debt; nonetheless, the projected credit under the Proposed Action without any new relinquishments indicates that there is still an opportunity for new relinquishments and subsequent new allocations for storage of Emergency Drought water without yielding cumulative credits below critical debt levels.

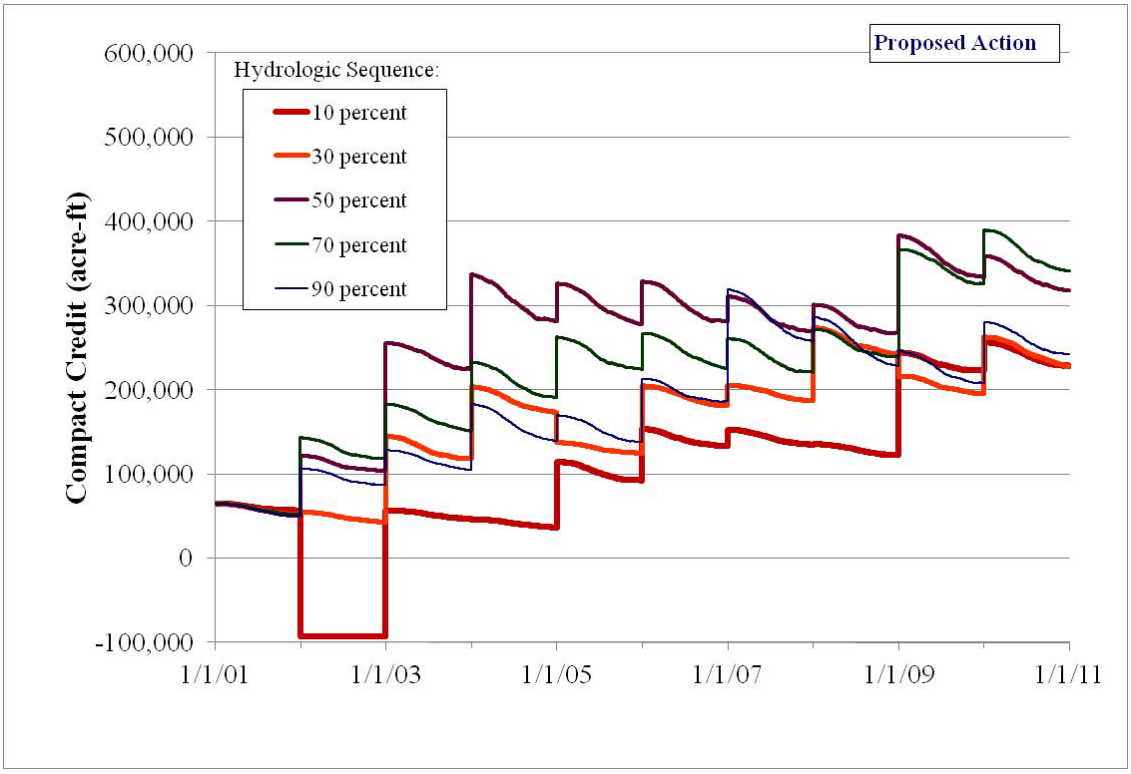

Figure 4.14. Cumulative Compact Credit under the Proposed Action for Each Hydrologic Sequence

4.1.4.1. El Vado Releases per Article VIII of the Compact

As discussed in section 2.3.2.6, the model was set up to simulate El Vado Dam releases that would be made based on a call by Texas per Article VIII of the Compact. Final model runs were reviewed to evaluate the impact of this policy, and results indicate that such releases are not ever triggered based on Article VIII policy. If there is a Compact debt, conditions do not occur when native Rio Grande water is in storage at El Vado Reservoir to release to bring the usable storage up to 600,000 acre-ft. Native Rio Grande water cannot be stored at El Vado Reservoir when the usable storage is less than 400,000 acre-ft, so this separate provision of the Compact effectively prevents water from being available at El Vado Reservoir during periods with low usable storage. When there is native Rio Grande water in storage, there is no Compact debt or the usable storage already exceeds the 600,000 acre-ft threshold to trigger a release per Article VIII of the Compact. The finding is that Article VIII of the Compact pertains to a very narrow window of system conditions that is not seen in the model results where native Rio Grande water would be in storage at El Vado Reservoir but usable storage is below 600,000 acre-ft while there is a Compact debt.

4.1.5. MRGCD Supply

Results for the simulations for the Proposed Action were reviewed to assess the status of MRGCD's water supply in storage under each of the hydrologic sequences. The supply is a function of the hydrology with releases set as needed to meet the MRGCD demand at Cochiti.

The supply primarily consists of native Rio Grande water, MRGCD's San Juan-Chama Project water, and Emergency Drought water at El Vado Reservoir. These three sources for the MRGCD supply are tracked with separate accounts in URGWOM and are plotted in Figures 4.15 through 4.19 from the model runs with each hydrologic sequence. Native Rio Grande water is stored as not needed to meet the daily demand if storage restrictions per Article VII of the Compact are not in effect. Emergency Drought water for MRGCD is from storage during the simulation, while restrictions per Article VII of the Compact are in effect, for the initial unused allocation of 50,500 acre-ft. MRGCD's San Juan-Chama Project is essentially banked and used when native supplies are exhausted. Periods with no San Juan-Chama Project water, no native Rio Grande water, and no Emergency Drought water in storage represent times when MRGCD would be in a shortage situation unless the native flows in the river provided the full demand and assuming no additional water is available at Heron or Abiquiu Reservoirs. As presented in Figure 4.19, extended shortage periods are evident from the model run with the driest 90 percent exceedence sequence.

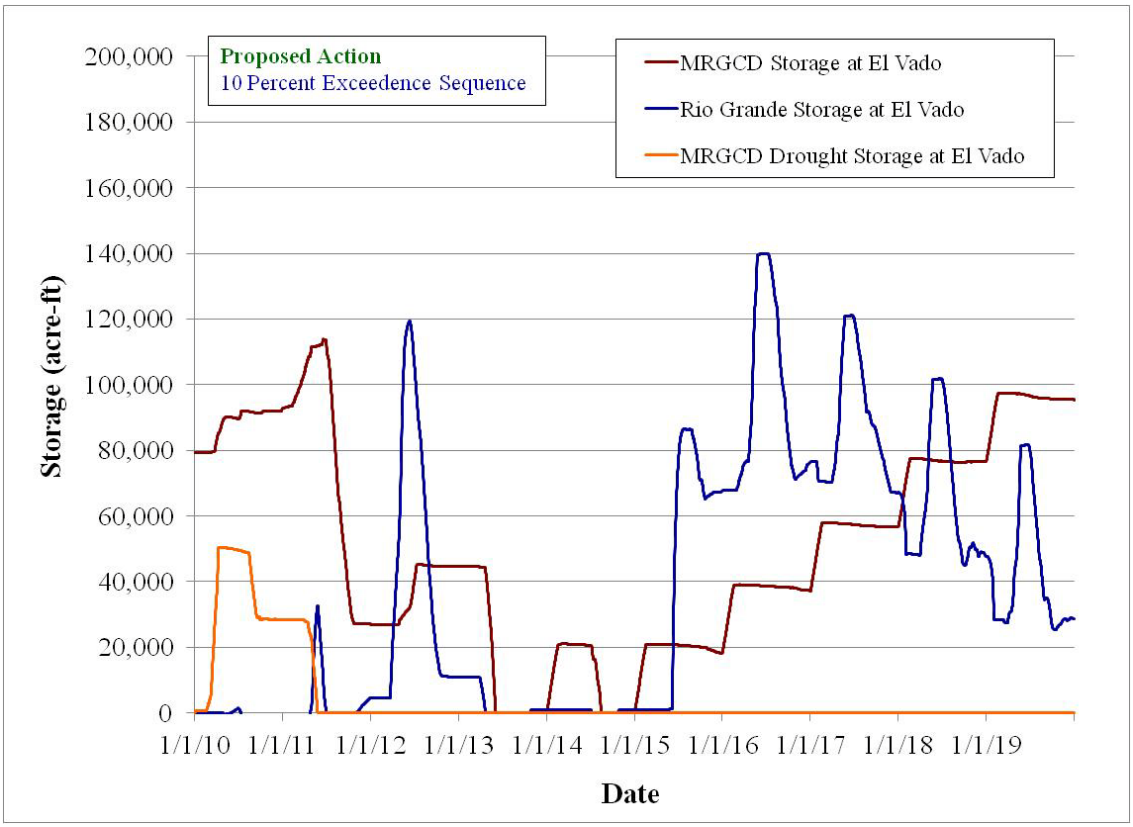

Figure 4.15. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 10 percent Exceedence Sequence

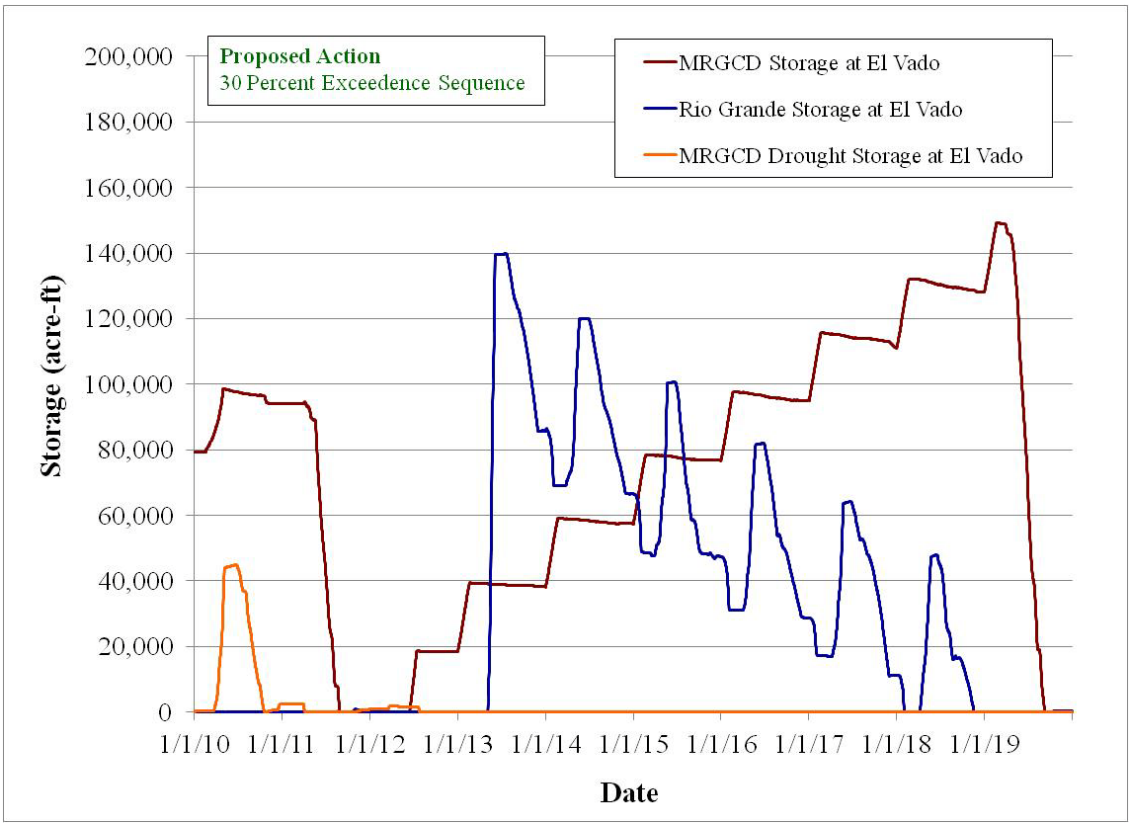

Figure 4.16. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 30 percent Exceedence Sequence

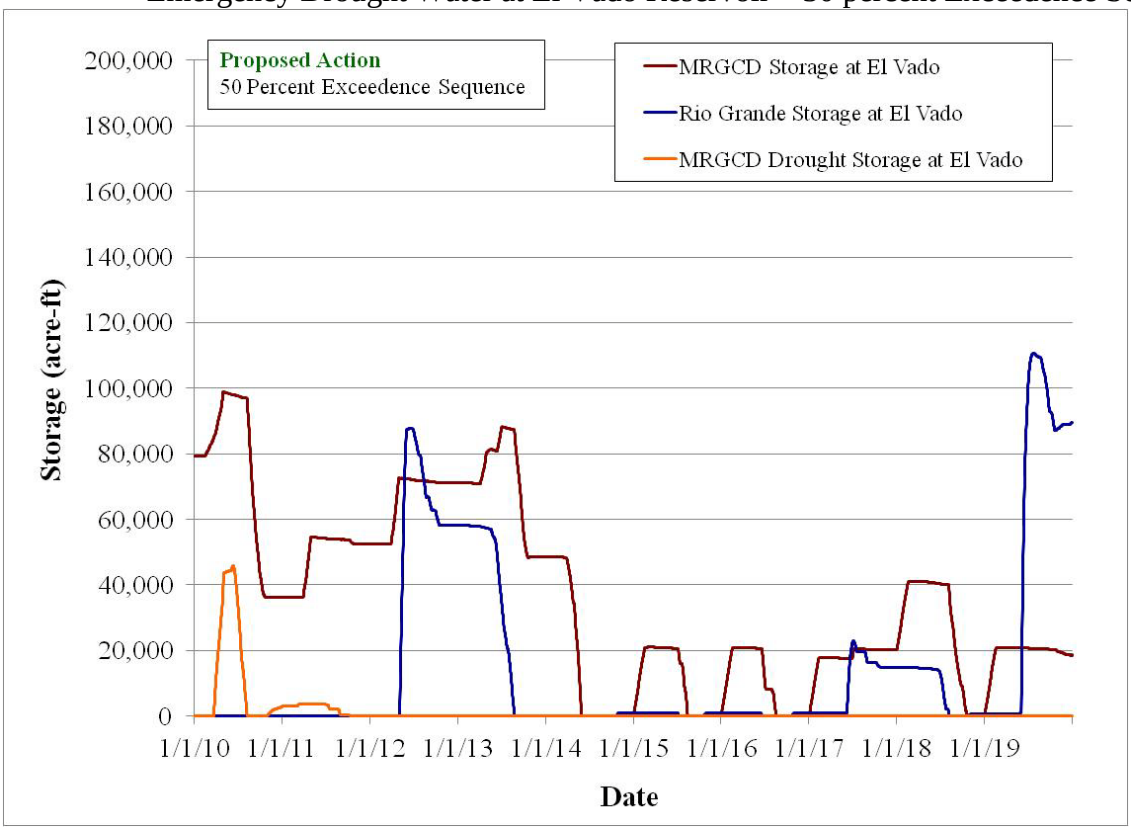

Figure 4.17. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 50 percent Exceedence Sequence

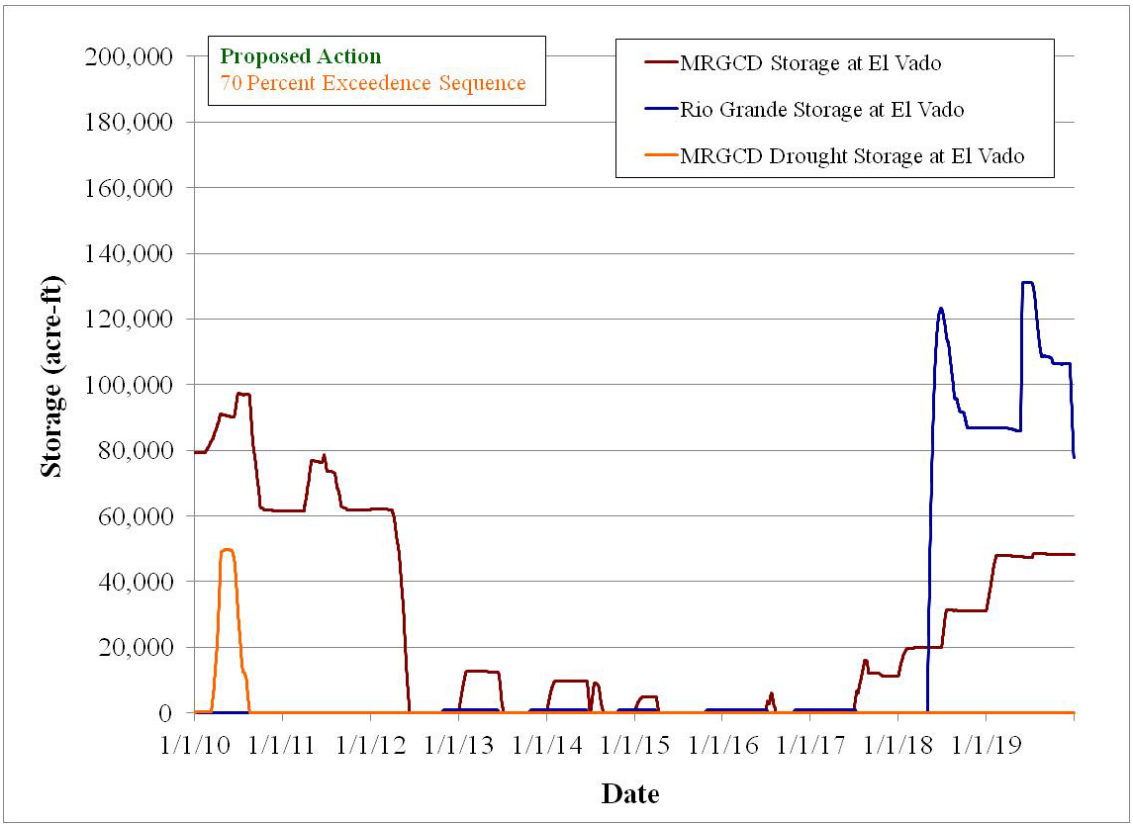

Figure 4.18. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 70 percent Exceedence Sequence

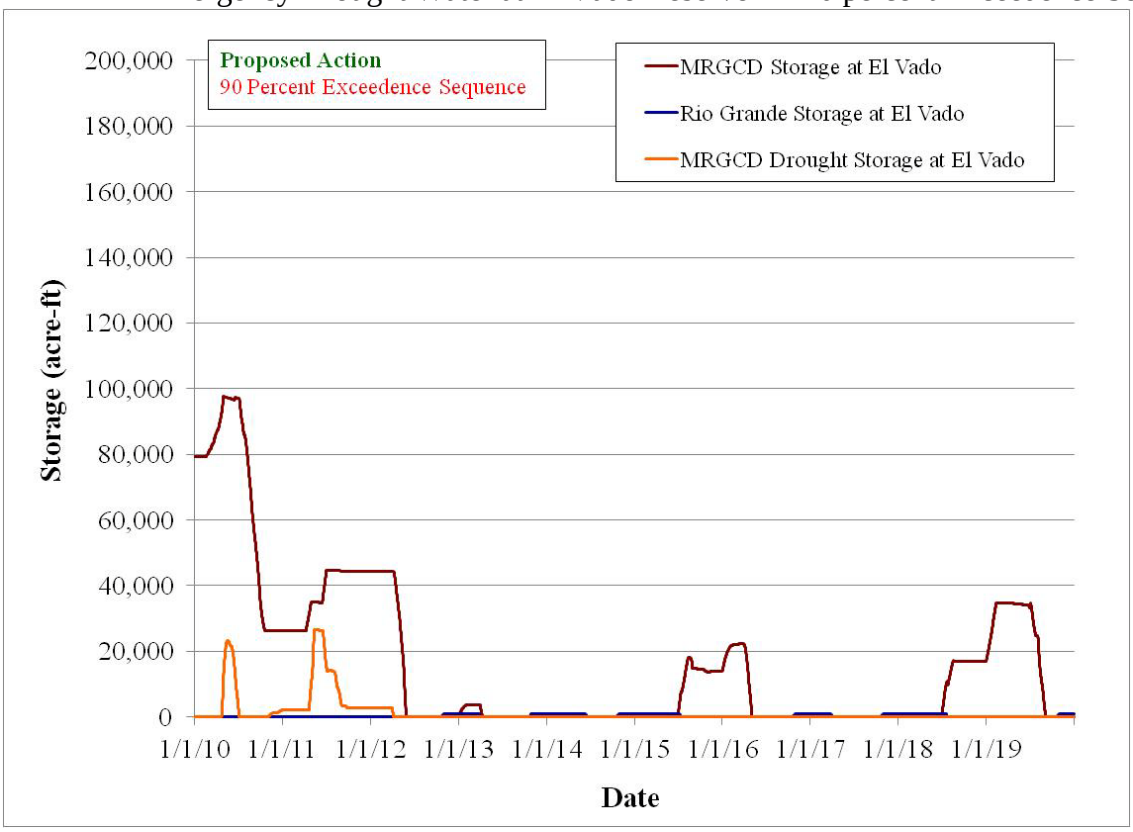

Figure 4.19. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 90 percent Exceedence Sequence

4.1.6. ABCWUA Supply

Results for the simulations for the Proposed Action were reviewed to evaluate the status of ABCWUA's water supply in storage under each of the hydrologic sequences. The supply is a function of the annual allocation of San Juan-Chama Project water and releases to meet the demands for the surface water diversion and letter water deliveries. With similar demand schedules regardless of the hydrologic sequence and a full allocation received in essentially every year, the supply is similar between the model runs for each sequence and mostly independent of the hydrology unless a full allocation of San Juan-Chama Project water is not received due to a shortage in the supply at Heron Reservoir. Refer to Figures 4.20 through 4.24 for plots of the ABCWUA supply at Heron and Abiquiu Reservoirs for the model runs completed with each of the five hydrologic sequences. The plots show an initial high storage of ABCWUA San Juan-Chama Project water with water at Heron eventually moved to Abiquiu Reservoir as space becomes available while utilizing a waiver at Heron Reservoir. With the higher demands as a result of the startup of the surface water diversion and higher ABCWUA letter water deliveries to payback for the impacts of past groundwater pumping, the supply is gradually drawn down to where ABCWUA is simply utilizing the full allocation each year.

Full allocations are made on January 1st for every year with the 10 percent exceedence sequence. Note that when full allocations cannot be made at Heron on January 1st, additional allocations are made on July 1st within URGWOM. With the additional allocations on July 1st, full allocations are made in every year with the 30 and 50 percent exceedence sequences. A full allocation still cannot be made for the sixth year under the 70 percent exceedence hydrologic sequence with only a 43% allocation made for that year. Also, full allocations cannot be made for the fourth, fifth, seventh, and eighth years under the 90 percent exceedence hydrologic sequence with 84%, 81%, 48%, and 57% of the full allocation made in those years, respectively. Allocations for all other contractors would be curtailed with same percentages. Results for ABCWUA's supply in the model runs with all PHVA flow tools included are similar as ABCWUA's supply is not impacted by the additional flow tools.

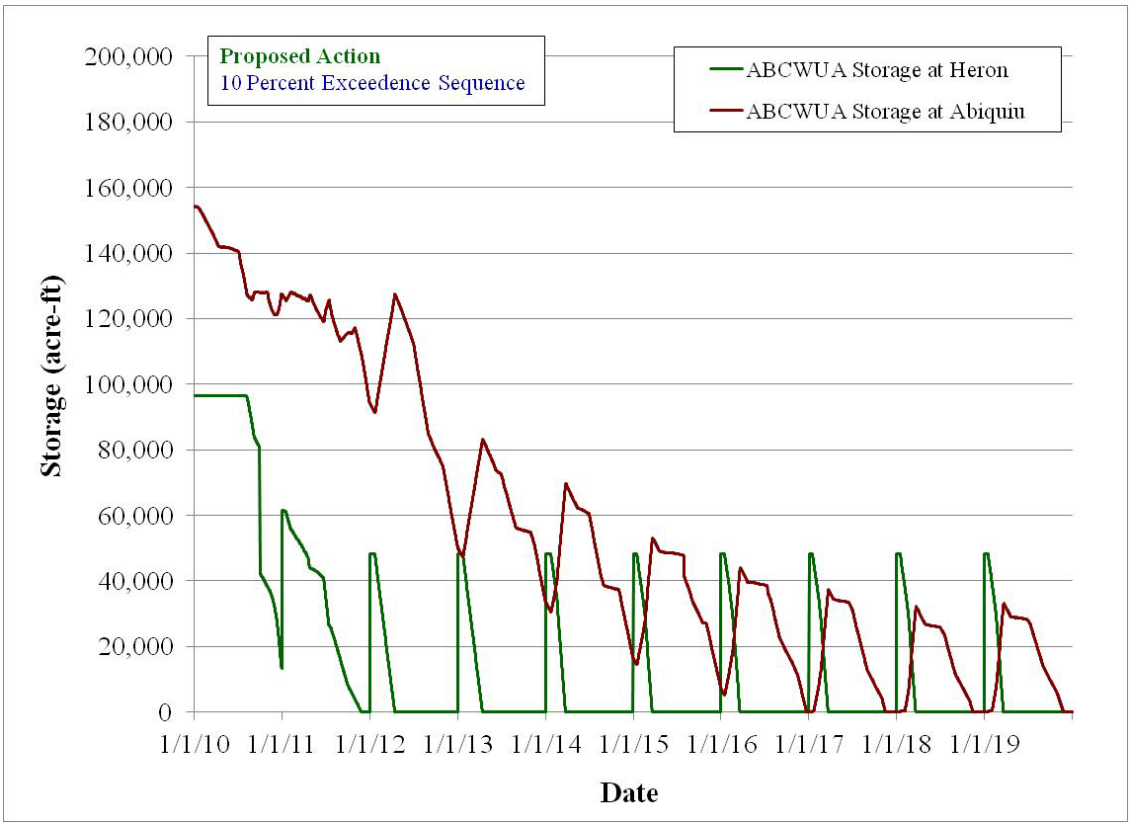

Figure 4.20. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 10 percent Exceedence Sequence

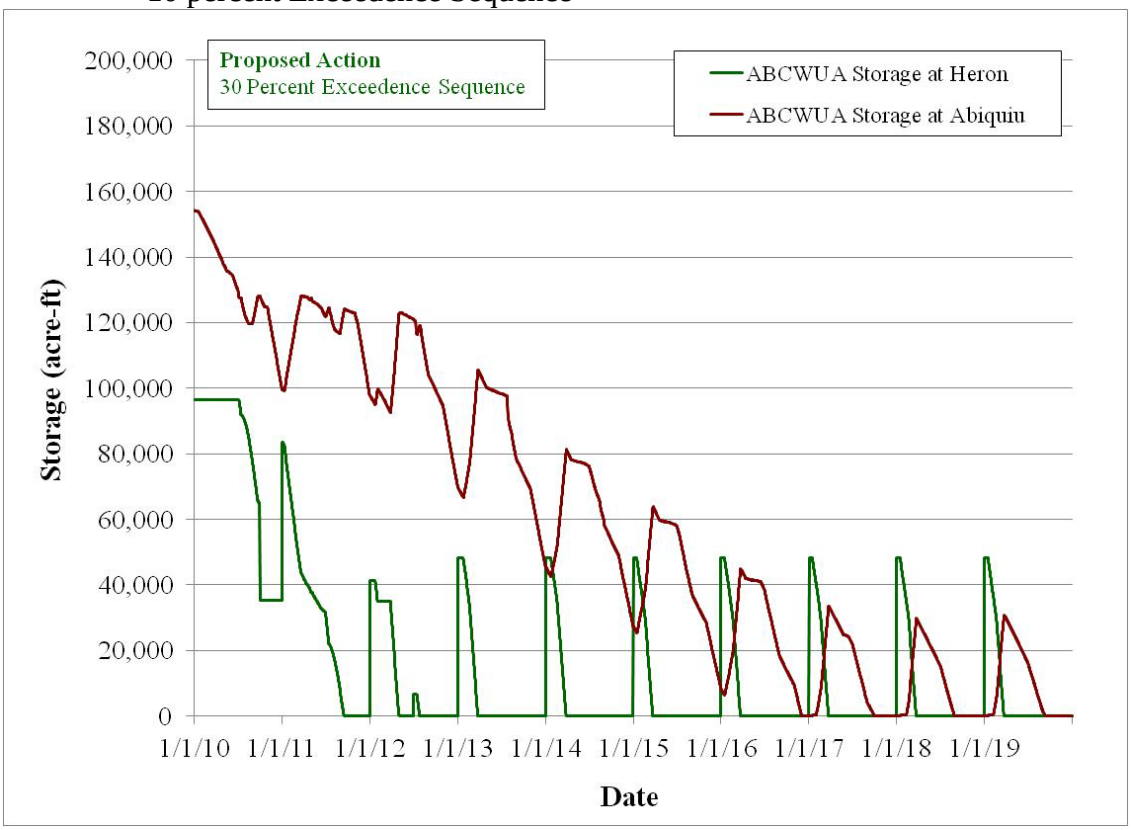

Figure 4.21. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 30 percent Exceedence Sequence

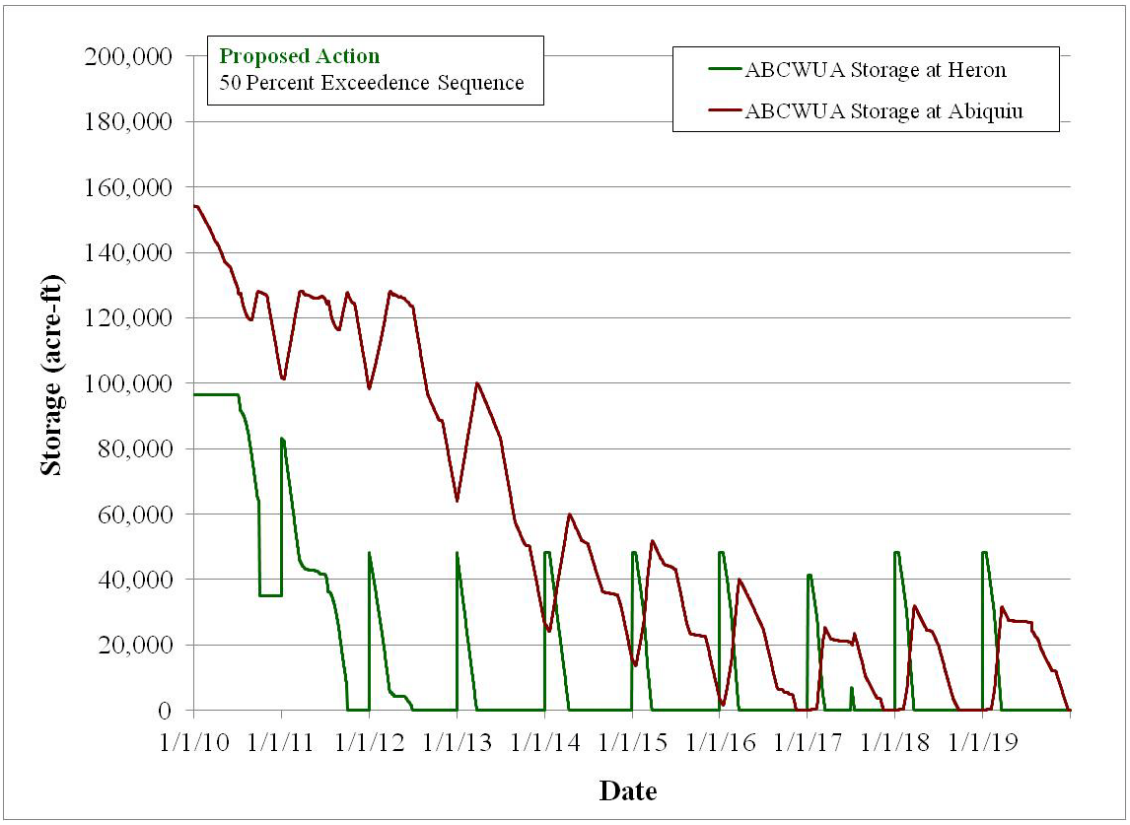

Figure 4.22. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 50 percent Exceedence Sequence

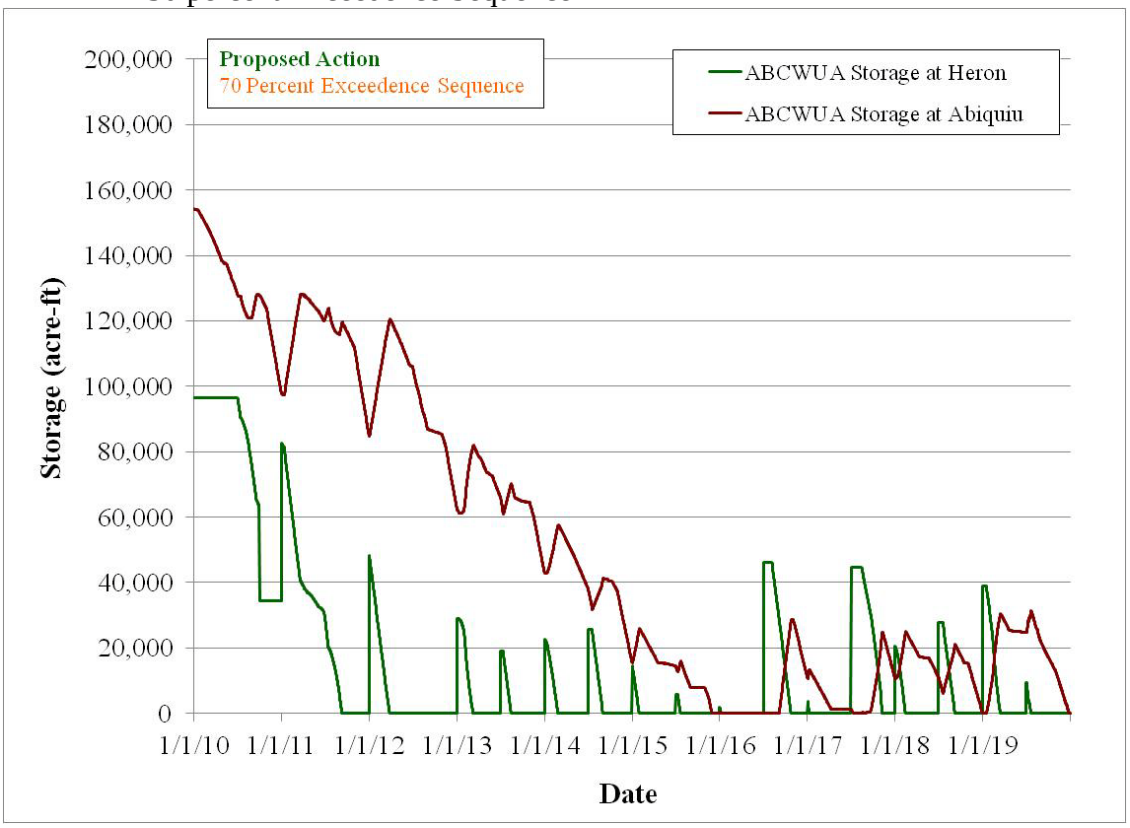

Figure 4.23. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 70 percent Exceedence Sequence

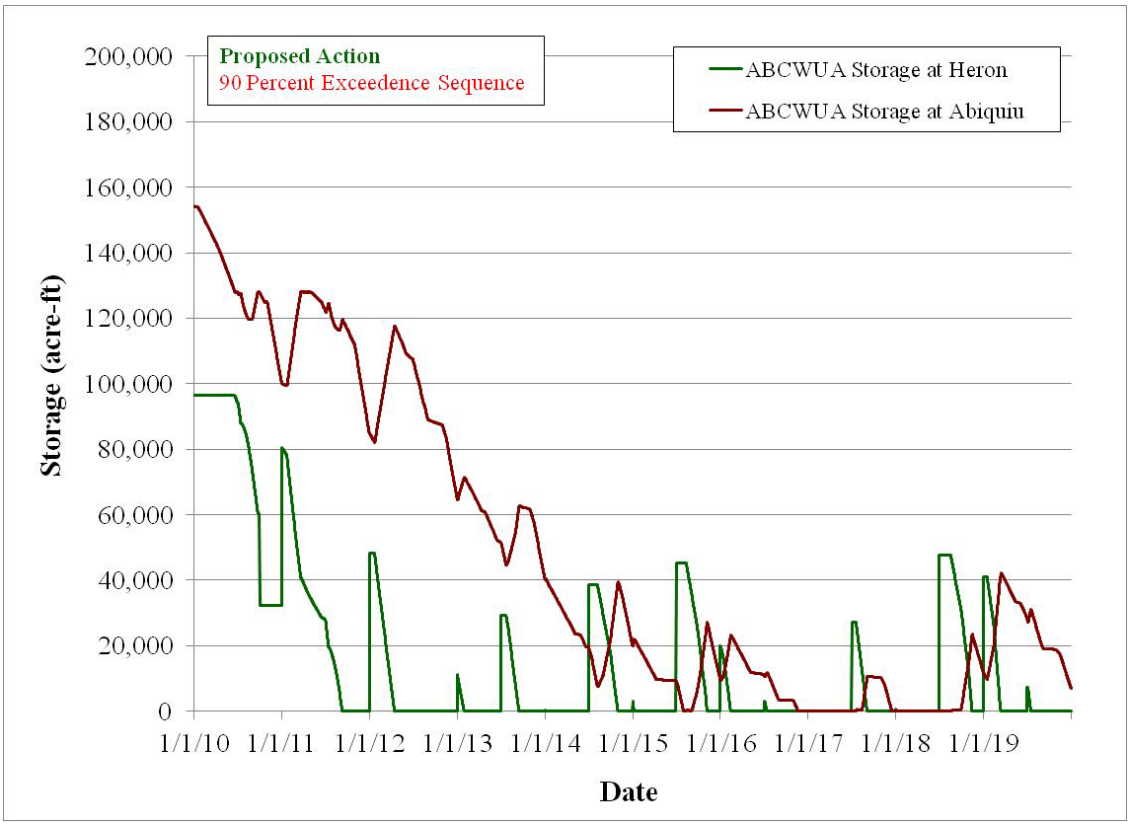

Figure 4.24. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 90 percent Exceedence Sequence

4.2. Reclamation Actions and Non-Fed Actions

Results were reviewed from model runs set up to evaluate the impact of Reclamation's water operations actions (Heron Dam operations for the San Juan-Chama Project and Middle Rio Grande Project operations along with the Supplemental Water Program) and non-Federal actions (including operations of the Middle Rio Grande diversion structures to provide flows to MRGCD and the six Middle Rio Grande pueblos) as described in section 3.4. Impacts were analyzed by utilizing the model runs set up by sequentially turning off each action, and flow exceedence curves are presented to illustrate the impacts of each action on the occurrence of low flows in the Middle Rio Grande from the fifty years of simulation results using the five 10-year hydrologic sequences.

4.2.1. Heron Dam Ops, El Vado Dam Ops, and the Supplemental Water Program

Reclamation's operations of Heron Dam for the San Juan-Chama Project result in augmented flows below Cochiti Dam as a result of ABCWUA deliveries to their surface water diversion and MRGCD deliveries during periods when native supplies may be exhausted and MRGCD would otherwise be in a shortage situation. Reclamation's leases of San Juan-Chama Project water also contribute to flows in the Middle Rio Grande with leased water released to meet flow requirements under the 2003 BO. Other uses of San Juan-Chama Project water are upstream and do not affect flows in the Middle Rio Grande. Many contractors use their San Juan-Chama Project water to provide an even offset for depletions caused further upstream, as administered

by the Office of the State Engineer. Cochiti Recreation Pool water is used to offset evaporation losses from the recreation pool upstream of the Middle Rio Grande.

El Vado Dam operations to store native Rio Grande flows for MRGCD and deliver this water later as needed to meet the need for MRGCD diversions results in augmented flows in habitat for the Rio Grande silvery minnow during low flow periods. Model run results indicate that recruitment or overbank flows would occur for a few extra days during some years with no El Vado Dam operations, but thresholds for defined recruitment or overbank flows would occur anyway during these years. Also, during drier years, storage at El Vado Reservoir often does not occur anyway due to storage restrictions in place per Article VII of the Compact or the inflows to the reservoir are too low for any appreciable storage to occur while still meeting the daily Middle Rio Grande Project irrigation demand. Also, storage at Abiquiu Reservoir for the 1800 cfs channel capacity below Abiquiu Dam results in curtailed flows from the Rio Chama during the runoff, and these curtailments would still occur if inflows were always bypassed at El Vado Dam. Reclamation's operations at El Vado Dam have a slight impact on the occurrence of recruitment or overbank flows.

Refer to Figure 4.25 for a comparison of exceedence curves developed for the Proposed Action with the Supplemental Water Program, the Proposed Action without the Supplemental Program, and MRGCD Diversions Only (or no Heron Dam operations or El Vado Dam operations). The difference in the curve for conditions with the MRGCD Diversions Only and the curve for the Proposed Action without the Supplemental Water Program depicts the benefits of Reclamation's actions of Heron Dam Operations for the San Juan-Chama Project and El Vado Dam operations. These operations result in augmented flows in the Middle Rio Grande with just a slight impact on higher flows. A comparison then to the curve for the Proposed Action with the Supplemental Water Program depicts the additional benefits from Reclamation's leases of San Juan-Chama Project water.

While increased flows are evident below Cochiti Dam and at Central from Heron Dam operations, much of the additional flows are diverted at the ABCWUA diversion or at MRGCD diversions at Cochiti, Angostura, or Isleta. Additional flows below Isleta from San Juan-Chama Project water are essentially entirely from leased water to Reclamation's Supplemental Water Program minus conveyance losses. Note that benefits of supplemental water used to meet targets will not be realized in lower reaches with no targets since supplemental water will be diverted by MRGCD if there are no downstream targets, and Heron Dam operations for the San Juan-Chama Project have essentially no impact on the occurrence of recruitment or overbank flows in the Middle Rio Grande. Also, available supplies of lease water are now limited but Heron Dam operations and the deliveries of San Juan-Chama Project water to ABCWUA and MRGCD and the remaining supplemental water will help to reduce the future occurrences of river drying. The positive impact of San Juan-Chama water will be most apparent during drier conditions when MRGCD would otherwise be out of native supplies and ABCWUA would be using groundwater to meet drinking water needs. Under these conditions, San Juan-Chama water will be the primary source for flows in the river and habitat for the silvery minnow.

The model results indicate that river drying would be more frequent with no El Vado Dam operations and more prolonged periods of river drying can be expected that coincide with an increased amount of time that MRGCD would be in a shortage situation as a result of not having the additional supply from storage at El Vado Reservoir during the runoff. With no storage at El Vado Reservoir, diversions at Angostura will be increased after the runoff every year to allow for

the available water to be used as efficiently as possible and allow for water to be delivered to the six Middle Rio Grande pueblos. At these times, river drying could be expected in the Albuquerque reach in addition to drying in typical problem areas along the Isleta and San Acacia reaches. Drying would be expected an additional eight percent of the time (28 more days/year on average) below the Isleta Diversion as indicated by the flow exceedence curves in Figure 4.25. It should also be noted that not including pumping operations from the Low Flow Conveyance Channel would also significantly increase the amount of river drying along the San Acacia reach. With no pumping operations, increased river drying can be expected below each pump site.

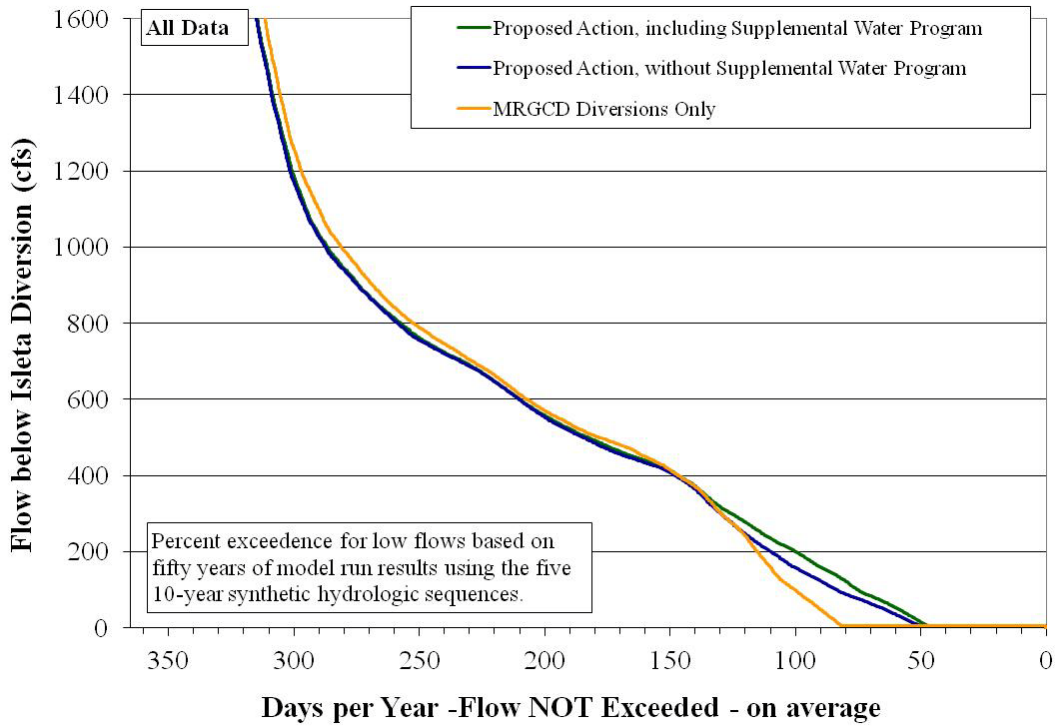

Figure 4.25. Flow Exceedence Curves Depicting the Impact of Reclamation's Actions (Heron Dam Operations for San Juan-Chama Project and El Vado Dam Operations) and the Supplemental Water Program on Flows at below the Isleta Diversion Dam

4.2.2. Middle Rio Grande Project Diversions

Middle Rio Grande Project diversions at Cochiti, Angostura, Isleta, and San Acacia are operated by MRGCD to divert and deliver water to MRGCD customers and also provide water to the six Middle Rio Grande pueblos. Demand for MRGCD begins with the irrigation season on March 1st each year and generally increases toward the middle of the irrigation season and subsequently decreases with water needs ending at the end of the irrigation season on October 31st. Diversions impact river flows up to the capacity of MRGCD diversions as river flows are available, and river flows would then subsequently be augmented downstream by return flows from drains and MRGCD wasteways.

Flows in the Middle Rio Grande would be significantly augmented as a result of no Middle Rio Grande Project diversions. Refer to Figure 4.26 for flow exceedence curves depicting the impact

on flows at Central where the additional flows with no diversion would essentially entirely occur during the irrigation season as indicated by Figures 4.27 and 4.28. It should be noted that calibrating URGWOM to simulate the occurrence of river drying under these conditions was particularly difficult due to the dearth of historical data under the situation of no Middle Rio Grande Project diversions, but it is emphasized that some river drying would still be expected during very dry periods directly below the Angostura diversion and along reaches of the Isleta and San Acacia reach that are most prone to drying.

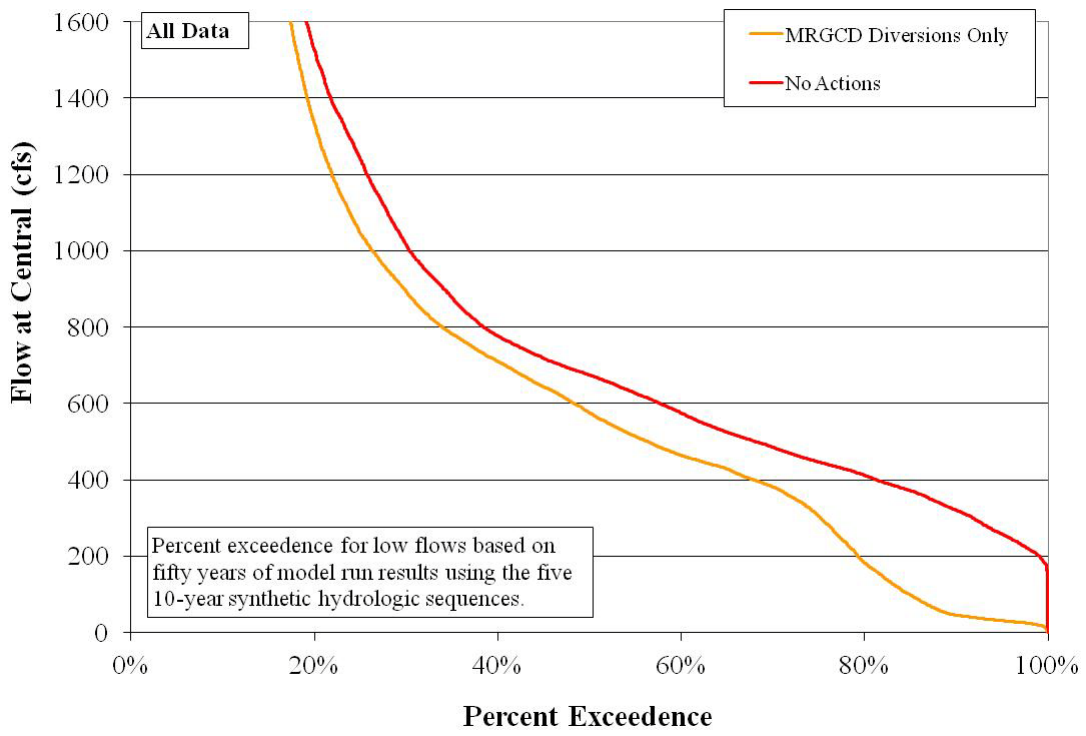

Figure 4.26. Flow Exceedence Curves Depicting Impacts of MRGCD Diversions on Flows at Central

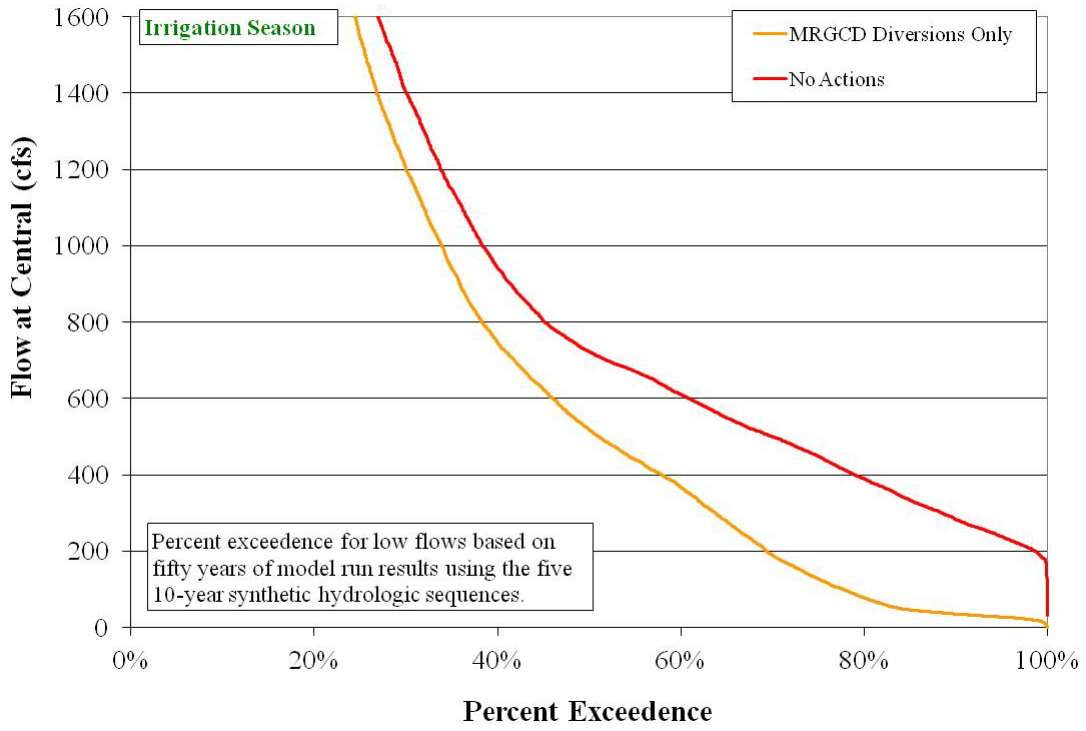

Figure 4.27. Flow Exceedence Curves Depicting Impacts of MRGCD Diversions on Flows at Central – Irrigation Season

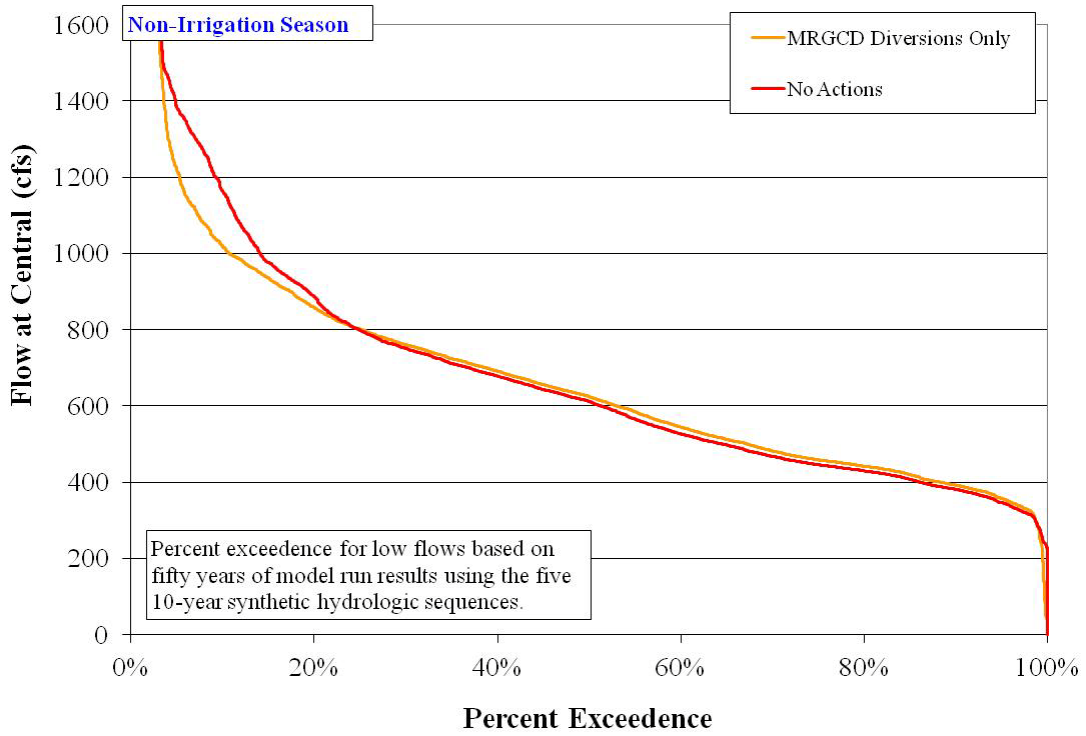

Figure 4.28. Flow Exceedence Curves Depicting Impacts of MRGCD Diversions on Flows at Central – Non-Irrigation Season

4.2.3. Contributions to Meeting Middle Rio Grande Project Diversion Demand

Results from the simulation of the Proposed Action were reviewed to evaluate the source for contributions to meeting the total demand at Cochiti for the Middle Rio Grande Project diversions between 1) natural flow, 2) releases of native Rio Grande water from storage at El Vado Reservoir, and 3) releases of MRGCD's San Juan-Chama Project water. Contributions are delineated in Figures 4.29 through 4.33 for the five model runs completed for the Proposed Action with each hydrologic sequence. Periods when MRGCD would be in shortage operations and their full demand could not be met are indicated by gaps between the contributions and the total demand. The plots clearly indicate years when MRGCD would be in an extended shortage situation if contributions from the release of native Rio Grande water from storage at El Vado Reservoir and/or MRGCD's San Juan-Chama Project water were not available. The breakdown in contributions for each model run as a percentage of the total demand is presented in Table 4.1 along with average percentages included based on all five model runs.

Table 4.1. Contributions to Meeting the MRG Project Diversion Demand at Cochiti Dam

Contribution	10 percent sequence	30 percent sequence	50 percent sequence	70 percent sequence	90 percent sequence	Avg
Natural Flow	78.8	80.8	82.0	79.3	74.5	79.2
Releases from Storage	12.0	8.4	6.3	4.9	4.0	5.9
SJC Project Water	4.8	7.2	6.8	5.9	6.8	6.7
Shortage	4.4	3.5	4.9	9.9	14.7	8.2

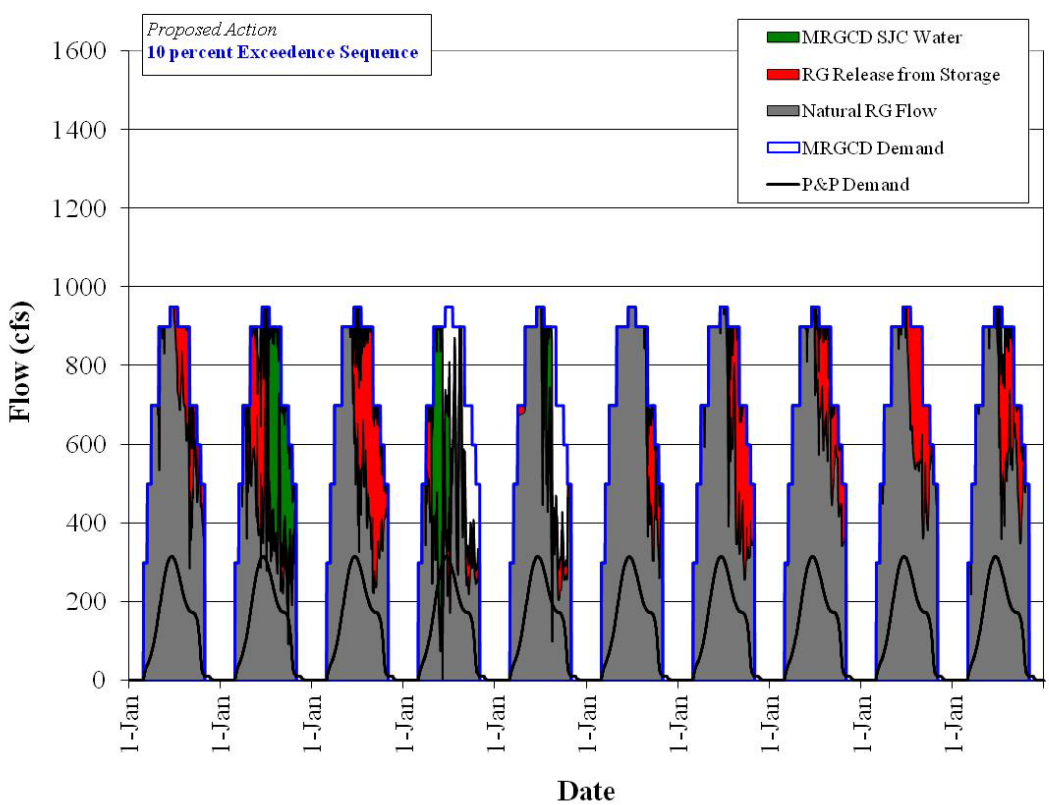

Figure 4.29. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 10 percent Exceedence Hydrologic Sequence

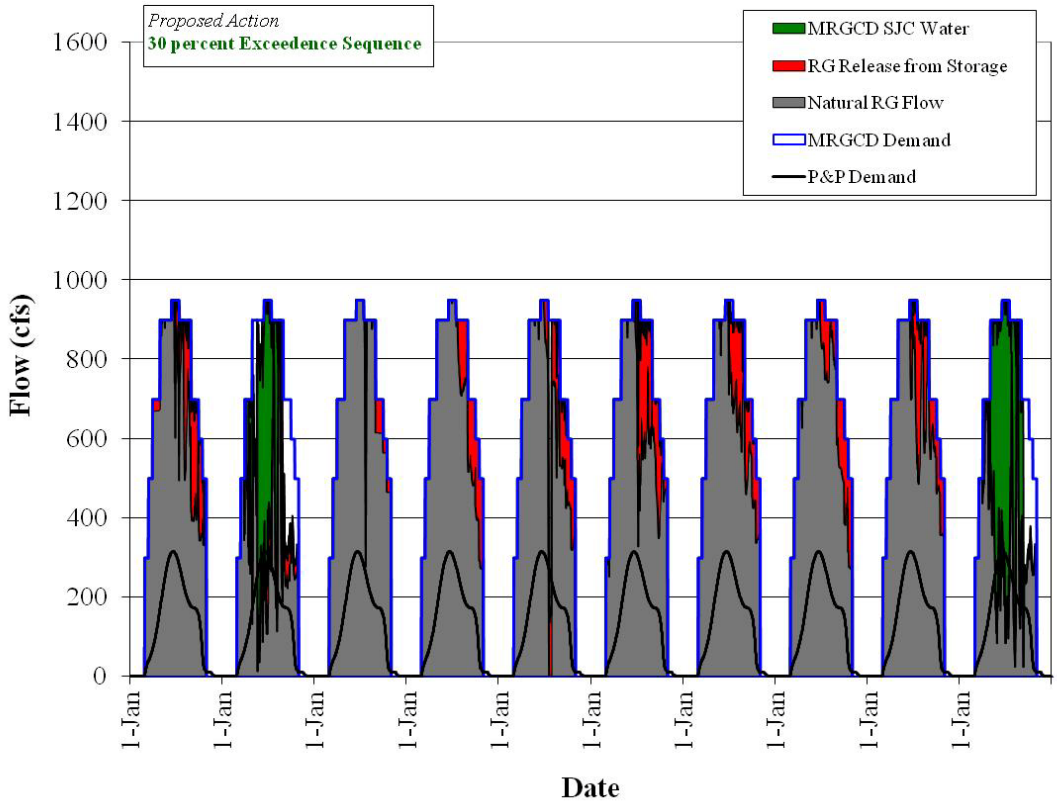

Figure 4.30. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 30 percent Exceedence Hydrologic Sequence

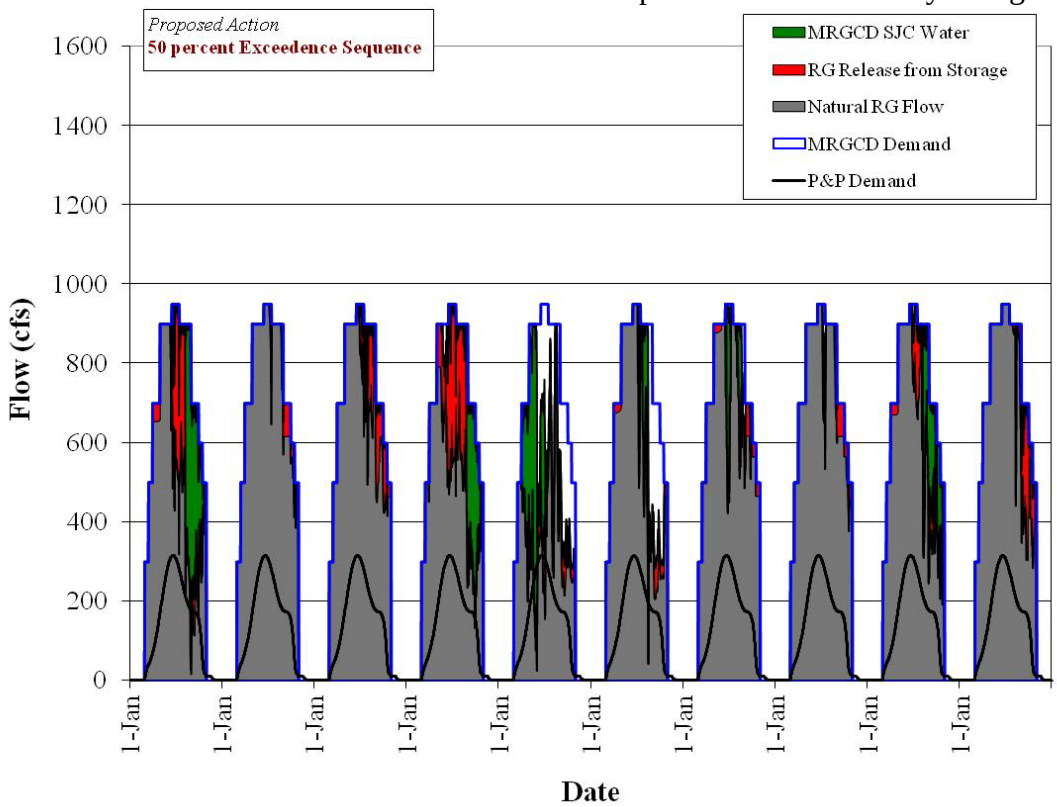

Figure 4.31. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 50 percent Exceedence Hydrologic Sequence

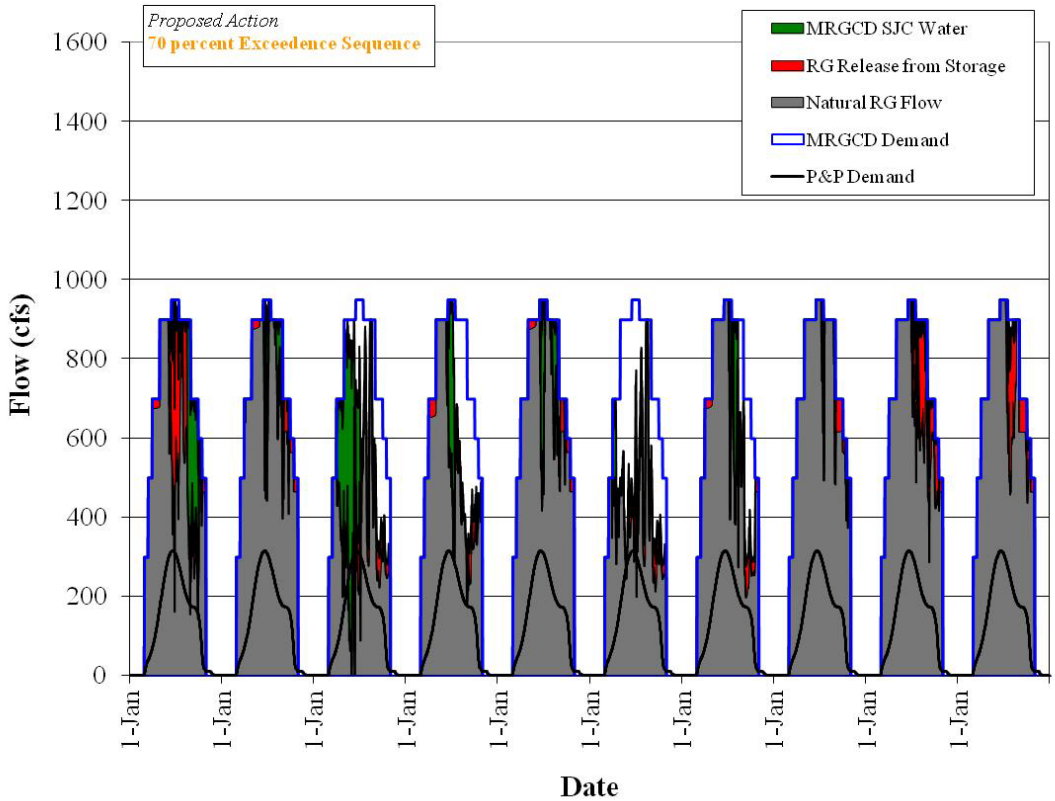

Figure 4.32. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 70 percent Exceedence Hydrologic Sequence

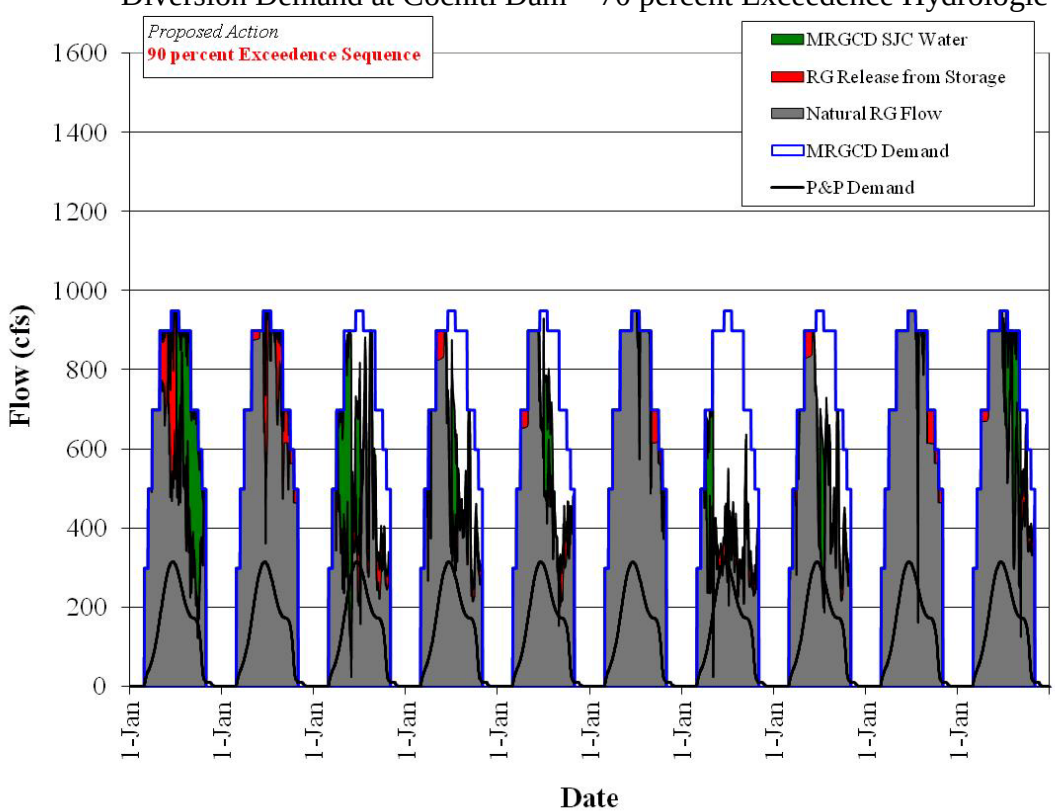

Figure 4.33. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 90 percent Exceedence Hydrologic Sequence

5.0. Coordination with PVA Work Group

The PHVA work group was created to provide hydrologic information needed by Reclamation and the Corps to write their Rio Grande water operations BAs for use in consultation with the Service (PHVA Work Group, 2010a). This effort was to include steps to provide information to the Population Viability Analysis (PVA) work group of the Collaborative Program for their work to assess impacts of scenarios on the southwestern willow flycatcher and Rio Grande silvery minnow. Working PVA models were not developed for preparing the Bas; however, the PHVA work group provided model output and documentation and participated in joint PHVA-PVA work group sessions and ongoing communicated with the PVA work group to provide information needed to test the PVA models. This communication included a PHVA refresher held on December 2, 2009 where all PHVA work group activities were reviewed in a formal presentation for the entire Collaborative Program, and a submittal was provided to the PVA work group in 2011 in response to a formal list of needs received from the PVA work group in July, 2011. The submittal included streamflow data, URGWOM rules documentation, and information on the synthetic hydrologic sequences.

5.1. Template Output Spreadsheet

Modeled May-June flow volumes at key locations in the Middle Rio Grande was identified early in the PHVA-PVA coordination process as a potential key input to the PVA models, and sample May-June flow volumes were provided for testing the PVA models. In addition, a template spreadsheet was developed that is configured to present other output information from URGWOM simulations completed by the PHVA work group. The spreadsheet includes various types of information that can be provided from the URGWOM runs including the expected timing and extent of river drying in the Middle Rio Grande, timing of recruitment and overbank flows, the timing that Cochiti deviations are implemented, and information on the use of supplemental water to meet flow requirements. Flow exceedence curves were provided that depict the percent of time that low flows are exceeded at different locations in the Middle Rio Grande for an analysis period. In addition to series output for different slots in URGWOM, the spreadsheets include summary tables and plots of river flows and reservoir storage. A sample spatial depiction of river drying was also developed that could be used to depict the timing and extent of river drying. Any output needed from URGWOM for the PVA models is likely included in the template spreadsheets, but a table with 192 URGWOM output slots was also provided to the PVA work group with a description of what each model slot represents and background information on the output that could be provided.

5.2. Key Points Document

A document was provided to the PVA work group during the summer of 2010 and updated with small edits in 2011 (PHVA work group, 2011). The document provides key points on the modeling and analyses completed by the PHVA work group and how information is determined for providing needed inputs for the PVA models. The report includes background information on the physical layout of the system in URGWOM, model calibration, initial conditions used for simulations, the synthetic hydrologic sequences, and flow tools analyzed by the PHVA work group for potentially meeting ESA needs. A summary is also presented in the document on how target flows are used to represent the use of supplemental water to meet flow requirements and

the approach for representing discretionary operations conducted under the 2003 BO. An approach for analyzing model output to estimate when river drying would be expected is also presented that includes boundary information on subreaches included in URGWOM.

5.3. Work to Set Up URGWOM for Potential 50-year Simulations

The PVA work group has emphasized the need for lots of output from multiple longer 50-year simulations to develop distributions for inputs to the PVA models, which are stochastic models. URGWOM is a daily timestep model that includes complex accounting and a detailed representation of physical processes in the basin, and as a result, continuous model runs for periods much longer than 10 years cannot be completed due to memory limitations. An analysis period of 10 years had been defined for preparing the BAs, but the URGWOM Technical Team has been working on different tasks to be able to eventually complete 50-year simulations.

Initially, an updated set of scripts were developed for use in an Excel wrapper to complete 50-year model runs as five 10-year simulations completed in series with any combination of the five existing 10-year synthetic hydrologic sequences. While the process works, it is very cumbersome and results in significant resources being required to complete model runs and review output. With this approach, all the output from the full 50-year simulations is then not contained in a single RiverWare model file but only the exported output is available in database files. Model checking and debugging becomes very difficult, and the full simulations take several hours to complete. Output from a 50-year model run completed with the Excel wrapper was provided to the PVA work group by the Interstate Stream Commission (ISC) to use to test the PVA models for a simulation for the Pre-ESA Management scenario. A description of the Pre-ESA Management scenario was provided in February 2010.

Reclamation and the Corps also contributed funding to the RiverWare developers at CADSWES to develop a version of RiverWare for 64-bit machines. The new version of RiverWare is now available. Representatives on the URGWOM Technical Team have begun working with the IT departments at their agencies to get set up with 64-bit machines and Windows 7 to run the new version of RiverWare for 64-bit machines. A 31-year test URGWOM run was completed by the URGWOM Technical Team using the available historical record. The Tech Team has also begun work on two key next steps to 1) develop new 50-year synthetic hydrologic sequences and 2) develop an approach for efficiently populating model runs with inputs for sequences. Historical data needed to run URGWOM are only available for years 1975 and later, so this is an issue that will need to be considered as part of developing new meaningful hydrologic sequences.

The URGWOM Technical Team has also completed a detailed review of the model to identify areas where the model could be adjusted to improve the efficiency for simulations and allow for longer model runs to be set up. Such changes include eliminating accounting supplies and exchanges that are no longer used in simulations and simplify the approach for representing movement of water allocated for different contractors for San Juan-Chama Project water. The Tech Team is also looking into a simpler approach for representing crop consumption from irrigated lands in the Middle Valley. The RiverWare developers have also provided some suggestions for changes to the approach for coding rules that should improve the model performance. The Tech Team has also initiated a long-term effort to develop a monthly timestep RiverWare model (Boroughs, 2011); although, it is not expected that needed inputs for the PVA models could be provided accurately with simulations completed at a monthly timestep.

6.0. Conclusions

URGWOM was used as a tool for providing needed information for the Corps and Reclamation to prepare their Rio Grande water operations BAs. After an extensive review of the existing model and ruleset and model enhancements were implemented to meet the needs for the analyses completed by the PHVA work group of the Collaborative Program, the model was used to analyze impacts of a final determined Proposed Action for Reclamation's BA. The Proposed Action entails meeting the 2003 BO requirements as possible utilizing an initial supply of supplemental water and future Reclamation leases of San Juan-Chama Project water (12,000 acre-ft/year for the first five years and 8000 acre-ft/year for the following five years). Pumping from the Low Flow Conveyance Channel is also included to manage the recession after the continuous flow requirement (or after the runoff).

Flow requirements under the 2003 BO cannot be fully met under the Proposed Action. More river drying will occur. Results from the modeling indicate the total annual amount of supplemental water needed to meet the 2003 BO flow requirements over the next ten years may average from 32,000 acre-ft/year to 49,000 acre-ft/year depending on the hydrology. The additional amount of supplemental water needed beyond the amount provided under the Proposed Action may average from 17,800 acre-ft/year to 35,900 acre-ft/year.

A review of the impact of Reclamation's actions including Heron Dam operations for the San Juan-Chama Project and El Vado Dam operations along with the Supplemental Water Program was completed. It was determined that Heron Dam operations help to augment flows in the Middle Rio Grande as a result of providing San Juan-Chama Project water to MRGCD and ABCWUA along with leases of San Juan-Chama Project water used for meeting flow requirements under the 2003 BO. El Vado Dam operations also help to augment flows in the Middle Rio Grande. Water stored during the runoff as not needed to meet the daily Middle Rio Grande Project irrigation demand, and when storage restrictions per Article VII of the Compact are not in effect, is released later in the summer and helps to provide additional flows in the Middle Rio Grande. It was determined that Middle Rio Grande Project diversions adversely impact flows; flows in the Middle Rio Grande would be augmented without diversions.

A review of other PHVA flow tools, throughout the modeling process, as not included with the Proposed Action indicates that additional Relinquished Credits would significantly contribute to the needed supply of supplemental water to meet flow requirements under the 2003 BO and reduce the amount of river drying, but a significant additional amount of supplemental would still be needed to always meet the 2003 BO flow requirements. Also, Cochiti deviations would continue to help with reducing prolonged periods with no recruitment or overbank flows.

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