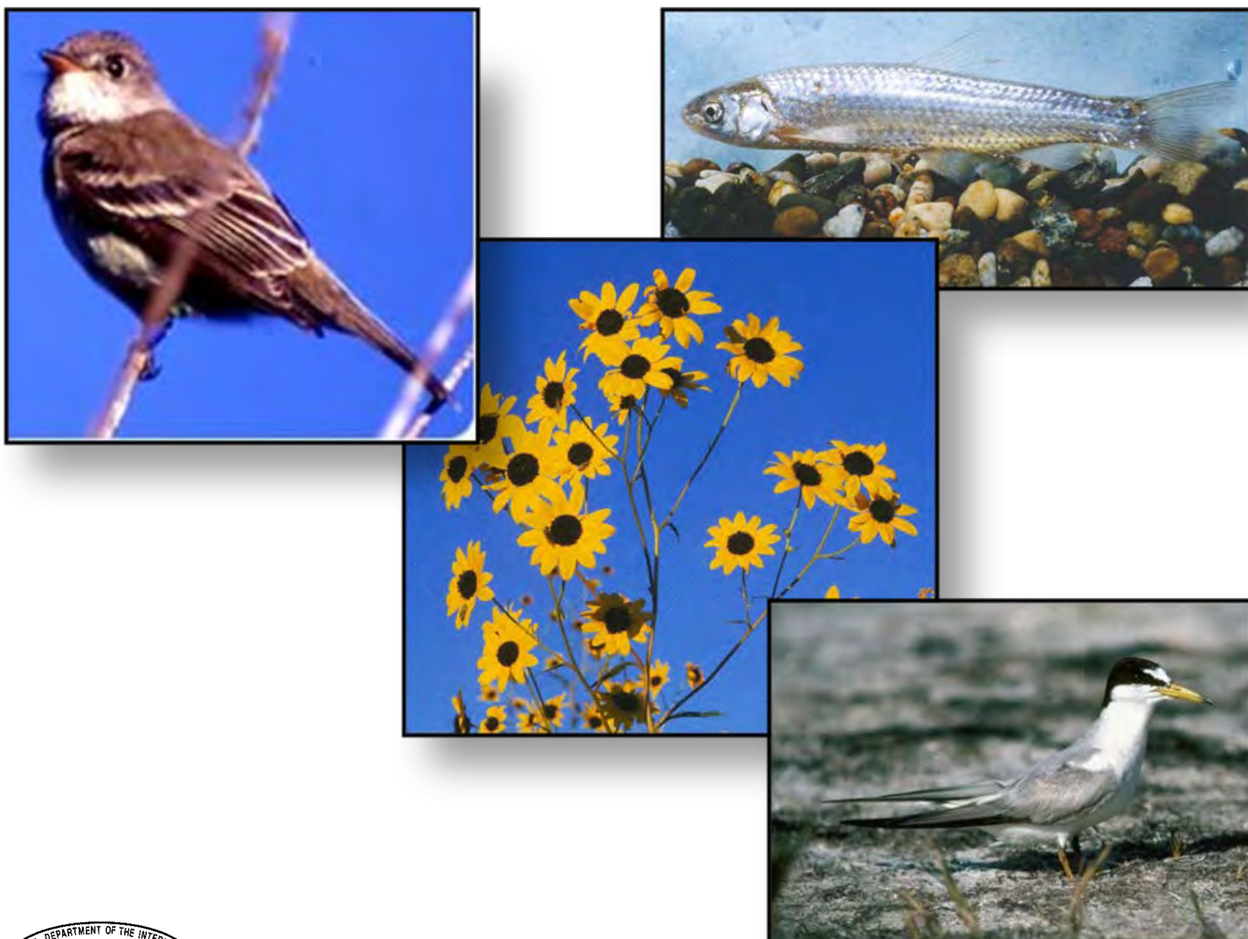
RECLAMATION

Managing Water in the West

Joint Biological Assessment

Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico

Middle Rio Grande Project, New Mexico
San Juan-Chama Project, New Mexico
Upper Colorado Region



U.S. Department of the Interior
Bureau of Reclamation

July 2012 (Amended January 2013)

Mission Statements

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

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

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Upper Colorado Region

Submitted to the U.S. Fish and Wildlife Service

Rio Grande Silvery Minnow	**Southwestern Willow Flycatcher**
Pecos Sunflower	**Interior Least Tern**

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Executive Summary

This biological assessment (BA) includes the Bureau of Reclamation's (Reclamation), the Middle Rio Grande Conservancy District's (MRGCD), and the State of New Mexico's (State) water management actions taken in the Middle Rio Grande (MRG), as well as State actions in the Upper Rio Grande. The BA also includes conservation measures proposed by Reclamation, the MRGCD, the State, the Albuquerque-Bernalillo County Water Utility Authority (Authority), as well as the offsetting actions taken by participants of the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program). The analysis for this BA is divided into three parts:

- Part I: Reclamation's and MRGCD's specifically-described water management actions and conservation measures, and the Authority's and the Collaborative Program's conservation measures (originally submitted to the U.S. Fish and Wildlife Service (Service) on July 31, 2012 and on September 14, 2102);

- Part II: A programmatic description of Reclamation's River Maintenance Program, as well as a description of specific maintenance actions on riverside drains taken in conjunction with the State and MRGCD maintenance actions on diversion structures and riverside delivery systems (originally submitted to the Service on July 31, 2012); and

- Part III: The State's specifically-described water management actions and conservation measures (originally submitted to the Service on August 15 (Revised August 27) and on September 17, 2102).

Three species are fully considered in the BA analysis: Rio Grande silvery minnow (RGSM), Southwestern willow flycatcher (SWFL), and Pecos sunflower. Least tern are considered "vagrant" within the MRG, would not be affected by the actions, and are not analyzed in this BA. The approach to this consultation differs in several ways from the approach of the 2003 consultation, which resulted in the March 17, 2003, Biological Opinion (2003 BiOp). In the 2003 consultation, Reclamation and the U.S. Army Corps of Engineers (Corps) prepared a joint BA, which used a total river depletions-based analysis that looked only at the amount of water reaching the species and critical habitat. It did not examine each action taken, the effect of discrete actions, or the extent of discretion exercised by each entity.

For this BA, Reclamation set out more specifically to identify and describe each of its actions, the actions of several non-Federal members of the Collaborative Program, and the nature and extent of discretion attendant with each action.

Reclamation determined that it does not have the discretion to operate the MRG Project diversion structures for several reasons, including that Reclamation does not and has never held any interest in the right to divert water for lands within the MRGCD.

The action area for Parts I and II extends from Heron Reservoir and Willow Creek downstream from Heron Dam, the Rio Chama downstream from the confluence with Willow Creek, and in the Rio Grande from Velarde, New Mexico, downstream to San Marcial above the full reservoir pool of Elephant Butte Reservoir. Reclamation and MRGCD have no actions that are considered in this analysis upstream of Velarde. Similarly the River Maintenance that occurs between Elephant Butte Dam and Caballo Reservoir was not included in the analysis. The scope of River Maintenance activities within this reach is not consistent with activities that occur within the Middle Rio Grande and occur under a different authority. Additionally, no endangered species currently are present in this reach.

The action area for the State's actions included for Part III extends from the Colorado state line to near San Marcial above the full reservoir pool of Elephant Butte Reservoir.

This BA evaluates the effects of the following water management actions and conservation measures for Reclamation, the MRGCD and the State, and offers the following conservation measures for the ABCWUA and the Collaborative Program:

1. Reclamation proposes the following water management actions:
    a. Operation of Heron Dam and Reservoir as part of the San Juan-Chama Project (SJC Project) to deliver water to downstream users; and
    b. Operation of El Vado Dam and Reservoir to store and release water, including response to requests by MRGCD, and in accordance with the State of New Mexico as authorized by NM Office of the State Engineer Permit number 1690.
2. MRGCD proposes the following water management actions:
    a. Operation of the MRG Project Diversion Dams to deliver water to meet the agricultural demand of lands with appurtenant water rights, including the lands of the Six MRG Pueblos;[1] and
    b. Operation of irrigation drains and wasteways to return water to the river.

[1] Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta Pueblos (the Six MRG Pueblos or Pueblos).

3. The State proposes the following water management actions as described in Part III of this BA.
4. Reclamation, the MRGCD and the State propose the following maintenance activities:
    a. Reclamation proposes a programmatic strategy for River Maintenance activities that will provide efficient water delivery and protect infrastructure along the Middle Rio Grande;
    b. Reclamation proposes maintenance activities for the Low Flow Conveyance Channel and former State Drains in coordination with the State; and
    c. MRGCD proposes to continue maintenance activities for their diversion dams and associated conveyance channels and facilities.

Specific conservation measures that have been developed and are offered by Reclamation, the MRGCD, the State, the ABCWUA and the Collaborative Program, and described in the BA are as follows:

1. Reclamation's conservation measures:
    a. To purchase or lease from willing parties, water, water rights or the right to store water for use in the Rio Grande to provide supplemental flows to the Rio Grande;
    b. To lease water from SJC Project contractors, depending on environmental conditions, water availability, funding, and the willingness of contractors to enter into leasing agreements;
    c. To use pre-1907 surface water rights acquired from Price's Dairy to benefit listed species;
    d. To release Supplemental Water Program water as needed, to meet downstream flow targets, while supplies last;
    e. To seek to enter into water acquisition agreements and/or water management agreements with SJC contractors and other interested parties;
    f. To release water stored pursuant to the Emergency Drought Water Agreement or other similar agreements, as is made available by the State of New Mexico, consistent with the Compact and with State and Federal law;
    g. To utilize its Supplemental Water Program water only when native flow management is insufficient to meet ESA requirements by exchanging leased SJC Project water with native Rio Grande water;

h. To authorize temporary waivers, which allow SJC Project contractors to take their water deliveries in the following calendar year, if such waivers will benefit the United States and not impact delivery into Heron Reservoir; and

i. To pump and convey water from the Low Flow Conveyance Channel to the Rio Grande, including the operation of an outfall near Escondida, New Mexico.

2. The MRGCD's conservation measures:

   a. Continuation of enhanced coordination of water operations with Reclamation and other water management agencies;

   b. Continued operation, and expansion of metering and monitoring stations throughout the MRGCD canal system to enhance the understanding of water movement and use in the MRG;

   c. Continued efforts to increase operational efficiency, which may reduce the need for Supplemental water, expand options for flow management, and minimize the effects of irrigation water storage on spring flow peaks;

   d. Development of an Operating Plan to promote the efficient management and delivery of irrigation water with appurtenant benefits to species water management for survival and recovery;

   e. Cooperation with State and Federal agencies in their creation and operation of a 30,000 af supplemental water pool in Abiquiu Reservoir for endangered species management purposes;

   f. Work toward completion of agreements with ABCWUA to store up to 50,000 acre-feet of supplemental irrigation water at Abiquiu Reservoir, and conjunctive management of releases with other water management entities to maximize flexibility in Rio Chama water operations for species and other benefits;

   g. Management of diversions and outfalls, when surplus water in excess of MRGCD needs is available, to return excess flows to the Rio Grande for habitat areas and other designated sites, or conveyance of water to these areas and sites;

   h. Cooperation and assistance with the creation and enhancement of specific habitat areas near MRGCD surface water outfalls to the Rio Grande;

   i. Construction of the Bernardo Siphon to enhance management options for San Acacia dam;

j. Construction of a return flow collection system at its southern boundary, with the assistance of the Bosque del Apache National Wildlife Refuge, to deliver excess water back to the Rio Grande for species purposes, to enhance Rio Grande Compact delivery options, and to provide more consistent water delivery for the Refuge;

k. Coordination with the Corps (subject to the limits of the Corps' Cochiti Reservoir Water Control Manual) to reduce the use of supplemental species water use during recession management for RGSM following precipitation-induced increases in flow;

l. Active participation in the creation of habitat to benefit the lifecycle of the RGSM;

m. Cooperation with efforts allowing groundwater users within the MRGCD with pre-1907 or pre-basin rights to offer water for lease to Reclamation or other entities for the express purpose of providing flows from wells for endangered species; and

n. Execution of a research agreement providing funding for current Collaborative Program population viability analysis and statistical data analysis efforts.

3. The Authority's conservation measures:
    a. Additional storage of native water;
    b. Conservation Storage Agreements;
    c. Lease Supplemental Water;
    d. Continued efforts towards water conservation; and
    e. Continued coordination with water releases and diversions.
4. The State's conservation measures as described in Part III of this BA.
5. The Collaborative Program's conservation measures:
    a. Habitat restoration and management;
    b. Water management;
    c. Population augmentation/propagation;
    d. Water quality management; and
    e. Species research, monitoring and adaptive management.

The status of the RGSM and SWFL has been variable in the last decade since the initiation of the 2003 BiOp. RGSM abundance was at its lowest levels in 2003 and 2012, and highest in 2005. The RGSM abundance has decreased from 2005 levels in recent years. This is likely due to a series of low runoff years. SWFL abundance has increased since the initiation of the 2003 BiOp due to the dense vegetation that established from several years of overbank inundation. Pecos sunflower are actively managed on the La Joya State Wildlife Area (SWA) and also were planted at a new location. The Pecos sunflower population appears to be stable to increasing within the Middle Rio Grande. The population variation for RGSM and SWFL is mainly driven by high flow events, while the main portion of the Pecos sunflower population on La Joya SWA is influenced by management activities that provide water through the irrigation system.

The Collaborative Program will use guidance from the Adaptive Management Plan Version 1 and adaptive management experience of this and other programs to develop a formal Adaptive Management Program. The Collaborative Program will identify specific management activities, monitoring, and research that will be used to evaluate and improve management decisions and will identify the decision-making framework for flexible water management and nonflow-related activities that supports meeting Collaborative Program goals.

The overall effect of water management-related activities is to modify the volume, timing, and distribution of flows in the Rio Grande through the Action Area, resulting at times in a decreased flow in particular subreaches from what would occur in the absence of the Proposed Action and at times in an increased flow in particular subreaches from what would occur in the absence of the Proposed Action. Maintenance activities all have short-term direct negative effects to species and their habitat, although long-term (indirect) effects are mixed and dependant on the actions. Components of the Proposed Action are likely to adversely affect all species. Conservation measures have been developed to attempt to mitigate these adverse effects.

During 2012, Reclamation, the MRGCD, the State, the ABCWUA and other Collaborative Program participants began taking concrete steps toward development of a MRG Recovery Implementation Program (RIP), which would include an adaptive management-based approach designed to make progress towards recovery of endangered species. All parties have worked in good faith to develop the RIP documents, including crafting a Program Document, an Action Plan and a companion Water Management Plan. Although significant progress has been made on all of these fronts, the RIP documents have not yet been endorsed by the Executive Committee of the Collaborative Program and the Water Management Plan is not yet complete; therefore, it is premature to include them in this BA. Nonetheless, Reclamation and its non-Federal BA partners expect that the RIP will be established and included during the formal consultation phase.

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Acronyms and Abbreviations

ABCWUA	Albuquerque Bernalillo County Water Utility Authority
ABQ SSWRP	Albuquerque South Side Water Reclamation Plant
AF	acre-feet
AFY	acre-feet per year
AM	adaptive management
AMAFCA	Albuquerque Metropolitan Arroyo Flood Control Authority
Annual Operating Plan	Middle Rio Grande Annual Operating Plan
BA	biological assessment
Basin	Rio Grande Basin
BDA	Bosque del Apache
BIA	Bureau of Indian Affairs
BiOp	biological opinion
Buckman Project	Buckman Direct Diversion Project
Bylaws	Collaborative Program’s bylaws
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeter
cm/sec	centimeter per second
Coalition	Coalition of the Six MRG Pueblos
Collaborative Program	Middle Rio Grande Endangered Species Collaborative Program
Compact	Rio Grande Compact
Corps	U.S. Army Corps of Engineers
CPUE	catch per unit effort
CWA	Conservation Water Agreement
Diversion Dams	Angostura, Isleta, and San Acacia Diversion Dams
DO	dissolved oxygen
EBID	Elephant Butte Irrigation District
EDWA	Emergency Drought Water Agreement

EPA	Environmental Protection Agency
EP#1	El Paso County Water Improvement District No. 1
ESA	Endangered Species Act.
FR	Federal Register
GIS	geographic information system
gpcd	gallons per capita per day
ha	hectare
Heron	Heron Dam and Reservoir
in.	inch
ISC	Interstate Stream Commission
JyS Plan	2003 Jemez y Sangre Regional Water Plan
km	kilometer
LFCC	Low Flow Conveyance Channel
LIDAR	Light Detection and Ranging
LJAA	La Joya Acequia Association
LTP	Long-Term Plan
m	meter
m^2	square meters
mi	mile
mg/L	milligrams per liter
mm	millimeter
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MRG	Middle Rio Grande
MRGAA	Middle Rio Grande Administrative Area
MRGCD	Middle Rio Grande Conservancy District
MRGESCP	Middle Rio Grande Endangered Species Collaborative Program
MRG Plan	Middle Rio Grande Regional Water Plan
MRG Project	Middle Rio Grande Project
NEPA	National Environmental Policy Act
NMDGF	New Mexico Department of Game and Fish

NMISC	New Mexico Interstate Stream Commission
NMOSE	New Mexico Office of the State Engineer
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
O&M	operation and maintenance
OM&B	operation, maintenance, and betterment
PCE	primary constituent elements
PDO	Pacific Decadal Oscillation
PHVA workgroup	Population and Habitat Viability Assessment/Hydrology workgroup
PIT	passive integrated transponder
Program	Reclamation's Supplemental Water Program
Project	Middle Rio Grande Project
Pueblos	Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta Pueblos (the Six MRG Pueblos)
PVA	Population Viability Analysis
RIP	Middle Rio Grande Recovery Implementation Program (Formal title to remain MRGESCP, but an alias containing "Recovery Implementation Program" will be developed by the Executive Committee)
RGSM	Rio Grande silvery minnow
RM	river mile
RPA	Reasonable and Prudent Alternative
RPM	reasonable and prudent measures
RR	Rio Rancho
Secretary	Secretary of the Interior
Service	U.S. Fish and Wildlife Service
SJC Project	San Juan Chama Project
Stat.	Statute
SS Plan	Soccoro-Sierra Regional Water Plan
SWFL	Southwestern willow flycatcher

TNC	The Nature Conservancy
URGWOM	Upper Rio Grande Water Operations Model
U.S.	United States
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WWTP	waste water treatment plant
1928 Act	Act of March 13, 1928 (45 Statute 312)
1935 Act	Act of 1935, 49 Statute 887
1981 Agreement	Agreement: Procedures for the Storage and Release of Indian Water Entitlement of the Six Middle Rio Grande Pueblos, approved by the Secretary of the Interior, December 28, 1981
2003 BiOp	March 17, 2003, Biological Opinion
°C	degree Celsius
°F	degree Fahrenheit
>	greater than
<	less than
%	percent
§	section

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1. Introduction

1.1 Biological Assessment Content and Scope

Section 7(a) (2) of the Endangered Species Act (ESA) requires Federal agencies to consult with the U.S. Fish and Wildlife Service (Service) over any discretionary actions that the agency authorizes, funds, or carries out, which may jeopardize a listed species or adversely modify its critical habitat. The Bureau of Reclamation (Reclamation), along with non-Federal members of the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program), are initiating a new consultation for those water management actions undertaken in and affecting the Middle Rio Grande (MRG) that may implicate ESA requirements.

This joint biological assessment (BA) analyzes water management effects on listed species in the project area: the Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow), the Southwestern willow flycatcher (*Empidonax traillii extimus*; flycatcher), the Pecos sunflower (*Helianthus paradoxus*, sunflower), and the interior least tern (*Sternula antillarum athalassos*, tern). The bald eagle (*Haliaeetus leucocephalus*) was removed from the Federal list of threatened and endangered species in August 2007 and is, therefore, not considered in this BA. There is no requirement to discuss de-listed species in an ESA consultation; however, activities conducted in the course of water management will be carried out in accordance with the Bald Eagle Protection Act and the Migratory Bird Treaty Act.

Reclamation and its non-Federal partners also are consulting on the programmatic aspects of maintenance activities as a separate component of this ESA, Section 7(a) (2), process.

The approach to this consultation differs in several ways from the approach of the 2003 consultation, which resulted in the March 17, 2003, Biological Opinion[1] (2003 BiOp). In the 2003 consultation, Reclamation and the U.S. Army Corps of Engineers (Corps) prepared a joint BA, which used a total river depletions-based analysis that looked only at the amount of water not reaching the species and critical habitat. It did not examine each action taken, the effect of discrete actions, or the extent of discretion exercised by each entity. As a result of this undifferentiated view of depletions, incidental take coverage was extended to

[1] *2003 Biological and Conference Opinions on the Effects of Actions Associated with the Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations ,U.S. Army Corps of Engineer's Flood Control Operation, and Related Non-Federal Actions in the Middle Rio Grande, New Mexico.*

most Federal and non-Federal MRG activities without evaluating the individual impacts associated with those activities.

At the time of the previous MRG consultation, the scope of Federal discretionary authority was uncertain, pending a decision from the Tenth Circuit Court of Appeals in *Rio Grande Silvery Minnow* v. *Bureau of Reclamation*. The 2003 Biological Assessment proposed several measures that the Federal agencies (Reclamation and the Corps) could take to avoid jeopardy to the silvery minnow, depending on the court's determination. Then, in December 2003, Congress enacted a rider to the 2004 Energy and Water Development Appropriations Act, which placed San Juan Chama Project (SJC Project) water beyond Reclamation's discretionary reach. Additionally, in 2010, the Tenth Circuit Court ordered that all prior rulings of the district court regarding the litigation be vacated, which included all of the lower courts' holdings regarding the scope of Reclamation's discretionary authority (601 F.3d 1096). In its opinion, the Tenth Circuit Court stated that the 2003 consultation was based on the "effects of total river depletions on listed species, without identifying particular aspects of the overall actions as 'discretionary or nondiscretionary'" and further found this approach to be incorrect.

To comply with the opinion of the 10th Circuit Court and to more fully meet the requirements of Section 7(a) (2) of the Endangered Species Act, for this BA Reclamation set out to more specifically identify and describe each of its actions, the actions of non-Federal members of the Collaborative Program, and the nature and extent of discretion attendant with each action. Reclamation parsed its discretionary actions related to the Middle Rio Grande Project (MRG Project, Project) from the actions within the Middle Rio Grande Conservancy District's (MRGCD's) authority. Reclamation determined that it does not have the discretion to operate the MRG Project diversion structures for several reasons, including that Reclamation does not and has never held any interest in the right to divert water for lands within the MRGCD.

Additionally, this BA involves the commitment of members of the Collaborative Program to carry out specific activities identified in the Annual Work Plan as a conservation measure to help offset adverse effects of Federal and non-Federal actions.

1.2 Projects Not Included in the Biological Assessment

Two projects, located along the Rio Grande to the north and south of the Middle Rio Grande Project, are outside of the action area and will not be considered in this BA. These are the San Luis Valley Project, which is located in Colorado and includes the Closed Basin Division and the Conejos Division, and the Rio Grande Project, which is located in southern New Mexico and west Texas.

The San Luis Valley Project, Closed Basin Division, located near Alamosa, Colorado, uses wells to salvage ground water from high water table conditions to assist Colorado in meeting its Rio Grande Compact (Compact) delivery requirements and the requirements of the 1906 Treaty between the United States and Mexico, to stabilize water levels in San Luis Lake and to provide mitigation water for the Alamosa Wildlife Refuge and the Blanca Wildlife Habitat Area. Flows delivered to the Rio Grande from the Closed Basin Division are part of the overall water supply available to Colorado, allowing Colorado to consume a like amount of water at a point upstream in the basin.

The San Luis Valley Project, Conejos Division, located in south-central Colorado, includes the Platoro Dam and Reservoir, which is operated for flood control and storage for irrigation, benefitting about 10,000 people on farms and six villages in the Conejos River area. The Conejos Division is a component of Colorado's Compact accounting and State line deliveries, and any changes in diversions simply would allow Colorado to minimize the accrual of debits or credits.

The Rio Grande Project, authorized by the United States Congress on February 25, 1905, extends from Elephant Butte Reservoir (New Mexico) to Ft. Quitman, Texas, and stores water for delivery to the Elephant Butte Irrigation District (EBID) in New Mexico, the El Paso County Water Improvement District No. 1 (EP#1) in Texas, and Mexico. Irrigation release rates and times are determined by Mexico, EP#1, and EBID and are calculated to meet daily irrigation demands. Reclamation manages water storage in Elephant Butte and Caballo Reservoirs in a manner that minimizes evaporation and maximizes the irrigation function of the Rio Grande Project. The total amount of water in storage in the Rio Grande Project is the result of inflows dictated by Compact guidelines for New Mexico and Colorado. The needs of irrigators and irrigation delivery orders are nondiscretionary. Reclamation cannot restrict or increase releases to affect Article VII restrictions on upstream States. The only discretionary measure in Reclamation's operational criteria not based upon irrigation delivery orders is when water is evacuated via a prerelease of storage water from Elephant Butte Reservoir to maintain space available for flood control purposes. Reclamation also has discretion to store SJC Project water in Elephant Butte Reservoir. Reclamation intends to reinitiate ESA Section 7 consultation specifically on Rio Grande Project operations in the near future.

The Temporary Channel into Elephant Butte Reservoir, established to facilitate the water delivery to the Rio Grande Project and largely contained within the Rio Grande Project area, has been and will continue to be consulted upon separately as part of the aforementioned Rio Grande Project consultation; therefore, it will not be considered in this BA.

1.3 Reclamation's Tribal Trust Responsibility and ESA Compliance

The United States Government has an Indian trust responsibility to protect and maintain rights reserved by or granted to Indian tribes by treaties, statutes, and Executive orders. Reclamation shares this responsibility and carries out its activities to protect trust assets and to avoid adverse impacts to tribes when possible. Consistent with the June 7, 1997, Secretarial Order on "American Indian Tribal Rights, Federal-Tribal Trust Responsibility, and the Endangered Species Act" (Secretarial Order No. 3206), the Bureau of Indian Affairs (BIA) has the primary responsibility for carrying out the Federal responsibility to administer tribal trust property and represent tribal interests during formal Section 7 consultation under the ESA. Reclamation implements its ESA responsibilities to respect the exercise of tribal sovereignty over the management of Indian lands and tribal trust resources.

The federally recognized Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia and Isleta Pueblos (the Six MRG Pueblos or Pueblos), as well as the San Ildefonso, Ohkay Owingeh, and Santa Clara Pueblos, exist within the action area of this BA. The interests of other federally recognized pueblos or tribes may also be affected. Reclamation is aware that the Indian pueblos and tribes do not concede that the ESA applies to their actions. Nonetheless, through this BA process, Reclamation has initiated government-to-government consultations with all pueblos and tribes in the action area or that may be affected by the actions to provide each with an opportunity to voice its comments and concerns. Reclamation has endeavored to address each pueblo's comments and concerns to date in this BA.

1.3.1 Indian Water Rights Settlements

Recently, several long standing water rights adjudications involving Indian claims to water rights in the Rio Grande Basin (Basin) have reached settlement. This BA does not include the actions or impacts related to the Indian water right settlements described below, since they will be included in separate consultations.

The Aamodt Adjudication is a complex, long-running adjudication of water rights in the Nambe-Pojoaque-Tesuque watershed north of Santa Fe. It has been the leading litigation to establish the nature and extent of pueblo Indian water rights.

It began in the 1960s and has involved numerous lawsuits and appeals. In 2000, after a series of court rulings, settlement discussions began in earnest. A settlement has been reached that involves a large water development project. On December 8, 2010, Congress signed the Claims Resolution Act of 2010 (Public Law 111-291) into law. Title VI of that Act authorizes the Aamodt Litigation Settlement and allocates major Federal funding to implement the regional water system project.

The other recent settlement involved the adjudications of the Rio Pueblo de Taos and Rio Hondo stream systems, which were filed in Federal court in 1969. The cases were consolidated and are now often referred to as simply *Abeyta*. In 2006, a settlement was reached among the Taos Pueblo, the State of New Mexico, the Taos Valley Acequia Association, the Town of Taos, El Prado Water and Sanitation District, and the 12 Taos-area Mutual Domestic Water Consumer Associations regarding the pueblos' and non-Indian water rights. In Title V of the Claims Resolution Act of 2010, Congress authorized the Taos Pueblo Indian Water Rights Settlement and appropriated significant funding towards its implementation.

For the Aamodt Settlement, Reclamation will contract for 1,079 acre-feet per year (AFY) of SJC Project water for use by the San Ildefonso, Pojoaque, Nambe, and Tesuque Pueblos. This water is intended, in part, to compensate the pueblos for agreeing to not fully exercise their right to call priority within the Rio Grande Basin. This water may not be physically exported out of the Basin. For the Abeyta Settlement, Reclamation will contract for 2,621 AFY of SJC Project water to the Taos Pueblo (2,215 AFY) and to the other settlement parties (406 AFY).

Like the claims of other non-Indian water users in the basin, the claims of other tribes that assert rights to water in the Rio Grande Basin, including the Six MRG Pueblos, are not yet quantified, are not in adjudication, and are not in settlement negotiations. The Federal Indian water rights of these pueblos and tribes are not:

1. Impaired by the Rio Grande Compact of 1938 (53 Statute [Stat.] 785).
2. Subject to State law restrictions.
3. Administered by the State of New Mexico.

Reclamation recognizes that who depletes and the amount they deplete based on these unquantified and unadjudicated rights may vary from year to year and in the future. Consequently, Reclamation and the non-Federal water users assume the risk that the future development of senior water rights, including Indian pueblo and tribal water rights, may result in shortages of water to junior users.

1.4 The Middle Rio Grande Endangered Species Collaborative Program

In April 2002, Reclamation together with Corps, the State of New Mexico, Pueblos, Middle Rio Grande Conservancy District, City of Albuquerque, and other parties executed a Memorandum of Understanding (MOU) to establish the Collaborative Program. In 2008, Congress directed the Secretary of the Interior (Secretary) to establish an Executive Committee for the Collaborative Program consistent with the Collaborative Program's bylaws (Bylaws) (110 Public Law 161). Subsequently a new Memorandum of Agreement (MOA) was signed by the parties. The Bylaws cite Section 4(f)(2) of the ESA as authority for the Collaborative Program: the Secretary is directed to develop and implement plans for the conservation of endangered species, and the Secretary may enlist the services of public and private agencies, individuals, and institutions in developing and implementing such recovery plans.

The purpose of the Collaborative Program as described in the 2008 MOA is two-fold:

- First, to prevent extinction, preserve reproductive integrity, improve habitat, support scientific analysis, and promote recovery of the listed species within the Program area in a manner that benefits the ecological integrity, where feasible, of the Middle Rio Grande riverine and riparian ecosystem; and,

- Second, to exercise creative and flexible options so that existing water uses continue and future water development proceeds in compliance with applicable federal and state laws.

To achieve these ends, the Program may not impair state water rights or federal reserved water rights of individuals and entities; federal or other water rights of Indian nations and Indian individuals, or Indian trust assets; San Juan-Chama Project contractual rights; and the State of New Mexico's ability to comply with Rio Grande Compact delivery obligations.

The Collaborative Program receives funding through congressional appropriations to implement projects designed to benefit the federally listed endangered silvery minnow and the flycatcher. The Collaborative Program implements activities required by the 2003 BiOp to support compliance with the BiOp providing ESA coverage for the two federal action agencies and broad coverage for participating non-federal entities. The 2003 BiOp also serves as a tool to conserve listed species, assist with species recovery, and help protect critical habitat.

To help identify and guide species' recovery needs, Section 4(f) of the ESA directs the Secretary to develop and implement recovery plans for listed species or populations. Recovery Recommendations identified in these plans are advisories aimed at lessening or alleviating the threats to the species and ensuring self-sustaining populations in the wild. The general Collaborative Program goals consistent with these recovery plan recommendations are:

- Alleviate jeopardy to the listed species within the scope of the Collaborative Program;

- Conserve and contribute to the recovery of the listed species:
    - Stabilize existing populations; and
    - Develop self-sustaining populations.

- Protect existing and future water uses; and

- Provide public outreach and education to communities within the scope of the Collaborative Program.

In November 2006, the Collaborative Program adopted a Long Term Plan (LTP) (MRGESCP 2006) with the following objectives:

- To serve as a road map for implementing activities within the scope of the Collaborative Program;

- To provide accountability through measurable objectives and an annual Collaborative Program assessment process; and

- To help integrate federal and non-federal budget processes for providing funding for future activities.

In August 2009, the Collaborative Program began drafting a new LTP to include future activities through 2020 that are linked to the silvery minnow and flycatcher recommended recovery activities and are within the scope of the Collaborative Program.

Collaborative Program activities are generally organized by seven LTP element categories: habitat restoration and management, water management, population augmentation/propagation, water quality management, research, monitoring, and adaptive management, public outreach, and program management. Work groups, e.g., the Executive Committee, the Coordination Committee, and the Program Management Team, engage in an iterative, annual work plan process to identify and prioritize activities needed in the upcoming year for BiOp compliance and to assist with recovery.

There is currently disagreement within the Collaborative Program on many of the aspects of silvery minnow life history and monitoring techniques and interpretation of associated scientific information. The biological information presented throughout this BA represents a summary of the multitude of information available and an analysis of effects on the listed species using this information based on the professional conclusions of Reclamation technical personnel. The analysis presented is not intended to be a population viability level analysis. The Collaborative Program is currently working on the development of two independent Population Viability Analysis/Biology (PVA) models that will aid the Service in their analysis of effects for the new BiOP.

1.5 Consultation and Litigation History

Reclamation has completed numerous ESA consultations since 1996, including individual and joint consultations with the Corps for Federal water operations on the MRG. From 1996–99, Reclamation and the Corps consulted informally on their water operations and river maintenance activities in the MRG. In May 1998, Reclamation and the Corps submitted to the Service a joint Programmatic BA addressing both agencies' water management actions.

In November 1999, environmental groups collectively filed suit *Rio Grande Silvery Minnow* v. *Keys, et al.*, CIV 99-1320-JP/KBM, against Reclamation and the Corps for alleged ESA and National Environmental Policy Act (NEPA) violations. The plaintiffs identified the central issue as the scope of discretionary authority that Reclamation and the Corps have over the MRG and SJC Projects' water deliveries and river operations.

Reclamation and the Corps resubmitted a joint BA June 2001, resulting in a BiOp covering actions during the period June 2001 through December 2003.

> "Completion of consultation resulted in the issuance of a Biological Opinion (BiOp) by the FWS in June of 2001, which was subsequently challenged by the plaintiffs. They sought to require that the BOR exercise discretion to utilize San Juan-Chama water from Heron Reservoir and curtail deliveries of water to the San Juan-Chama contractors to meet the minimum flows required for the minnow. They also sought curtailment of native Rio Grande water deliveries to irrigators, primarily in the MRGCD. The Federal district court ruled in April 2002,[2] upholding the 2001 BiOp but also holding that the Reclamation had discretion over use of both the SJC Project and native water in the MRG Project for ESA purposes while the Corps did not have such discretion over its operations." (Kelly 2011)

[2] *Rio Grande Silvery Minnow* v. *Keys, et al.*, CIV 99-1320-JP/KBM, April 2002, Memorandum Opinion and Order.

In June 2002, Reclamation predicted it would not be able to meet the 2001 BiOp flow requirements due to extreme drought.

> "Environmental plaintiffs filed for emergency injunctive relief to seek release of a limited amount of SJC water from Heron Reservoir in order to comply with the June 29, 2001, BiOp and avoid massive drying in the Middle Rio Grande. A hearing was held immediately and the court subsequently ruled in favor of the plaintiffs that the September 2002 BiOp was arbitrary and capricious. However, the Court imposed its own interim flow standards, allowing the U.S. to meet lower flow levels than those required by the 2001 BiOp. The Court directed Reclamation to take SJC water from the contractors if necessary…The ruling on the injunctive relief was immediately appealed to the Tenth Circuit Court of Appeals by the Federal defendants and interveners, which stayed the ruling pending the appeal. Oral arguments were heard in January 2003 before a three-judge panel, which affirmed the district court's ruling in June 2003.[3] The Federal defendants and interveners petitioned for rehearing *en banc*." (Kelly 2011).

Meanwhile, in August 2002, Reclamation and the Corps re-initiated Section 7 consultation to address proposed water management through December 2002; and in September 2002, the Service issued a new "jeopardy" biological opinion with no Reasonable and Prudent Alternative (RPA). Late season rains enabled Reclamation to maintain operations consistent with the June 2001 BiOp, including the incidental take statement and, therefore, the June 2001 BiOp remained in effect.

In February 2003, Reclamation and the Corps jointly re-initiated consultation with the Service; and, subsequently, a BiOp was issued in March 2003 covering continued operations through February 2013. In 2004, Congress enacted legislation that limited Reclamation's discretion to use San Juan Chama project water for ESA purposes (Public Law 108-447).

> "In October 2003, the Tenth Circuit requested additional briefing from all parties on the question of whether the case was moot and its June 2003 ruling should be vacated. On January 5, 2004, the Tenth Circuit vacated the panel opinion as moot because the time frame covered by the District Court's 2002 ruling had expired. Furthermore, the New Mexico delegation had introduced, and Congress later enacted, legislation restricting the Federal Government from using San Juan-Chama Project water to meet ESA obligations. The district court was ordered to determine whether there were unresolved issues to be tried.

[3] *Rio Grande Silvery Minnow* v. *Keys*, 333 F.3d 1109 (10th Circuit Court, 2003).

> . . .
> Plaintiffs filed a Motion to Dismiss Remaining Claims without prejudice. The defendants responded that the prior rulings (Memorandum Opinions and Orders of April 19, 2002, and September 23, 2002) should be vacated for mootness and lack of subject matter jurisdiction. Subsequently, on April 26, 2004, plaintiffs withdrew their motion to dismiss. Plaintiffs asked Judge Parker not to vacate his rulings but to incorporate them into a final judgment that could be appealed yet again to the Tenth Circuit should defendants wish to do so.
>
> …
> On November 22, 2005, the Court ruled on the mootness and vacatur issues sent down from the 10th Circuit Court of Appeals from the appeal in 2003. Judge Parker held that, because of the 2003 and 2004 minnow riders, the issue of BOR discretion to reduce water deliveries to the San Juan-Chama Project was moot. However, he ruled that because Congress was silent on the issue of BOR discretion regarding Middle Rio Grande Project waters, this issue remained justiciable." (Kelly 2011)

The judge ruled that, in future consultations under the ESA, Reclamation must consult with the Service over the full scope of Reclamation's discretion concerning MRG Project operations. Judge Parker's November rulings were appealed to the 10th Circuit Court of Appeals.

> "On April 21, 2010, the [Tenth Circuit Court of Appeals] ruled that the intervening 2003 Biological Opinion and subsequent minnow riders had mooted the claims of the environmental groups. The court based its mootness ruling on the fact that the environmental groups' claims and relief sought were related to consultation over discretionary aspects of the 2001 and 2002 BiOps. Therefore, even though the Middle Rio Grande Project water was not explicitly mentioned in the minnow riders, the 2003 BiOp had superseded the earlier BiOps, taking away any claim for relief." (Kelly 2011)

The Court dismissed the appeal, remanded to the district court to vacate its memorandum opinions and orders of 2002 and 2005, and to dismiss the environmental groups' complaint with regard to their scope-of-consultation claim under the ESA.

1.5.1 Early Coordination Efforts

As early as 2006, Reclamation anticipated insufficient supplies of Supplemental Water available to meet environmental needs (Supplemental Water) coupled with hydrologic conditions that will prevent Reclamation from meeting the flow requirements of the 2003 BiOp in the future. Therefore, Reclamation and the Corps began planning for reinitiating Section 7 consultation with the Service.

In 2008, the Collaborative Program's ad hoc workgroup, Population and Habitat Viability Assessment/Hydrology (PHVA workgroup), was created to perform hydrologic analyses and develop water management scenarios for use in this consultation process and for input into the PVA models developed by the PHVA workgroup. The PHVA workgroup began this work by performing an interagency review of potentially hydrologically viable actions that might impact or benefit listed species in the MRG ecosystem. It evaluated available water, operational flexibility, management considerations in key reaches (Angostura, Isleta, and San Acacia Reaches), and biological considerations for the silvery minnow and identified a suite of alternate water management scenarios or strategies for evaluation to meet operational and ESA needs.

Originally, 11 operational scenarios were identified and modeled. Supplemental water needs to meet target flows for the 11 scenarios were identified, and shortages against the projected available Supplemental Water were quantified. Reclamation completed a screening procedure to rank scenarios considering numerous parameters, including the duration and extent of river drying in critical river reaches, May–June flow volumes to promote effective species reproduction, Supplemental Water use requirements, and the ability to bank Supplemental Water for critical situations.

By 2009, the PHVA workgroup had narrowed the suite to five management scenarios that considered the use of available water to support the habitat needs of the silvery minnow while maintaining operational flexibility to adapt to unforeseen circumstances. These five scenarios included:

- **BiOp Targets:** The same operations and flow targets as were specified under the 2003 BiOp
- **Dry-Year Targets:** Use in all years of the flow targets specified in the 2003 BiOp for "dry years"
- **BiOp Targets - No Continuous Flow:** Use of the 2003 BiOp flow targets without the requirement for continuous flows in the winter
- **Angostura-Isleta Management A:** Flow targets in the Angostura Reach (100 cubic feet per section [cfs]at Central Avenue gage at all times) and Isleta Reach (100 cfs at Isleta diversion structure at all times) only
- **Angostura-Isleta Management B:** Flow targets in the Angostura Reach (100 cfs at Central Avenue gage at all times) and Isleta Reach (50 cfs at Isleta diversion structure at all times) only.

From these scenarios, Reclamation implemented a screening process that identified Angostura-Isleta Management B option as the initial preferred option.

The five alternative management scenarios, along with the recommendation from Reclamation, were presented at the April 16, 2009, meeting of the Executive Committee of the Collaborative Program. This information also was presented to the Service at this time, but further evaluation was needed. Therefore, no alternate water management scenarios are presented for consideration or analysis in this BA.

In February 2009, the Corps decided to pursue its own Section 7 consultation and to develop a BA addressing only the Corps' authorized, discretionary flood control operations. Therefore, both agencies are submitting separate BAs addressing their respective operations.

Reclamation has requested, and the Service has tentatively agreed, that the new biological opinion will not have a specified termination date.

1.6 Quiet Title Litigation History

> "In 2002 the MRGCD filed a cross-claim to quiet title to ownership of El Vado Reservoir and the Angostura and San Acacia Diversion Dams and other land and irrigation works within the MRGCD. MRGCD also sought a declaratory judgment interpreting the effect of their 1963 transfer of State Water Rights Permit No. 1690 to the United States. The Federal defendants opposed this claim and environmental plaintiffs sided with the Federal Government on this issue." (Kelly 2011)

The United States' position in this cross-claim was that the MRGCD conveyed the MRG Project properties to the United States and that these properties remain in the name of the United States until, among other things, Congress authorizes title transfer; additionally, that the repayment contract also stays in effect until such time.

> "On July 25, 2005, the Federal District Court ruled on the cross-claim by MRGCD to quiet title to El Vado Reservoir and other Middle Rio Grande Project works. The District Court ruled the 12-year statute of limitation under the Quiet Title Act had run because MRGCD had been on notice since 1951 that the United States claimed an adverse interest in the properties. The District Court went on to rule that ownership of these properties and certain specific tracts identified in the cross-claim was declared to be in the United States of America. The Court also ruled that Permit No. 1690 must remain in the name of the United States unless Congress authorizes its conveyance to the MRGCD. The MRGCD appealed.
>
> …
> The 10th Circuit Court of Appeals ruled…[i]n March [2010] that the District Court did not clearly err in finding that the MRGCD action to quiet title in El Vado Reservoir and the other properties conveyed to [Reclamation] through the 1951 contract was untimely under the 12-year statute of limitations.[4] The Court adopted the District Court's account of the evidence as plausible, and ruled against MRGCD's argument that because the property may have been conveyed as easements and not in fee simple, that the MRGCD did not have notice of the adverse claim of the United States until 2000. The Court held further that any abandonment of property rights by the United States would have to be explicitly authorized by Congress. However, because timely filing of a quiet title action is what confers jurisdiction on the Court, the lack of

[4] *Rio Grande Silvery Minnow* v. *Bureau of Reclamation*, 599 F.3d 1165 (2010).

> timely filing meant that the District Court did not have jurisdiction to rule on the merits. The 10th Circuit vacated the District Court's judgment on the merits quieting title in the [Reclamation]. Therefore, the title issue remains unresolved." (Kelly 2011)

For the purpose of this BA, Reclamation acknowledges that the MRGCD disagrees with Reclamation's position regarding title to El Vado, the Cochiti heading, and Angostura, Isleta, and San Acacia Diversion Dams (Diversion Dams), other land and irrigation works within the MRGCD, and New Mexico Office of the State Engineer (NMOSE) Permit No. 1690 for storage in El Vado Reservoir. El Vado was constructed and paid for by MRGCD funds, and MRGCD claims that title to El Vado was never transferred to Reclamation; even if it were, it would have been only as a security interest for repayment of the 1951 Contract. That contract having been paid, the title reverted as a matter of law.

2. Action Area: Overview of Project Components and Water Operations

2.1 Action Area

The project area is the area where Reclamation's and the non-Federal entities' proposed actions occur, while the action area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 Code of Federal Regulations [CFR] 402.02). For this BA, the project area and action area are considered to be the same. The action area for this consultation includes Heron Reservoir and Willow Creek downstream from Heron Dam, the Rio Chama downstream from the confluence with Willow Creek, and in the Rio Grande from the Velarde downstream to San Marcial above the full reservoir pool of Elephant Butte Reservoir (figure 1). The lateral extent of the action area generally is defined by the riverside drains and associated levees located to the east and west of the main stem of the river. In situations where levees do not exist on either or both sides, the lateral extents are confined by the historical flood plain (geological constraints, such as terraces and rock outcroppings or anthropogenic constraints, such as irrigation facilities).

The river mile (RM) designations used in this document are those included in the 2002 controlled aerial photography. Caballo Dam is considered RM 0, and mile designations increase in an upstream direction.

2.2 Overview of Project Components

This section provides background on the SJC Project and the MRG Project, which is necessary to identify the nature and limitations of both Reclamation's discretionary actions and non-Federal actions.

2.2.1 The San Juan-Chama Project

Reclamation's SJC Project consists of a transbasin diversion that takes water from the Navajo, Little Navajo, and Blanco Rivers, upper tributaries of the San Juan River (of the Colorado River Basin), for use in the Rio Grande Basin in New Mexico. The firm yield[5] of the SJC Project is 96,200 AFY, which provides Supplemental Water supplies for various communities and irrigation districts.

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[5] Firm yield is the amount of water that can be provided by a basin and reservoir system with reasonable certainty each year.

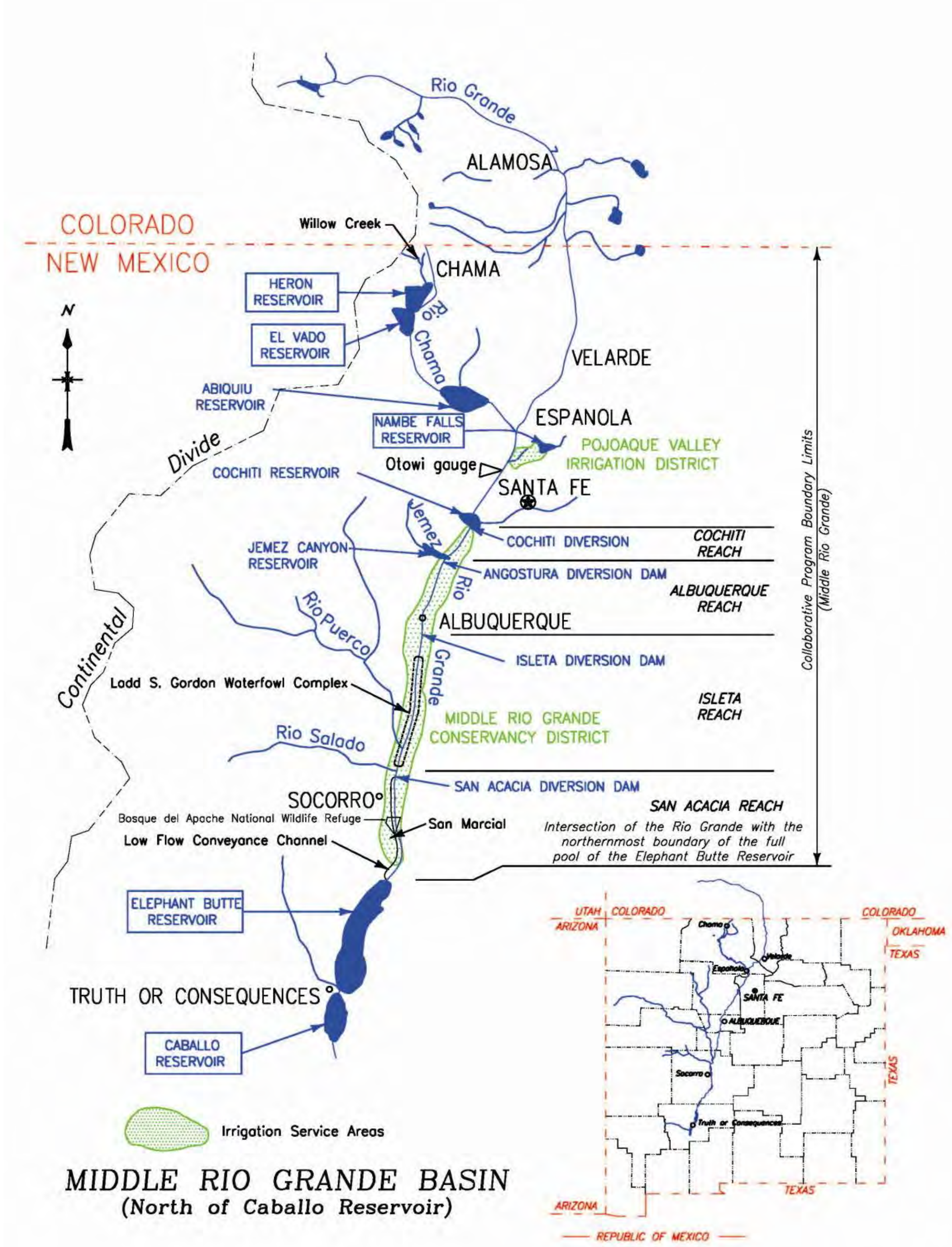

Figure 1. Map of the Rio Grande Basin – major Federal water project facilities.

Reclamation maintains this water in a Project pool at Heron Reservoir; and depending upon the available supply, Reclamation allocates the water to contractors on January 1 of each year. The diversions out of the Colorado River Basin are limited by statute, and the releases from Heron for SJC Project contractors are limited by statute and contract.

This influx of water into the Rio Grande Basin is allowed because Congress authorized the SJC Project in 1962 (Public Law 87-483), which amended the Colorado River Storage Project Act of 1956 (Public Law 84-485) to allow diversion of a portion of New Mexico's allocation of Colorado River Basin water into the Rio Grande Basin of New Mexico. A limit of the SJC Project water is that it must be beneficially consumptively used in New Mexico.

2.2.1.1 Heron Dam and Reservoir

Heron Dam and Reservoir (Heron) on Willow Creek in northern New Mexico was built in the late 1960s and is the principal storage reservoir for SJC Project water from the San Juan River system of the upper Colorado River Basin. Only imported SJC Project water may be stored in Heron Reservoir requiring all native flows to be bypassed; therefore, Rio Grande Compact requirements do not apply. Contractors take possession of the water at the outlet works of Heron Dam upon release and are required to take delivery of their annual allotment by December 31 of the irrigation year, unless a waiver for delivery in the subsequent year is authorized. Carryover storage across multiple years is not currently authorized at Heron Reservoir; therefore, water not used by the required date reverts to the SJC Project pool.

2.2.1.2 Nondiscretionary Duties and the Minnow Rider

Reclamation has discretion over the timing of releases of SJC Project water to the extent that those releases are consistent with the contractors call for water. Reclamation has the following nondiscretionary duties with the respect to Heron Reservoir:

- Meet contract obligations within the SJC Project firm yield to contractors, consistent with calls from contractors regarding timing and volume of releases.

- Maximize storage to yield sufficient water to fulfill contracts in current year and out-years.

- Keep within a safe storage amount of approximately 401,000 acre-feet (AF).

In 2004, Congress enacted legislation that limited Reclamation's discretion to use San Juan Chama Project water for ESA purposes (Public Law 108-447). Section 208(a) of the legislation states that:

> "Reclamation, may not obligate funds… and may not use discretion…to restrict, reduce, or reallocate any water stored in Heron Reservoir or delivered pursuant to SJC Project contracts…to meet the requirements of the Endangered Species Act, unless such water is acquired or otherwise made available from a willing seller or lessor and the use is in compliance with the laws of the State of New Mexico…."

While not challenged directly, the court has already construed the statute as a permanent bar to nonvoluntary use of SJC Project water for ESA purposes, which is a significant restriction in Reclamation's discretion over the use of SJC Project waters.

2.2.2 The Middle Rio Grande Project, Including the MRGCD

The MRG Project is comprised of El Vado Dam and Reservoir on the Rio Chama, and the Diversion Dams, which are used to divert water and deliver it to lands within the MRGCD service area, including lands of the Six MRG Pueblos. Reclamation owns and operates El Vado Dam and Reservoir and owns the Diversion Dams; however, MRGCD operates and maintains the Diversion Dams, as well as the delivery infrastructure and riverside drains and wasteways. Reclamation does not have discretion to operate the diversion of Rio Grande flows through the Diversion Dams because Reclamation does not hold the New Mexico State Engineer permit, which authorizes such diversion of water.

2.2.2.1 The History of the MRG Project

Irrigated agriculture in the MRG dates back to the Pueblos' diverting the waters of the Rio Grande for irrigation purposes. Spanish colonists expanded upon earlier irrigation systems and created a system of Acequia's during the 17th and 18th centuries and irrigated agriculture expanded further during the 19th century. However, during the first half of the 20th century the habitability and agricultural productivity of the Middle Rio Grande Valley declined because of inefficient water delivery, poor drainage, and frequent floods. The MRGCD was formed to address these problems in a comprehensive manner.

In 1923, the New Mexico legislature passed the Conservancy Act (New Mexico [NM] Stat. section [§] 73-14-1 through 73-19-5), which provided the legal framework for the organization and operation of conservancy districts throughout the State. On August 26, 1925, pursuant to that law, New Mexico's District Court approved the organization of the MRGCD, which is a quasi-governmental entity, with established geographic boundaries, a publicly elected Board of Directors, with specific powers and authorities, including the power to make assessments within its boundaries for services. One of its purposes was to rehabilitate existing irrigation systems and to consolidate the river headings of approximately 80 independent Acequia associations into a more efficient and manageable system. MRGCD originally combined these headings into six locations, later reduced to four diversions off the Rio Grande. In addition, a system of drains and wasteways was created to return unused water back to the Rio Grande, eliminating water logging and alkali problems that had plagued the early Acequia systems.

MRGCD's plan to reclaim land and provide a more stable water supply in the MRG included the construction of drainage and irrigation works, levees for flood control, and El Vado Dam and Reservoir. The geography of the Middle Rio Grande Valley is such that the lands of the Six MRG Pueblos are interspersed between non-Indian lands. Therefore, engineering logistics and the need for rights of way on Pueblo lands required that MRGCD include the Pueblos in its plan to reclaim the valley. Additionally, because the project would benefit those Pueblos, MRGCD sought a contribution of construction costs as well as future operation, maintenance, and betterment works costs from the United States on behalf of the Pueblos.

Congress passed the Act of March 13, 1928 (1928 Act) (45 Stat. 312) to support the Conservancy Project, which included funding for the Pueblos' share of construction costs and obligated the MRGCD to operation, maintenance, and betterment (OM&B) the works for the benefit of Pueblo lands. The 1928 Act divides Pueblo lands into two categories:

1. Lands that were irrigated at the time and were "prior and paramount to any rights of the district."
2. Lands that would be "newly reclaimed" by the Conservancy Project.

The Act obligated the MRGCD to provide future OM&B benefitting the "prior and paramount" lands free of charge, and stated that "newly reclaimed lands shall be recognized as equal to" non-Pueblo lands in the MRGCD, and "protected from discrimination in the division and use of water." Pursuant to the 1928 Act, the BIA and the MRGCD entered into an agreement (the 1928 Agreement) whereby MRGCD agreed to construct works and provide OM&B for the Pueblos. Specifically, MRGCD agreed to provide OM&B to prior and paramount lands free of charge and to newly reclaimed lands for a proportional share of costs. In 1935, Congress enacted legislation ("1935 Act," [49 Stat. 887]), which stated that MRGCD shall treat the Pueblos' newly reclaimed lands the same as other district lands and reiterated that the MRGCD shall OM&B prior and paramount lands without charge.

Beginning in 1930, the MRGCD created drains, levees and diversion dams, consolidated the irrigation network through a system of new main and lateral canals, and built El Vado Dam and Reservoir on the Rio Chama. In 1935, construction was effectively completed; and El Vado Reservoir began operating. However, after construction, MRGCD had difficulty raising tax revenue in the agricultural valley struggling under the Great Depression. Catastrophic flooding in 1941 and 1942 destroyed the ability of the Rio Grande to efficiently transport water to Elephant Butte Reservoir. Coupled with a series of dry years following the flooding, New Mexico fell into a debit status on its obligation to deliver a portion of Rio Grande water to Texas under the Rio Grande Compact. In 1947, Reclamation and the Corps completed a comprehensive plan intended to improve and stabilize the Rio Grande through the MRG and to facilitate Rio Grande Compact deliveries to Texas. This plan included dams for flood and sediment control, rehabilitation of the Middle Rio Grande Valley's irrigation and drainage system, and extensive river channelization works. Congress authorized the recommended plan in the Flood Control Acts of 1948 and 1950 (Public Law 80-858; Public Law 81-516). Congress authorized the Corps to construct flood control reservoirs and levees for flood protection, authorized Reclamation to undertake the rehabilitation of the Conservancy Project and maintenance of the river channel, and to pay off outstanding MRGCD bond indebtedness.

In exchange for rehabilitating its project and paying its debts, MRGCD entered into a repayment contract with Reclamation in 1951 (1951 Contract), whereby it agreed to convey to the United States title to MRGCD's "works" and its storage permit at El Vado. [6, 7] The 1951 Contract confirmed MRGCD's obligation to OM&B the MRG Project for the Pueblos and authorized Reclamation to eventually relinquish OM&B duties associated with the Diversion Dams to the MRGCD. In the 1970s, Reclamation fulfilled its statutory requirement under Reclamation law to transfer OM&B duties associated with project irrigation works to the owners of the lands irrigated, by transferring OM&B duties associated with the Diversion Dams to the MRGCD.[8] Reclamation exercised its statutorily authorized discretion to retain the OM&B duties associated with storage and release of water at El Vado, but MRGCD became obligated to pay for those services.

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[6] Section 6 of the Reclamation Act of 1902 states: "title to and the management and operation of the reservoirs and the works necessary for their protection and operation shall remain in the Government until otherwise provided by Congress." (32 Stat. 389)

[7] Paragraph 13(e) of the 1951 Contract, obligates the MRGCD to pay OM&B costs associated with the Pueblos' newly reclaimed lands if Congress fails to appropriate sufficient funds to cover the costs.

[8] Section 6 of the Reclamation Act of 1902 (32 Stat. 389) states: "when payments required by this Act are made for the major portions of the lands irrigated from the waters of any of the works herein provided for, then the management and operation of…irrigation works **shall** pass to the owners of the lands irrigated." See the August 24, 2011, Memorandum from the Regional Solicitor, Intermountain Region, to the Regional Director, Bureau of Reclamation, Upper Colorado Region (finding that Acts of Congress subsequent to the 1902 Act have not altered the requirement that irrigation districts take over operation and maintenance of the project's "irrigation works" once the users have made the required payments to Reclamation).

2.2.2.2 El Vado Dam and Reservoir

MRGCD initiated construction of El Vado Dam in 1929 and completed it in 1935. Reclamation operates El Vado Dam and Reservoir pursuant to the 1951 contract with the MRGCD. The total maximum storage of El Vado Reservoir is about 196,000 AF, though sediment and operational restrictions have reduced its effective capacity to about 180,000 AF. El Vado is used to store native Rio Grande and SJC Project water for MRGCD and to store native flows to ensure there is sufficient supplies for the prior and paramount lands of the Six MRG Pueblos pursuant to the "Agreement: Procedures for the Storage and Release of Indian Water Entitlement of the Six Middle Rio Grande Pueblos," approved by the Secretary of the Interior, December 28, 1981, (1981 Agreement) (discussed below). MRGCD is not a party to the 1981 Agreement. When space is available, Reclamation and MRGCD may store SJC Project water in El Vado Reservoir for other users and other purposes. Storage of large volumes of SJC Project water may take place for extended periods of time.

Consistent with Article XVI[9] of the Compact, water is held in El Vado each year regardless of Article VII restrictions, to ensure that water can be provided to meet the demand for the Six MRG Pueblos, which is tracked separately with a daily accounting model and released to specifically meet the demand for the Pueblos. Pursuant to the 1928 Act, the Pueblos have the prior and paramount right to divert Rio Grande natural flow; but due to diversions by others, sufficient natural flow may not always be available to the Pueblos when needed. Consequently, the Secretary of the Interior designates space in El Vado Reservoir to ensure that water is available for prior and paramount lands of the Six MRG Pueblos should the natural flow prove insufficient. This water can be released to meet irrigation demand for prior and paramount lands, as discussed below.

Within El Vado Dam sits a Federal Energy Regulatory Commission-regulated hydroelectric plant that is owned and operated by Los Alamos County. The plant operates as a "run of the river" facility; therefore, releases are not made for the sole purpose of generating power, but power is a byproduct of releases made for MRG Project purposes.

2.2.2.3 The MRGCD Divisions

MRGCD is comprised of four divisions: Cochiti, Albuquerque, Belen and Socorro, serving irrigated lands from Cochiti Dam to the Bosque del Apache National Wildlife Refuge (BDANWR). At the downstream end of the MRGCD, remaining water from the MRGCD system is delivered onto the BDA.

[9] "Nothing in this Compact shall be construed as affecting the obligations of the United States of America to Mexico under existing treaties, or to the Indian Tribes, or as impairing the rights of the Indian Tribes."

2.2.2.3.1 Cochiti Division

MRGCD diversions begin at Cochiti Dam to the Cochiti East Main and Sile Main Canals and deliver water to irrigators on both sides of the Rio Grande. Diversions at the Cochiti Dam serve the Cochiti, Santo Domingo, San Felipe and Santa Ana Pueblos together with the communities of Peña Blanca, Sile, and Algodones.

2.2.2.3.2 Albuquerque Division

Angostura Diversion Dam, a concrete low head fixed weir, diverts water from the Rio Grande to serve the Albuquerque Division of the MRGCD. The Albuquerque Division provides irrigation water for the Sandia, Santa Ana, and Isleta Pueblos and non-Indian irrigators from various communities, including Bernalillo, Corrales, Alameda, Albuquerque, Los Ranchos, and the South Valley area.

2.2.2.3.3 Belen Division

Isleta Diversion Dam diverts water from the Rio Grande to serve the Belen Division of the MRGCD. Isleta Dam is a low-head (4.3-foot) structure comprised of a series of radial gates, which may be lifted entirely from the water if desired, or lowered to whatever position is required to provide the operating head for the intake works. Isleta Diversion Dam is located on Isleta Pueblo. Belen is the largest division in the MRGCD, accounting for nearly 50 percent (%) of irrigated lands. The Belen Division serves Isleta Pueblo, several New Mexico Department of Game and Fish refuges, the Sevilleta National Wildlife Refuge, and irrigators from various communities including Bosque Farms, Peralta, Los Lunas, Tome, Los Chavez, Belen, Casa Colorado, and Las Nutrias.

2.2.2.3.4 Socorro Division

About 55 miles downstream from the Isleta Diversion Dam, the San Acacia Diversion Dam provides water for the Socorro Division of MRGCD. San Acacia Diversion Dam is similar to Isleta Dam, being a series of radial gates across the Rio Grande, though with a larger operating head of approximately 7.5 feet (ft). In addition to San Acacia Dam, the Socorro Division relies substantially on return flows from Belen Division via the Unit 7 Drain. At the southern end of the Socorro Division, two canals and two drains have delivered water onto the BDA, in addition to the Low Flow Conveyance Channel (LFCC).

2.2.2.4 The MRG Project Diversion Dams

MRGCD constructed the Diversion Dams in the 1930s, including the Isleta Diversion Dam, which was constructed on lands belonging to the Isleta Pueblo. Pursuant to the MRG Project authorization, Reclamation rehabilitated Isleta Diversion Dam in 1955, San Acacia Diversion Dam in 1957, and Angostura Diversion Dam in 1958. In 1975, the original Cochiti Diversion Dam was demolished by the Corps during construction of Cochiti Dam and was replaced by intake works for the Sile Canal and Cochiti Main Canals incorporated into the Corps' structure. After completion of Cochiti Dam construction, the Corps transferred the rebuilt canal headworks to Reclamation. MRGCD currently operates the Diversion Dams as "transferred works" under the 1951 Contract, within the bounds of Federal law, and within the scope of its conferred authority.

The annual quantity of water that the MRGCD has diverted over the last 10 years is as follows:

Total surface water diversion from Rio Grande: 368,610–375,772 AFY

Average surface water diversion from Rio Grande: 371,516 AFY

Cochiti Diversion:	58,623–68,030 AFY	Average: 63,802 AFY (17%)
Angostura Diversion:	77,511–86,692 AFY	Average: 81,833 AFY (22%)
Isleta Diversion:	206,417–208,866 AFY	Average: 207,951 AFY (56%)
San Acacia Diversion:	14,923–21,364 AFY	Average: 17,931 AFY (5%)

2.2.2.5 The MRG Project and MRGCD Water Rights[10]

In 1930, the MRGCD obtained NMOSE Permit No. 1690 (Storage Right) to appropriate and store up to 198,110 AF of water in El Vado Reservoir for lands newly reclaimed by the MRGCD (both Pueblo and non-Pueblo lands). In 1931, the MRGCD obtained NMOSE Permit No. 0620 (Natural Flow Diversion Right), which changed the points of diversion for natural flow water rights appurtenant to lands irrigated prior to the formation of the MRGCD from 71 existing irrigation systems (Acequias) to the Diversion Dams, and authorized use of the Diversion Dams to divert water for those lands.[11]

In accordance with Federal Reclamation law and New Mexico law, the MRGCD and/or the property holders served by the MRGCD, including the Six MRG Pueblos, retain the Natural Flow Diversion Right (Permit No. 0620). Pursuant to the 1951 Contract, as security for repayment of that contract, on May 28, 1963, the MRGCD executed a "Transfer and Assignment of Water Rights," whereby it conveyed Storage Right (Permit No. 1690) to the United States; but in accordance with section 8 of the Reclamation Act of 1902, which requires Reclamation to follow State law, the right to use the water appropriated under that permit remained appurtenant to the land irrigated in the MRGCD. The 1951 Contract has now been fully repaid. MRGCD erroneously attempted to transfer the Natural Flow Diversion Right pursuant to the 1951 Contract;

[10] The water rights of the property holders served by the MRGCD, or any possible water rights of the MRGCD itself, have not yet been quantified or adjudicated.

[11] In its application for Permit No. 0620, the MRGCD asserted water rights appurtenant to 123,267 acres of land: 80,785 acres of land irrigated prior to the Conservancy Project; and 42,482 acres of land reclaimed through the Conservancy Project.

however, the New Mexico Supreme Court ordered the MRGCD to retain its right (Permit No. 0620) to divert the natural flow through the Diversion Dams. [12] The Court stated that the MRGCD was only permitted by New Mexico law to transfer "new filings and new water" to Reclamation.

2.2.2.6 The Low Flow Conveyance Channel

The floods of the early 1940s and the drought of the 1950s created a condition where the Rio Grande river channel below BDANWR had become a series of disconnected segments separated by sediment plugs and delta deposits. Depletions due to evaporation and use by growing vegetation increased, and caused difficulties for New Mexico to meet its Compact delivery obligations beginning in the mid-1940s.

To reduce consumption of water, provide more effective sediment transport, and improve valley drainage, and as part of the MRG Project's river channelization program, Reclamation constructed a 54-mile long artificial channel, the LFCC, running alongside the Rio Grande between San Acacia, New Mexico and Elephant Butte Reservoir. The LFCC is protected from the river by a continuous spoilbank levee, and is the subject of complex hydrologic interactions between the Rio Grande and irrigated lands. Operation and maintenance of the low flow channel are continuing Reclamation responsibilities.

The basic concept behind the LFCC is that depletion of water can be reduced by diverting some or all of the river's flow into a narrower, deeper, and more hydraulically efficient channel. The LFCC exposes relatively less water surface area to evaporation and is less prone to loss of water by seepage than the natural river channel. The higher flow velocities in the low flow channel can also move more sediment than the river, especially at lower discharges. The LFCC has a nominal capacity of 2,000 cfs, and the maximum recorded mean daily discharge of the LFCC at San Acacia is 1,950 cfs.

At its upper end, the LFCC behaves as a canal, but downstream from Escondida, New Mexico, it transitions to function as a drain. The LFCC can discharge to the Rio Grande, under certain conditions at the 9-mile outfall near Escondida; however, there is typically little or no flow in the LFCC at that point.

12 *Middle Rio Grande Water Users Association* v. *Middle Rio Grande Conservancy District*, 57 NM 287, 299–300 (1953).

2.3 Overview of Water Operations

Beginning as early as March of each year, water management agencies, including Reclamation, the MRGCD, the State, the Service, the BIA, the Albuquerque Bernalillo County Water Utility Authority (ABCWUA), and the United States Geological Survey (USGS), participate in coordination calls to share information regarding current river flows, reservoir storage, target releases, areas of drying, the status of the silvery minnow and other timely issues.

The tools that Reclamation uses for its water operations include flow and storage data provided by stream gages and computer models that predict water availability and account for water as it moves through the reservoir and river system of the MRG. Reclamation uses these tools to operate its facilities, account for the movement and co-mingling of SJC Project and MRG Project water supplies, and develop annual operating plans based on forecasted snow melt runoff and other factors. Water operations are facilitated by monitoring to ensure that desired flows are achieved.

Reclamation's primary tool for meeting the forecasted ecological needs of listed species is its Supplemental Water Program (Program), which is included as a conservation measure in this BA. The Program consists of:

1. Water acquisition and storage
2. SJC Project waivers of mandatory release dates from Heron Reservoir
3. Pumping and conveying water from the LFCC to the Rio Grande

2.3.1 The Rio Grande Compact and Article VII Storage Restrictions

The 1938 Rio Grande Compact (53 Stat. 785) is a Federal law that poses significant restrictions on water management in the MRG. The Compact apportions the native waters of the Rio Grande among the States of Colorado, New Mexico, and Texas; and the provisions of the Compact are administered by the Rio Grande Compact Commission. For purposes of the Compact, "New Mexico" is the reach between Otowi gage and Elephant Butte Reservoir, which is roughly equivalent to the action area for this BA. The allocation excludes tributary inflows along this reach of river—these inflows are not subject to Compact restrictions. Article XVI of the Compact states:

> "Nothing in this Compact shall be construed as affecting the obligations of the United States of America to Mexico under existing treaties, or to the Indian Tribes, or as impairing the rights of the Indian Tribes."

Also, SJC Project water is imported transbasin water, subject to the terms of the Upper Colorado River Compact; but after diversion by Reclamation, this water is not subject to Rio Grande Compact restriction.

The Compact does not require Colorado or New Mexico to deliver the exact amount of water scheduled annually each and every year but allows for the accumulation of over-deliveries (credit) and under-deliveries (debit). Although it is up to each State to decide how its water is used, any new use has to be balanced by reduction of an existing use or through the use of a new or imported source of water, such as SJC Project water, since the Compact puts an upper limit on basinwide water depletions.

Regardless of how wet a period may be, New Mexico's depletions between Otowi gage and Elephant Butte Reservoir are capped at 405,000 AFY plus local tributary inflows. In wet years, the increasingly higher flows must be delivered downstream, and associated carriage losses for that water must be made up for out of New Mexico's allocation; in very wet years, these carriage losses can deplete New Mexico's entire allocation. For this reason, wet years are more likely than dry years to result in a Compact debit; in many cases, debits accrued in wet years must be made up for in dry years. This eliminates the possibility of "saving" water in wet years for use to meet the needs of endangered species in dry years.

Several Compact restrictions affect reservoir operations in post-Compact reservoirs (constructed after 1929) and associated surface water management. Reclamation's Heron Reservoir is excluded from these restrictions because it is only authorized to store imported transbasin SJC Project water.

Under Article VI of the Compact, New Mexico's maximum accrued debit is limited to 200,000 AF. If New Mexico is in debit status, New Mexico must retain water in storage at all times to the extent of its accrued debit. If a spill occurs, the accrued credits for Colorado or New Mexico, or both, are reduced in proportion to their respective credits by the amount of the actual spill. Colorado or New Mexico may release accrued credits in part or in full in advance of an actual spill. Following an actual or hypothetical spill, all accrued debits for Colorado or New Mexico, or both, are cancelled.

Under Article VII of the Compact, whenever usable water in the Rio Grande Project storage account at Elephant Butte and Caballo Reservoirs is less than 400,000 AF, New Mexico and Colorado may not increase the storage of native Rio Grande Basin water in upstream reservoirs constructed after 1929. Usable water is defined as water in Elephant Butte and Caballo Reservoirs that is available for release to the Rio Grande Project. In New Mexico, the primary impacts of Article VII storage prohibitions are experienced at El Vado Reservoir. Article VII also provides that, upon acceptance by Texas, New Mexico may relinquish accrued delivery credits so that New Mexico may store an equivalent amount of water in post-1929 upstream reservoirs when storage restrictions are in effect.

2.3.2 Water Accounting

All water flowing through the basin is accounted for to ensure that it is used in compliance with applicable laws. This includes SJC Project water that moves between reservoirs or is released for contractors, water acquired and stored under Reclamation's Supplemental Water Program, and MRGCD's irrigation water. All reservoir storage and flows at particular gages are accounted for to ensure that Colorado is meeting its Compact obligation to New Mexico and that New Mexico is meeting its obligation to Texas.

2.3.3 Snowmelt Forecasting and the Upper Rio Grande Water Operations Model

The snowmelt runoff forecast for a given year is a key factor in Reclamation's annual water operations. Starting in January or February, Reclamation begins monthly tracking of the Natural Resources Conservation Service's (NRCS) snowmelt runoff forecasts. NRCS operates and maintains an extensive, automated system (SNOwpack TELemetry or SNOTEL) designed to collect snowpack and related climatic data in the Western United States and Alaska. NRCS field staff collects and analyzes data on depth and water equivalent of the snowpack and provides estimates of annual water availability and spring runoff on a monthly basis from January–May. Reclamation, in coordination with the Corps, enters the projected March–July runoff volumes into the Upper Rio Grande Water Operations Model (URGWOM) to model the flows for the entire year. URGWOM is a set of daily time-step, river reservoir models for the basin using RiverWater® software. URGWOM was used for the hydrologic effects analyses in this BA.

2.3.4 The Annual Operating Plan

Each year, Reclamation's Albuquerque Area Office develops the Middle Rio Grande Annual Operating Plan (Annual Operating Plan) in coordination with the Corps and with additional input from water users such as the MRGCD, the New Mexico Interstate Stream Commission (NMISC), ABCWUA, and Santa Fe. The planning process includes compiling the necessary data, making key assumptions, and modeling water operations to estimate actual operations from the present through the remainder of the year. The Annual Operating Plan combines compiled data and major assumptions such as: the runoff forecast; predicted monsoon conditions; forecasted environmental needs; river recession;[13] silvery minnow recruitment flows; and drought storage of Supplemental Water. The model includes the following:

- Snowmelt runoff projection.
- Projection of percentage of average Heron Reservoir inflow.
- Whether MRGCD can anticipate a full irrigation season.
- How much storage MRGCD will need to utilize through the irrigation season.
- How much native water should be maintained in El Vado to assure the Six MRG Pueblos have sufficient water for their prior and paramount lands.
- How forecasted environmental needs will be met throughout the irrigation season.
- Whether and the degree to which Supplemental Water Program releases will be needed to meet environmental needs.
- Whether additional Supplemental Water supplies may be needed.
- Whether or for how long Article VII of the Compact will remain in effect.
- When weekend recreational flows can be provided on the Rio Chama.

The Annual Operating Plan estimates for each reservoir the daily amount of acre-feet stored and the rate of inflow and outflow for a period of time beginning April 1 and ending December 31. The Annual Operating Plan is presented in April to respective agency staff as well as to the public. The below graph (figure 2) is an example of an operating plan hydrograph for El Vado Reservoir. The Annual Operating Plan is a prediction and rarely plays out through the year precisely as expected. While snowpack projections are generally sound by mid-April, variability in the pattern of melt and, in particular, the amount and distribution of summer precipitation tend to cause actual water flow and management to increasingly deviate from the Annual Operating Plan as the year progresses.

[13] Drying of the river after June 15 must be managed carefully so that the drying limits outlined in the 2003 BiOp are not exceeded. Reclamation, the Corps, NMISC, and the MRGCD determine the plan for the managed recession.

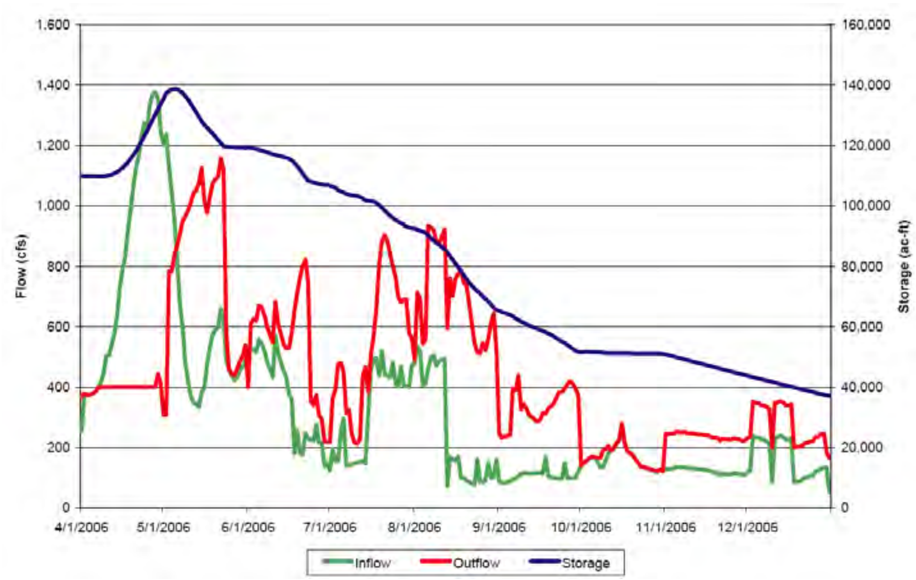

Figure 2. Annual operating plan hydrograph for El Vado Reservoir.

2.3.5 Operation for Prior and Paramount Lands

The 1981 Agreement between the Six MRG Pueblos Irrigation Committee,[14] the Secretary's Designated Engineer, BIA, and Reclamation established U.S. Department of the Interior policy for designating a volume of water in storage at El Vado Reservoir to ensure water demand on the Pueblos' lands with prior and paramount water rights can be met each year. The 1981 Agreement sets out the often overlapping responsibilities and authorities of Reclamation, BIA, and the MRGCD related to ensuring the Pueblos' prior and paramount water rights for 8,847 acres of land, although the MRGCD is not a party to the 1981 Agreement.

It provides that Reclamation, jointly with the Designated Engineer, calculate the storage requirements of the Six MRG Pueblos, and that Reclamation and MRGCD annually store water in and release water from El Vado Reservoir to satisfy Pueblo water entitlements. It also provides the protocol for the Six Pueblos to call for releases of the water stored for their prior and paramount water needs. As discussed in section 1, MRGCD is obligated by statute, contract, and State permit to divert water for the Pueblos; and those actions are included in the description of MRGCD's proposed actions. The prior and paramount operations ensure that the Pueblos will receive an adequate supply of water for lands with prior and paramount water rights.

[14] The Six Middle Rio Grande Pueblos Irrigation Committee was the predecessor organization to the Coalition of the Six Middle Rio Grande Pueblos.

2.3.6 MRGCD Water Management

MRGCD operates pursuant to Federal and State statute and contractual authority. MRGCD meets irrigation demand with smaller diversions. This, in turn, allows MRGCD to remain in full operation for a longer irrigation season or to save water for subsequent seasons.

MRGCD regularly coordinates its operations and plans with other water management agencies, which helps ensure that sufficient water is available to meet irrigation demands as well as the needs of listed species. MRGCD's coordination includes:

- Regular participation in Reclamation's MRG Coordination Conference calls, in which the MRGCD relays information on:
    - Plans for diversion at each of its diversion structures; any plans it has for "bypass" of flows (leaving of water in the river rather than diverting it).
    - Changes in conditions or operations that may affect Reclamation's requirement to release Supplemental Water.
- Coordination with Reclamation's RiverEyes program and the Service's fish rescue program. As noted previously, MRGCD has, at times, intentionally routed flows to wasteways or drains to assist the Service with rescue.
- Emergency flow releases at specific locations as needed for ESA purposes.

2.3.6.1 MRGCD Borrow/Payback Arrangements

MRGCD participates in "borrow/payback" arrangements with Reclamation and the ABCWUA for water storage and movement between Heron, El Vado, and Abiquiu Reservoirs. These arrangements may be either to increase flows on the Rio Chama Wild and Scenic portion to an appropriate level for recreational whitewater rafting or to increase winter base flows for health of sport fisheries on the Rio Chama. "Borrow/payback" arrangements most commonly involve moving water for ABCWUA water from Heron Reservoir to Abiquiu. For a variety of practical reasons (measurement, gate adjustment, evaporation loss, etc.), the movement of this water sometimes occurs by borrowing MRGCD's SJC Project water from El Vado Reservoir and replacing it at a later date with the ABCWUA's SJC Project water from Heron Reservoir. The "borrow/payback" arrangements also sometimes may involve Reclamation's Supplemental Water for the Rio Grande silvery minnow (RGSM).

2.3.6.2 MRGCD Measurement

MRGCD operates and maintains a system of measurement stations, or gages, along its canal and drain network. These gages report water level and rates of flow back to the MRGCD on 30-minute intervals. This includes information on water diverted from the Rio Grande, how water is being distributed to various canals or service areas, and water being returned to the Rio Grande through wasteway and drain outfalls. Data is collected via FM radio telemetry, processed (converted from raw electronic signals to usable values and units), then transferred by the current file transfer protocol to three separate computer databases (MRGCD, Reclamation, and the Corps). This entire process occurs automatically, 24 hours a day, throughout the year. Reclamation hosts a Web site, created and maintained jointly by Reclamation and MRGCD, on which this data is displayed publicly. Data is displayed in near real-time (20 to 30 minutes after collection).

At present, MRGCD provides data from about 130 sites on its system and continues to add several new locations each year. In addition, MRGCD collects, processes, and distributes data from Reclamation's RGSM pumping sites in Socorro County and the NMISC's RGSM Atrisco habitat project in Bernalillo County. Processed information also is collected from other entities, including the USGS (stream flow gages on the Rio Grande) and the ABCWUA (diversion from and return flow to the Rio Grande). All of this data is displayed along with MRGCD information on the Reclamation Web site, allowing both the public and water managers to quickly observe water movement and distribution throughout the MRG.

MRGCD maintains its gage network through periodic calibration measurements using a variety of flow measuring devices. In addition, MRGCD makes flow measurements in ungaged areas of its system and along the Rio Grande itself. Measurements made on the Rio Grande by MRGCD are often used to understand where nontypical or unexpected loss is occurring. MRGCD shares this information with Reclamation, the USGS, and other water management entities.

3. Description of Proposed Actions

3.1 Introduction

This BA evaluates the effects of the following water management actions and conservation measures for both Reclamation and non-Federal entities:

1. Reclamation's proposes the following water management actions:
    a. Operate Heron Dam and Reservoir as part of the SJC Project to store and deliver water to downstream users.
    b. Operate El Vado Dam and Reservoir to store and release water, including response to requests by the MRGCD.
2. Non-Federal entities propose the following water management actions:
    a. MRGCD proposes the following actions:
        i. Operate the MRG Project Diversion Dams to deliver water to MRGCD lands to meet agricultural demand of lands with appurtenant water rights, including the lands of the Six MRG Pueblos.
        ii. Operate irrigation drains and wasteways to return water to the river.
3. Proposed conservation measures to offset any adverse impacts caused by the above actions are as follows:
    a. Reclamation's conservation measures:
        i. The Supplemental Water Program.
        ii. Adaptive management.
        iii. Environmental water operations.
    b. MRGCD's conservation measures:
        i. Enhanced coordination;
        ii. Changes in operation to support instream habitat and flow management.
        iii. Changes in operation to support spring peak flows.
    c. ABCWUA's conservation measures:
        i. Additional storage of native water;
        ii. Conservation Storage Agreements;

iii. Lease Supplemental Water;

iv. Continued efforts towards water conservation; and

v. Continued coordination with water releases and diversions.

d. Collaborative Program conservation measures:

i. Habitat restoration and management;

ii. Water management;

iii. Population augmentation/propagation;

iv. Water quality management; and

v. Species research, monitoring and adaptive management.

These actions are described more fully in the sections below.

3.2 Description of Reclamation's Proposed Water Actions

Reclamation operates Heron and El Vado Dams and Reservoirs in consideration of a complex Web of variables, including precipitation, drought, allocation of water supplies, MRGCD requests, and the Pueblos' prior and paramount water rights, and also in accordance with Federal statute, NMOSE permit, and contracts with water users. Reclamation operates the two facilities for the following purposes:

- Storage and delivery of water for agricultural uses (Heron and El Vado), and municipal, and industrial uses (Heron).
- Assistance to New Mexico in meeting its downstream water delivery obligations mandated by the Rio Grande Compact of 1938 (El Vado).

Additionally, incidental purposes of Reclamation's operations include fish and wildlife benefits, recreation for both Heron and El Vado, and flood control for El Vado. Reclamation operates both reservoirs in compliance with the Endangered Species Act and to manage water in Reclamation's Supplemental Water Program. Reclamation will use adaptive management as part of its future water operations.

3.2.1 SJC Project Operations at Heron Dam and Reservoir

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 SJC Project accounting. Water allocated to MRGCD is released from Heron Dam each year at the request of the MRGCD, typically for delivery to El Vado Reservoir where it is then released as needed to meet MRGCD's daily demand. Water allocated to the ABCWUA is released from Heron Dam to Abiquiu Reservoir, at the request of the ABCWUA, and eventually is delivered to ABCWUA's surface water diversion structure in Albuquerque or is used to offset depletions to surface water supplies caused by ground water pumping, as assessed by the Office of the State Engineer (i.e., letter water deliveries). Water allocated to other contractors also may be released from Heron Dam to offset depletions (which generally either is directed to Elephant Butte or El Vado, depending on if the calculated depletion impacted the Rio Grande Compact or the MRGCD), as determined by the Office of the State Engineer, or may be released for storage in allocated space at El Vado, Abiquiu Reservoir, and/or Elephant Butte Reservoir. Beginning in 2011, water allocated to Santa Fe is being released from Heron Dam to provide water to Santa Fe's Buckman Direct Diversion.

SJC 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. This action, as it relates to the Corps' operation of Cochiti Reservoir, is described in more detail as an interrelated and interdependent activity in section 6.

3.2.1.1 SJC Project Contractor Allocation

Once Reclamation releases SJC Project water from Heron Reservoir, it belongs to SJC contractors and can be used immediately or stored in other facilities for future use. The total annual SJC Project contractor allocation is based on a firm yield analysis for Heron Reservoir that sets the annual allocation at 96,200 AF. Reclamation does not have discretion to release more than this firm yield amount. All of the existing contracts are repayment contracts with no expiration date; thus, potential renegotiation of SJC Project contracts and associated terms is not considered under this BA. Table 1 summarizes SJC Project contracts, including a listing of the individual contractors, contract initiation dates, and the annual amount of SJC Project water allocated to each contractor.

3.2.1.2 Third Party Subcontracting of SJC Project Water

Reclamation authorizes SJC Project contractors to subcontract water stored in Heron Reservoir to third parties. Reclamation's Supplemental Water Program consists primarily of SJC Project water that Reclamation subcontracts. Since 2003, all of the SJC Project contractors with the exception of Pojoaque Valley Irrigation District have subcontracted their water, at one time or another, to Reclamation.

Contracts with the following SJC Project contractors grant Reclamation a first-right-of-refusal to subcontract SJC Project water stored in Heron Reservoir:

- Village of Los Lunas
- Village of Taos Ski Valley
- Town of Taos
- City of Santa Fe
- Santa Fe County
- City of Espanola
- County of Los Alamos

Table 1. San Juan Chama Project contracts

Contractor	Allocated Water Amount (AF)	Date Initiated	Purpose
Albuquerque-Bernalillo County Water Utility Authority	48,200	1963	M&I
Middle Rio Grande Conservancy District	20,900	1963	Irrigation
Jicarilla Apache	6,500	1992	M&I
City of Santa Fe	5,230	1976	M&I
Cochiti Recreation Pool[1]	5,000	1964	Recreation
Taos Pueblo	2,215	2011	M&I
Ohkay Owingeh Pueblo	2,000	2001	M&I
Incorporated County of Los Alamos	1,200	1977	M&I
Pojoaque Valley Irrigation District	1,030	1972	Irrigation
City of Espanola	1,000	1978	M&I
For Aamodt Indian Water Rights Settlement	775	Allocated, but Uncontracted	
Town of Belen	500	1990	M&I
Village of Los Lunas	400	1997	M&I
Town of Taos	400	1981	M&I
Town of Bernalillo	400	1988	M&I
County of Santa Fe	375	1976	M&I
Town of Red River	60	1990	M&I
Village of Taos Ski Valley	15	1978	M&I
TOTAL ALLOCATION:	96,200		

[1] SJC Project water is released to maintain a 1,200-surface-acre permanent pool for recreation and fish and wildlife purposes at Cochiti Reservoir; and 5,000 AFY is delivered to Cochiti to offset evaporative losses associated with maintenance of this pool. (Public Law 88-293)

3.2.1.3 SJC Project Offset of Pojoaque Tributary Unit Depletions (Nambe Falls)

The Pojoaque Tributary Unit, a component of the SJC Project, stores water at the Nambe Falls Dam and Reservoir located on the Rio Nambe, which is a tributary to the Rio Grande, and provides approximately 1,030 AF of Supplemental Water for about 2,768 acres of irrigated lands. About 34% of the irrigated lands are Indian lands located on the Nambe, Pojoaque, and San Ildefonso Pueblos. Construction of Nambe Falls Dam began in June 1974 and was completed in June 1976. Cyclical operations of Nambe Falls consist of non-irrigation season operations and irrigation season operations and cause depletions to native Rio Grande water.

To offset these depletions and to keep the river whole, Reclamation releases SJC Project water from Heron Reservoir, as is described in the 1972 Contract (#14-06-500-1986) between Reclamation and the Pojoaque Valley Irrigation District. An annual depletion amount is calculated for Nambe Falls operations for the entire year, and the offsetting SJC Project water is released from water allocated for this purpose at Heron Reservoir. The actual annual SJC Project water allocation used to offset the effects of Nambe Falls Reservoir storage has varied.

3.2.1.4 Summary of Reclamation's Proposed Actions for SJC Project Operations of Heron Dam and Reservoir

Reclamation proposes to continue operating and maintaining Heron Dam and Reservoir consistent with current agreements to store water and in accordance with constraints and conditions applicable to the SJC Project. Reclamation can only store SJC Project water pursuant to statute and is prohibited from releasing water for ESA purposes unless Reclamation purchases the water from a willing contractor.

Reclamation delivers SJC Project water to users in the MRG based on water contracts with various entities, commonly referred to as SJC Project contractors, and based on subcontracts between SJC Project contractors and third parties. Delivery of SJC Project water is authorized for municipal, industrial, irrigation, and recreational purposes. Incidental benefits provided by operation of Heron Reservoir include domestic and fish and wildlife uses. SJC Project water must be consumptively and beneficially used in New Mexico, at a downstream destination, and without harm to native Rio Grande water. Reclamation generally makes releases as follows:

- Releases for delivery of contractors' annual allocations to downstream storage occur at a rate between 165–500 cfs and typically occur in the months of November and December; however, releases may be made at the call of contractors throughout the year.

- Releases to offset depletions caused by contractors' ground water pumping and/or actions upstream of the Otowi gage occur approximately every 3–4 months at a rate of between 50–200 cfs.
- Releases occur to compensate evaporation losses at the Cochiti Recreation Pool to restore a minimum pool area of 1,200 surface acres at Cochiti Lake (Public Law 88-293).
- Releases occur to offset the operations of the Pojoaque Tributary Unit of the SJC Project, including storage in Nambe Falls Reservoir.
- Releases are deferred when ice cover on Heron Reservoir poses public safety issues.
- Releases cannot be made to meet ESA obligations unless Reclamation acquires the SJC Project water from one of its contractors.
- Waivers to extend the required date of delivery of the contractors' annual allocation until April 30 or September 30 of the following year are granted on a case-by-case basis if there is a benefit to the United States.

3.2.2 Operation of El Vado Dam and Reservoir

As discussed in section 2, MRGCD constructed El Vado Dam and Reservoir in 1935, and Reclamation and the Corps developed the MRG Project. With the establishment of the MRG Project, MRGCD pays Reclamation for operation of El Vado Dam and Reservoir. Pursuant to the Flood Control Acts, the 1951 Contract with the MRGCD, and Permit No. 1690, Reclamation stores water in and release water from El Vado Reservoir at the request of MRGCD and to provide incidental flood control.

Both native Rio Grande water and SJC Project water are stored in El Vado Reservoir. Storage of native water may occur if native flows are available on the Rio Chama in excess of downstream Rio Chama direct flows rights and the MRGCD river diversion demand and restrictions on storage are not in place per Articles VII and VIII of the Rio Grande Compact.[15] (See section 2 for a discussion of the Rio Grande Compact and Article VII). Storage and release of SJC Project water are conducted according to contract. El Vado Reservoir also provides recreational opportunities and allots space for sediment control.

[15] When the amount of usable Rio Grande Project storage in Elephant Butte Reservoir is below 400,000 AF, the Rio Grande Compact limits upstream storage of river flows in reservoirs constructed after 1929. For further discussion, see section 5.

3.2.2.1 Irrigation Operations for the MRGCD

The plan for filling El Vado is to store all native flows into the reservoir that are in excess of downstream requirements, such as those for Rio Chama water rights holders. In general, native water is stored during the spring runoff for release later in the year when flows are lower than MRGCD's river diversion demand for delivery of water to its constituents. Reclamation releases water as requested from the MRGCD from El Vado Reservoir when natural flow of the Rio Grande is not sufficient to meet the demands of the MRGCD and the Six MRG Pueblos. SJC Project water released from Heron Reservoir for immediate use downstream from El Vado Reservoir is simply passed through El Vado Dam.

Reclamation's irrigation operations primarily consist of changing the rate and timing of storage released from El Vado Reservoir, which increases flows in the MRG that the MRGCD diverts to meet its irrigation needs. Irrigation needs generally are determined by MRGCD, and Reclamation adjusts El Vado's gates to meet those needs.

3.2.2.2 Operations for Prior and Paramount Lands

As described in section 1, Reclamation shares the United States Government's trust responsibility to Indian tribes, including the Six MRG Pueblos, and Congress declared through the Act of March 13, 1928 (45 Stat. 312) that 8,847 acres of pueblo lands in the Middle Rio Grande had water rights that were "prior and paramount" to water rights for other lands.[16] Reclamation performs operations to reserve water at El Vado for use on these lands with prior and paramount rights. The Designated Engineer, currently from BIA, and Reclamation perform the following computation procedure. The flow of water necessary at Otowi gage to meet prior and paramount needs is determined by:

1. Identifying crop demand.
2. Applying field application and conveyance efficiencies from the point of diversion on the Rio Grande.
3. Applying river efficiencies from the Otowi gaging station to diversion points on the river.

Next, the Designated Engineer forecasts the monthly supply of water at the Otowi gaging station using historically dry years as a baseline: March to July is based on the monthly distribution of flows as a percentage of the total in 1934; August to October is based on 1956; the May runoff forecast is used to project natural flow for May through July and is adjusted downward by 20% for uncertainties associated with the forecast; and an adjustment using coefficients specified in the 1981 Agreement is made to the forecasted supply because the entire flow of the river cannot be captured at the river diversions.

[16] The 1928 Act adjudicated prior and paramount water rights for 8,346 acres of Pueblo lands, but on May 16, 1938, the Secretary of the Interior determined that the actual acreage was 8,847.

Pursuant to the 1981 Agreement, the Designated Engineer and Reclamation calculate the need to store water in El Vado based on months in which the forecasted supply of the river is inadequate to meet the forecasted demand of 8,847 acres. Monthly forecasted shortages between supply and demand are increased by 20% to cover transportation and carriage loss in the river. Monthly adjusted shortages are totaled resulting in the quantity of water to be managed for the pueblos in El Vado. The 1981 Agreement is nonspecific regarding release procedures. Currently, the Designated Engineer uses a spreadsheet tool for monitoring the daily natural supply at Otowi and uses the 1956 crop demand curve for monitoring daily demand until a better tool is developed. The Coalition of the Six MRG Pueblos (Coalition) currently directs the Designated Engineer to order Reclamation to make release of stored water over specified periods of time. MRGCD delivers this water to the pueblos as appropriate through downstream diversions. Unused prior and paramount water in El Vado that was stored when Compact Article VII restrictions were in place is released to satisfy Rio Grande Compact obligations after the irrigation season ends, usually in November or December. Unused water stored for the prior and paramount lands without Compact restrictions in place is reassigned as native Rio Grande water for use by the MRGCD, which is then available for use on non-pueblo and pueblo land within the MRGCD.

3.2.2.3 Summary of Reclamation's Proposed Actions for Operation of El Vado Dam and Reservoir

Reclamation proposes to continue operating and maintaining El Vado Dam and Reservoir consistent with current agreements, the Compact, and the operational and hydrologic constraints and conditions of the MRG Project. Reclamation proposes to continue storing the flow of the Rio Chama in El Vado Reservoir as requested by MRGCD and to ensure delivery of water as requested by the MRGCD and as requested by the Designated Engineer as part of prior and paramount operations. Retention and regulation of native Rio Grande flows will be performed consistent with the Doctrine of Prior Appropriation[17] and in coordination with the State of New Mexico, and to meet downstream senior flow rights.

Reclamation proposes to operate and maintain El Vado Dam and Reservoir as follows:

- Store water in and release water from El Vado Dam and Reservoir pursuant to the Flood Control Acts of 1948 and 1950, the 1951 Contract with MRGCD, in accordance with NMOSE Permit No. 1690, and to meet the downstream channel capacity of 4,500 cfs.

[17] New Mexico water law follows the Doctrine of Prior Appropriation, which provides that water users that apply water to beneficial use earlier in time (senior users) will have a better right against later water users (junior users) in times of shortage. (NM Constitution, Article II, Section 2).

- Carry out NMOSE water user delivery requirements, Compact requirements, and MRGCD requests for water storage and release.
- Maintain safe storage elevation of El Vado Reservoir per standard operating procedures except under specific exceptions that consider flood routing criteria, water surface elevation, and river flow in the Middle Rio Grande Valley.
- Store native flows when Article VII of the Compact is not in effect.
- Store native flows as needed for the prior and paramount lands of the Six MRG Pueblos and release this water for the Six MRG Pueblos as requested by the Designated Engineer pursuant to the 1981 Agreement when Article VII of the Compact is in effect.
- Store and release SJC Project water, if requested by the MRGCD.
- Bypass native Rio Grande water flows into El Vado Reservoir up to 100 cfs between April 1 and September 1 to meet demands of Rio Chama water rights holders downstream from Abiquiu Dam.
- Operate to stay within the safe downstream channel capacity on the Rio Chama per standard operating procedures.

Additional considerations for Reclamation's operation of El Vado Dam and Reservoir are as follows:

- When water is available for release to downstream users or storage reservoirs, Reclamation manages releases to benefit fisheries below El Vado Dam from November to March.
- When water is available for release to downstream users or storage reservoirs, and in cooperation with effected parties, Reclamation manages releases for rafting during weekends in July, August, and September.

3.3 Non-Federal Proposed Actions

3.3.1 The Middle Rio Grande Conservancy District

MRGCD requests releases of water from El Vado Reservoir and diverts Rio Grande surface water to provide water for irrigated agriculture using the works at Cochiti Dam and operates diversion structures at Angostura, Isleta, and San Acacia (collective the Diversion Dams). Additionally, MRGCD diverts from three diversion structures on the Low Flow Conveyance Channel: the 1200 check structure, Neil Cupp, and Lemitar.

3.3.1.1 MRGCD Water Operations

MRGCD uses water stored in El Vado during times when native Rio Grande flows are insufficient to meet irrigation demand (typically, these times are between June and September). It requests that Reclamation store native water in El Vado during times when Article VII restrictions are not in place. During times when Article VII restrictions are in place, MRGCD may request storage up to the extent that New Mexico has relinquished credit water to Texas and authorized use by the MRGCD. During normal operations, when the natural system is producing less water than required by the MRGCD to meet irrigation demand, MRGCD uses water from storage to augment the Rio Grande up to its needs. MRGCD utilizes water from available and authorized water sources. In general, MRGCD prioritizes the water released to supplement the natural flow as follows:

1. Rio Grande water stored under normal conditions (no Compact restrictions)
2. Water stored due to Rio Grande Compact credit relinquishment
3. SJC Project water

MRGCD may reduce diversions, or cease calling for releases from El Vado Reservoir before the scheduled end of the irrigation season to conserve water for subsequent irrigation seasons. This becomes carryover storage in El Vado.

MRGCD follows shortage-sharing operations at times when the natural flow is insufficient to meet the full irrigation demand, and there is not sufficient water in storage at El Vado to make up the difference, or MRGCD chooses to not call for release of available water in storage to make up the shortfall. At these times, the water needs for the prior and paramount lands of the Pueblos are met first, using flows from the main stem of the Rio Grande and upstream tributary flows, and then if natural flows are not sufficient with water held at El Vado Reservoir to benefit the prior and paramount lands of the Six MRG Pueblos. The delivery of water to Pueblo lands with prior and paramount water rights is carefully scheduled and monitored and involves a high level of coordination between Reclamation, BIA, the Six MRG Pueblos, and MRGCD. Water to meet the needs of these lands primarily is diverted at the Cochiti Dam outlet works and at Angostura. Although much of Isleta Pueblo is served from the Angostura Diversion, small diversions sometimes are required at Isleta Dam to serve parts of the Isleta Pueblo. Water delivery to Isleta Dam is most efficient and effective if the needed water is diverted at Angostura and routed through the MRGCD system. Any water remaining downstream from Isleta Pueblo after prior and paramount needs are met is shared equally among all users. Newly reclaimed lands of the Pueblos receive water similar to non-Pueblo lands.

Reclamation coordinates with the MRGCD for releases of irrigation water from El Vado Reservoir at the request of MRGCD. During periods of high runoff on the Rio Chama and absent any restrictions on storage due to the Compact, MRGCD may request Reclamation to store up to 100% of the natural Rio Grande flow entering El Vado Reservoir.

MRGCD requests releases of supplemental irrigation water from El Vado Reservoir for the benefit of all irrigators in the most efficient manner practical, minimizing times when MRGCD is in prior and paramount operation. Minimizing prior and paramount operation periods benefits the species by reducing the need for Supplemental Water for the species. It also benefits the Pueblos by providing fully for their needs without the more restrictive scheduling and monitoring necessitated by prior and paramount operation.

To determine the rate of release, MRGCD evaluates the amount of native flow moving downstream in the Rio Grande at the Embudo gage and the amount of native flow contributed by the Rio Chama and other tributaries. That combined amount then is compared with the MRGCD's estimated diversion demand. Irrigation storage is released only when the natural flow is insufficient to meet MRGCD's irrigation demands. Natural flow is generally only sufficient to meet that need during the snowmelt runoff early in the irrigation season and during periods of heavy monsoon activity late in the irrigation season.

MRGCD has a small (2,000 AF) re-regulation pool at Abiquiu Reservoir for its share of SJC Project water. While, in general, this has little effect on flows in the MRG, it occasionally is used to produce recreational benefits on the Rio Chama. Small blocks of water may be moved to Abiquiu Reservoir specifically to increase flow on the Wild and Scenic portion of the Rio Chama to an appropriate level for recreational whitewater rafting. This water is released later from Abiquiu Reservoir when needed to meet irrigation needs. This is done on a larger scale with movement of ABCWUA water supply from upstream reservoirs to Abiquiu; but when ABCWUA is not moving water, the MRGCD re-regulation pool at Abiquiu will continue to be used for this purpose.

3.3.1.2 MRGCD's Water Diversions and Returns

The water that MRGCD diverts consists of natural flows of the main stem of the Rio Grande and its tributaries (including the Rio Chama, if the water is passed through without being stored in El Vado), SJC Project water, native Rio Grande flows stored at El Vado (including water stored as the result of New Mexico credit relinquishment pursuant to the Compact [relinquishment water]). Under certain operations for Pueblo lands with prior and paramount water rights, MRGCD diverts native Rio Grande water stored in El Vado by Reclamation. MRGCD operates the Diversion Dams to match actual agricultural demand as closely as practical. This allows the MRGCD to release less water from storage and, therefore, may allow it to extend its irrigation season.

Typically, MRGCD diverts and delivers water from March 1–October 31 each year. The MRGCD Board of Directors determines the duration of the irrigation season. In recent years, the Six MRG Pueblos have requested delivery of irrigation water through November 15. MRGCD has complied with this request for Pueblo lands, but has continued to end non-Indian deliveries on October 31. Irrigation demand correlates closely with climatic conditions and the physiologic properties of agricultural crops. Demand is highest during the months of May, June, and July, tapering off in August and through September. During the early and late part of the irrigation season, much of the water diverted by MRGCD is returned directly to the Rio Grande. During the peak growing season, most water diverted is consumed by crops; and return flows are minimal. From March through mid-June, natural flows in the Rio Grande are generally greater than MRGCD consumptive needs. However, after the end of the spring snowmelt runoff, naturally occurring flows often drop precipitously and are generally less than the consumptive needs of MRGCD. At this time, MRGCD augments the natural flow of the Rio Grande, up to its consumptive needs, through requests that Reclamation release stored water from El Vado Reservoir.

MRGCD diversion flows are higher than consumptive use of water. This additional flow, often referred to as "carriage water," is a common and necessary component of gravity-fed irrigation systems worldwide. It can lead to misrepresentations of agricultural water consumption. Much of MRGCD's carriage water returns to the Rio Grande through a variety of paths. Some simply passes down the length of a canal and returns directly to the Rio Grande through a wasteway. Some canals, farm ditches, and fields discharge surface water directly to MRGCD drains. Some water seeps from canals or from field applications into the ground water system and then is intercepted by MRGCD drains to once again become surface flow. Flow recovered in MRGCD drains may be discharged back to the Rio Grande or be recycled to another canal. However, some carriage water is truly lost from the system through evaporation, consumption by riparian vegetation along irrigation canals, and seepage to ground water (which then is pumped and consumed by other users).

MRGCD's wasteways and drain outfalls provide water that may be re-diverted downstream; and, therefore, the accounting of the total MRGCD diversion may account the same water a number of times. See figure 3 below.

Return flow from the Cochiti division comprises about 18% of the supply for the Albuquerque Division. Return flows from the west side of the Albuquerque Division supply a portion of water directly to the west side of the Belen Division and Isleta Pueblo. Return flow from the east side re-enter the Rio Grande a short distance upstream of Isleta dam and are then diverted for re-use. Direct Albuquerque division return flow comprises about 13% of supply for the Belen Division. When combined with indirect returns (returned to the Rio Grande before being re-diverted), Albuquerque division provides about 35% of Belen Division supply.

The Belen division diverts water to both sides of the Rio Grande. The east side system is comprised of the Peralta Main Canal, San Juan Main Canal, and many laterals and Acequias. Return flows from the east side may be delivered back to the Rio Grande from 4 outfalls, or routed all the way to the Lower San Juan Drain outfall, about 9 miles upstream of San Acacia Dam. At its terminus, the east side system delivers water to the La Joya Acequia Association (LJAA), an independent system not part of the MRGCD.

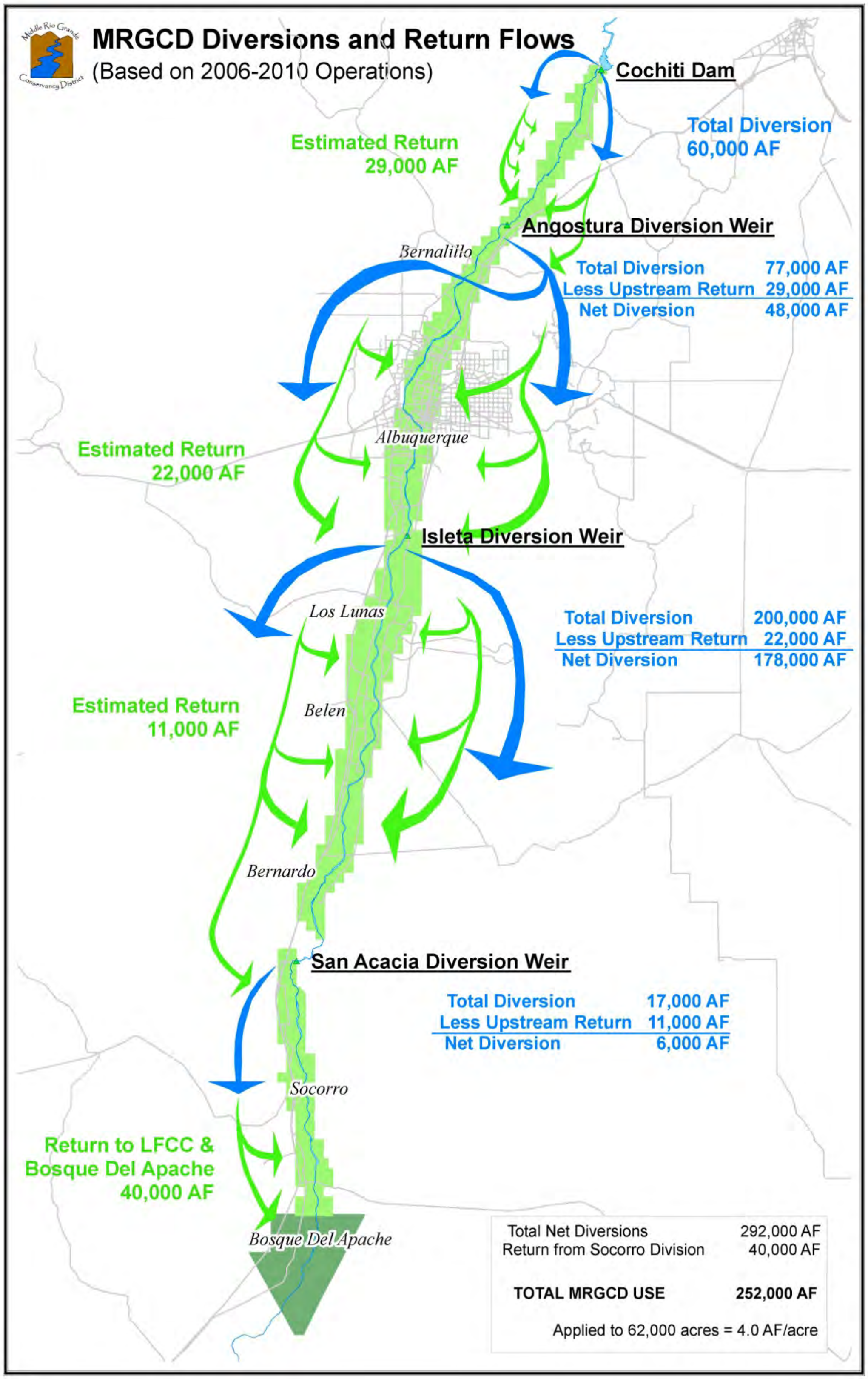

Figure 3. MRGCD diversions and return flows.

The west side system diverts water to the Belen High Line Canal, which supplies laterals and Acequias. Return flows from the west side may be directed back to the Rio Grande at seven locations or may be delivered directly into the Socorro Division, via the Unit 7 Drain Direct Belen division return flow, comprises about 79% of supply for the Socorro Division.

San Acacia Diversion Dam is used primarily to supplement flows when necessary, or during periods when the Belen Division is unable to supply water. When flows in the Rio Grande are high, San Acacia Dam may be used preferentially over Belen return flows due to a lower salt content in the water at certain times of the year. During much of the year, water is intentionally diverted at Isleta Dam and routed to Socorro Division to minimize the very high evaporative conveyance losses incurred by the river during the summer months. The Socorro Main Canal receives water from both the Unit 7 Drain and from San Acacia Dam. The Socorro Main Canal has a North, Center, and South portion. To a large degree, return flows are collected from the North section to supply the Center section, and from the Center section to supply the South section. The LFCC recycles Socorro Division water supplies at three locations.

MRGCD returns surface water from its canals directly to the LFCC at four wasteway points. The MRGCD then may divert this recovered water into its canal system at three locations. There is a single, small MRGCD wasteway that can return water directly to the Rio Grande by discharging to the Brown arroyo, which crosses over the LFCC to enter the Rio Grande.

3.3.1.3 Summary of MRGCD'S Proposed Actions

MRGCD proposes to continue coordinating with Reclamation for the release of irrigation water from El Vado Reservoir, operating the Diversion Dams and delivering return flows to the Rio Grande, as has been done since 1935, to provide water for beneficial use by the Six MRG Pueblos and as provided for by New Mexico law to non-Pueblo water users within the MRGCD service area, as described above, and in compliance with State and Federal law.

MRGCD proposes to request releases from El Vado Reservoir and to operate and maintain the Diversion Dams pursuant to the 1923 New Mexico Conservancy Act, Federal Congressional Acts of 1928 and 1935, NMOSE Permit No. 0620, and the 1951 Contract to meet the following requirements:

- Divert and deliver water stored in and released from El Vado Dam and native Rio Grande water to satisfy the needs of private property holders and users of water within its service area, prior and paramount lands, and newly reclaimed lands of the Six MRG Pueblos.

- During times of shortage, divert and deliver native Rio Grande water for lands of the Six MRG Pueblos with prior and paramount water rights, as requested by the BIA Designated Engineer.

- Re-divert MRGCD's contracted SJC Project water, which, by statute, cannot be used by the United States for ESA purposes, except upon a willing seller basis.

3.4 Proposed Conservation Measures

3.4.1 Reclamation's Conservation Measures

3.4.1.1 Reclamation's Supplemental Water Program

Reclamation's Supplemental Water Program is a proposed conservation measure to aid Reclamation's ESA compliance for its MRG Project operations and river maintenance program. The Program is fully within Reclamation's discretionary and budgetary control, and was identified as a specific Federal responsibility in 2008 congressional legislation. In 2011, Reclamation completed an updated NEPA analysis of the Program and issued a finding of no significant impacts. The current Program consists of three components:

1. Water acquisition and storage.
2. SJC Project waivers of mandatory release dates from Heron Reservoir.
3. Pumping and conveying water from the LFCC to the Rio Grande, including the operation of an outfall near Escondida.

3.4.1.1.1 Water Acquisition

Supplemental Water Program water acquisition and storage includes several sources. Reclamation has acquired most of its Program water by entering into temporary lease agreements with many SJC Project contractors on a willing lessor basis. However, as SJC Project contractors develop facilities to put their contracted water to beneficial use, less water will be available in the future for lease to supplement species needs.

Reclamation had leased previously unallocated SJC Project water for use in its Supplemental Water Program; however, that water was allocated for the Aamodt and Abeyta Pueblo water rights settlements in 2010. Reclamation proposes to seek lease agreements for newly allocated SJC Project water from the Pueblos until the water projects associated with the settlements are completed.

With the support of the MRGCD, the SJC Project water used in the Program is exchanged with native Rio Grande water. Reclamation also releases water captured, stored, and made available under an agreement between Reclamation and the NMISC, the Emergency Drought Water Agreement, as amended, to meet the needs of the MRG Project and to benefit the federally listed endangered species. Additionally, Reclamation has entered into agreements with the MRGCD and the ABCWUA to store the leased SJC Project water that Reclamation acquires for the Program in El Vado and Abiquiu Reservoirs, respectively.

Reclamation also is seeking to acquire pre-1907 surface water rights as part of the U.S. Department of the Interior's Americas Great Outdoor initiative – Price's Dairy. The Service, working in partnership with the Reclamation, Bernalillo County, the city of Albuquerque, and local residents, is proposing to create a new national wildlife refuge along the Rio Grande in the South Valley of Albuquerque. It will encompass the 570-acre Price's Dairy property, one of the largest remaining agricultural properties in the metro region. The mission of the refuge will be to protect and restore wildlife habitat, enhance public recreation, preserve open space, and offer environmental education programs for visitors from across New Mexico and beyond. The 546 AF of senior water rights associated with the dairy would be used for onsite habitat restoration, agro-ecosystem demonstration, and environmental flows for ESA compliance in the MRG. Specifically, the portion of water rights acquired by Reclamation would be used as part of the Supplemental Water Program; and a portion of the water rights acquired by the Service will be used, as available, to support environmental flows.

3.4.1.1.2 SJC Project Waivers

Reclamation regularly authorizes extension of the date that SJC Project contractors take delivery of their annual allocation of SJC Project water if it benefits the United States and does not impact the delivery of imported water into Heron Reservoir. Through this process, contractor water that will be leased to Reclamation can be retained in storage at Heron Reservoir by the contractor, or Reclamation, into the year after the year the water was allocated to the contractor. This helps to ensure that the Supplemental Water still will be available when it is needed to meet flow requirements or storage space for the Supplemental Water will be available at downstream reservoirs. Waivers generally allow SJC Project water to remain in Heron Reservoir through April 30 of a given year. Waivers beyond April 30 have occurred infrequently under extreme conditions. Reclamation has authorized waivers at times when maintaining water in Heron allowed the use of such water as part of the Program at a later date or when the changing of delivery timing helped maintain fishery and recreational flows on the Rio Chama.

3.4.1.1.3 Pumping from the LFCC

Program pumping of water from the LFCC is used to support flows in the San Acacia Reach of the Rio Grande. Each year and as necessary, Reclamation reinstalls pumps at four locations along the LFCC, shown on figure 4, which are used to convey Supplemental Water from the LFCC to the Rio Grande for the benefit of the silvery minnow and the flycatcher.

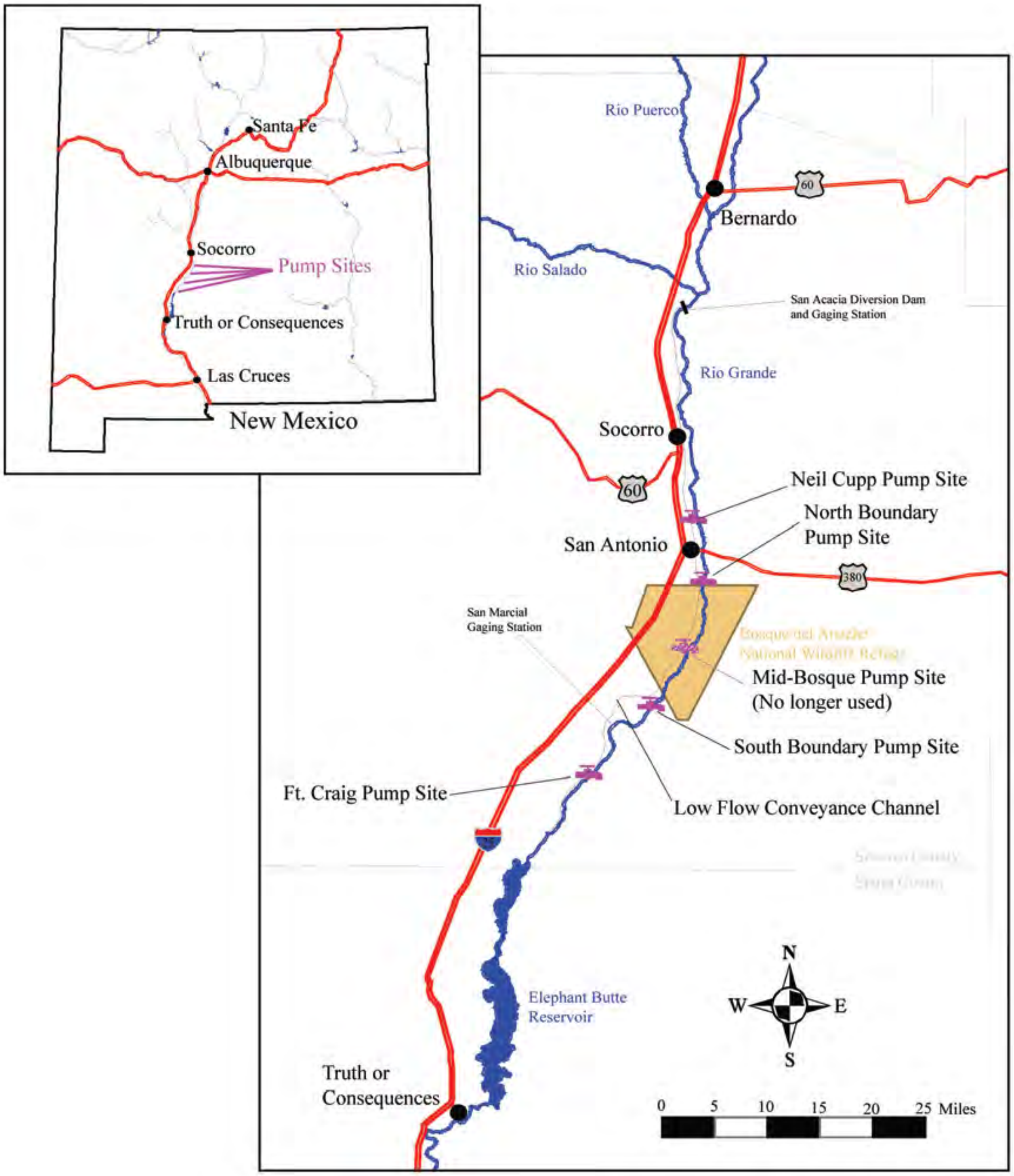

Figure 4. Current and historical LFCC pumping site locations.

Maintenance, including sediment and aquatic vegetation removal, and necessary rehabilitation of discharge channels, including riprap lining, to a point sufficient to convey target water flows from pumps and unintended floodwater without erosion or degradation of pumping infrastructure. The annual maximum acreage of impact from the sum of areas described by the inlet to the pumps stretching to the outfall at the river is 2.6 acres. Much of this work is done with traditional heavy machinery including excavators, backhoes, dump trucks, and small hand-held power equipment.

Vegetation control, related to Supplemental Water pumping operations, occurs in two different areas. The first area is within 100 feet of either side of a given discharge channel or pipe network centerline at each of the four historic pumping sites. The maximum impact area of this first area is a total of 12 acres. The second area is along the corridors (10 lateral feet of either side) of evacuation routes that would be used by Reclamation and authorized contractor personnel who are working specifically in pumping operation and maintenance (O&M). The evacuation routes from the Neil Cupp and North Boundary pump sites are along the LFCC eastern road up to Highway 380. The evacuation routes for the Ft. Craig and South Boundary Sites are along the LFCC eastern road, including the bridge across the LFCC and east/west road to the San Marcial Yard. The maximum impact area of this second area is 126 acres. Vegetation control, or mowing, typically will be done with a radial blade mounted to a backhoe or other heavy equipment and can impact an annual total maximum of 138 acres for total pumping operations-related mowing. Historically, pumping-related mowing rarely amounts to more than one-fourth of the total maximum acreage, or about 34.5 acres. Acreage impacted from native willow harvesting, done for habitat restoration or remediation at locations outside of the pumping mowing-related boundaries, is not intended to be counted in the proposed acreage limits of mowing. Willow harvesting acreage is not expected to exceed a total of 5 acres and is typically done in the winter seasons when the species is dormant. Mowing is not expected to take place April 15 to August 15 to respect the guidelines set forth in the Migratory Bird Treaty Act of 1918. On occasion, circumstances may warrant violation of these dates; in which case, Reclamation will consult with the Service to ensure endangered or threatened avian species will not be disturbed as a result of mowing or other vegetative clearing.

Established protocols related to these functions will be followed that minimize or eliminate impacts to endangered species. If possible, planned work in-channel will be done when water is not present. When water is present within a discharge channel, various approved methods will be employed with the intent of safely removing potential endangered species prior to beginning work. When vegetative removal is necessary associated with pumping operations tasks, Reclamation biologists will survey the intended area of action for possible endangered species prior to clearing.

3.4.1.1.4 Adaptive Management

Reclamation is developing an implementation plan for a pilot adaptive management program in 2012. Reclamation proposes to examine water operations, including Supplemental Water and LFCC pumping, with the goal of optimizing the use of available water to support silvery minnow habitat and viability. Reclamation's AM efforts are intended to supplement and aid the RIP's adaptive management plan, discussed above.

3.4.1.1.5 Summary of Reclamation's Proposed Conservation Measure – the Supplemental Water Program

Reclamation proposes the following specific conservation measures related to its Supplemental Water Program:

- To purchase or lease from willing parties, water, water rights or the right to store water for use in the Rio Grande to provide supplemental flows to the Rio Grande.
- To lease water from SJC Project contractors, depending on environmental conditions, water availability, funding, and the willingness of contractors to enter into leasing agreements.
- To acquire pre-1907 surface water rights from Price's Dairy, in partnership with the Service.
- Reclamation proposes to release Program water as needed, to meet downstream flow targets, while supplies last.
- To seek to enter into water acquisition agreements and/or water management agreements with SJC contractors and other interested parties.
- To release water stored pursuant to the Emergency Drought Water Agreement or other similar agreements, as is made available by the State of New Mexico, consistent with the Compact and with State and Federal law.
- To utilize its Program water only when native flow management is insufficient to meet ESA requirements by exchanging leased SJC Project water with native Rio Grande water.
- To authorize temporary waivers, which allow SJC Project contractors to take their water deliveries in the following calendar year, if such waivers will benefit the United States and not impact delivery into Heron Reservoir.
- To pump and convey water from the LFCC to the Rio Grande, including the operation of an outfall near Escondida, New Mexico.

3.4.1.2 Reclamation's Environmental Water Operations

A significant amount of coordination between Reclamation, the Corps, the MRGCD, and State and local water management agencies is necessary to successfully accomplish environmental water operations, also known as "River Eyes," which includes coordination of water and river operations to improve system operations and to benefit habitat for listed species. The actions include daily observations of river conditions with written summer reports distributed via email to recipients of water operations conference call notes and verbal reports given during water operations conference calls. River reconnaissance generally is performed early enough in the day so that observations can be relayed to water operations staff by 8:00 a.m. and may be followed up with late afternoon reconnaissance. Handheld global positioning system units are used to record spatial characteristics of receding and advancing edges of running water habitat. Irrigation wasteways also are surveyed to determine if they are actively contributing to river flows. Daily coordination of water operations between Federal and non-Federal partners are especially critical during periods of limited water availability and river drying.

Reclamation proposes, as a conservation measure, to continue its interagency efforts and environmental water operations.

3.4.2 MRGCD's Proposed Conservation Measures

In conjunction with its proposed actions, the MRGCD proposes the following general and specific conservation measures. In addition to the measures described below, the MRGCD proposes to continue participating in the Collaborative Program and funding PVA research and model development.

Through inclusion in this BA, the MRGCD recognizes the need to continue to cooperate with Reclamation in achieving ESA compliance. As a part of this effort, the MRGCD Board of Directors approved a suite of specific conservation measures it is committed to in support of the Collaborative Program's goals (or a RIP, should one develop). These specific MRGCD commitments are included in Section 3.4.2.2 below, and in Appendix 8.

3.4.2.1 MRGCD's Enhanced Water Operations

3.4.2.1.1 Enhanced Coordination

MRGCD proposes to continue water operations, in coordination with Reclamation, the Corps, and State and local water management agencies, as was described above in Reclamation's environmental water operations. MRGCD's environmental water operations included the following:

- Participation in the regular management of water operations throughout the MRG, in conjunction with Reclamation, the Corps, NMISC, ABCWUA, and the Service with the goal of meeting irrigation water needs through providing efficient water management. Such conjunctive management should assist with meeting the needs of all State of New Mexico permitted water uses, remaining in compliance with the Rio Grande Compact, and benefitting the species to the greatest extent practical.

- Provision of access to MRGCD managed lands for operational and scientific purposes involving species (including guides, keys, etc.), including activities related to habitat restoration projects, fish monitoring. and fish salvage.

- Operation and maintenance of measurement stations, telemetry equipment, computer processing, and data exchange networks to collect and distribute information on MRGCD water operations to other water management entities and the general public.

- Expansion and refinement of the network of MRGCD measurement stations to contribute to a more thorough scientific understanding of water movement, distribution, and use throughout the MRG.

- Support for efforts by Reclamation and the NMISC to fully understand Rio Grande depletions from all sources through participation in river measurements made by various entities.

- Support for management of Supplemental Water by Reclamation and species salvage by the Service, through participation in river measurements during critical periods.

3.4.2.1.2 Changes in Operation to Support Instream Habitat and Flow Management

The primary purpose of the operational measures described below is to benefit listed species.

- The MRGCD will continue to improve its system's operational efficiency and, therefore, minimize the amount of water from El Vado that is needed to augment MRG flows for irrigation demand. These actions can decrease significantly the requirement for Supplemental Water if they are able to keep the irrigation system from going into shortage operations. Shortage operations are "run-of-the-river" operations in which there is no available water in storage for non- prior and paramount irrigators and insufficient natural flow. During these operations, Reclamation's Supplemental Water is expended quickly, especially if there are any flow requirements beyond Isleta Dam. Efficient MRGCD operations allow flow targets to be met without Supplemental Water when MRGCD is operating normally and decrease the amount of Supplemental Water to cover times that the MRGCD is in shortage operations, since the efficiency helps to minimize the amount of time that the MRGCD is in shortage operations.

- In coordination with Reclamation's Supplemental Water Program, MRGCD will manage conveyance of Supplemental Water for delivery to drain outfalls and wasteways to better meet the needs of RGSM. These releases provide discrete wetted sections that serve as refugia for RGSM, with possible SWFL benefit and are most beneficial to the species when the release rates are managed for consistency.

- On occasion, when water is physically available, and in coordination with Reclamation and the Service, the MRGCD will manage its returns flows to assist the Service with its RGSM rescue efforts.

- Minimize or temporarily suspend diversions during periods of peak egg production to minimize incidental entrainment of eggs and larvae into irrigation canals; subject to rates of flow, agricultural needs, and coordination with the Service.

- During normal MRGCD operations, MRGCD will convey Reclamation's Supplemental Water as far as the Isleta Diversion Dam without incurring any consumptive losses for ESA.

- MRGCD will divert Reclamation's Supplemental Water as necessary at the Diversion Dams, leaving an equivalent amount of native Rio Grande water undiverted. This water accounting exercise provides that the Supplemental Water Program's SJC Project water is fully consumed within the MRG, which is consistent with the intent of the SJC Project to provide for beneficial use of Colorado River water in New Mexico.

- During normal MRGCD operations, the MRGCD will allow a flow of native Rio Grande water equivalent to 50% of Reclamation's Supplemental Water arriving at Isleta Diversion Dam to pass through the San Acacia diversion after an appropriate time delay. MRGCD will bear a variable portion of losses to Reclamation's Supplemental Water, dependent on rates of flow and time of year.

- During MRGCD shortage/conservation operations and when the ABCWUA has agreed to suspend diversions of native Rio Grande water, MRGCD will, if deemed necessary, reduce diversions at Angostura Diversion Dam to the minimum practical rate of flow required to meet irrigation demand within the Albuquerque division, as occurred during the fall of 2011.

- Under certain conditions, by mutual agreement and to prevent delay, when Reclamation has begun releasing Supplemental Water but that water has not yet reached its intended destination, MRGCD will assist Reclamation to achieve intended rates of flow below the Diversion Dams.

- Under certain conditions, by mutual agreement and contingent on water being physically present, MRGCD will take actions to maintain a small discharge, not to exceed 8 cfs (normal gate leakage) below the Isleta Diversion Dam.

- Under certain conditions, by mutual agreement and contingent on water being physically present, MRGCD will take actions to maintain a small discharge, not to exceed 8 cfs (normal gate leakage) below the San Acacia Diversion Dam.

- During normal operation, and when water in excess of irrigation demand is available, MRGCD will manage its diversions and outfalls to return flows to the Rio Grande to specific habitat areas near drain and wasteway discharge locations. MRGCD will identify key target areas where water can be returned, especially during critically dry periods, to maintain wetted habitat for silvery minnow when drying is occurring elsewhere in the river. Figure 3 in section 3.3.1.2 illustrates the locations where MRGCD can best enhance river flows.

- When not in normal operations, or when MRGCD water supplies are severly constrained, MRGCD may convey Reclamation Supplemental Water for delivery to drain outfalls and wasteways. These deliveries will be in coordination with Reclamation's Supplemental Water Program to maintain discrete wetted sections that serve as refugia for silvery minnow, with possible Southwestern willow flycatcher benefit.

3.4.2.1.3 Changes in Operation to Support Spring Peak Flows

- MRGCD will request that Reclamation store water at El Vado Reservoir in a manner that minimizes the impact of storage operation on the magnitude and duration of spring runoff hydrographs. To the extent practical and consistent with MRGCD storage requirements, storage should occur early during the runoff period so that more water may pass through El Vado during times most advantageous to spawning of the silvery minnow. MRGCD may request that Reclamation use an increased rate of storage at El Vado during times when releases from Abiquiu Reservoir are at channel capacity to minimize reduction to peak discharge through the MRG.

- To the extent practical, MRGCD will coordinate its storage requests with Reclamation, NMISC, and the Corps with the intent of reaching its storage objectives maximizing peak discharge and/or duration of the spring runoff through the MRG for the benefit of the species.

3.4.2.2 Proposed Conservation Measures: July 24, 2012

At its July 24, 2012 Board of Directors meeting, the MRGCD approved additional conservation measures to be included in Reclamation's July 31, 2012 BA. However, at that time, Reclamation and the MRGCD anticipated that the Middle Rio Grande Recovery Implementation Program (RIP) would be included as the conservation measure serving as the means for ESA compliance. In this amended BA, Reclamation provides that the Collaborative Program will serve as the means for including non-Federal actions in its Section 7 consultation, and that conservation measures proposed by Reclamation, MRGCD, the State and the

Authority, together with the conservation actions currently taken by and through the Collaborative Program will serve to offset the adverse impacts of the proposed actions described in this BA. What follows are the proposed conservation measures approved by the MRGCD on July 24, 2012, without revision.

Proposed MRGCD Conservation Measures

Preamble

1. Pursuant to its statutory general grant of powers (NMSA 1978, § 73-14-48), MRGCD has authority to enter into an endangered species Recovery Implementation Program (RIP) and to undertake certain species survival and recovery actions to be incorporated within the MRGRIP Action Plan. However, MRGCD has no authority to violate its statutory obligations and MRGCD is specifically prohibited from relinquishing control of the waters or lands of the District or from administering or managing District waters in such a way as to impair the private water rights of individual irrigators or its own statutory water rights (NMSA 1978, § 73-14-47).[18]

2. MRGCD has the authority to develop an Operating Plan to carry out some of the programs within the RIP that will benefit listed species (NMSA 1978, §§ 73-14-48 *et seq.*), but MRGCD has no authority to relinquish its authority to implement the terms of such an Operating Plan to any third party, particularly when such implementation may involve control of the use of the District waters or lands (NMSA 1978, § 73-14-47).

3. MRGCD has the authority to lease or otherwise provide reservoir storage space for a "supplemental water pool" and to assist in developing programs for use of that storage to provide protection for the RGSM consistent with the RIP, and as a contribution to cost-share, but it cannot do so in a way that reduces storage for persons entitled to receive water from the MRGCD (NMSA 1978, § 73-14-47).

Consistent with the above limitations, the MRGCD proposes the following actions for conservation of the species:

A. The MRGCD recognizes the need for ESA compliance and the need to continue to cooperate with Reclamation in future compliance efforts, which include the conjunctive management of water for species needs, municipal withdrawals, RGC obligations, and irrigation needs. The MRGCD will develop annually an

[18] *See Gutierrez v. MRGCD*, 34 N.M. 346, 282 P. 1 (1929) (citing the full protection of private water rights afforded by Section 316 of the Conservancy Act).

Operating Plan. This Plan will coordinate the delivery of irrigation water to water rights holders and water users within the MRGCD. The Plan will also assist in meeting the needs of the listed species for population survival and recovery, including spawning, recruitment and survival habitat needs as determined by using the best available scientific information. The development and implementation of this MRGCD Operating Plan will be incorporated into the Middle Rio Grande Recovery Implementation Program (MRGRIP) Action Plan as part of the conservation actions and/or tasks which are expected to permit the MRGRIP to attain and maintain compliance with the ESA.

B. The MRGCD will cooperate with state and federal agencies in creation and operation of a "supplemental water pool" consisting of up to 30,000 AF to be stored in available space in Abiquiu reservoir. Water stored for ESA purposes may, subject to ISC approval, be stored under the authority of the Strategic Water Reserve. Water stored separately by MRGCD for irrigation purposes will be managed by the MRGCD under its authority contained in the Conservancy Act. The conjunctive management of MRGCD water will provide some environmental and biological benefits to RGSM. The creation of the SWR was authorized by the NM Legislature in 2005, for the purposes of providing a water reserve to help New Mexicans manage through drought periods. In addition to meeting the needs of water users and NM's delivery obligations under the RGC, a goal of the pool will be to assist in providing flows needed for ESA purposes, and in so doing, to protect the rights of existing water users. Storage space at Abiquiu Reservoir for the pool was set aside by the ABCWUA as a result of a settlement between ABCWUA and Environmental groups when the ABCWUA was seeking to permit and construct its SJC Diversion works.

Water supply for the pool may come from a variety of sources including uncontracted SJC water and purchases of SJC water by the Federal Government from willing sellers. The use of surplus SJC water would be a primary choice for development of water supply, along with RG water stored as a result of NM having relinquished credit water in Elephant Butte reservoir to Texas under the Rio Grande Compact. Use of this water would be subject to the limitations of New Mexico water law. MRGCD is the largest and most likely recipient of credit water stored as a result of relinquishment and in the absence of ESA requirements would logically be the recipient of most of this water. Relinquishment credit water (more correctly stated as the right to store water against relinquished NM RGC credits) is made available by the New Mexico Rio Grande Compact Commissioner. MRGCD will urge that a percentage of water resulting from credit relinquishments to the pool be allocated for ESA purposes. MRGCD will cooperate with appropriate entities to maximize NM credit status under the RGC, and increase the opportunities for future credit relinquishment to benefit both the ESA needs and MRGCD water supply. Concurrently, MRGCD will expand its opportunity for storage to manage through drought by completion of agreements with ABCWUA to store up to 50,000 AF of water at Abiquiu Reservoir. Space at Abiquiu reservoir for this purpose was pledged by ABCWUA as a result of MRGCD withdrawing its objections to permitting and construction of the ABCWUA SJC diversion works. While MRGCD has authority over water it holds in storage, MRGCD will cooperate and coordinate with NMISC, ABCWUA, BOR and other appropriate entities to conjunctively manage releases from storage and releases from the pool to maximize flexibility in Rio Chama water operations for the benefit of environmental/recreational concerns, and to minimize evaporative or conveyance losses.

C. Depending on the available water supply and consistent with its primary statutory mission of conveying and delivering water for its use in agriculture, when MRGCD has water surplus to the needs of its irrigators within its canal system, the MRGCD will manage its diversions and outfalls to return excess flows to the Rio Grande for habitat areas and other designated sites, as determined by, and consistent with tasks identified within the MRGRIP Action Plan. The MRGCD will participate with other MRGRIP entities, in particular with the U.S. Fish and Wildlife Service, the MRGRIP Science Coordinator and scientific workgroups, and the MRGRIP management and Executive Committee, to identify and study key habitat areas to which water can be returned, especially during critically dry periods, to serve species population needs for survival and recovery, as determined by the best available scientific information, by maintaining wetted habitat for silvery minnow when drying is occurring elsewhere in the river. This commitment will not compel the District to deliver water to habitat or other sites when it is needed to serve irrigators' requirements.

When the MRGCD determines that water surplus to irrigation needs is not available within the MRGCD system, and flow to designated habitat or other areas for species needs is desired, MRGCD will convey water to these areas from available species water resources. MRGCD's contribution will be to bear the conveyance loss from point of release at a reservoir to point of delivery at habitat area, if MRGCD is delivering water along these same pathways for irrigation purposes. An exception may occur if delivery of water to a designated habitat area requires the use of a canal or other water pathway which is not normally or currently in use, in which case species water would be required to incur actual conveyance losses.

D. The MRGCD will cooperate and assist with the creation and enhancement of specific habitat areas, the so-called "String of Pearls" to provide a series of refuge areas where RGSM populations may be maintained during normal periods of low and intermittent flow in the MRG. These areas tend to be located near MRGCD outfalls which typically discharge excess water, or which can be readily used to convey species water with minimal losses. These areas are located in the Albuquerque, Isleta, and San Acacia reaches of the Rio Grande. The MRGCD will maintain its outfalls and, consistent with existing agreements, the federal agencies will provide maintenance and enhancement of river areas through channel shaping, bank modification, vegetation management, food management, and biological management (non-native or predator removal) to provide conditions suitable to preserving maximum numbers of RGSM in good health for extended periods of time. The "String of Pearls" will provide RGSM refugial habitat between Cochiti reservoir and Bosque del Apache. The locations of the pearls are illustrated in the following map:

E. To allow more precise control and management of water supply to San Acacia dam, MRGCD will pursue construction of a siphon near Bernardo, NM to deliver excess irrigation returns from the San Juan Riverside Drain system directly to the Unit 7/Socorro Main Canal system. This is envisioned to allow for more reliable water supply to the MRGCD Socorro division while simultaneously reducing the total annual volume of water required for diversion at San Acacia dam. This would be anticipated in turn to benefit peak flows through San Acacia dam, and sediment movement and river morphology upstream and downstream of San Acacia dam with associated benefits for RGSM. During times of low or no flow, the Bernardo siphon could be envisioned to assist with management of the "String of Pearls" by creating a refugial area downstream of the siphon itself, and creating a more dependable water supply at San Acacia dam for the maintenance of a refugial area downstream of the dam. It is anticipated that costs of this project operations will be borne in part by the MRGCD, and in part by the federal government. Once the anticipated water supply benefits of the Bernardo Siphon Project have been realized, distribution of water supplies resulting from the Project could be directed by the District to meet the needs of water users in the MRGCD Socorro division in conjunction with those of the listed species.

F. To provide a water supply for the last pearl on the string, MRGCD will construct a return flow collection system at its southern boundary. Excess water from the San Antonio Acequia, the Socorro Main South Canal, the Socorro Riverside Drain, and the Elemendorf Drain will be routed to a central collection/distribution point. At the distribution point, water will be directed into the Low Flow Conveyance Channel and will be lifted back to the Rio Grande through a permanent electrically powered pumping station to be constructed by the MRGCD and operated and maintained by the BOR. It is anticipated that costs of these operations will be supported as cost-share by the MRGCD, and also by the federal agencies and the MRGRIP. Distribution of water at this point will be to meet the needs of the listed species, the water rights of the Bosque del Apache National Wildlife Refuge, and RGC delivery obligations.

G. Recession Management

During inevitable low and intermittent flow periods on the RG, RGSM mortality may be greatly reduced by controlled rates of recession, allowing individuals to move to suitable habitat locations (the String of Pearls). Controlling this rate of recession can be challenging, and has in the past resulted in usage of large amounts of species water. This may be at the conclusion of the spring snowmelt period, or after periods of heavy precipitation. To the extent permitted by the Rio Grande Compact, a controlled rate of recession may be produced by USACE reducing releases from Cochiti reservoir in a series of small steps. As a part of the conservation measures to the MRGRIP, the MRGCD will establish a policy where during times of floodwater storage and managed recession for RGSM, MRGCD available natural flow will be determined by the theoretical release from Cochiti reservoir in the absence of any such managed recession. In this way, USACE may have greater flexibility in controlling the rate of recession for RGSM without affecting NM's RGC deliveries to Elephant Butte. This mechanism would require an update to the Water Control Manual for Cochiti reservoir.

H. The MRGCD will actively participate in the creation of habitat to benefit the lifecycle of the RGSM. Habitat creation will be the responsibility of an interagency team consisting of MRGCD, the NMISC, BOR, USFWS, and USACE. The MRGCD will provide assistance in obtaining funding (cost share, etc.) and/or land for habitat restoration. Habitat restoration may be focused on enhancing the interconnection between active river channel and floodplain, as well as other types of restoration. Habitat restoration will be engineered to provide progressively greater levels of inundation at increasing flows, resulting in a range of habitat types. An initial goal over a XX year period will be 75 acres of RGSM habitat across the range of discharges.

I. To the degree permitted by New Mexico water law, the MRGCD will cooperate with efforts to establish a program whereby groundwater users within the MRGCD may offer water for lease to BOR or other groups for the express purpose of providing flows from wells for endangered species. Water provided to this program will be from willing lessees with pre-1907 or pre-basin groundwater pumping rights for agricultural use. Transfers of use of irrigation wells to instream uses will need to go through the OSE application and permitting process. Administration of this program must necessarily involve close coordination with the NMOSE and MRGCD to establish appropriate volumes of water and rates of flow, and to insure and verify that land from which pre-1907 water rights have been transferred for species use do not continue to be irrigated (absent an MRGCD water bank withdrawal).

J. While the development of new modeling and analysis continues to assist in addressing species management uncertainties, the MRGCD will continue to fund the current PVA and statistical data analysis efforts through a research agreement with Montana State University as a contribution to the scientific understanding of the RGSM.

3.4.3 ABCWUA's Conservation Measures

3.4.3.1 Additional Storage of Native Water

The Albuquerque Bernalillo County Water Utility Authority (Water Authority) proposes to continue developing potential additional storage of native water at Abiquiu Reservoir. While perhaps ten years or more may be required, the Water Authority is proceeding with property lease and condemnation activity as necessary to increase the elevation of water storage at Abiquiu(6220 to 6230 elevation) . The Water Authority has been working with the USACE, starting a project development team at the USACE, determining status of contract modification with the USACE, and evaluating real estate considerations and NEPA analysis. In general, increased storage of water is difficult within the Middle Rio Grande, but could provide additional opportunities for the management of water to benefit endangered species and water users.

3.4.3.2 Conservation Storage Agreements

The Water Authority has agreements with environmental groups to potentially store 30,000 acre feet of water for conservation storage in the facilities where the Water Authority currently stores SJC water. While this activity is currently not allowed under existing permits held by the Water Authority, details are being negotiated with the ISC and the BOR.

3.4.3.3 Lease Supplemental Water

The Water Authority will consider potentially leasing water to the BOR within the Supplemental Water Program. This would depend upon availability of water, timing and amount of lease, environmental compliance considerations, the participation of others in the program and other stipulations. SJC project waivers continue to be a mechanism for BOR to provide fishery and recreational flows on the Rio Chama. Third party sub-contracting of Water Authority SJC water is not currently being done, but remains an option for the Water Authority, and other water users.

3.4.3.4 Continued Efforts Towards Water Conservation

The Water Authority operates a rate payer water conservation program and posts frequent updates. The program continues to meet required and previously determined goals ahead of planned schedules and will be expanded to increase effectiveness.

3.4.3.5 Continued Coordination With Water Releases/Diversions

The Water Authority will continue to coordinate with other entities. Specific releases and amounts of water may occur when it is feasible and can be accomplished with the diversion schedules and amounts necessary to comply with Water Authority operations and requirements. Closer coordination with all Rio Grande water users is called for within the development of the RIP of the Middle Rio Grande Endangered Species Collaborative Program. The Water Authority participates through development of the BOR Annual Operating Plan, and developing the Adaptive Management framework being considered within the Collaborative Program.

3.4.4 Middle Rio Grande Endangered Species Collaborative Program

A conservation measure proposed in this BA for both Reclamation and the non-Federal entities is the continued implementation of the Collaborative Program. The purpose of the Collaborative Program as described in the 2008 MOA is two-fold:

- First, to prevent extinction, preserve reproductive integrity, improve habitat, support scientific analysis, and promote recovery of the listed species within the Program area in a manner that benefits the ecological integrity, where feasible, of the Middle Rio Grande riverine and riparian ecosystem; and,

- Second, to exercise creative and flexible options so that existing water uses continue and future water development proceeds in compliance with applicable federal and state laws.

To achieve these ends, the Program may not impair state water rights or federal reserved water rights of individuals and entities; federal or other water rights of Indian nations and Indian individuals, or Indian trust assets; SJ-C Project contractual rights; and the State of New Mexico's ability to comply with Rio Grande Compact delivery obligations.

3.4.4.1 Reliance on Collaborative Program for ESA Compliance

Section 7(a)(2) of the ESA requires Federal agencies to ensure their actions are not likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat (see 50 CFR 402.01). This ESA requirement also includes any non-Federal actions that have a Federal nexus, where a Federal agency funds, authorizes, or carries out the action in whole or in part. Section 9 of the ESA prohibits Federal and non-Federal parties subject to the jurisdiction of the United States from "taking" endangered species. In the MRG basin, a variety of Federal and non-Federal activities related to water operations, water management and use, river maintenance, and flood control are subject to the ESA.

The Collaborative Program receives funding through congressional appropriations to implement projects designed to benefit the federally listed endangered silvery minnow and the flycatcher. The Collaborative Program implements activities required by the 2003 BiOp to support compliance with the BiOp providing ESA coverage for the two federal action agencies and broad coverage for participating non-federal entities. The 2003 BiOp also serves as a tool to conserve listed species, assist with species recovery, and help protect critical habitat.

Implementation of the Collaborative Program is presented in this section as a conservation measure to offset the effects of the water management-related activities described in chapters 3 of Parts I, II and III of this BA. Collaborative Program conservation measures for the aggregate set of adverse effects presented in the effects analyses have been designed to offset or minimize both direct and indirect adverse effects of the proposed action as well as of interrelated and interdependent actions.

3.4.4.2 Collaborative Program Elements and Work Groups

Collaborative Program activities are generally organized by seven LTP element categories: habitat restoration and management, water management, population augmentation/propagation, water quality management, research, monitoring, and adaptive management, public outreach, and program management.

The Executive Committee establishes work groups as needed to provide assistance and expertise to address specific Collaborative Program tasks. The Coordination Committee carries out the directives of the Executive Committee and reviews and provides recommendations on all aspects of the Program to the Executive Committee. The Habitat Restoration Work Group helps to restore habitat in the Middle Rio Grande to contribute to accomplishing biological opinion requirements for the benefit of the listed species. The Science Work Group provides scientific recommendations, technical assistance, and expertise. Other established work groups include the Species Water Management Work Group and the Public Information Outreach Work Group. Temporary ad hoc work groups may also be formed and consist of individuals with expertise and/or interest in a specialized subject necessary to implement a Collaborative Program task.

3.4.4.3 Annual Work Plan

Work groups, e.g., the Executive Committee, the Coordination Committee, and the Program Management Team, engage in an iterative, annual work plan process to identify and prioritize activities needed in the upcoming year for BiOp compliance and to assist with recovery.

3.4.4.4 Adaptive Management

The Collaborative Program Executive Committee acknowledges that there are still a number of critical uncertainties and hypotheses about the listed species and their habitat that are integral to water management and species recovery activities. AM is a structured and systematic approach for designing, implementing, monitoring, and evaluating management actions to maximize learning about critical scientific questions and to reduce uncertainties that affect management decisions regarding the use of Collaborative Program resources to achieve Collaborative Program goals. Learning resulting from adaptive management activities and monitoring will be used as a tool to improve management decisions to more quickly and cost-effectively attain Program objectives.

The adaptive management framework drafted by contractors to the Collaborative Program (Middle Rio Grande Endangered Species Collaborative Program Adaptive Management Plan Version 1, October 25, 2011) provides guidance for the development of a scientifically defensible AM design specific to the Program. It also includes a set of principles for designing AM actions and examples of management actions and appropriate monitoring plans. As an important priority, the Collaborative Program will use the AM framework and experience of this and other programs to develop a formal AM Plan. The Collaborative Program will identify specific management activities, monitoring, and research that will be used to evaluate and improve management decisions and will identify the decision making framework for flexible water management and other activities that provide for meeting the Program goals.

Adaptive management is not intended as a broad-based research program. In keeping with the purpose of AM, only learning relevant to management decision making will be sought through the AM process. AM will be implemented within the existing financial and hydrological resources available to the Collaborative Program.

4. Species Description, Federal Listing Status and Life History

4.1 Rio Grande Silvery Minnow

4.1.1 Species Description

The Rio Grande silvery minnow (*Hybognathus amarus*) (silvery minnow) is a small-bodied minnow reaching a maximum size of approximately 4 inches (Sublette et al. 1990). The silvery minnow are part of the genus *Hybognathus* that has at least seven recognized species, which are very similar morphometrically (Bestgen and Propst 1996). The taxonomic status of silvery minnow has changed several times since its original description by Girard in 1856 in the vicinity of Brownsville, Texas. Pfliger (1980) was the first to separate out the silvery minnow as its own species, *H. amarus.* This status has been supported by several publications investigating morphometric and genetic characteristics (Cavender and Coburn 1988, Hlohowskyj et al. 1989, Mayden 1989, Cook et al. 1992, Schmidt 1994, Bestgen and Propst 1996).

4.1.2 Distribution

Historically, silvery minnow occurred in the Rio Grande from Española, NM, to the gulf coast of Texas and in larger tributaries including the Pecos River encompassing more than 1,500 river miles (2,400 kilometers [km]). There are few early sampling records in the Rio Chama. There is also some historic information from tribal sources that silvery minnow may have occupied the Rio Chama up to approximately Abiquiu (Parametrix 2010). Today, silvery minnow are restricted to the reach of the Rio Grande in New Mexico, much of which is susceptible to drying, from the vicinity of Bernalillo downstream to the headwaters of Elephant Butte Reservoir. The occupied distance is approximately 10% of its presumed historic range (approximately 150 river miles [241 km]). This area is mainly encompassed within the action area for this consultation. The last silvery minnow collected outside the Middle Rio Grande was in the Pecos in 1968 (Museum of Southwestern Biology Records). There have been no silvery minnow collected in the Big Bend reach of the Rio Grande since 1961; however, silvery minnow from the propagation facilities supported by the Collaborative Program were stocked in the Big Bend reach in 2008, 2009, and 2010. Initial surveys have found evidence of reproduction, though it is too early to determine if the population will become self-sustaining.

The portion of river between Cochiti Dam and Angostura Diversion Dam is still considered to be occupied, but very few surveys have been conducted in this reach to confirm this. Egg monitoring was conducted in the Angostura Canal, just downstream from the Angostura Diversion Dam, over the past decade. During this time, only three eggs were reported (in 2003), and those were not preserved for confirmation. The lack of eggs in the Angostura Canal suggests that silvery minnow density upstream of Angostura Diversion Dam is extremely low if present (Service 2009).

4.1.3 Listing Status – Critical Habitat

Silvery minnow is currently listed as endangered on the New Mexico State list of endangered species, having first been listed May 25, 1979, as an endangered endemic population of the Mississippi silvery minnow (*Hybognathus nuchalis*). On July 20, 1994, the Service published a final rule to list the silvery minnow as an endangered species with proposed critical habitat (Federal Register [FR] 1994). The Service initiated a 5-year review of the status of the species in 2010 (75 FR 15454–15456). Current science was submitted to the Service for consideration by many entities, including MRGCD and NMISC; but the review has not been published at this time.

Critical habitat was designated for silvery minnow in 1999 (64 FR 36274-36290), with revisions published February 19, 2003 (68 FR 8088-8135). Designated critical habitat in the Rio Grande extends through Sandoval, Bernalillo, Valencia, and Socorro Counties, New Mexico, generally beginning at Cochiti Dam downstream to the utility line crossing the Rio Grande at the upstream end of the Elephant Butte Reservoir full pool. This marks the southern boundary of the action area for this consultation and the beginning of Reclamation's Rio Grande Project. The lateral extent of critical habitat includes those areas bounded by existing levees. In areas without levees, the lateral extent of critical habitat, as proposed, is defined as 300 feet (91.4 meters [m]) of riparian zone adjacent to each side of the river.

The critical habitat designation also includes a 5-mile segment of the Jemez River from Jemez Canyon Dam to the upstream boundary of Santa Ana Pueblo, Sandoval County. Pueblo lands in Santo Domingo, Santa Ana, Sandia, and Isleta Pueblos are excluded from critical habitat. The Service considered the Rio Grande around Big Bend National Park and the Pecos River between Ft. Sumner Dam and Brantley Reservoir as essential to conservation but did not designate them as critical habitat.

The Service identified four primary constituent elements (PCE) in the critical habitat designation (68 CFR 8114–8117):

1. A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats, such as, but not limited to, the following: Backwaters (a body of water connected to the main channel, but with no appreciable flow), shallow side channels, pools (that portion of the river that is deep with relatively little velocity compared to the rest of the channel), eddies

(a pool with water moving opposite to that in the river channel), and runs (flowing water in the river channel without obstructions) of varying depth and velocity—all of which are necessary for each of the particular silvery minnow life-history stages in appropriate seasons. The silvery minnow requires habitat with sufficient flows from early spring (March) to early summer (June) to trigger spawning, flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow, and a relatively constant winter flow (November through February).

2. The presence of low-velocity habitat (including eddies created by debris piles, pools, or backwaters, or other refuge habitat (e.g., connected oxbows or braided channels) within unimpounded stretches of flowing water of sufficient length (i.e., river miles) that provide a variety of habitats with a wide range of depth and velocities.
3. Substrates of predominantly sand or silt.
4. Water of sufficient quality to maintain natural, daily, and seasonally variable water temperatures in the approximate range of greater than 1 degree Celsius (°C) (35 degrees Fahrenheit[°F]) and less than 30 °C (85 °F) and reduce degraded water quality conditions (decreased dissolved oxygen, increased pH, etc.).

4.1.4 Life History and Ecology

Historically, the occupied range of silvery minnow included a broad range of environmental parameters from those typical of the arid Southwest to the gulf coast of Texas. Current knowledge of silvery minnow life history and requirements are based on studies that have been conducted within the species' contemporary range, an environment that has been dramatically altered over historic times. It is unknown how the minnow's life history attributes may have differed in now unoccupied portions of its range.

In the Middle Rio Grande, silvery minnow generally spawn in the spring, from late April through June (Platania and Dudley 1999–2010). Peak egg production typically occurs in mid- to late-May, coinciding with high spring discharge produced by snowmelt runoff. Spawning also is thought to be sometimes triggered by summer flow spikes in years with negligible snowmelt runoff. It is likely that several environmental variables influence the timing of silvery minnow spawning (e.g., photoperiod, temperature, and water turbidity).

Reproductively mature females are typically larger than males. Each female produces several clutches of eggs during spawning, ranging from 2,000–3,000 (Age 1) to 5,000+ eggs (Age 2) per female (Platania and Altenbach 1996). The majority of the population captured by population monitoring during prespawn seining surveys is comprised of Age 1 fish (1 year old) with older, larger fish (Age 2+) constituting less than 10% of the spawning population

(Platania and Altenbach 1996, Horwitz et al. 2011). In paired sampling trials, the mean size of silvery minnow captured during spring sampling of inundated overbank habitats with fyke nets is slightly larger than the mean of those collected with seines (SWCA 2011).

Age determination for museum specimens collected in 1874 based on scales (Cowley et al. 2006) indicated minnows may live up to 5 years. However, more recent analysis of the same museum material and contemporary specimens indicate a maximum age of 3 (Horwitz et al. 2011). In most years, few adult silvery minnows are captured by late summer. In October 2009, the majority (greater than [>] 99%) of silvery minnows collected were Age 0 and 1 fish (Horwitz et al. 2011). Captive minnows can live much longer. Some preliminary estimates of survival from the 1993–1999 monitoring data were developed and presented to the PVA workgroup (R. Valdez PowerPoint to PVA, March 31, 2010). However, these analyses were based upon five age classes and the Cowley et al. age determinations from scales which may not be as accurate as the otolith based comparisons.

Silvery minnow are generally found in schools, so sampling results and habitat studies are often affected by this grouping behavior. Dudley and Platania (1997) studied habitat preferences of the silvery minnow in the MRG at Rio Rancho and Socorro. Both juvenile and adult silvery minnow primarily used mesohabitats with moderate depths (15–40 centimeters [cm]), low water velocities (4–9 centimeters per second [cm/sec]) and silt/sand substrates. Young-of-year silvery minnow are generally found in shallower and lower velocity habitats than adult individuals. During winter months, silvery minnow become less active and seek habitats with cover such as debris piles and low water velocities. During spring sampling, large concentrations of reproductively mature silvery minnow are often collected on inundated lateral overbank habitats (Hatch and Gonzales 2008, LL Study).

Adult, silvery minnow are strong swimmers capable of moving upstream during high flow events (Bestgen et al. 2010). However, studies conducted tracking hatchery fish indicate that there is not likely a population wide migration behavior for silvery minnow. It appears that movement is somewhat random with a net downstream trend for marked individuals though a few individuals moved upstream substantial distances (25 km). The distance traveled by recaptured fish ranged from 0.26 km (0.16 mile [mi]) to over 25 km (15.54 mi) (Platania et al. 2003). More recently, passive implant transponder (PIT) tags were implanted into hatchery fish to study the utilization of a fish passage structure built around the water treatment facility in Albuquerque (Archdeacon and Remshardt 2012). They found that the tagged silvery minnow moved through the facility from both upstream (19 km) and downstream (13 km) stocking locations.

Silvery minnow are thought to be omnivorous or herbivorous consuming a variety of diatoms and algae. A study of historic (1874) and more recent (1978) preserved specimens revealed a variety of diatoms as well as allochthonous organic matter present in the gut contents (Shirey 2004, Cowley et al. 2006). Magana (2009) found that larval silvery minnow showed preference for certain species of diatoms that may be based on the growth form of the diatom. A study of silvery minnow in outdoor hatchery ponds found insects were present in 66% of fish, followed by formulated feed (60%), diatoms (40%), cladocerans (36%), rotifers (35%), filamentous algae (32%), bryozoan statoblasts (19%), copepods (11%), protozoa (9%), plant material (9%), ostracods (6%), detritus (5%), and sand (4%). Among size groups, small and medium fish consumed a greater variety of foods than large fish (Watson et al. 2009).

Silvery minnow are pelagic spawners producing numerous semi-buoyant nonadhesive eggs typical of the genus *Hybognathus* (Platania and Altenbach 1998). Further hypothesis testing to determine if silvery minnow exhibit preferential use of lateral habitat (including overbank) for spawning is underway. Surveys of inundated overbank habitats often capture large numbers of gravid females (Gonzales and Hatch 2009). The specific gravity of silvery minnow eggs ranges from 1.012–1.00281 as a function of time postfertilization (Cowley et al. 2005). Egg hatching time is temperature-dependent, occurring in 24–48 hours at water temperatures of 20–30 ºC (Platania 2000). Recently hatched silvery minnow larvae are approximately 3.7 millimeters [mm] in length.

Eggs and larvae are vulnerable to downstream displacement by the current until larvae are able to actively seek out low velocity habitats, which generally occurs within 3–5 days. Many eggs incubate as they drift downstream (Dudley and Platania 2007, SWCA 2011). The distance that eggs and larvae may be displaced downstream is highly correlated with the level of discharge and habitat structure (Dudley and Platania 2007, Widmer et al. 2012). Habitat complexity is associated with discharge stage; at discharge levels that inundate the associated flood plain, there is a dramatic increase in available low velocity habitats. Retention of gellan beads was higher in the Isleta Reach than the Angostura Reach, likely due to the greater habitat complexity and flood plain connectivity at the discharge tested (Widmer et al. 2012). The proximity of spawning to the habitat also may determine how far eggs may disperse. Retention of propagules in upstream reaches is important to maintain the species within the upper portions of the range, especially in river systems that have been fragmented and where fish have reduced opportunity to move upstream.

The availability of nursery habitat appears to be determined by spring runoff with higher flows inundating terrestrial surface used as nursery areas (Porter and Massong 2004). Overbank habitats often provide low velocity, higher temperature, and high primary productivity habitats for larval fish development (Pease et al. 2006). Data indicate that most years with flow that inundates overbank habitats have much greater recruitment of larval fish into the fall population. However, flood pulse inundation may have negative implications for water quality such as decreased dissolved oxygen due to increased respiration in areas that are infrequently flooded (Valett et al. 2005). Contributions from the stagnant floodwaters into the main channel also would be expected to decrease the oxygen content within the Rio Grande downstream. For example, Abeyta and Lusk (2004) reported a fish kill due to low oxygen in a large stagnant flood plain pool after overbank flooding along the Middle Rio Grande. Therefore, the frequency of inundation also may play a role in creating the type and quality of habitats for larval fish development.

4.1.5 Reasons for Decline

The silvery minnow was historically one of the most abundant and widespread fishes in the Rio Grande Basin including the Pecos River. Similar to many fish species in the western portions of North America, silvery minnow likely started to decline concurrent with human encroachment and development along the Rio Grande and its tributaries. Though small scale water development was present in the drainage for more than 500 years, major water development projects and flow modifications began in the late 1800s in the San Luis Valley and in 1913 with the completion of Elephant Butte Reservoir (Service 2003). By 1993, when the silvery minnow was proposed for listing, there were upwards of 20 large dams and irrigation structures along the Rio Grande and its major tributaries (Pecos, Rio Chama, and Jemez River). Additionally, demands for water increased greatly in the 20th century.

Trevino-Robinson (1959) documented the early 1950s “cosmopolitan” occurrence of silvery minnow in the Rio Grande downstream from its confluence with the Pecos River. Due to the extended drought, they noted a portion of the lower Rio Grande went dry in 1953. It is unknown how much drying occurred after this event. Extended drying also was documented between El Paso and the Rio Conchos (Chernoff et al. 1982). Increased agricultural and municipal water demands have increased the magnitude and duration of low flow conditions. In addition to low water conditions, poor water quality conditions were noted in the lower portions of the Rio Grande, including increased salinity and the presence of agricultural chemicals in fish tissues (White et al. 1983, Andreasen 1985). Silvery minnow have not been documented below Elephant Butte Dam on the Rio Grande since the mid-1950s (Hubbs et al. 1977, Sublette et al. 1990, Edwards and Contreras-Balderas 1991). Prior to the recent stocking in Big Bend National Park, silvery minnow had not been documented from this lower portion of the Rio Grande since the mid-1950s (Edwards and Contreras-Balderas 1991). Silvery minnow were last sampled above Cochiti Dam near Velarde 5 years after the closing of Cochiti Dam in 1973 (Bestgen and Platania 1991).

Hybridization and/or competition with nonnative congener species operated to displace the silvery minnow from its formerly occupied range in the Pecos River. The silvery minnow was displaced in the Pecos River of New Mexico by its congener *H. placitus* (plains minnow) that was probably introduced during 1968 into the Pecos drainage from the Canadian drainage (Cowley 1979). The displacement that ensued was complete in less than one decade (Hoagstom et al. 2010). Initial studies to investigate hybridization of plains minnow and silvery minnow did not produce viable offspring (Caldwell 2003), but the results were not conclusive for whether the species could produce viable offspring or not. The study did demonstrate that, under hatchery conditions, the species would mate with each other. Further research is warranted to determine if some type of competitive reproductive interference may have occurred. Heterospecific matings and hybridization are types of reproductive interference that can lead to fitness losses for species due to wasted reproductive effort and in viable offspring (Groning and Hochkirch 2008).

Predation and competition with other fish species has also been cited as a factor possibility contributing to the decline of the species (Service 1999, Service 2003). A wide range of fish species are native to the Rio Grande and Pecos Rivers and coevolved with silvery minnow. Accidental or intentional releases of fishes outside of their native ranges, have established numerous exotic fish species in the Rio Grande Basin (Sublette et al. 1990) representing potential competitors or predators with the silvery minnow outside of those that silvery minnow evolved with. Lotic conditions, created by dams and diversions, often favor large predatory species such as bass. Avian predation is also a factor especially during periods of low or no flow. Very few studies have been conducted to determine the effect of predation or interspecific competition on silvery minnow by the various species that now exist within the Rio Grande.

The entrainment of silvery minnow (primarily eggs and larvae) in the infrastructure of irrigation systems that derive water directly from the Rio Grande has been cited as a factor contributing to the decline silvery minnow (Service 1999). Egg entrainment in irrigation canals has been monitored since 2001. Low numbers of eggs have been found in the sampling. Management strategies at the diversions have likely minimized the number of eggs that are currently entrained. Low densities of silvery minnow likely persist within the permanently watered channels such as the low flow conveyance channel and MRGCD drains (Cowley et al. 2007, Lang and Altenbach 1994, Reclamation Data 2010). These channels may provide some refuge for silvery minnow during extreme dry periods though it is unlikely that they can complete their life cycle within canals due to very limited habitat and high numbers of nonnative predators.

Historically, river engineering projects to manage geomorphic processes have variable effects on silvery minnow habitat quality and area depending on how they are implemented. Traditional river engineering activities within the Rio Grande in combination with regulated flows have confined the Rio Grande to a narrower channel and reduced the connectivity with overbank habitat to reduce depletions of water. Upstream reservoirs also stop sediment transport that often results in channel incision further reducing flood plain connectivity. Contemporary river engineering projects incorporate features (point bars, side channels, islands) that decrease the impacts to, or increase, silvery minnow habitat.

The original listing of the species as endangered (58 FR 11823) cited the presence of mainstream dams; growth of agriculture and cities in the Rio Grande Valley; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation, particularly during periods of low or no flow; inadequacy of existing regulatory mechanisms including the lack of recognition that instream flows are a beneficial use of State waters; dewatering of a large percentage of its habitat, including dewatering downstream from San Acacia. In the revised recovery plan, the Service (2010) reassessed the pressures or threats to the species that can threaten its continued existence in the MRG. These are dewatering and water diversion, water impoundment, river modification, water pollutants, disease, predation and competition, and loss of genetic diversity.

4.2 Southwestern Willow Flycatcher

4.2.1 Species Description

The southwestern willow flycatcher (*Empidonax traillii extimus*) is a small passerine bird, approximately 15 cm (5.75 inches) in length. Phillips (1948) described the Southwestern subspecies as *E. t. extimus*. The flycatcher is one of four subspecies of the willow flycatcher currently recognized (Hubbard 1987, Unitt 1987), though Browning (1993) suggests a possible fifth subspecies (*E. t. campestris*) in the Central and Midwestern United States. The willow flycatcher subspecies are distinguished primarily by subtle differences in color and morphology and by habitat use. Recent research (Paxton 2000) concluded that *E. t. extimus* is genetically distinct from the other willow flycatcher subspecies.

4.2.2 Distribution

The species occurs in southern California, Arizona, New Mexico, southern portions of Nevada and Utah, and possibly southwestern Colorado (50 CFR 10693). No reporting from standardized surveys has been received from the state of Texas (Durst et al. 2008). In 2007, the population along the Gila River drainage was the largest with 30.1% of all territories rangewide followed by the population along the Rio Grande drainage with 23.3% (Durst et al. 2008).

In New Mexico, the flycatcher has been observed in the Rio Grande, Rio Chama, Zuni, San Francisco, Pecos, Canadian, and Gila River drainages. Flycatchers were first reported at Elephant Butte State Park in the 1970s, although the exact locations of the sightings were not documented (Hubbard 1987). Because surveys were not consistent or extensive prior to the listing of this species, a comparison of historic numbers to current status is not possible; however, the available native riparian habitat overall along the Rio Grande has declined, and it is assumed populations may have declined from historic numbers as well.

A standardized survey protocol and consistent reporting system have been followed since 1994 using guidelines provided by the Service. The fundamental principles of the standardized methodology for presence/absence surveys have remained the same since the original protocol development and have proven to be an effective tool for locating flycatchers rangewide (Sogge et al. 2010).

In the MRG, surveys for flycatchers in selected areas occurred because of environmental compliance activities for various projects. Although a systematic survey effort throughout the entire riparian corridor of the MRG has not occurred, reaches of the river with the most suitable habitat for flycatchers have been surveyed. Presence/absence surveys and nest monitoring along selected areas of the Rio Grande have been conducted from 1993–2011. With expanded or increased survey efforts during this 18-year period, several sites have been located where flycatcher territories have consistently been established. Once located, most of these core breeding areas have been monitored annually.

Since the initial surveys of the Rio Grande Valley in the 1990s, breeding pairs have been found within the MRG Project area from Elephant Butte Reservoir upstream to the vicinity of Taos. Several locations along the Rio Grande have consistently held breeding flycatchers. These areas have one or more flycatcher pairs that have established a territory in an attempt to breed, with most birds returning annually. In some locations, these local populations appear to be expanding with an increased number of territories being detected. Some local populations have remained small (10–15 territories, or fewer) but stable; other sites have been abandoned and no longer contain territorial flycatchers.

Five general locations of flycatcher populations have been established throughout the MRG (figure 5). These areas consistently have held several territories; however, the number of territories, pairs, nest attempts and successful nests has varied through the years.

4.2.3 Listing Status and Critical Habitat

A final rule was published in the February 27, 1995, Federal Register to list the Southwestern United States population of the flycatcher as an endangered species under the ESA with proposed critical habitat. However, the final rule of July 22, 1997, designating critical habitat in for the species rangewide did not include the Rio Grande (62 CFR 39129). A proposal to re-designate critical habitat was published October 12, 2004, (69 CFR 60706), with a final designation published October 19, 2005, (70 CFR 60886).

Figure 5. Five general locations of flycatcher populations within the MRG.

The 2005 final designation of critical habitat defines two units located along the Rio Grande: the Upper Rio Grande Management Unit that includes 664 hectares (ha) (1,640 acres), encompassing 66 km (41 miles), and the Middle Rio Grande Management Unit designates 13,410 ha (33,137 acres) along 135 km (84 miles).

The segments mentioned above are characterized as follows (figure 6):

Upper Rio Grande Management Unit:

- The Upper Rio Grande New Mexico Segment is considered the area from the Taos Junction Bridge to the upstream boundary of Ohkay Owingeh Pueblo.

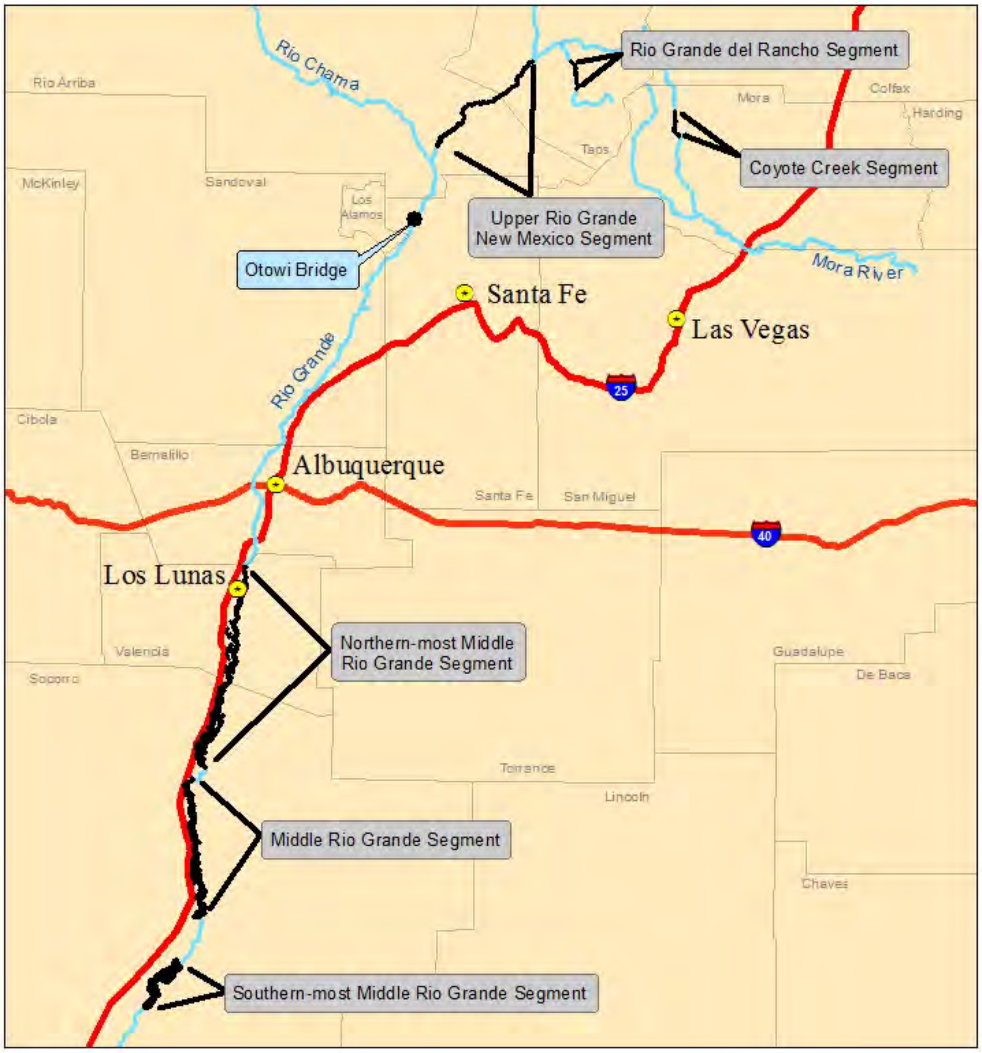

Figure 6. 2005 final critical habitat designations

- The Rio Grande del Rancho Segment is considered the area from Sarco Canyon downstream to the Arroyo Mirando confluence.
- The Coyote Creek Segment is considered the area from 2 km (1.2 miles) above Coyote Creek State Park to the second bridge on State Route 518.

Middle Rio Grande Management Unit:

- The northern-most Middle Rio Grande Segment is considered the area from the southern boundary of the Isleta Pueblo to the northern boundary of the Sevilleta National Wildlife Refuge (NWR).

- The central Middle Rio Grande Segment is considered the area from the southern boundary of the Sevilleta NWR to the northern boundary of the BDANWR.

- The southern-most Middle Rio Grande Segment is considered the area from the southern boundary of the BDANWR to the overhead power line near Milligan Gulch at the northern end of Elephant Butte Reservoir (approximately river mile 62).

The Service released a new proposal for critical habitat in August 2011 (76 CFR 50542). Along the Rio Grande in New Mexico (and within our project boundaries), the proposed revision would include all areas historically listed as critical habitat with the addition of:

- The Rio Fernando area (.25 mi) in the Upper Rio Grande Management Unit (just upstream of the Rio Lucero confluence) near Taos and an extended area from the north boundary of Ohkay Owingeh Pueblo downstream to Otowi Bridge.

- An extended area within the Middle Rio Grande Unit. With the new proposed rule, the southern boundary of the Middle Rio Grande Unit would extend farther south into Elephant Butte Reservoir to approximately just south of river mile 36 (or about 9 river miles north of the dam). The previously designated habitat within this Unit also excluded the BDANWR and the Sevilleta NWR because they have specific flycatcher management plans that outline actions they undertake to benefit the species. Both refuges are proposed for critical habitat designation at this time.

Several areas within the Upper and Middle Rio Grande Units will be considered for exclusion from the final designation of flycatcher critical habitat under section 4(b)(2) of the ESA. Those areas include:

- Tribal lands within the San Ildefonso Pueblo, the Santa Clara Pueblo, and the Ohkay Owingeh Pueblo. These will be considered for exclusion due to their tribal management plans and partnerships.

- The water storage area of Elephant Butte Reservoir. This area will be considered due to the development of plans for the operation of the reservoir as well as a flycatcher management plan. This area also is being considered for exclusion based on initial evaluation of potential impacts of water operations of the dam and reservoir.

In both the final 2005 critical habitat designation (70 CFR 60886) as well as the newly proposed critical habitat designation in 2011 (76 CFR 50542), the Service identified two PCEs that were recognized as the physical or biological features essential to the conservation of the flycatcher. Those PCEs are as follows:

PCE 1—Riparian Vegetation

Riparian habitat in a dynamic river or lakeside, natural or manmade successional environment (for nesting, foraging, migration, dispersal, and shelter) that is comprised of trees and shrubs (that can include Gooddings willow, coyote willow, Geyers willow, arroyo willow, red willow, yewleaf willow, Pacific willow, boxelder, tamarisk, Russian olive, buttonbush, cottonwood, stinging nettle, alder, velvet ash, poison hemlock, blackberry, seep willow, oak, rose, sycamore, false indigo, Pacific poison ivy, grape, Virginia creeper, Siberian elm, and walnut) and some combination of:

a. Dense riparian vegetation with thickets of trees and shrubs that can range in height from about 2–30 m (about 6–98 ft). Lower-stature thickets (2–4 m or 6–13 ft tall) are found at higher elevation riparian forests, and tall-stature thickets are found at middle and lower-elevation riparian forests,

b. Areas of dense riparian foliage at least from the ground level up to approximately 4 m (13 ft) above ground or dense foliage only at the shrub or tree level as a low, dense canopy.

c. Sites for nesting that contain a dense (about 50–100%) tree or shrub (or both) canopy (the amount of cover provided by tree and shrub branches measured from the ground).

d. Dense patches of riparian forests that are interspersed with small openings of open water or marsh or areas with shorter and sparser vegetation that creates a variety of habitat that is not uniformly dense. Patch size may be as small as 0.1 ha (0.25 acre) or as large as 70 ha (175 acre).

PCE 2—Insect Prey Populations

A variety of insect prey populations found within or adjacent to riparian flood plains or moist environments, which can include: flying ants, wasps, and bees (Hymenoptera); dragonflies (Odonata); flies (Diptera); true bugs (Hemiptera); beetles (Coleoptera); butterflies, moths, and caterpillars (Lepidoptera); and spittlebugs (Homoptera).

4.2.4 Life History and Ecology

Flycatchers are neotropical migrant birds that overwinter in such places as southern Mexico, Central America, and likely South America for about 8 months before migrating back to the Southwestern United States (76 CFR 50542). Unfortunately, little is known about the ecology and distribution of flycatcher populations during migration. However, it appears flycatchers use a wide range of habitat types in their wintering grounds (Schuetz et al. 2007). In general, winter habitat is a combination of four main habitat components including standing or slow moving water and/or saturated soils, patches or stringers of trees, woody shrubs, and open areas (Schuetz et al. 2007, Koronkiewicz and Sogge 2000). The main body of knowledge of flycatchers surrounds breeding and nesting success in its summer range.

Flycatcher breeding chronology is presented in figure 7 and falls within the generalized breeding chronology expected of Southwestern willow flycatchers (based on Unitt 1987, Brown 1988, Whitfield 1990, Skaggs 1996, Sogge 1995, Maynard 1995, Sferra et al. 1997, Sogge et al. 2010, Service 2002).

Each stage of the breeding cycle represents a greater energy investment in the nesting effort by the flycatcher pair and may influence their fidelity to the nest site or their susceptibility to abandon if the conditions in the selected breeding habitat become adverse.

Extreme dates for any given stage of the breeding cycle may vary as much as a week from the dates presented. Egg laying begins as early as late-May but more often starts in early- to mid-June. Chicks can be present in nests from mid-June through early-August. Young typically fledge from nests from late-June through mid-August but remain in the natal area 14–15 days. Adults depart from breeding territories as early as mid-August but may stay until mid-September in later nesting efforts. Fledglings likely leave the breeding areas 1-2 weeks after adults. Most flycatchers only live 1 or 2 years as adults, but there have been rare occurrences of flycatchers living at least 9 years (Paxton et al. 2007).

The flycatcher is an obligate riparian species occurring in habitats adjacent to rivers, streams or other wetlands characterized by dense growths of willows (*Salix* sp.), seepwillow (*Baccharis* sp.), arrowweed (*Pluchea* sp.), saltcedar (*Tamarix* sp.), or other species (50 CFR 10693). Species composition, however, appears less important than plant and twig structure (Moore and Ahlers 2011). Slender stems and twigs are important for nest attachment. Nest placement is highly variable as nests have been observed at heights ranging from 0.6–20 m and generally occur adjacent to or over water (Sogge et al. 2010). Along the MRG, breeding territories have been found in young and mid-age riparian vegetation dominated by dense growths of willows at least 15 feet high, as well as in mixed native and exotic stands dominated by Russian olive and saltcedar (Moore and Ahlers 2009).

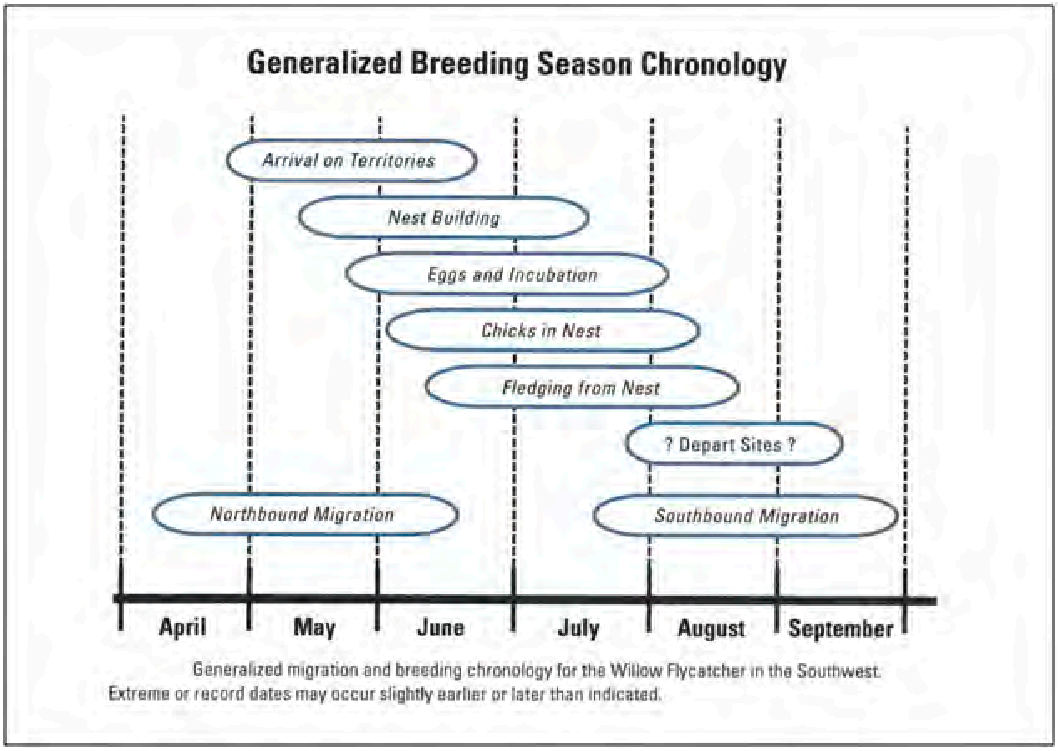

Figure 7. Generalized breeding chronology of the Southwestern willow flycatcher (from Sogge et al. 2010).

A majority of the birds within the MRG select habitat patches dominated by native species, usually dense willows, for nesting. Within these willow patches, nests have been found on individual saltcedar plants, especially in older, taller willow patches where an understory of saltcedar provides suitable nesting substrate. It appears that the tree species with the vertical structure of more slender stems and twigs on younger plants in the understory vegetation is selected for nest placement (Moore and Ahlers 2011). Most recently, nests located at the Sevilleta NWR and La Joya State Wildlife Management Area have been established in areas adjacent to the river dominated by saltcedar and Russian olive; however, the overall vegetation type of most of the flycatcher territories established in the MRG is dominated by native species and not saltcedar (Moore and Ahlers 2011).

A critical component for suitable nesting conditions is the presence of water, usually provided by overbank flooding or some other hydrologic source. Reclamation has found that 97% of all flycatcher nests in the Reclamation-surveyed areas of the MRG from 2004–2010 (n=1,429), occur within 100 m of surface water, and 94% occur within 50 m (Moore and Ahlers 2011). The presence of surface water at the onset of nest site selection and nest initiation is likely critical, though not absolutely necessary. For example and particularly observed in reservoir sites, a flycatcher territory may have vegetation completely immersed in water during a wet year or thoroughly dry and hundreds of meters away from surface water in drought years (76 CFR 50542).

Flycatchers and many other species of neotropical migrant land birds also use the Rio Grande riparian corridor as stopover habitat during migration. Studies have shown that, during the spring and fall migration, flycatchers are more commonly found in willow habitats than in other riparian vegetation types, including the narrow band of coyote willows that line the LFCC above the BDANWR (Finch and Yong 1997). During presence/absence surveys in May and early June, migrating flycatchers are frequently observed throughout the project area. These birds use a variety of vegetation types during migration, many of which are classified as "low suitability" for breeding habitat (Ahlers and White 1997).

Evidence gathered during multiyear studies of color-banded flycatcher populations show that, although most male flycatchers return to former breeding areas, flycatchers regularly move among sites within and between years (Ellis et al. 2008). Between 1997 and 2005, of the 1,012 relocated banded flycatchers rangewide, 595 (59%) banded flycatchers in Arizona returned to the breeding site of the previous year, while 398 (39%) moved to other breeding areas within the same major drainage; and 19 (2%) moved to a completely different drainage (Paxton et al. 2007). Overall distance moved among adults and returning nestlings ranged from 0.03–444 km with mean distance moved by adults (9.5 km) much less than the mean fledgling dispersal distance (20.5 km) (Paxton et al. 2007). Although most returning flycatchers showed site fidelity to breeding territories, a significant number move within and among sites. Movement patterns are strongly influenced by reproductive success. The age class of habitat patches also may be of consideration (Paxton et al. 2007).

Flycatcher prey base is relatively understudied, but it does appear that flycatcher food availability may be largely influenced by density and species of vegetation, proximity to and type of water, saturated soils, and temperature and humidity (76 CFR 50542). The flycatcher is an insect generalist and can feed on a variety of different prey. Prey includes, but is not limited to, wasps and bees (Hymenoptera), flies (Diptera), beetles (Coleoptera), butterflies, moths and caterpillars (Lepidoptera), and spittlebugs (Homoptera) (76 CFR 50542). In a comparison between native, exotic, or mixed habitat types, it appears that the arthropod community is statistically indistinguishable among habitats (Durst 2004). The difference in relative quality among the habitat types also was indistinguishable (Durst 2004). In the same study and between years (drier in 2002 versus wetter year in 2003), prey base was believed to be driven by differences in relative insect abundances (2003 yielded a five-fold increase in total arthropod biomass). In the drier year with less relative humidity, greater distance to water, and less food availability, flycatcher nest success in this area of the study decreased substantially (Smith et al. 2003).

4.2.5 Reasons for Decline

During the last two centuries, human-induced hydrological and ecological changes have heavily influenced the composition and extent of flood plain riparian vegetation along the MRG (Bullard and Wells 1992, Dick-Peddie 1993). Introduction of exotic species, such as saltcedar, has decreased the availability of dense willow and associated desirable vegetation and habitat important to flycatchers. The destruction and fragmentation of forested breeding habitat also may play a role in population reduction of migratory birds (Lynch and Whigham 1984, Wilcove 1988). In addition, the rapid rate of deforestation in tropical areas has been cited as a possible reason for population declines in forest-dwelling migrant land birds (Lovejoy 1983, Rappole and McDonald 1994, Robbins et al. 1989).

Brood parasitism by brown-headed cowbirds (*Molothrus ater*)(cowbird), has been implicated in the decline of songbirds, including those found in the Western riparian habitats (Gaines 1974, 1977, Goldwasser et al. 1980, Laymon 1987). Cowbirds have increased their range with the clearing of forests and the spread of intensive grazing and agriculture. Flycatchers are more susceptible to cowbird nest parasitism because of the ease of egg laying in the flycatcher's open cup nest design. Habitat fragmentation and forest openings allow cowbirds easy access to host nests located near these edges. Nest parasitism, combined with declining populations and habitat loss, has placed this species in a precarious situation (Mayfield 1977, Rothstein et al. 1980, Brittingham and Temple 1983, Laymon 1987). Grazing cattle often are associated with cowbird activity; however, in a recent report (Broadhead et al. 2007), parasitism by cowbirds was more closely associated with habitat types, particularly vegetation, patch size and edge effect.

4.3 Pecos Sunflower

4.3.1 Species Description

Pecos sunflower is an annual, herbaceous plant. It grows 1–3 m (3.3–9.9 ft) tall and is branched at the top. The leaves are opposite on the lower part of the stem and alternate at the top, lance-shaped with three prominent veins, and up to 17.5 cm (6.9 inches) long by 8.5 cm (3.3 inches) wide. The stem and leaf surfaces have a few short, stiff hairs. Flower heads are 5-7 cm (2.0–2.8 inches) in diameter with bright yellow rays around a dark purplish brown center (the disc flowers). Pecos sunflower looks much like the common sunflower (*Helianthus annuus*) seen along roadsides throughout the West but differs from the common sunflower by having narrower leaves, fewer hairs on the stems and leaves, smaller flower heads, and narrower bracts (phyllaries) around the bases of the heads. The prairie sunflower (*Helianthus petiolaris*) also has narrow leaves and phyllaries, but is distinguished from Pecos sunflower by having white cilia in the dark center of the flower head and a branching pattern from the base of the plant that imparts a bushy appearance. Common sunflower and prairie sunflower usually bloom earlier in the season (May–August depending on location) than Pecos sunflower (September and October), and neither occupies the wet, saline soils that are typical of Pecos sunflower habitats. Pecos sunflower has a highly disjunctive distribution, yet there appears to be very little phenotypic variation between populations.

4.3.2 Status and Distribution

Pecos sunflower was known only from a single population near Fort Stockton, Pecos County, Texas, when it was proposed as a candidate for listing as endangered under the ESA on December 15, 1980 (45 FR 82480). Subsequent field surveys for this plant found additional populations in New Mexico and Texas on a variety of State and Federal lands and several private land holdings. The species faces a moderate degree of threat. The plant is associated with spring seeps and desert wet meadows (cienegas) habitats, which are very rare in the dry regions of New Mexico and Texas. Little is known about the historic distribution of the Pecos sunflower, but there is evidence these habitats have historically, and are presently, being reduced or eliminated by aquifer depletion or severely impacted by agricultural activities and encroachment by alien plants (Poole 1992, Sivinski 1996).

Pecos sunflower is presently known from only seven populations—two in west Texas and five in New Mexico (figure 8). The type of locality (location from which the species was first described) is near Fort Stockton in Pecos County, Texas. Near Fort Stockton, a large population with several hundred thousand plants currently exists at The Nature Conservancy's (TNC) Diamond Y Spring Preserve, with a smaller group of plants downstream at a nearby highway right-of-way. A second Texas population occurs at Sandia Spring Preserve (TNC) in the Balmorhea area of Reeves County, Texas.

Most Pecos sunflower habitats are limited to less than 2 hectares (5 acres) of wetland. Some are only a small fraction of a hectare; however, one near Fort Stockton and another near Roswell are more extensive. The number of sunflowers per site varies from less than 100 to several hundred thousand. Because Pecos sunflower is an annual, the number of plants per site can fluctuate greatly from year to year with changes in precipitation and depth to ground water. Stands of Pecos sunflower can change location within the habitat as well (Sivinski 1992). If a wetland habitat dries out permanently, even a large population of Pecos sunflower would disappear (Service 2005).

Figure 8. Distribution of Pecos sunflower.

In New Mexico, the five Pecos sunflower populations are located in the Roswell/Dexter region, Santa Rosa, two locations in the Rio San Jose Valley, and on the MRG. In the Roswell/Dexter region of the Pecos River valley in Chaves County, Pecos sunflower occurs at 11 spring seeps and cienegas. Three of these wetlands support many thousands of Pecos sunflowers, but the remainder are smaller, isolated occurrences. Springs and cienegas within and near the town of Santa Rosa in Guadalupe County have eight wetlands with Pecos sunflower—one of which consists of a few hundred thousand plants in good years. Two widely separated areas of spring seeps and cienegas in the Rio San Jose valley of western New Mexico each support a population of Pecos sunflower. One occurs on the lower Rio San Jose in Valencia County and the other is in Cibola County in the vicinity of Grants. Neither are especially large populations. Another larger population on the Rio Grande at La Joya Waterfowl Management Area in Socorro County occurs near the confluence of the Rio Puerco, which has the Rio San Jose as a tributary stream. This large population is managed by the New Mexico Department of Game and Fish (NMDGF) and is the only population within the MRG water management action area.

Additionally in 2008, a cooperative effort established a reintroduced population on private property in Socorro County. This population has expanded its range in the short time since establishment, but no population estimates are available. Additionally this population currently has not been proposed as critical habitat.

4.3.3 Listing Status and Critical Habitat

Pecos sunflower (*Helianthus paradoxus* Heiser) was listed as a threatened species by the Service on October 20, 1999 (64 FR 56582-56590). Critical habitat for the species was designated effective May 8, 2008 (73 FR 17762-17807), with PCEs for the species identified as desert wetland or riparian habitat components that provide:

1. Silty clay or fine sand soils that contain high organic content, are saline or alkaline, are permanently saturated within the root zone (top 50 cm of the soil profile), and have salinity levels ranging from 10 to 40 parts per thousand.
2. Low proportion (less than 10%) of woody shrub or canopy cover directly around the plant.

The State of New Mexico lists Pecos sunflower as endangered under the regulations of the New Mexico Endangered Plant Species Act (19 New Mexico Administrated Code 21.2). This species is also listed as threatened by the State of Texas (31 Texas Administrative Code 2.69(A)).

The population of Pecos sunflower on the Rio Grande (Valencia County, La Joya Waterfowl Management Area) contains all of the PCEs in the appropriate spatial arrangement and quantity, and is threatened by encroachment of nonnative vegetation. The site was determined to be essential to the conservation of the species because it is occupied by a very large (estimated between 100,000 and 1,000,000 individuals) stable population and is sufficiently distant (over 40 mi (64 km)) from other populations to serve as an additional locality that contributes to the conservation of genetic variation (Service 2005). This population was excluded from critical habitat designation because the NMDGF (2008) has developed a habitat management plan for the Pecos sunflower. The management plan was developed to support conservation of the species on the La Joya WMA by: controlling invasive species, protecting the natural spring in Unit 5 from motorized vehicles and heavy equipment, monitoring core populations by digitizing these areas annually, and restoring native habitat through revegetation. The Service concluded that the plan was complete and provided for the conservation and protection of the physical and biological features essential to the conservation of the species (73 FR 17762-17807).

4.3.4 Life History and Ecology

Pecos sunflower grows in areas with permanently saturated soils in the root zone. These are most commonly desert springs and seeps that form wet meadows called cienegas. These are rare wetland habitats in the arid Southwest region (Hendrickson and Minckley 1984). This sunflower also can occur around the margins of lakes, impoundments, and creeks. When Pecos sunflowers grow around lakes or ponds, these are usually impoundments or subsidence areas within natural cienega habitats. The soils of these desert wetlands are typically saline or alkaline because the waters are high in dissolved solids, and high rates of evaporation leave deposits of salts, including carbonates, at the soil surface. Soils in these habitats are predominantly silty clays or fine sands with high organic matter content. Studies by Van Auken and Bush (1995) and Van Auken (2001) showed that Pecos sunflower grows in saline soils, but seeds germinate and establish best when precipitation and high water tables reduce salinity near the soil's surface. Like all sunflowers, this species requires open areas that are not shaded by taller vegetation.

Plants commonly associated with Pecos sunflower include *Distichlis spicata* (saltgrass), *Sporobolus airoides* (alkali sacaton), *Phragmites australis* (common reed), *Schoenoplectus americanus* (chairmaker's bulrush), *Juncus balticus* (Baltic rush), *Muhlenbergia asperifolia* (alkali muhly), *Limonium limbatum* (southwestern sea lavender), *Flaveria chloraefolia* (clasping yellowtops), *Cirsium wrightii* (Wright's marsh thistle), *Tamarix* sp. (saltcedar), and *Elaeagnus angustifolia* (Russian olive) (Poole 1992, Sivinski 1996). All of these species are indicators of wet, saline, or alkaline soils. Pecos sunflowers often occur with saltgrass between the saturated soils occupied by bulrush and the relatively drier soils with alkali sacaton (Van Auken and Bush 1998).

4.3.5 Reasons for Decline

Spring seeps or cienega habitats are very rare in the dry regions of New Mexico and Texas. There is evidence that these habitats have historically, and are presently, being reduced or eliminated by aquifer depletion or severely impacted by agricultural activities and encroachment by alien plants (Poole 1992, Sivinski 1996). The Southwestern United States is currently experiencing a period of prolonged drought that is exacerbating this habitat degradation. The trend of decreasing habitat availability and suitability justified listing Pecos sunflower as a threatened species. Recovery actions to reverse or stabilize this trend and ensure the long-term sustainability of this species include identifying the ecological parameters of Pecos sunflower habitat and enlisting the cooperation of the various habitat owners in the long-term conservation of the species (Service 2005).

4.4 Interior Least Tern

4.4.1 Status and Distribution

The interior least tern (*Sternula antillarum athalassos*, tern) was listed as endangered by the Service in 1985 (50 CFR 21784). This subspecies historically bred along the Colorado (in Texas), Red, Rio Grande (in Texas), Arkansas, Missouri, Ohio, and Mississippi River systems and has been found on braided rivers of southwestern Kansas, northwestern Oklahoma, and southeastern New Mexico (American Ornithologists' Union 1957). In New Mexico, the tern was first recorded (including nesting) at Bitter Lake NWR in 1949; and since then, it remained present essentially annually (Marlatt 1984, NMDFG 2008). The species also occurs as an occasional breeder in Eddy County, New Mexico (Moore 2011). The tern has been observed as a 'vagrant' or 'highly unusual' species among the 377 avian species detected on the BDANWR since 1940 (Service 1995). In 2005, a rangewide survey of terns was completed, and the Rio Grande/Pecos River systems collectively made up 0.8% of the population (Lott 2006). Historically, tern nesting has been confirmed on six reservoirs along the Rio Grande/Pecos reach at Bitter Lake NWR, Brantley Lake, and Imperial Reservoir on the Pecos; and Lake Casa Blanca, Amistad Reservoir, and Falcon Reservoir on the Rio Grande in Texas (Lott 2006) (figure 9).

4.4.2 Life History and Ecology

Breeding habitat requirements for this species include the presence of bare or nearly bare ground on alluvial islands, shorelines, or sandbars for nesting, the availability of food (primarily small fish), and the existence of favorable water levels during the nesting season so nests remain above water (Ducey 1981). Breeding colonies contain from 5–75 nests. Although most nesting occurs along river banks and reservoirs, the tern also nests on barren flats of saline lakes and ponds. Nests are constructed by scraping a depression within the sand.

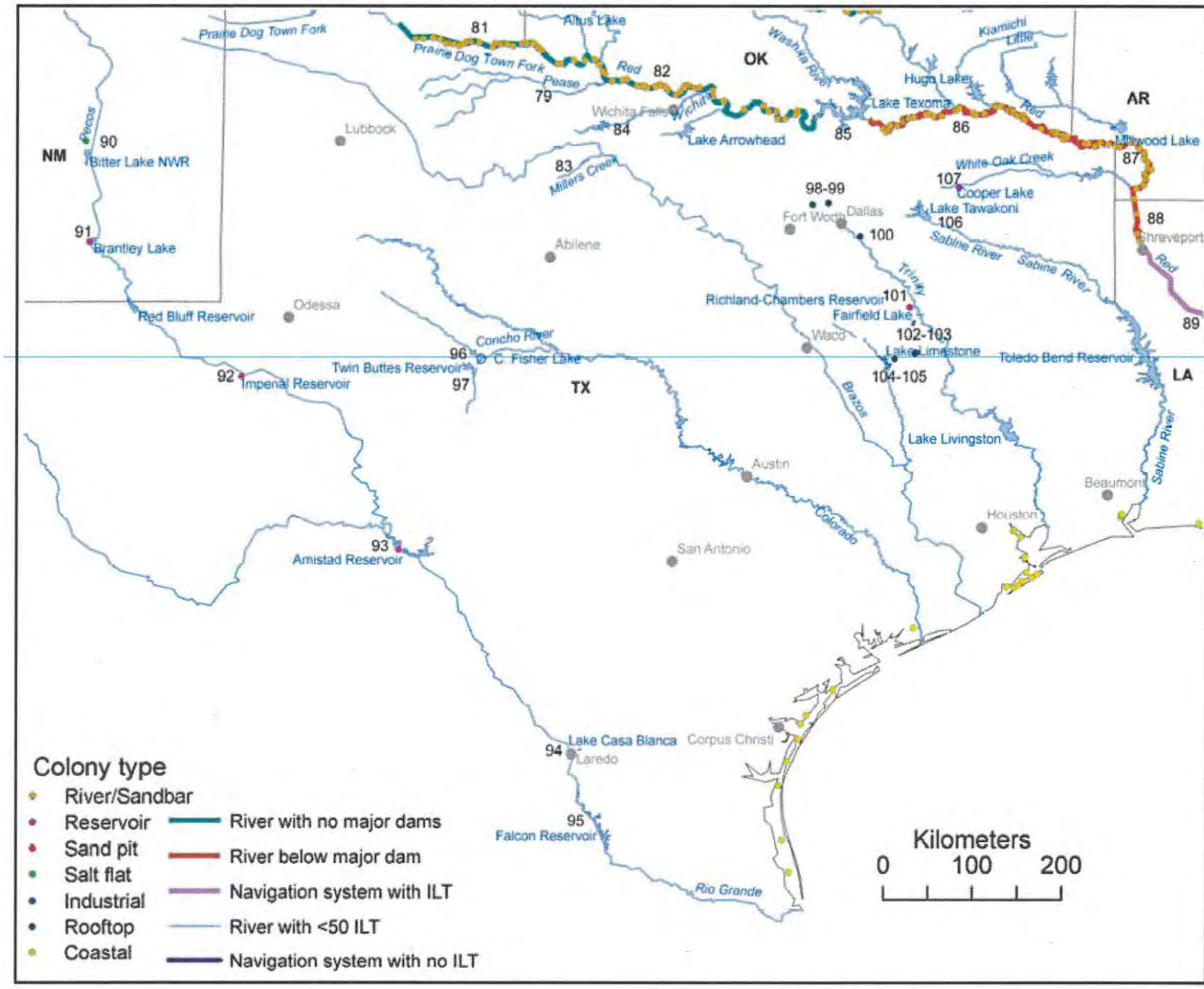

Figure 9. Distribution of the 2005 tern (ILT in figure) breeding colonies within New Mexico and Texas (Lott 2006).

Eggs are typically a pale to olive beige color and specked with chocolate marks, blending in with the sand or mudflat habitat. Little is known about the wintering areas occupied by the tern, but it is believed that they can be found along the Central American coast and the northern coast of South America from Venezuela to northeastern Brazil (Service 1990).

4.4.3 Reasons for Decline

Loss of nesting areas through permanent inundation or destruction by reservoir and channelization projects was identified as the major threat to the species (Service 1995). Alteration of natural river or lake dynamics has caused unfavorable vegetation succession on many remaining islands, curtailing their use as nesting sites by terns. Recreational use of sandbars, releases of water from upstream reservoirs, and annual spring floods often inundate nests.

5. Environmental Baseline

5.1 Historical Perspective

Largely due to the limited water supply and the highly variable streamflows in the Rio Grande, humans have modified the Rio Grande system over time to protect themselves from floods and to maximize their beneficial use of water. Human activities, taking advantage of flows in the Rio Grande system, extend back to the agricultural traditions of pueblo peoples since time immemorial. Pueblo oral histories convey, and the early Spanish accounts of the Rio Grande confirm, that pueblo peoples had developed advanced systems of irrigated agriculture long before the coming of Europeans. Beginning with the arrival of Spanish settlers in the late 16^{th} century, these irrigation activities were expanded in such a way that they affected the flows in the Rio Grande system. The subsequent agricultural practices and administration of the river, as well as the intensive use of nonirrigated lands within the Rio Grande Basin, under the Spanish, Mexican, and American periods brought about changes to the shape and behavior of the river, the distribution of flows in time through that river, and the habitat of the species that depend on that river for life. The greatest of these changes, by far, have been made over the past century.

Modifications leading to current conditions include dam and levee construction, irrigation/drain system development, land use, and channelization activities, which took place from the 1930s to the 1970s, as well as ground water pumping, which has expanded greatly from the 1940s to the present, especially in the Angostura Reach. Operation of the flood control and water storage dams alter the shape of the hydrograph, as well as the amount of water that is conveyed through the river. The alteration of the hydrograph and highly variable streamflows that have resulted in cycles of drought on the MRG also have influenced vegetation changes on the MRG. Figure 10, below, diagrams the major events over the past century that have affected the hydrology and geomorphology—and, therefore, the habitat for listed species in the MRG.

Eight major dams (El Vado, Abiquiu, Nambe Falls, Cochiti, Galisteo, Jemez Canyon, Elephant Butte, and Caballo) plus three cross-river diversion structures and minor diversions between Embudo and Espanola have been constructed on the MRG or its tributaries over the past century by the Corps, Reclamation, the MRGCD, and in cooperation with other non-Federal partners. These dams and diversion structures affect the flow and sediment distribution in the MRG. They alter flows by storing and releasing water in a manner that generally decreases flood peaks and alters the distribution in time of the flows in the annual hydrograph. The major dams also trap significant amounts of sediment, causing buildup and increases in channel elevation upstream, and riverbed degradation and coarsening in the reaches below the dams.

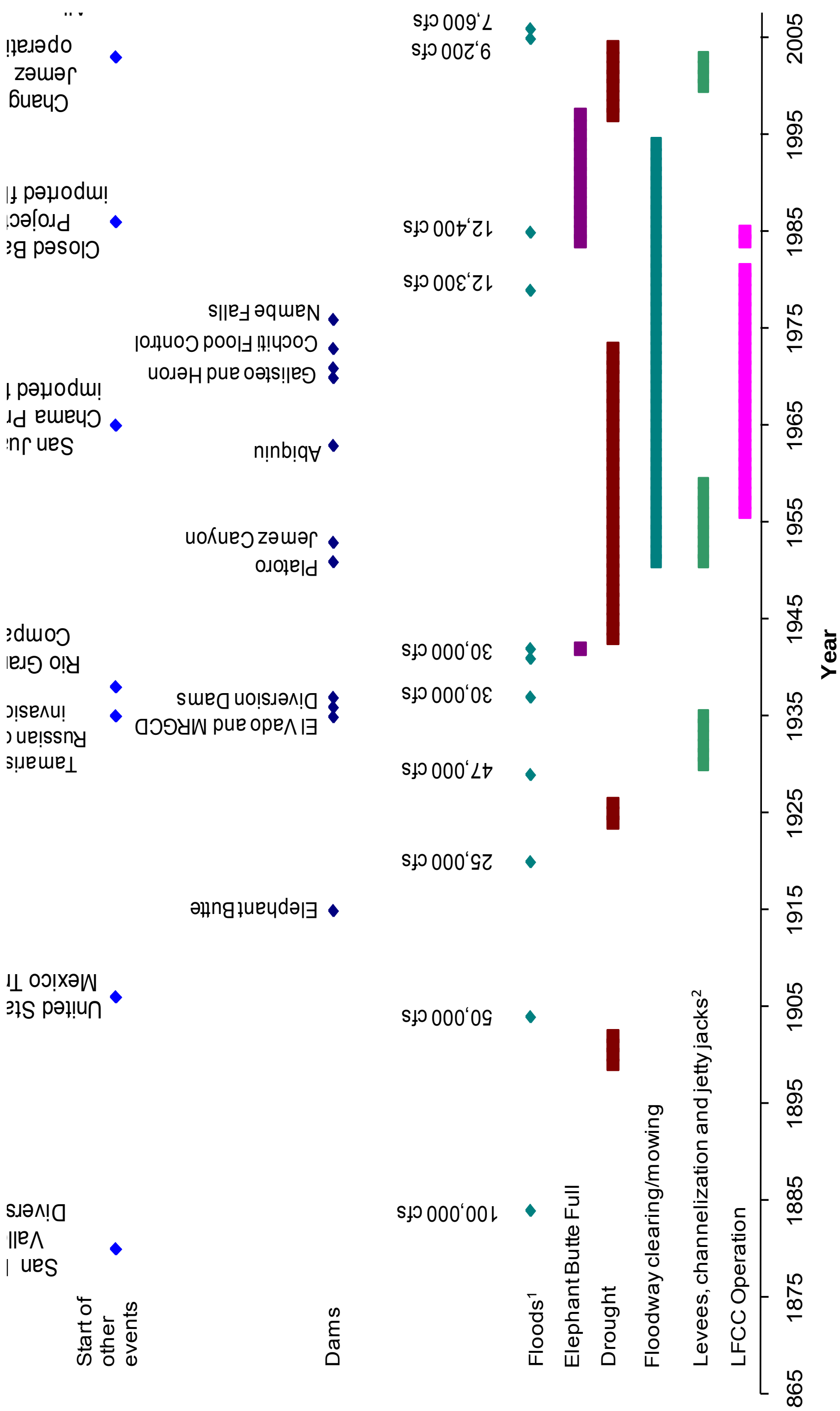

Figure 10. Timeline of significant events influencing the hydrology and geomorphology of the MRG. Flood events listed are measured at various locations between Otowi and San Marcial.

Ground water use has exceeded 170,000 AFY in the Albuquerque Basin and has caused ground water level declines of up to 160 feet. (McAda and Barroll, 2002). Ultimately, the water pumped is made up for by seepage from the river into the ground water system.

The historic development of the MRG has ongoing impacts on listed species. Silvery minnow use a diversity of wetted habitats throughout the year; low velocity habitats are important for all life stages, and egg and larval development are strongly tied to the magnitude and duration of runoff that inundates overbank habitats. Overbank flooding is needed to create shallow, low velocity backwaters that are used by silvery minnow larvae and maintains and restores native riparian vegetation for flycatcher habitat. Also, summertime river flows that supported both species were historically dependent on ground water inflows; today, losses from the river to the ground water system increase the chances of river drying, and decrease the longevity of isolated pools for minnow to refuge during periods of drying. Water and sediment management have resulted in a large reduction of suitable habitat for the flycatcher, as a result of the reduction of high flow frequency, duration, and magnitude that helped to create and maintain habitat for this species. Habitat elements for the flycatcher are provided by thickets of riparian shrubs and small trees and adjacent surface water, or areas where such suitable vegetation may become established (Service 2005).

Prior to documented development of water resources, the MRG had a high sediment load and an active, braided river channel with a mobile sand bed. The river's active watercourse was up to a half-mile wide, and included numerous braids. Over time, the active watercourses filled with sediment, then broke out into the flood plain and possibly avulsed to create new active watercourses. This process would cause aggradation across the flood plain. During periods in which peak flows were low for several years in a row, the active channel narrowed, through vegetation encroachment along the channel margins and colonization of bars. Sediment stored during these low flow times would be remobilized during subsequent large floods, which would re-establish a wider active channel. This process caused sediment to build up fairly uniformly across the flood plain. This active channel and flood plain connection provided habitat for all life stages of the silvery minnow and various successional stages of vegetation along the riparian corridor, used as breeding habitat by flycatchers.

Today, the river through much of the MRG is a single–thread channel as a result of both anthropogenic and natural changes throughout the system that is now confined into a narrow corridor between levees. Between Cochiti Dam and Elephant Butte Reservoir headwaters, there are 235 miles (378 km) of levees (includes distances on both sides of the river) (Service 2005). Changes on the MRG in the last century have increased the channel uniformity, eliminating thousands of acres of the shallow, low velocity habitats required by both silvery minnow and flycatchers. The loss of habitat complexity may cause eggs and larvae of the silvery minnow to drift downstream longer distances than in more complex channels. A comparison of river habitat changes between 1935–1989 shows a 49% reduction of river channel habitat from 22,023 acres (8,916 ha) to 10,736 acres (4,347 ha) (Crawford et al. 1993). The MRG also has been fragmented by cross-channel diversion structures, which silvery minnow can pass in a downstream direction but not in an upstream direction. Due to the reproductive strategies of silvery minnow, upstream reaches continually lose offspring to lower reaches.

The channel in the upstream portion of the MRG is deeper and swifter and more isolated from the surrounding flood plain, which is now the bosque. The abandonment of the flood plain in these reaches and the establishment of exotic species, such as Russian olive and saltcedar, have made overbank habitat inaccessible to the silvery minnow and decreased the availability of dense willow and associated native vegetation and habitat important to flycatchers.

The lower portion of the MRG, below San Acacia Diversion Dam, currently is a combination of an upstream incised channel isolated from the historical flood plain and a downstream perched river for much of which the LFCC (that currently functions like a riverside drain) serves as the low point in the valley in many areas. River flow is lost to the surrounding flood plain, drains, and ground water system. The perched river system, in turn, makes the river channel more prone to drying under low flow conditions. Overbank inundation also occurs more often in the downstream portions of this reach; however, there is not always a direct path back from the overbank areas to the river, which may cause fish to be stranded as the flows drop. Today, this reach generally is aggrading with some channel degradation occurring when the Elephant Butte Reservoir pool is low, as is currently the case.

These changes in hydrology and construction of major features along the river also have modified the river in ways that directly affect the habitat of listed species. Historically, the silvery minnow occupied the Rio Grande from approximately Espanola, NM, to the gulf coast of Texas and also occupied some of the larger tributaries. Today, silvery minnow are restricted to a reach of the Rio Grande in New Mexico, from the vicinity of Bernalillo downstream to the headwaters of Elephant Butte Reservoir, approximately 150 river miles.

The channel narrowing trend in the Rio Grande and the resulting degradation of aquatic habitat will continue under the current river management regime. Returning the river to its earlier state—wide, braided, and sandy—would require recurring major flow events, which would exceed the safe channel capacity below Cochiti Dam. As an alternative, Collaborative Program participants have undertaken efforts to mechanically construct features that provide more favorable habitat conditions for aquatic species under the available hydrologic conditions. Generally, these efforts attempt either to modify the banks of the Rio Grande to encourage overbanking or to expand lower elevation channel capacity to create springtime habitat more suitable for silvery minnow spawning and riparian conditions more suitable for the growth of native vegetation. In most years, native flows cause inundation of these "habitat restoration sites"; however, in some low water years, releases of spikes of water from Cochiti Reservoir then are needed to inundate the modified areas. While these habitat restoration projects generally are unable to shift the broader geomorphic trends, they have created localized enhancements to aquatic habitat and have resulted in a significant increase in the availability of overbank habitat during most spring snowmelt runoff periods.

The Rio Grande is and will continue to be a highly managed system. Similarly, silvery minnow populations have been managed by a variety of activities ranging from the habitat restoration projects described above to population augmentation with fish reared in hatcheries. Unlike the silvery minnow, which currently only exists in,[19] and must complete its entire life cycle within, the MRG, the flycatcher is mainly dependant on the project area and other similar areas in the Southwest for breeding and rearing of young and completes other portions of its life cycle elsewhere. Flycatcher populations are dependent on riparian conditions within their breeding area. Within the United States, the species occurs in southern California, Arizona, New Mexico, southern portions of Nevada and Utah, and possibly southwestern Colorado. The species is likely extirpated from west Texas. Rangewide, changes in hydrology and active management of and development in river corridors have reduced the availability of suitable habitat for the flycatcher and contributed to population decline.

Because of the above factors, active management and persistence of habitat for both species is important for maintaining viable populations.

5.2 Climate

Climate varies across the Rio Grande Basin in both time and space. Most of the basin is arid or semiarid, generally receiving less than 10 inches of precipitation per year. In contrast, some of the high mountain headwater areas receive an average of over 40 inches of precipitation per year. Climatic conditions in the basin are highly variable, as is indicated by the previously mentioned order of magnitude variability in the annual unregulated flow volumes at Rio Grande stream gages.

Annual variations in timing and volume of streamflow are strongly influenced by ocean circulation patterns, such as the El Nino-southern oscillation, which affects annual variability, and the Pacific Decadal Oscillation (PDO), which affects climate and streamflow on a multiyear to multidecade basis. These oceanic patterns modulate seasonal cycles of temperature and precipitation and affect snow accumulation and melting (JISAO 2012). Particular combinations of these

[19] Viability of the reintroduced population in the Big Bend Reach is currently not established.

ocean circulation patterns also can result in extended drought or wet periods. An extended period of below average precipitation occurred in New Mexico from the 1940s through the mid 1970s, correlating with a negative/cool phase of the PDO; above average precipitation then prevailed from 1981 through the mid-1990s, correlating with a positive/warm phase of the PDO. Drought returned in the late 1990s through 2004, along with the negative phase of the PDO (JISAO 2012, Corps et al. 2007).

Over the course of the 20th century, the Rio Grande Basin has become warmer. As is shown by the blue dots on figure 11, which represent a moving average, the basin average temperature has increased by 1–2 °F over the course of the 20th century. This warming of the Rio Grande Basin has not been steady in time. The basin's average temperature increased steadily from roughly the 1910s to the mid-1940s and then declined slightly until the 1970s before increasing steadily through the end of the century. This temporal pattern of warming is consistent with findings for other basins within the region. In northern New Mexico, recent annual average temperatures have been more than 2.0 ºF (1.1 ºC) above mid-20th century values (D'Antonio 2006, Rangwala and Miller 2010). The San Juan Mountains, the headwaters of the Rio Grande, have experienced a 1 ºC increase from 1895–2005, with most of the warming occurring during 1990–2005.

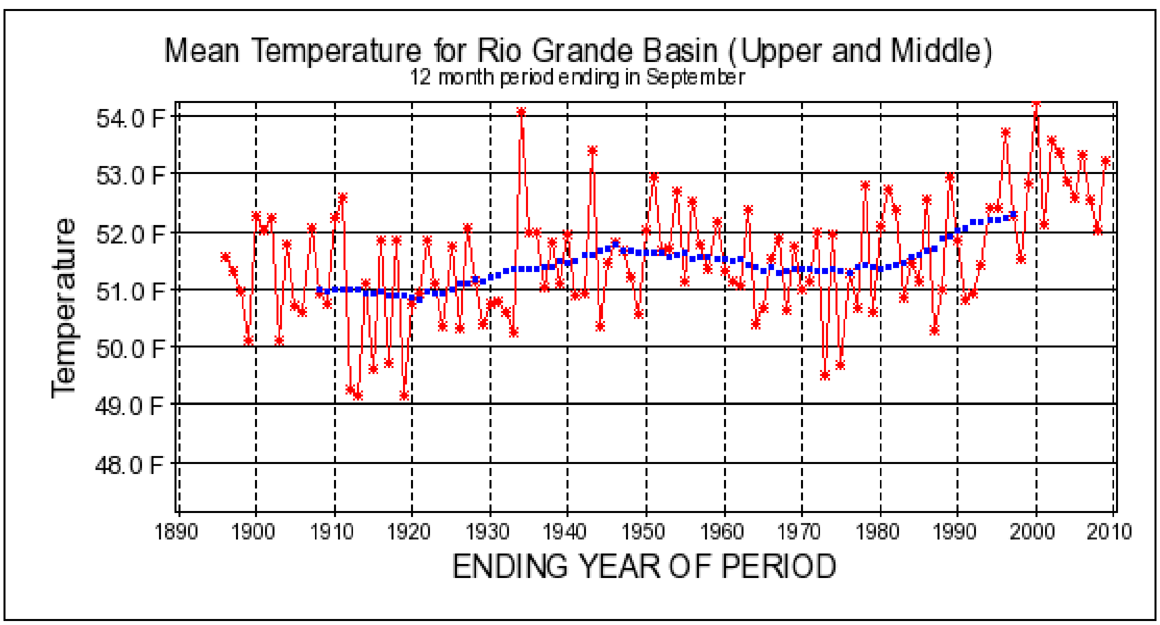

Figure 11. Observed annual temperature, averaged over the Rio Grande Basin above Elephant Butte.

A slight increase in basin precipitation is evident over the past century (figure 12); however, this apparent change in precipitation is subtle relative to annual variability.

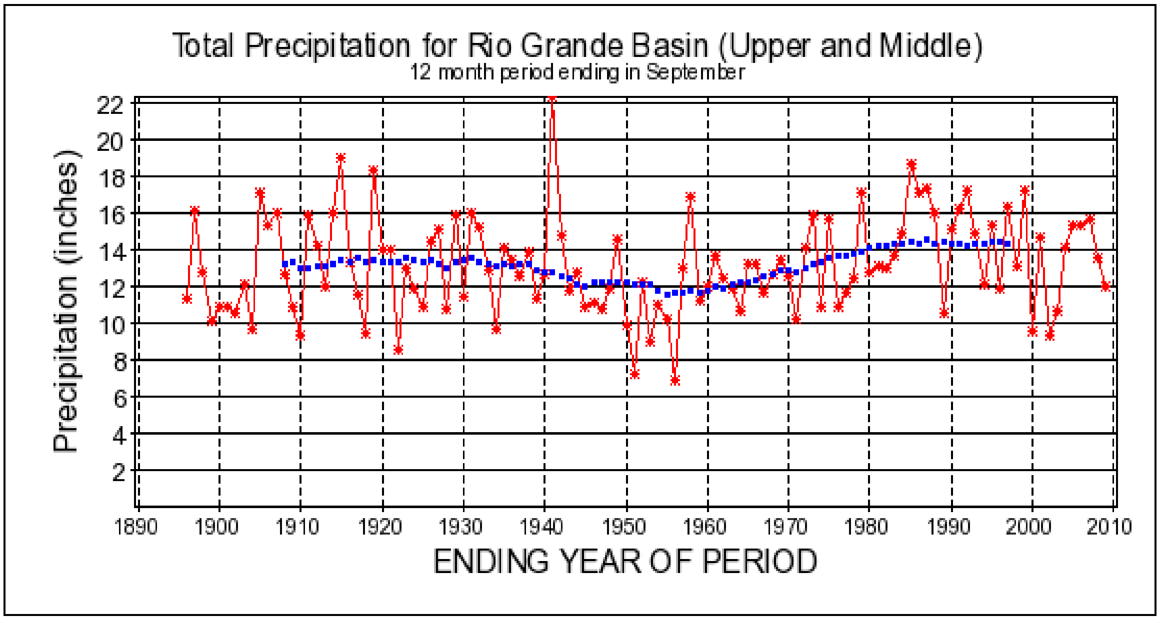

Figure 12. Observed annual precipitation, averaged over the Rio Grande Basin above Elephant Butte.

Source: Western Climate Mapping Initiative (WestMap) available at: http://www.cefa.dri.edu/Westmap/. Red line indicates annual time series for the given geographic region. Blue line indicates 25-year moving annual mean.

Peak snowmelt runoff across northern New Mexico occurred, on average, 7 days earlier over the past half century than during the first half of the 20th century (Stewart et al. 2005, Enquist et al. 2006). In addition, streamflow in the winter months of January, February, and March has increased over the last quarter century relative to the century as a whole (Passell et al. 2004; Woodhouse et al. 2007).

5.3 Status of Listed Species

This section is a summary of status and monitoring activities for listed species covering approximately the past decade within the Proposed Action area. Summary information of all baseline activities that affect listed species including hydrology, channel conditions, and management activities are reviewed in section 5.7.

The information presented in section 5.3.1, discussing the Rio Grande silvery minnow, reflects to a great extent the analyses done in the annual reports from the contractors carrying out the Collaborative Program's Population Monitoring and Population Estimation Program and related studies.[20] This approach endeavors to document the status of the silvery minnow population and its annual reproductive success through efforts to measure the year-to-year abundance, density, and distribution of individuals of the species at 20 locations in the Middle Rio Grande. The primary stated objective of the monitoring program has been to document temporal trends in silvery minnow abundance at these 20 sites, with secondary objectives of documenting population monitoring correlations with discharge patterns, documenting mesohabitat usage patterns, documenting changes in relative abundance among fish species over time, and determining site-specific sampling variation.[21]

The efforts of recent Collaborative Program studies within the program's workgroup have undertaken a thorough analysis of the population monitoring data. Initial results indicate that silvery minnow population viability in the MRG should incorporate measures of minnow resilience and density dependence in the population dynamics, in addition to measures of abundance, and should attempt to discern the responses of the population to different environmental conditions in terms of minnow reproduction, survival, and recruitment. Since the minnow can exhibit extreme population volatility from year to year, it is to be expected that distribution and abundance results from a given point in time, or trends inferred from year to year, may be less relevant for determining viability than measures of environmental and management conditions that a PVA analyses reveals as the most important factors to maintain the species' persistence.[22]

The PVA Workgroup has worked to compile existing minnow population monitoring data sets and to reach scientific consensus as to the quality, integrity, and completeness of these data. This consensus data set will be used in the end PVA products that the Collaborative Program will use to inform the updated description of species status and population viability. Further data and analyses may be supplied during the course of the consultation, and extension of the consultation to obtain and analyze outstanding data may be appropriate.[23]

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[20] See the Middle Rio Grande Endangered Species Act Collaborative Program Interim Monitoring Plan (September 22, 2006, Draft), Appendix A, Rio Grande Fish Community Monitoring ("2006 Fish Monitoring Plan").

[21] See, e.g., Rio Grande Silvery Minnow Population Monitoring Program Results from September 2009 to October 2010.

[22] See 16 United States Code § 1536(a)(2) (requiring the use of the "best scientific and commercial data available" by Federal agencies in fulfilling their ESA Section 7 consultation requirements); *Consolidated Salmonid Cases*, 791 F.Supp.2d 802, 825-27 (E.D. Cal. 2011) (requiring the National Marine Fishery Service to "apply generally recognized and accepted biostatistical principles, which constituted best available science").

[23] See Federal Register 50 CFR Ch IV (October 1, 2008, Edition) Sec. 402.14:

5.3.1 Rio Grande Silvery Minnow

5.3.1.1 Population Monitoring Activities

There are several ongoing activities that are performed to monitor the current status of silvery minnow in the project area. Reclamation, through the Collaborative Program, funds silvery minnow population monitoring that occurs each month except for January and March using seines and collects catch per unit effort (CPUE) data on the small bodied fish community of the Rio Grande. Similar methods have been used since 1993. Principal objectives of this study are to provide timely monitoring of the temporal trends for silvery minnow within the Rio Grande.

The PVA work group determined that this set of data was also credible for estimating relative brood strength, and annual cohort survival for years 1 and 2 (D. Goodman power point presentation, March 27, 2011).[24] October surveys are assumed to be the best available indicator of annual population status and annual recruitment due to the generally stable base flow conditions and warm water temperatures (Collaborative Program Appendix A, 2006) leading to lower sampling variability (SWCA 2010, Task 1). An additional study using repeated sampling occurred at all sites in November 2009 and 2010 (4 days in a row) to investigate the level of sampling variation for this type of sampling, results showed that variation within that timeframe is low and consistent for studies in 2009 and 2010 (Dudley and Platania 2011).

A gear evaluation study is underway to examine the strengths and weaknesses of various sampling methodologies. Initial findings indicate that large numbers of samples are needed to detect small population changes with the current methodology (SWCA 2010, Task 1) especially when population numbers are low. The study also indicates that the mean size of minnows captured by seining may be smaller than with fyke nets, especially during spring sampling in overbank habitats (SWCA 2011). As far as community monitoring, seines captured the highest number of species when compared with fyke nets and electrofishing. As with all fish sampling techniques, this study has indicated that gear suitability is dependent on study objectives, methods used, target species, and logistical and budgetary constraints (SWCA 2011).

In addition to population monitoring, population estimation has been conducted in October since 2006. The population estimate uses a closed sampling method, utilizing cages and electrofishing within mapped sections of the river. There

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(d) "…The Federal agency requesting formal consultation shall provide the Service with the best scientific and commercial data available or which can be obtained during the course of the consultation for an adequate review…"
(f) "…When the Service determines that additional data would provide a better information base from which to formulate a biological opinion, the Director may request an extension of formal consultation and request that the Federal agency obtain additional data…"

[24] D. Goodman PowerPoint presentation, March 27, 2011.

appears to be a close relationship between the 2008–2010 population trends obtained from the population estimation program and population monitoring (Dudley et al. 2011); however, there is a divergence between the two datasets in 2011. There are not enough data points currently to establish if there is a relationship between the two studies. The riverwide population estimate has ranged from a high of 1.4 million in 2009 to a low of 267,000 in 2010.

Each spring, egg drift is monitored within the river channel and canals annually during spring run-off. This monitoring is a requirement of the 2003 Biological Opinion and provides information on the timing and magnitude of spawning in the MRG. The number of monitoring stations has varied among years but has been at least two within the river at standard locations. These stations are deployed within the river, and the number of eggs per volume is calculated on a daily basis. Hourly catch rates also are recorded by crews collecting eggs for propagation purposes.

Project specific monitoring also occurs for habitat restoration and river maintenance projects. These will be discussed more specifically in section 5.6.

5.3.1.2 Status of Silvery Minnow in the MRG

Egg monitoring has shown a large variation in the number of eggs that are detected in the river on an annual basis. Timing of spawning appears to be related to a combination of discharge and water temperature conditions. Though the total numbers of eggs collected in low flow years is generally higher than in high flow years, when adjusted for total volume of water, the number of eggs transported in high flow years is still substantial (several million eggs) (Dudley and Platania 2010). Small numbers of eggs annually are collected in irrigation canals. Improvements in the way diversions have been managed have minimized the number of eggs that are entrained. Temperature monitoring during egg monitoring indicates that, while mean daily temperatures across years are similar during spawning events, temperatures during high flow years are more constant and experience less diel variation (Platania and Dudley 2006). It is unknown how this temperature fluctuation affects spawning or larval development.

Silvery minnow spawning has been detected each year that monitoring was conducted. As can be seen in figure 13, there is no significant correlation of the catch rate of eggs at the two monitoring sites with October CPUE ($R = 0.708$, $p = 0.352$). Silvery minnow have a large possible reproductive output (> 2,000 eggs per female) (Platania and Altenbach 1996). It is difficult to infer a measure of annual recruitment success from the number of eggs detected in the drift. Recruitment from egg to post-larval stages may be a more important dynamic and is dependent on habitat quantity and quality. Upcoming analysis by PVA modelers may provide further information of what the most important population limiting factors are for silvery minnow.

Population dynamics of silvery minnow have been highly variable (figure 14). Since 1993, catch rates of silvery minnow bounced back in a short time period from a low in 2003 and were at the highest level recorded in 2005. Population monitoring indicates that from 2001–2010, 4 years (2002, 2003, 2006, and 2010)

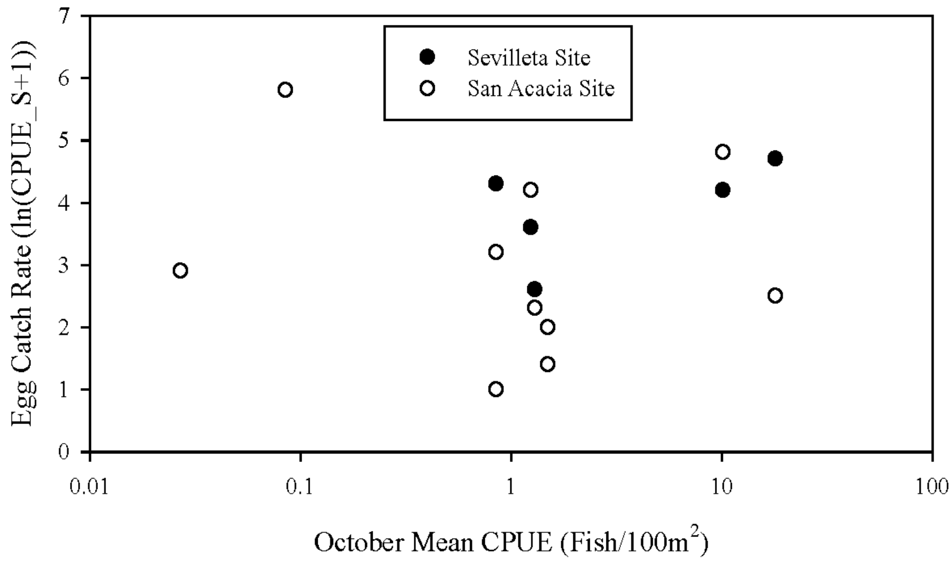

Figure 13. Scatter diagram of egg catch rate for Sevilleta (2006–2011) and San Acacia (2002–2004, 2006–2011) sites (Dudley and Platania 2011) with October CPUE data (population monitoring data).

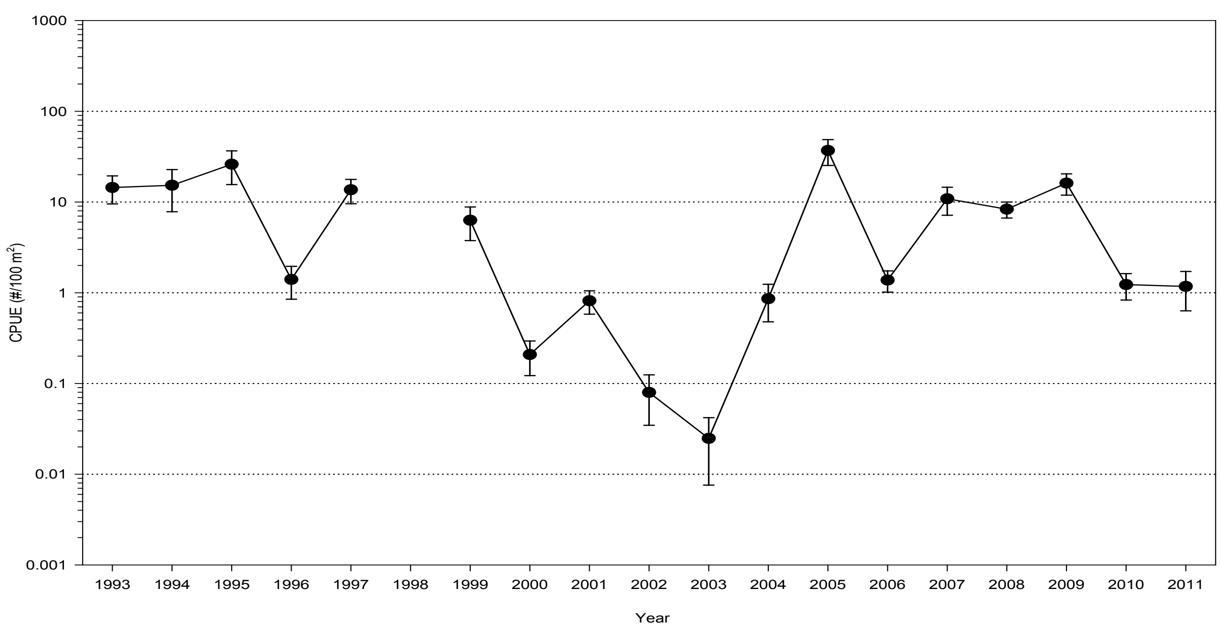

Figure 14. Rio Grande silvery minnow densities (CPUE) during October, at all sampling sites, by sampling year (1993–1997, 1999–2011). Solid circles indicate means, and error bars represent the standard error. Note log scale for y axis (population monitoring data, ASIR).

did not have a strong recruitment (meaning the fall catch rates were less than the prespawn levels) (figure 15). All of these years, except 2010, were years with little to no spring run-off (figure 44, shown later in this report). Population estimation modeling from 2008–2010 also shows a substantial decline in silvery minnow populations in 2010 in all reaches (Dudley et al. 2011). Estimates for of the 2010 population was 67–90% lower than 2008 and 2009 estimates depending on the reach and method used. It is uncertain what circumstances caused population decline in 2010. Initial findings of the 2011 draft data analysis indicate that the October catch rates are similar between 2010 and 2011.

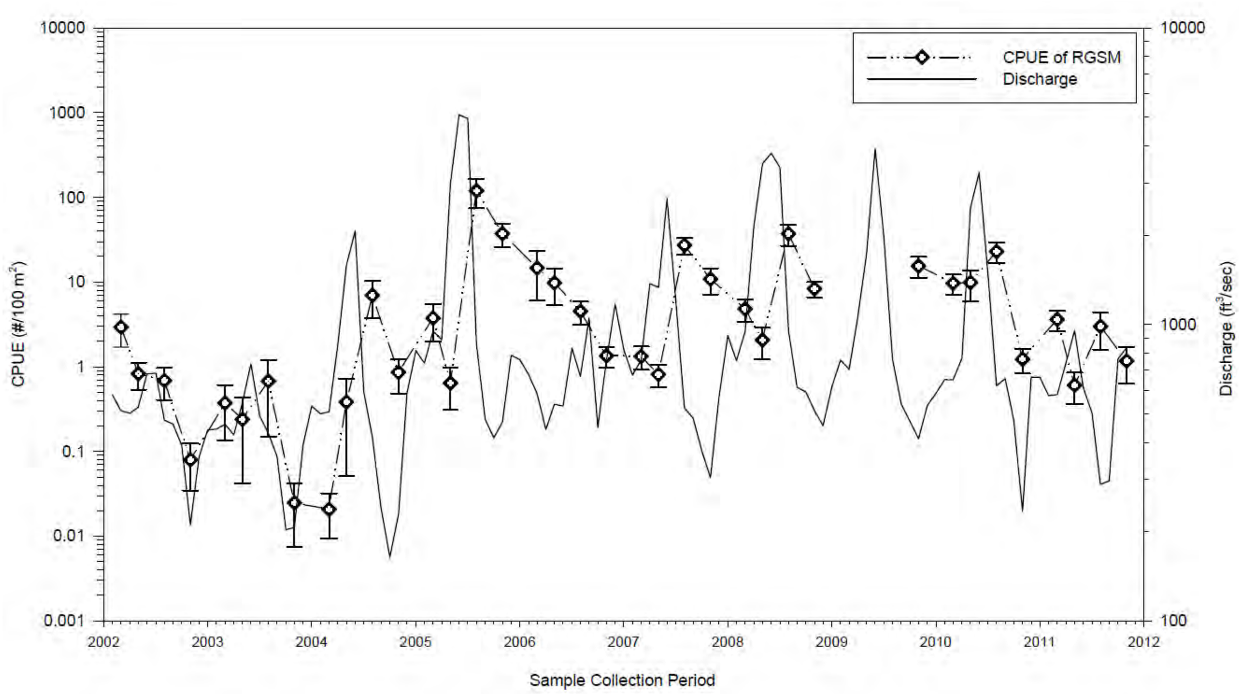

Figure 15. Time sequence of quarterly Rio Grande silvery minnow densities of the past decade (2001–2010) at population monitoring program collection sites and mean monthly discharge at USGS Gage #08330000 (Rio Grande at Albuquerque, New Mexico). Diamonds indicated sample means for each survey, and capped bars represent standard error (from Dudley and Platania, 2012).

Analysis of the population monitoring data indicates a strong positive relationship with spring flow and mean October densities (figure 16, Dudley and Platania 2011). Further analysis of this data by the Collaborative Program PVA group has demonstrated that one of the most important variables is spring flow, which sets the carrying capacity for reproductive output.[25] Dr. Goodman's presentation did

[25] D. Goodman PowerPoint presentation March 27, 2011.

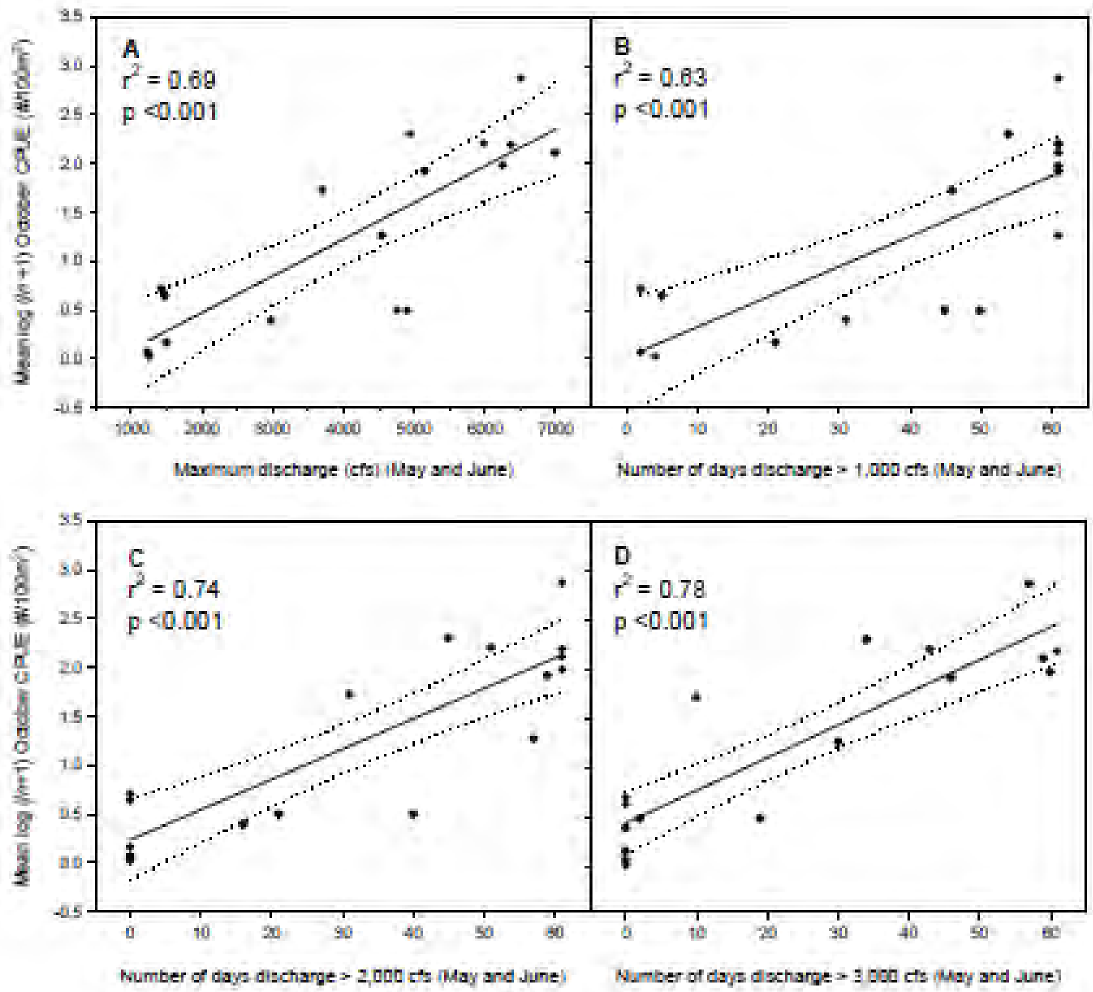

Figure 16. Regression analysis of Rio Grande silvery minnow log-transformed mean October densities (1993–1997,1999–2010) and select hydraulic variables (during May and June) for USGS Gage #08330000 (Rio Grande at Albuquerque, New Mexico). Graph shows regression line (solid) and 95% confidence intervals (dotted). From Dudley and Platania 2010).

not indicate that summer flows enhance survival through the summer using mean summer CPUE (July–September). However, the regression analysis of October CPUE by Dudley and Platania indicated that silvery minnow CPUE increased significantly with delayed onset of low flows and increased mean daily discharge (as measured at the San Marcial gage) (figure 17). There were also significant negative relationships between October silvery minnow densities and number of days with discharge below threshold values (i.e., less than [<] 200 and < 100 cfs) (Dudley and Platania 2011).

The current silvery minnow population in the MRG has been annually augmented with hatchery produced fish. The program began stocking a few fish in 2001; large numbers of fish were stocked starting in 2003 (Remshardt 2010). The

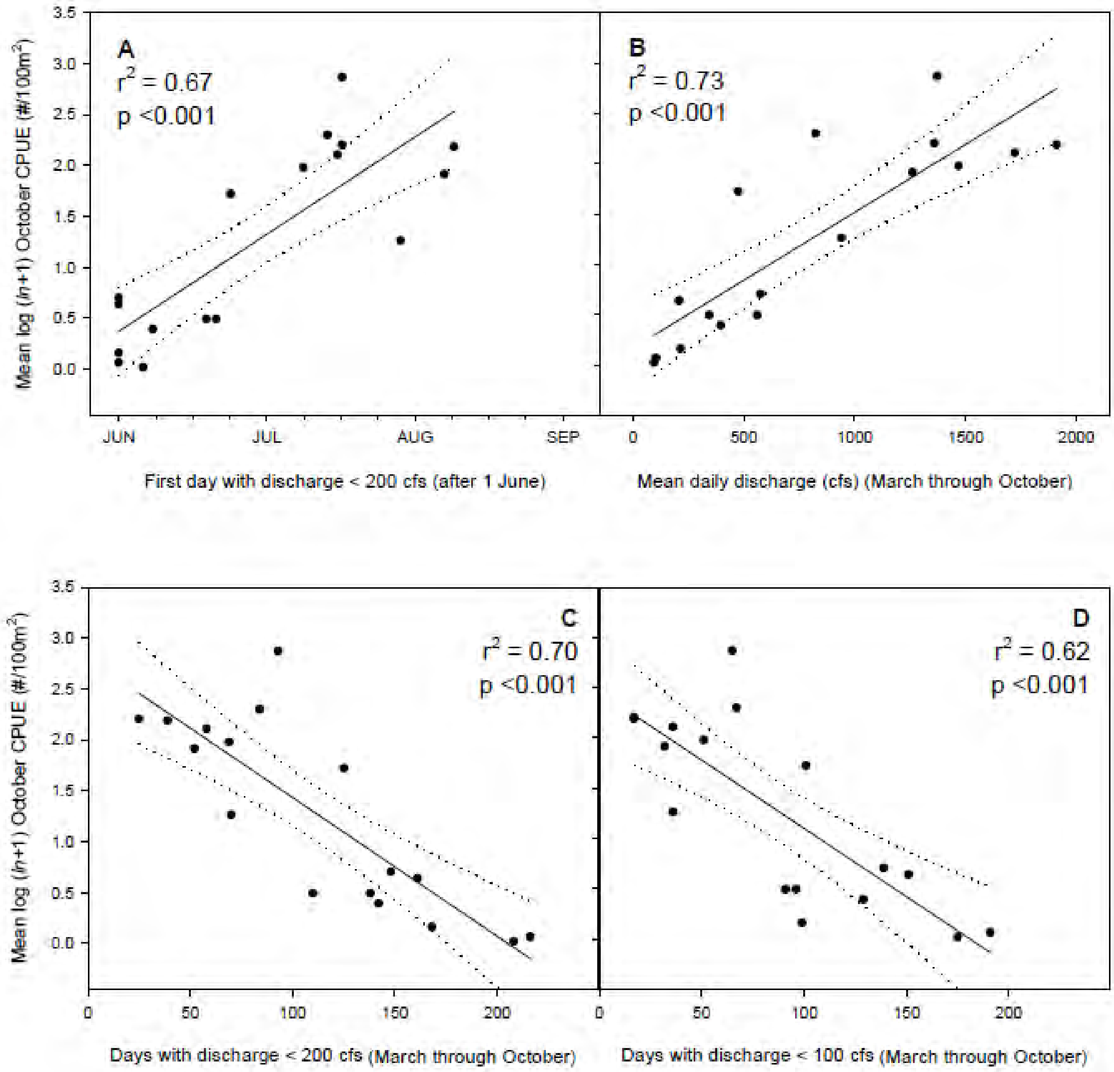

Figure 17. Regression analysis of Rio Grande silvery minnow log-transformed mean October densities (1993–1997, 1999–2010) and different hydraulic variables for USGS Gage #08358400 (Rio Grande Floodway at San Marcial, New Mexico). Graph shows regression line (solid) and 95% confidence intervals (dotted) (from Dudley and Platania, 2011).

numbers of fish stocked annually is based on a formula to achieve an overall density 10 minnows per 100 square meters as determined by fall monitoring results (Remshardt 2012). All stocked silvery minnow are marked with visible implant elastomer tags.

Generally, low numbers of hatchery fish are captured in monitoring efforts (< 3% of the total catch). Riverwide, the only year that a substantial number of marked fish were collected during population monitoring was during 2003, when approximately 10% of the total numbers of silvery minnow collected were hatchery fish, 20% in the Angostura Reach. The only fish stocked in the

Angostura Reach since 2008 have been those fish implanted with PIT tags to study use of the fish passage built around the Albuquerque drinking water diversion. Though few hatchery fish are recaptured, it appears that the augmentation program has had an effect on maintenance of genetic diversity within the three reaches. This is discussed further in the next section.

The propagation program also provides security against catastrophic failure of the species within the MRG since it is currently the only established population of silvery minnow. Silvery minnow also are salvaged from isolated pools in sections of the river that are prone to drying. The initial salvage program moved fish to upstream reaches. Since 2007, salvaged silvery minnow are only moved within a reach. Salvage and propagation activities are discussed more fully in section 5.6.3.

From 2001–2010, there was variation in the community composition of fishes in the Rio Grande. Silvery minnow comprised a higher fraction of the total ichthyofaunal community from 2005–2009 than from 2000–2004 (Dudley and Platania 2011). Seining surveys most often captured flathead chub, longnose dace, and white sucker in the Angostura Reach. Red shiner, common carp, silvery minnow, fathead minnow, river carpsucker, channel catfish, and western mosquitofish were most common in the Isleta Reach. Silvery minnow was more common in the Isleta and San Acacia Reaches as compared to the Angostura Reach. Reclamation has annually electrofished portions of the river in February. These surveys most often captured channel catfish, common carp, and river carp sucker in the Angostura Reach, while silvery minnow were the most common species captured in the Isleta and San Acacia Reaches for the past 5 years (Reclamation 2010, Reclamation 2012).

5.3.1.3 Genetics Monitoring

Genetic monitoring has been conducted on silvery minnow since 1999. Historically, population bottlenecks have occurred that likely caused the loss of rare alleles and limited the allelic diversity of the population. Genetic variation and heterozygosity are often maintained unless the bottleneck is very severe and lasts for several generations (Nei et al. 1975). Heterozygosity provides a good measure of the capability of a population to respond to selection immediately following a bottleneck. However, the number of alleles remaining is important for the long-term response to selection and survival of populations and species (Allendorf 1986). It is important to maintain a species genetic diversity for long-term population persistence to allow species the ability to adapt and respond to environmental changes.

The current genetic monitoring measures a variety of diversity metrics based on microsatellite and mitochondrial DNA markers. Prior to augmentation, there was considerable variation in diversity measures. Since the initiation of augmentation, diversity statistics have stabilized (figure 18), indicating that alleles frequencies

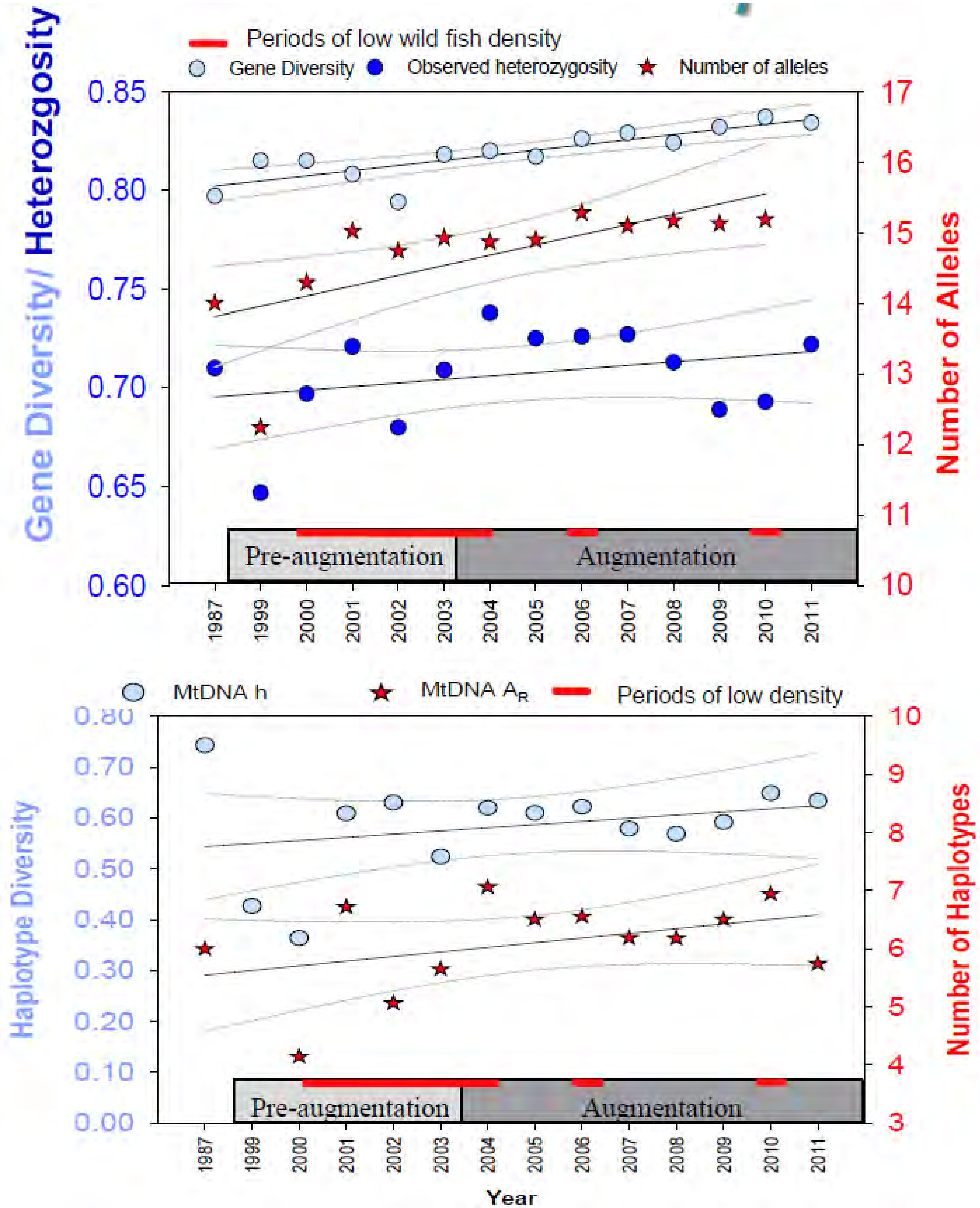

Figure 18. Diversity metrics of Rio Grande silvery minnow from genetic monitoring program from Osborne and Turner (PowerPoint presentation to Collaborative Program 2011).

are maintaining within the population. Heterozygosity has continued to be variable (Osborne et al. 2012). The investigation of the genes of the immune response, major histocompatiblilty complex, indicates that the silvery minnow shows similar variation to other cyprinid fishes studied (Osborne and Turner 2011).

Generally, recovery plans for rare species often reference a goal of attaining a minimum effective population size of 500 (Frankel and Soulé 1981). This number was derived using theoretical numbers based calculations for "ideal" populations without regard to the actual genetic diversity within the population. Temporal estimates of "genetic" effective population (N_e) size using various genetic methods have found that actual N_e of most wild populations is much lower than would be calculated using population size estimates (Palsta and Ruzzante 2008). Many fish species with type III survivorship curves (high fecundity, high early mortality) show a very low ratio of N_e/N (adult census size). Factors that contribute to this include fluctuating population size, biased sex ratios, variance in reproductive success between individuals, and metapopulation dynamics (Turner et al. 2002).

The revised recovery plan (Service 2010) states that the effective population size of silvery minnow is estimated to be around 100. There are several ways to estimate genetic effective size. Each type of estimator has biases associated with it. In variable populations, there is not generally correlation between variance effective size (NeV) and inbreeding effective size (NeI). NeV measures the variance in allele frequencies between two time points. NeI measures the probability of identity by descent. In a declining population, NeI > NeV. In a growing population, NeI < NeV. Depending on the method used, the variance effective size has been in the range from 200–400 in the last decade (PBS&J 2011). Inbreeding effective size estimates are higher, ranging from 500 to infinity, but the variability is heavily influenced by sample size (Osborne and Turner 2011 PowerPoint). Though the estimates of variance effective size are small, they have stabilized and show a slightly increasing trend (Osborne et al. 2012).

The current silvery minnow population is confined to a limited area and does not have the possibility of occasional immigration from a disconnected population. In addition, gene flow between subsets of the population is limited to a downstream direction due to the presence of migration barriers. There is no correlation between CPUE levels and effective population size. For silvery minnow, there are likely several factors that influence genetic effective size beyond population size including augmentation of the population by captive stocks. Generally, captive stocks from wild caught origins have higher variance effective size than those that are produced from hatchery broodstock. The availability of wild caught eggs for broodstock has been variable, and most recent stockings have been from captive spawning. Large numbers of eggs were collected in 2011, which should add to the genetic diversity of the hatchery stocks. Though low numbers of hatchery fish are captured in monitoring efforts, generally, it appears that augmentation has positive effects for maintaining genetic diversity of the population, especially during low population years.

5.3.1.4 Water Quality and Fish Health Monitoring

There are two general types of water quality concerns in the Rio Grande. Point source discharges generally occur near water treatment facilities or storm water discharges that can cause fish kills. These have been documented occasionally within the Rio Grande within the Angostura Reach. New Mexico Game and Fish or New Mexico Environment Department investigate any reports of fish kills and try to determine a cause. There is not a coordinated effort for a long-term record keeping process for these fish kills. In the last few years, fish kills have been documented from various causes including ash flows from forest fire areas, low oxygen events from storm water, and high chlorine levels in wastewater treatment effluent. In New Mexico, storm water-related issues are led by the New Mexico Environment Department and local governments. Currently, the city of Albuquerque has a program to improve the effectiveness of the storm drainage system within the city of Albuquerque and to safeguard the quality of the storm water runoff discharging into the Rio Grande. Currently, substances that enter the storm drain system flow directly to the Rio Grande, usually via neighborhood arroyos. New Mexico has not assumed the National Pollutant Discharge Elimination System (NPDES) storm water program, and Environmental Protection Agency (EPA) implements the NPDES program in New Mexico. The New Mexico Department of Transportation, the city of Albuquerque, the Albuquerque Metropolitan Arroyo Flood Control Authority, and the Southern Sandoval County Arroyo Flood Control Authority produced the Storm Water Management Guidelines for Construction and Industrial Activities manual in 2003.

In addition to these short-term issues, there is concern about long-term, chronic conditions that may affect fishes through long-term exposure and cause reproductive effects, health issues, or death. Sublethal impacts of various chemicals contribute to the overall conditions of environmental stress in the MRG, which could lead to declines in the population of silvery minnow and other aquatic life. A risk assessment was conducted using data available through 2003. This assessment's primary conclusion was that there is no clear "smoking gun" chemical that can be singled out as an agent likely to have produced significant riverwide historical impacts to silvery minnow. Nor can any chemical be specifically targeted as currently impairing the recovery of silvery minnow within the MRG (Tetra Tech 2005).

A study, conducted by the New Mexico Environment Department from 2006–2008 (NMED 2009), identified only a few water quality issues—notably elevated *E coli*, one sample with an ammonia concentration of 9.12 milligrams per liter (mg/L)—five times the acute criteria, low dissolved oxygen (DO) during brief periods of time, and some samples elevated in metals such as aluminum, copper, and chromium. Temperature exceedences of their 32.2 °C criterion were few, and the magnitude of exceedence was never greater than 3 °C. For pH, no exceedences of the 6.6 to 9.9 standard units criterion were documented from deployed data loggers at any locations except for one sample in 2007 at NM Highway 550 Bridge. Buhl (2008) established several preliminary parameters specific to silvery minnow: Water temps > 36 °C acutely lethal, DO < 0.6 mg/L acutely lethal.

There were several instances of dissolved oxygen readings that were lower than the 5 mg/L standard within the Angostura Reach. NMED states in their report that these will be investigated more fully in the current monitoring period (2010–2012). In their draft 2006–2008 silvery minnow health study, the Service (2012) found that many of these low dissolved oxygen readings may be associated with storm events.

Fish tissue-based testing was conducted in 2007 within the Angostura Reach using a variety of species from the MRG. Four sites were sampled: below North Albuquerque Metro Area Flood Control Authority (AMAFCA), Albuquerque South Side Water Reclamation Plant (which included the Rio Grande below South AMAFCA).

These fish showed levels of zinc, and DDT higher than levels established by the United States Department of Agriculture Forest Service BEST Program as potentially having toxic effects on various fish species (NMED 2008). Fish collected in this survey contained several chemicals above method detection limits but below toxic levels. The only contaminants not detected were lead and selenium for all samples and cadmium at two of the four sites. The sampling that took place near the Highway 550 site contained the highest concentration of cadmium and arsenic. Sampling near the Rio Rancho Waste Water Treatment Plant (WWTP) contained the highest concentrations of mercury. The Albuquerque WWTP sample contained the highest concentrations of zinc.

The service draft fish health study of the wild silvery minnow population found no pathonogenic viruses present in fish of the MRG. There was no obvious pattern of parasitic infections at various sites; however, bacterial infections were more prevalent during warm temperatures. Many species exhibited shortened opercula, including silvery minnow. It is unknown if water quality issues influence this defect.

Buhl (2011) conducted in situ experiments in the water from an irrigation waste way drain to inform the feasibility of creating refugial habitat with this water during dry periods. There were no significant differences in survival, total length, weight, or condition factor of fish across sites, but absolute weight loss and relative reduction in condition factor were significantly greater in fish at the site just below the drain (wetted in stream habitat site) compared to those at a nearby river site. Some of these differences may have been related to the depth of the site and not directly attributable to the water quality.

A 2003 survey of various pharmaceutically active compounds did not detect estrogenic hormones within the Rio Grande. Antibiotic concentrations in the Rio Grande were minimal with only sulfamethoxazole being detected (Brown 2006). Currently USGS is conducting a study of estrogenic biomarkers and the effects of these compounds on Rio Grande silvery minnow.

Water quality criteria were established for salvage of silvery minnow from isolated pools based on a series of survival tests (Caldwell et al. 2010). Fish in isolated pools are often very stressed from crowding, suboptimal water quality, and temperature fluctuations that cause them to be more susceptible to parasites and bacterial diseases. Thus, survival of these stressed fish is low. For a pool to be considered for salvage, a pool must meet the following conditions: (1) water temperature < 34 °C, (2) dissolved oxygen > 2.0 mg/L, (3) pH < 9.0 (4) no observable dead fish, (5) no moribund fish as indicated by lethargy, and (6) no fish exhibiting hemorrhagic lesions. If any of these secondary criteria are not met, the pool is not rescued.

5.3.1.5 Other Information

In addition to the monitoring activities, there are several studies supported by Reclamation and the Collaborative Program that have been (or are currently) conducted to inform future management. Bixby and Burdett (2011) investigated the correlation of nutrient availability and periphyton growth in the MRG from 2007–2010. They found that periphyton distribution is highly influenced by variation in turbidity and nutrients. In the summer months, high turbidity from tributaries creates a light-limited environment where primary production is limited to a littoral zone "bathtub ring." Additionally, there is a gradient of nutrient inputs as the river flows through urban landscapes as concentrations of phosphate and nitrates vary.

There were similar findings of Valdez et al. in review, who studied food availability within the MRG in 2005 and 2006. In addition to the large allochthonous load of organic matter, there was also significant autochthonous production along shallow shorelines where there was sufficient light penetration for photosynthesis and where velocity was low with little scour so that macroinvertebrate and aufwuchs communities could establish. Mesohabitats that support autochthonous production and the greatest food sources for fish comprise relatively small wetted areas of the channel, which coincide with low-velocity mesohabitats used by silvery minnow. They concluded that the abundance and diversity of food resources available during their study did not suggest a food limitation for Rio Grande silvery minnow.

Fragmentation of rivers has been documented as one of the leading causes of extirpation of many species of pelagic spawning fishes (Perkin and Gido 2011). Much debate has surrounded the fish passage conservation measure for silvery minnow, the potential effects of providing fish passage at the diversion dams at Angostura, Isleta, and San Acacia. A peer review of the science surrounding the need for fish passage found that there was much uncertainty surrounding what the goals for fish passage are, and how many fish would need to use it to accomplish these goals (PBS&J 2011).

5.3.2 Southwestern Willow Flycatcher

5.3.2.1 Species Status

The current range of the flycatcher (figure 19) is very similar to the historical range; however, suitable habitat within that range has diminished considerably due to habitat loss or modification via dams and reservoirs, diversions and ground water pumping, channelization and bank stabilization, phreatophyte control, livestock grazing, recreation, fire, agricultural development, and/or urbanization (Service 2002). Brood parasitism by cowbirds also has been a contributing factor in flycatcher population decline. Prior to the listing of the flycatcher, relatively little was known about the natural history of this subspecies. Estimates of overall territory numbers rangewide in 1993 were approximately 140 distributed among 41 known sites (Durst et al. 2008).

As of 2007, the population of flycatchers rangewide increased to approximately 1,299 territories distributed among 288 sites (Durst et al. 2008; figure 20). Large populations are located along the Gila River and Rio Grande in New Mexico; the Kern, Owens, San Luis Rey, Santa Ana, and Santa Margarita Rivers in California; and the Gila, San Pedro, and Salt River drainages in Arizona (Durst et al. 2008). Currently, the Elephant Butte Reservoir (classified as south of river mile 62 for purposes of this analysis) population is the largest group of flycatchers within New Mexico, and the population within the BDANWR is the second largest along the Rio Grande (New Mexico Flycatcher Database).

A total of approximately 415 flycatcher territories were found within the entire Rio Grande Basin of New Mexico during the 2011 breeding season. Occupied sites were scattered from the Orilla Verde Recreation Area near Taos, downstream to Radium Springs near Las Cruces. During the 2011 breeding season, most suitable habitat within the main stem of the Rio Grande was surveyed, and it is highly unlikely that any large populations of flycatchers have gone undetected; however, sites supporting a few undetected territories may exist in some isolated patches of habitat throughout the Rio Grande Basin.

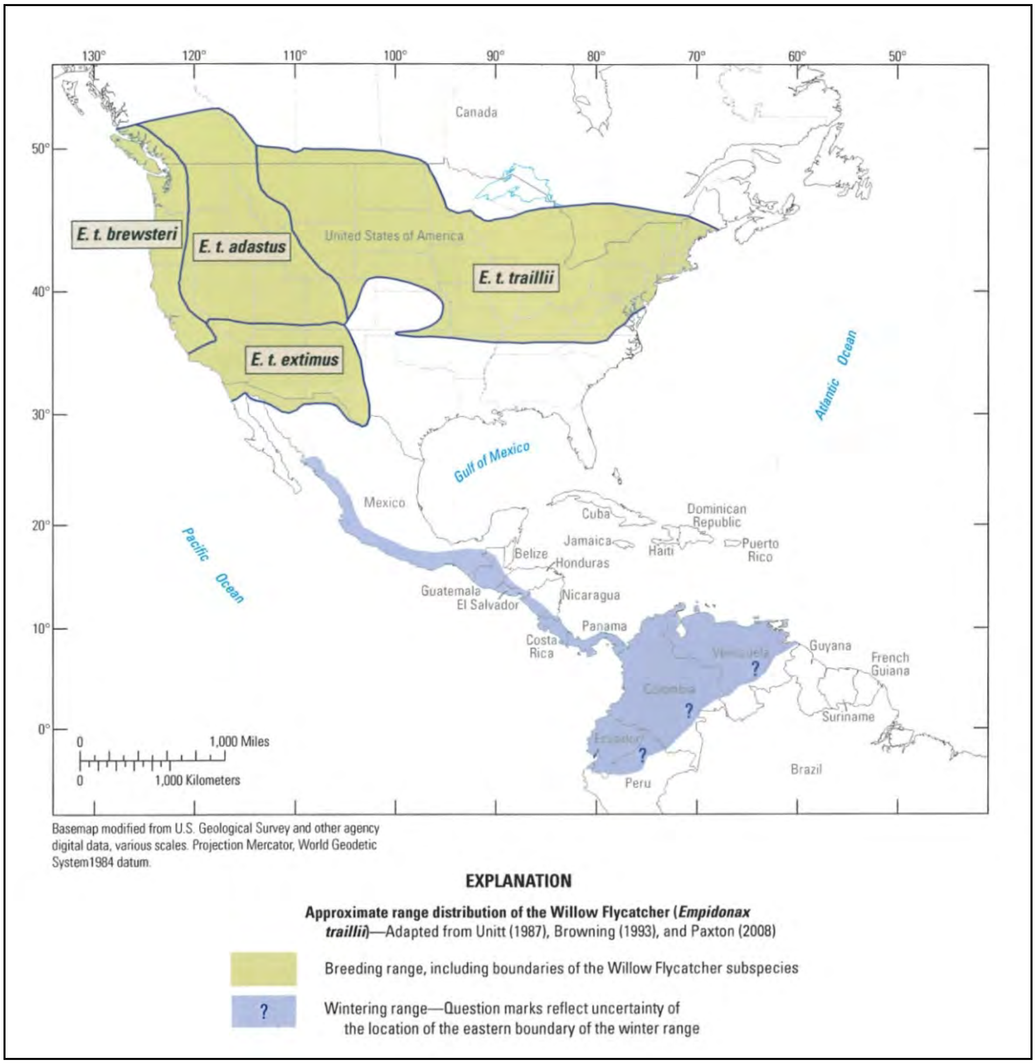

Figure 19. Breeding ranges of the willow flycatcher subspecies (from Sogge et al. 2010).

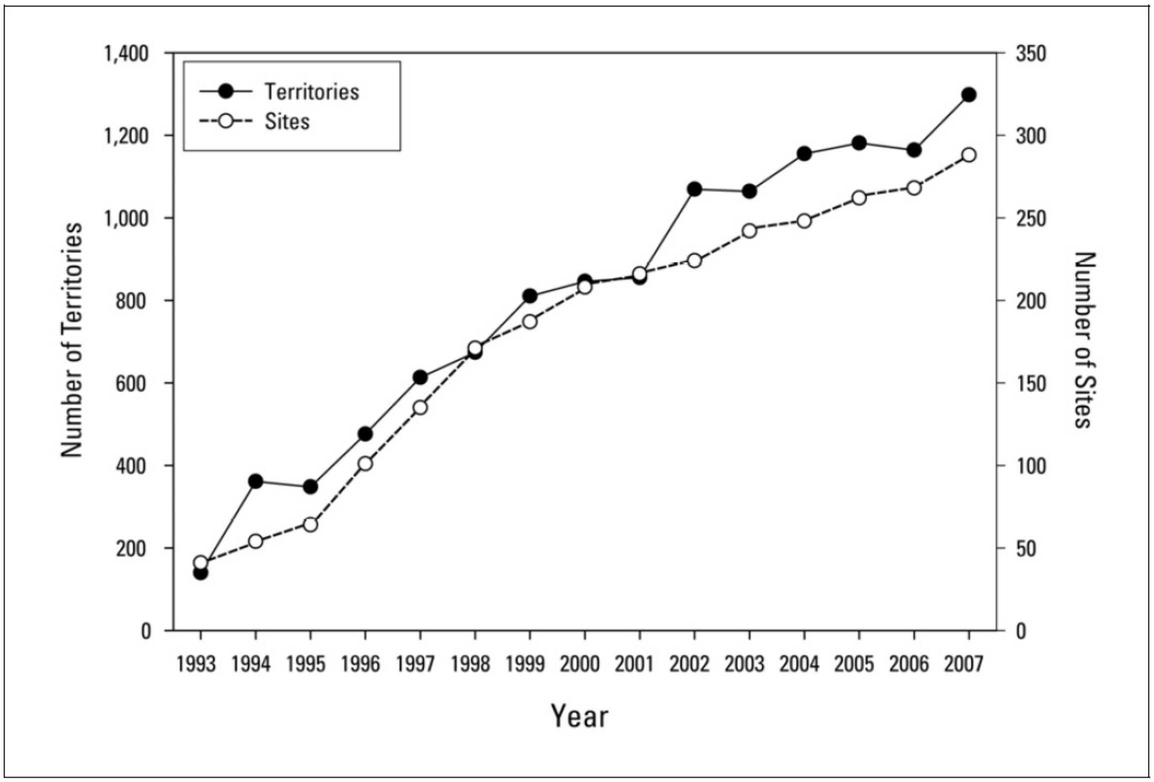

Figure 20. Estimated number of flycatcher territories and sites rangewide from 1993–2007 (from Durst et al. 2008).

Since 1993, flycatchers have been reported from 19 sites within the Rio Grande Basin; however, several of these sites no longer support flycatchers. The majority of currently occupied sites within the entire Rio Grande Basin support isolated populations of fewer than six territories. Sites such as Tierra Azul, Ohkay Owingeh, and Selden Canyon/Radium Springs have been fairly consistent in territory numbers since 1993, which is indicative of somewhat stable populations within these sites.

The Elephant Butte Reservoir population was first recorded in 1993 when four flycatcher territories were found. The population has steadily increased to 314 in 2011. Approximately 75% of the total known territories found within the Rio Grande Basin during the 2011 season were within the conservation pool of Elephant Butte Reservoir that is south of both the currently designated Middle Rio Grande Management Unit critical habitat as well as the project action area.

A total of 84 flycatcher territories were detected during the 2011 survey season along the MRG. This also includes populations from the Stateline to Otowi Bridge, a portion of which is outside the action area. Territory numbers generally have increased since surveys began in 1993 (table 2).

Table 2. Flycatcher territory[1] totals along MRG. This also includes populations from the Stateline to Otowi Bridge, a portion of which is outside the action area.

River Reach	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Rio Chama Stateline to Confluence	2	4	2	5	4	3	NS	NS	4	NS	NS	1	NS	NS	NS	0	NS	NS	NS
Stateline to Otowi Bridge	5	6	11	20	17	2	2	18	1	0	1	12	12	13	12	18	34	21	23
Otowi Bridge to Cochiti Dam	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1	1	NS	2
Cochiti Dam to Angostura Diversion Dam	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Angostura Diversion Dam to Isleta Diversion Dam	NS	3	4	3	NS	NS	NS	14	NS	NS	4	7	6	9	12	16	0	0	0
Isleta Diversion Dam to Rio Puerco	NS	NS	NS	NS	NS	NS	NS	NS	0	2	1	0	4	1	8	1	3	6	10
Rio Puerco to San Acacia Diversion Dam	NS	NS	NS	NS	NS	NS	4	7	11	11	16	17	18	21	14	31	18	13	9
San Acacia Diversion Dam to Arroyo de las Cañas	NS	NS	NS	NS	0	0	0	0	0	2	0	0	0	0	0	3	1	1	1
Arroyo de las Cañas to San Antonio Bridge	NS	NS	NS	NS	NS	0	0	0	0	1	0	0	0	1	0	0	0	3	7
San Antonio Bridge to River Mile 78	NS	NS	NS	NS	NS	0	0	0	0	4	0	1	0	2	5	5	19	37	44
River Mile 78 to River Mile 62	0	11	6	7	0	2	5	4	3	7	7	16	3	14	9	8	9	7	11
Total	5	20	21	30	17	4	11	43	15	27	29	53	43	61	60	83	85	88	84

[1] Territories: A single male or pair of flycatchers detected throughout the breeding season.
Note: Data collected from NM Rangewide Database 1993- NS: Not Surveyed. UN: Unknown.

The only two areas within the action area that have shown significant population changes over the past decade are located in the Rio Puerco to San Acacia Reach (near Sevilleta NWR/La Joya SWA) and the San Antonio to River Mile 78 Reach (near BDANWR). The population along the Rio Grande within the Sevilleta NWR and La Joya SWA was first detected in 1999.

Formal surveys were initiated in 2000, and seven territories were detected. The population increased to 17 in 2004 and remained relatively stable until 2008 when approximately 31 territories were detected. In 2011, the population declined to nine territories. Conversely, the population within the BDANWR has been increasing in numbers and distribution areas over the last 6 years. In 2009 with a population of 19, this area became one of the most highly occupied reaches along the MRG and was again in 2010 and 2011 when the population more than doubled to 37 and 44, respectively.

5.3.2.2 Flycatcher Breeding Habitat Characteristics

Many flycatcher breeding sites are composed of spatially complex habitat mosaics, often including both exotic and native vegetation. Within a site, flycatchers often use only a part of the patch, with territories frequently clumped or distributed near the patch edge. Therefore, the vegetation composition of individual territories may differ from the overall composition of the patch (Sogge et al. 2002).

Generally, four broad categories have been developed to describe species composition at breeding sites and include the following:

Native: > 90% native vegetation
Mixed: > 50% native (50–90% native vegetation)
Mixed: > 50% exotic (50–90% exotic vegetation)
Exotic: > 90% exotic vegetation

Habitat patches comprised of native vegetation account for approximately half (44%) of the known flycatcher territories in the Southwest. As of the 2007 breeding season, rangewide, 50% of breeding territories occurred in mixed patches and 4% in patches > 90% exotic (Durst et al. 2008). In many cases, exotics are contributing significantly to the habitat structure by providing the dense lower-strata vegetation that flycatchers prefer (Sogge et al. 2002).

Data collected and analyzed on nest substrate and surrounding habitat patch communities in the MRG (from Reclamation nest monitoring activities from Velarde to Elephant Butte, primarily nests from areas: Sevilleta/La Joya, BDANWR and San Marcial) indicate that flycatchers may key in on areas dominated by native vegetation but often select exotic vegetation, particularly saltcedar as a nest substrate. Saltcedar actually may be the flycatchers' substrate of choice due to its dense and vertical twig structure. From 1999–2010, approximately 40% of 1,690 nests located in these river reaches were physically constructed on exotic plants (Russian olive [*Elaeagnus angustifolia*] 2.2% and saltcedar [*Tamarix* spp.] 38.0%) (Moore and Ahlers 2011). A very large percentage given that, in the MRG, between 1999–2010, 74 nests (4.4%) with known outcomes were in saltcedar-dominated territories; 1,283 (75.9 %) were in willow (*Salix*)-dominated territories; and 333 (19.7 %) were in mixed-dominance territories (Moore and Ahlers 2011).

The saltcedar leaf beetle (*Diorhabda* spp.)(beetle) was released in field cages in six States (California, Nevada, Utah, Texas, Colorado, and Wyoming) in 1999 and field released in 2001 (DeLoach et al. 2003). The beetles defoliate saltcedar during the growing season, which corresponds to the flycatcher breeding season, and take multiple years of continuous defoliation to eventually kill saltcedar (Paxton et al. 2011). The abundance of beetles may provide a temporary food source for flycatchers, however, once defoliation takes place it is likely that other foliage feeding insects would disperse (Paxton et al. 2011). With reduced canopy cover as well as food source, flycatchers occupying habitat composed of mainly saltcedar would be at a disadvantage.

At this time, the beetle has been observed as close as Highway 313 just north of Albuquerque. Within the MRG, flycatchers use saltcedar as a nesting substrate at a disproportionate rate, which is a concern due to the inevitable expansion of the beetle. However, the vast majority of flycatcher territories are in native-dominated stands, and the defoliation or mortality of a few saltcedar trees within those stands likely will not reduce overall habitat quality (Moore and Ahlers 2011).

5.3.2.3 General Habitat Description/Condition

Suitable and flycatcher occupied riparian habitat within the MRG from the Stateline to river mile 62 include dense stands of willows and other woody riparian plants adjacent to or near the river. Some areas along that same stretch of the MRG support local areas of suitable willow flycatcher habitat (using Hink and Ohmart vegetation classification), however no birds have been observed establishing territories—thus, indicating that suitable habitat is not a limiting factor.

For the purposes of this flycatcher baseline, the area from the Stateline to river mile 62 has been divided into reaches as follows: Rio Chama (Stateline to Confluence), Stateline to Otowi Bridge (a portion of which is outside the action area above Velarde); Cochiti Dam to Angostura Diversion Dam; Angostura Diversion Dam to Isleta Diversion Dam; Isleta Diversion Dam to Rio Puerco; Rio Puerco to San Acacia Diversion Dam; San Acacia Diversion Dam to Arroyo de las Cañus; Arroyo de las Cañus to San Antonio Bridge; San Antonio Bridge to River Mile 78; and River Mile 78 to River Mile 62.

In general, the bosque in the Stateline to Otowi Bridge and Cochiti Dam through Isleta Reaches contain mainly single-aged stands of older cottonwoods (*Populus* spp.) and lack the diversity of a healthy, multiaged riparian forest. Exotic vegetation such as Russian olive and Siberian elm also has become established. In many areas, significant channel narrowing and degradation have significantly limited overbank flooding and reduced the potential for recruitment of native riparian vegetation, especially cottonwoods and willows. There are some areas within this stretch that currently do have suitable habitat in the form of lower terraces with backchannels, native willows, and marsh like conditions.

Known flycatcher habitat in the Rio Puerco area (reaches from Isleta Diversion Dam through San Acacia Diversion Dam) occurs adjacent to the river and is dominated by coyote willow (*Salix exigua*), saltcedar, and Russian olive. The trend of channel narrowing and degradation reduces the amount of overbank flooding and the potential to enhance existing sites or establish new native vegetation.

From San Acacia to River Mile 78, habitat varies greatly from deep, incised channels with dry, high terraces consisting of mainly saltcedar vegetation to areas that experience overbank flooding in high flow events with cottonwood galleries and young native patches of vegetation. The vegetation is very mixed in this large area that typically is not occupied by flycatchers (with the exception of the area within the BDANWR) and also consists of mesquite, Russian olive, saltbush, quailbush, New Mexico olive, and a variety of other species.

Within the BDANWR, habitat varies from dense monotypic saltcedar to mature cottonwood galleries. Mature coyote willow and Russian olive also typically line the banks, which is where large populations of flycatchers have established territories within the past couple breeding season.

South of the BDANWR to river mile 62 consists of mainly saltcedar and Russian olive with mature cottonwoods interspersed. In areas south of the railroad trestle, habitat contains less saltcedar and Russian olive and contains larger quantities of mature cottonwood and willows. However, in recent years, these areas have become very dry; and the mature cottonwoods have been very susceptible to mistletoe (*Viscum album)*. Foliage in the canopy is now very sparse.

5.3.2.4 Suitable Habitat Classification

Development of a Geographic Information System- (GIS) based flycatcher habitat suitability model was initiated in 1998 for the MRG Basin and continues to be refined based on changes in hydrology and updated vegetation maps. Riparian vegetation in the MRG Basin between San Acacia Diversion Dam and Elephant Butte Reservoir had been classified using the Hink and Ohmart (1984) classification system through a cooperative effort with the U.S. Forest Service. This system identifies vegetation polygons based on dominant species and structure. Plant community types are classified according to the dominant and/or codominant species in the canopy and shrub layers.

During the summer and fall of 2002, as part of the Collaborative Program, Reclamation personnel updated vegetation maps from Belen to San Marcial using a combination of ground truthing and aerial photo analysis. During the summer of 2004, the conservation pool of Elephant Butte Reservoir was again aerially photographed (true color), and vegetation heights were remotely sensed using Light Detection and Ranging (LIDAR) methods. The area was ground truthed again during the summer of 2005. In 2008, the conservation pool of Elephant Butte Reservoir again was reviewed; and habitat mapping was updated based on ground-truthing and aerial photography flown in late summer of 2007. These areas are continually being reviewed as vegetation matures and develops in new areas so that components of the flycatcher habitat suitability model remain current.

In 2008, breeding habitat suitability was refined by identifying all areas that were within 50 meters of existing watercourses, ponded water, or in the zone of peak inundation. Using the vegetation maps and the flycatcher territories detected from 2006–2009, guidelines for categorizing each vegetation type into habitat suitability classes were established based on structure and density of vegetation. Factors used in making these determinations are explained below.

Suitable – Suitable habitat included vegetation in which a high percentage of flycatcher territories was detected. Areas with a significant structural component—primarily intermediate-sized trees (15-40 ft) with or without understory or stands with dense shrubby growth (5–15 ft)—also were considered suitable if a high percentage of territories occurred within the vegetation type. Other qualifying vegetation types were those that included a combination of important plant species, especially tree willows, coyote willows (particularly in the canopy layer), Russian olive, and saltcedar (however, not monotypic saltcedar) and also vegetation classes with a "d" qualifier, which indicated > 50% aerial vegetation cover.

Moderately Suitable – Moderately suitable habitat included vegetation in which a fairly high percentage of territories occurred from 2006–2009. Areas that provided a good structural component (primarily the same community types as described in suitable habitat) and occasionally community type 1, which consisted of tall/mature trees with well developed canopy (> 40 ft) also could be considered moderately suitable. This category required an adequate combination of vegetation species with at least 50% of the species composition made up of the more desirable plant species (those listed under "Suitable" habitat).

Unsuitable – Unsuitable habitat included vegetation in community types with tall/mature trees with or without understory (> 40 ft) or communities with very young and low growth. These were habitats in which vegetation was either too sparse or too mature, or the majority of the polygon consisted of the lower priority plant species. If fourwing saltbush (*Atriplex canescens*), honey mesquite (*Prosopis glandulosa*), screwbean mesquite (*Prosopis pubescens*), creosote (*Larrea tridentata*), or New Mexico olive (*Forestiera pubescens*) were a component of the classification, then the vegetation type was determined to be unsuitable.

Nonhabitat – Nonhabitat for SWFLs included five classifications, which were open areas with no woody overstory (e.g., open water or marsh) and human developments (e.g., roads and railroads).

Results from the study, entitled Southwestern Willow Flycatcher Habitat Suitability 2008, Highway 60 Downstream to Elephant Butte Reservoir, NM, indicated that tree willow was the most important plant species for providing flycatcher habitat. Over 20% of flycatcher territories from 2006–2009 were found in two habitat classifications: TW/TW-CW3 (tree willow overstory with a relatively dense understory comprised of tree willow and coyote willow) and TW/CW-SC3 (tree willow overstory with a relatively dense understory comprised of coyote willow and saltcedar); 78% of the vegetation types surrounding territories had a tree willow component.

Although saltcedar and Russian olive are invasive and often considered undesirable plant species, they do provide suitable habitat for flycatchers in the study area. Of all the territories, 43% had a saltcedar component, and saltcedar was the dominant species within 6% of the vegetation types in which territories were found. Russian olive was a component in 9% of flycatcher territories and dominated vegetation types in 5% of the territories.

Cottonwood was a component in 11% of the vegetation types that included flycatcher territories and was the dominant species in 6% of these vegetation types. Cottonwood and saltcedar were the dominant species in an equal percentage of the vegetation in which flycatcher territories were detected.

Although not within the action area, the vast majority of suitable habitat and flycatcher territories were found within the conservation pool of Elephant Butte Reservoir, which was a vital component in determining habitat suitability composition. There were 4,208 acres of suitable and moderately suitable flycatcher habitat mapped within this area, far beyond any of the other reaches. Areas near Sevilleta NWR/La Joya SWA provided the next highest amount of suitable and moderately suitable habitat with 796 acres. The development of such high quality habitat in the conservation pool of Elephant Butte Reservoir can be attributed to a decline in the reservoir levels, which exposed soils and provided moist sites for willow to establish. The suitability of this habitat for flycatchers was substantiated by the occurrence of 893 territories documented from 2006–2009, again far more than in any of the other reaches in the study area. The Sevilleta NWR/La Joya SWA area had 97 flycatcher territories from 2006–2009, which was second in territory numbers (Ahlers et al. 2010). Ultimately, the structure and density of flycatcher habitat are likely what are most attractive, rather than the plant species composition (Moore and Ahlers 2008, 2009)

Flycatchers (and many other species of neotropical migrant landbirds) use the Rio Grande riparian corridor as stopover habitat during migration. Studies have shown that, during the spring and fall migration, flycatchers more commonly are found in willow habitats than in other riparian vegetation types, including the narrow band of coyote willows that line the LFCC (Finch and Yong 1997). Presence/absence surveys during May have detected migrating flycatchers throughout the project area in vegetation types that would be classified as “unsuitable” for breeding habitat (Ahlers and White 1997).

5.3.2.5 Development and Status of Suitable Southwestern Willow Flycatcher Breeding Habitat Within the MRG

It is commonly recognized that one of the primary causes for the decline of neotropical migrants, along with numerous other terrestrial species, is the decrease in the abundance of riparian vegetation over the past hundred years. The removal of the dynamic components of river systems is a main reason for this decline in riparian vegetation.

The Rio Grande and associated riparian areas historically have been a very dynamic system in constant change; without this change, the diversity and productivity decreases. Sediment deposition, scouring flows, inundation, and irregular flows are natural dynamic processes that occurred frequently enough in concert to shape the characteristics of the Rio Grande channel and flood plain. Flycatcher habitat historically has developed in conjunction with this hydrologically dynamic system where habitat was created and destroyed in a relatively short period of time. It is this type of dynamic, successional system that flycatchers depend on for the establishment and development of their breeding habitat. Through the development of dams, irrigation systems, and controlled flows, the dynamics of the river system have been eliminated except for localized areas such as within reservoirs where water storage levels frequently change with releases and inflows. It is no coincidence that flycatchers have expanded and dispersed within the delta of the Elephant Butte Reservoir. In previous years, this has been the only large scale area with this dynamic process in favor of flycatcher habitat expansion in the form of changing reservoir elevations. Cottonwoods and willows are aggressive colonizers of disturbed sites in a variety of ecological situations (Reichenbacher 1984).

The interaction of river discharge (timing and magnitude), river channel morphology, and flood plain characteristics are vital components that can favor the establishment of native vegetation and enhance the development of suitable willow flycatcher breeding habitat within the MRG. To recreate these dynamic processes in a very static river system, manmade procedures have been developed and implemented such as mechanical disturbance, herbicide treatments, prescribed fire, channel realignment, operational flows, avulsions, and river realignment. These manmade processes manipulate the river and flood plain in an attempt to restore the diversity of a healthy river system.

Successful cottonwood and willow recruitment has been shown to coincide with the descending limb of the spring runoff hydrograph. The timing and rate of decline of receding flood flows such as those that occur at the conservation pool of Elephant Butte have been documented as important factors affecting seedling survival (Sprenger et al. 2002). Newly scoured area of the river channel or flood plain and areas where sediment has been deposited also provide conditions for regeneration of native species and can stimulate vegetation health. An example of this was the sediment plug in the BDANWR in 2008 and the response to that event by the large increase in suitable habitat and flycatcher territories.

Habitat modeling throughout the MRG (including areas south of the action area) has shown that there currently is suitable unoccupied habitat, thus indicating that habitat availability is presently not a limiting factor to this population. The reason that flycatchers do not expand into all areas of suitable habitat is possibly a result of their relatively strong site fidelity. However, the availability of suitable habitat is likely to decline over the next few years, particularly within the conservation pool of Elephant Butte Reservoir due to natural succession, extended flooding from the LFCC, and channel degradation in the Rio Grande. The distribution of flycatcher territories within the MRG has shifted and will continue to shift in response to these habitat changes.

5.3.3 Pecos Sunflower

In the Middle Rio Grande, the main Pecos sunflower population presently exists within the La Joya SWA, a unit of the Ladd S. Gordon Waterfowl Complex. This is one of the largest populations of *H. paradoxus*, consisting of 100,000 to 1,000,000 plants. This property is owned by the New Mexico State Game Commission. It is managed by the NMDGF for migratory waterfowl habitat, which is compatible with preservation of wetlands for *H. paradoxus*.

This site was first discovered in 2004 and has been found to be occupied every year since then. It represents one of the largest populations of *Helianthus paradoxus* in the range of the species (Hirsch 2006). The site contains all of the PCEs in the appropriate spatial arrangement and quantity but is threatened by encroachment of nonnative vegetation.

First discovered in 2004, this population is located in an area distinct from any other population in the range of the species. As such, it may contain genetic variation not found anywhere else in the range of the species. The La Joya SWA was excluded from the critical habitat designation for *H. paradoxus* due to the development of a habitat management plan that adequately protects the species (NMDGF 2007). The management plan is to support conservation of the species on the La Joya SWA by: (1) annually controlling invasive species, (2) protecting the natural spring in Unit 5 from motorized vehicles and heavy equipment, (3) monitoring core populations by digitizing these areas annually, (4) conserving *H. paradoxus* by adjusting invasive species treatment area boundaries, and (5) restoring native habitat through re-vegetation.

In accordance with the management plan, NMDGF maps core sunflower population areas annually (table 3). Areas that contain a mix of Pecos and annual sunflower are not mapped. Conservation measures include avoiding herbicide use within delineated core population areas. In 2008, seeds from the La Joya population were used to establish a new population on a private land area. Initial surveys of this area indicate that the population has established itself.

Table 3. Acreage of core Pecos sunflower population on La Joya SWA

Year	Acres Mapped
2004	66
2005	143
2006	159
2007	160
2008	209
2009	262
2010	262
2011	224

Source: J. Hirsh NMDGF Records.

Additionally, in 2010, a ditch that delivers water from Pond 3 to Pond 4 on La Joya SWA was cleared of salt cedar. Part of the cleared area was seeded with a mix of Pecos sunflower and annual sunflower. In 2011, Pecos sunflower and annual sunflower re-colonized the disturbed ground. Most of these areas are located adjacent to the La Joya Ponds.

5.3.4 Interior Least Tern

As previously mentioned in the Status and Distribution section of this analysis, the interior least tern can be considered a vagrant on the MRG and no interior least tern nesting has been recently documented (Service 1995). According to the recovery plan from the Service in 1990, the only documented breeding along the Rio Grande takes place in Texas, and the only documented breeding within the state of New Mexico can be found on the Pecos River (Service 1990), similar conclusions are drawn in the complete rangewide survey collected in 2005 (Lott 2006). Due to the low potential for occurrence and that the interior least tern likely only would be present infrequently and/or temporarily (i.e., during migration), the interior least tern would likely not be affected by the project; and no further analysis will be completed on behalf of the species.

5.4 Hydrologic Regime

This section provides the hydrologic setting of the MRG and shows the following:

- The water supply to the MRG is limited and highly variable.
- Modifications have been made to the timing, distribution, and magnitude of flows in the MRG for purposes of flood control and maximization of the beneficial use of water, and include.
    - Suppression of large, channel-forming flows by flood-control dams.
    - Redistribution of flows by water storage reservoirs, so that water is available for water supplies and, consequently, for river flows during the irrigation season.
    - Diversion of surface water and drain flows for irrigation, which decreases the flow in the river.
    - Pumping of ground water, so that significant ground water drawdowns have developed, and the ground water system now draws water from the river.

The hydrologic changes documented in this section are interconnected with the other changes that have occurred in this system, primarily geomorphic changes to the river channel, as discussed in the following section. Because of these geomorphic changes, the current hydrology is not sufficient to provide overbank flows in the upstream portions of the MRG. In the Angostura Reach, significant overbank flows begin to occur at flows above 6,500 cfs (figure 21). However, the maximum releases from Cochiti under its flood control rules are 7,000 cfs. Therefore, the available hydrologic operations have a very limited ability to provide significant overbank flows, which are important to the life cycle of the silvery minnow.

In the more downstream reaches, potential for overbank flows is more widespread, but diversions from the river decrease the flows that are conveyed to these reaches, and perching of the river channel makes it less likely that this channel will be able to maintain the flows that it receives from upstream. Frequent drying of the more downstream reaches of the MRG after the snowmelt runoff limits the degree to which they can support the postspawn survival of the silvery minnow.

This subsection begins with a discussion of the water and river operations over the past decade, organized geographically from north to south, and concludes with the current hydrologic conditions.

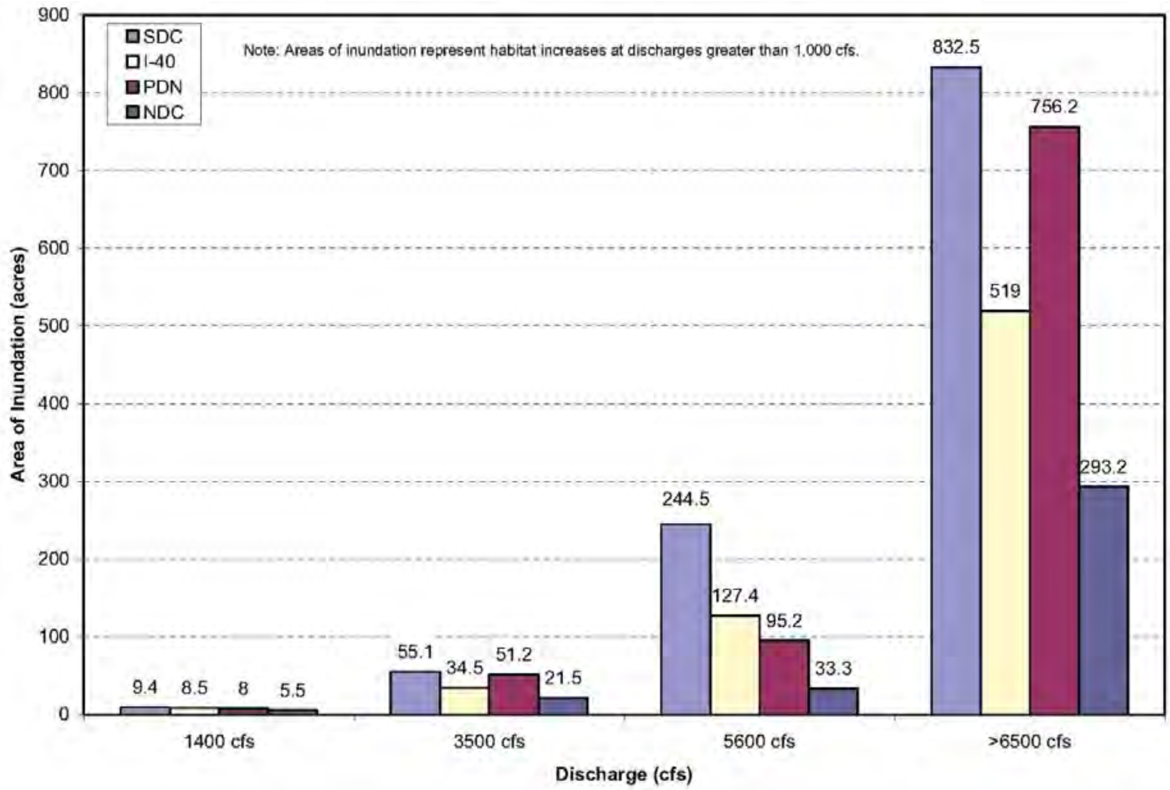

Figure 21. Bar graph showing area of overbank inundation in four subreaches of the Albuquerque Reach (the South Diversion Channel (SDC); Interstate 40 (I-40); Paseo del Norte (PDN), and North Diversion Channel (NDC) subreaches) prior to habitat restoration efforts by the Collaborative Program (Mussetter Engineering, Inc. 2006).

5.4.1 Baseline Water Operations

The term "water operations" describes the human operations of dams and diversions and activities that put water to beneficial use. Five types of water operations are implemented, often simultaneously, within the MRG system: 1) flood control; 2) irrigation; 3) municipal and industrial diversion, use, and return flow; 4) environmental operations; and 5) recreational/rafting.

5.4.1.1 An Overview of MRG Water Management Facilities and Operations

The MRG is an engineered system. River flow and water movement throughout the Rio Chama and MRG are constrained by the physical capabilities and existing authorities associated with the system's water management facilities, operations, and policies. The MRG is affected by Colorado State line Compact deliveries, Rio Chama and other tributary inputs, imported SJC Project waters, the Corps' flood control reservoirs along the Rio Chama and Rio Grande, and the MRG Project, all of which contribute to or regulate flows along the Rio Chama and the MRG.

Figure 22 is a schematic representation of the Rio Chama and Rio Grande that shows the major facilities and/or entities that impact flows in the MRG—from Heron Reservoir operations at the top to the Bosque Del Apache Wildlife Refuge at the bottom.

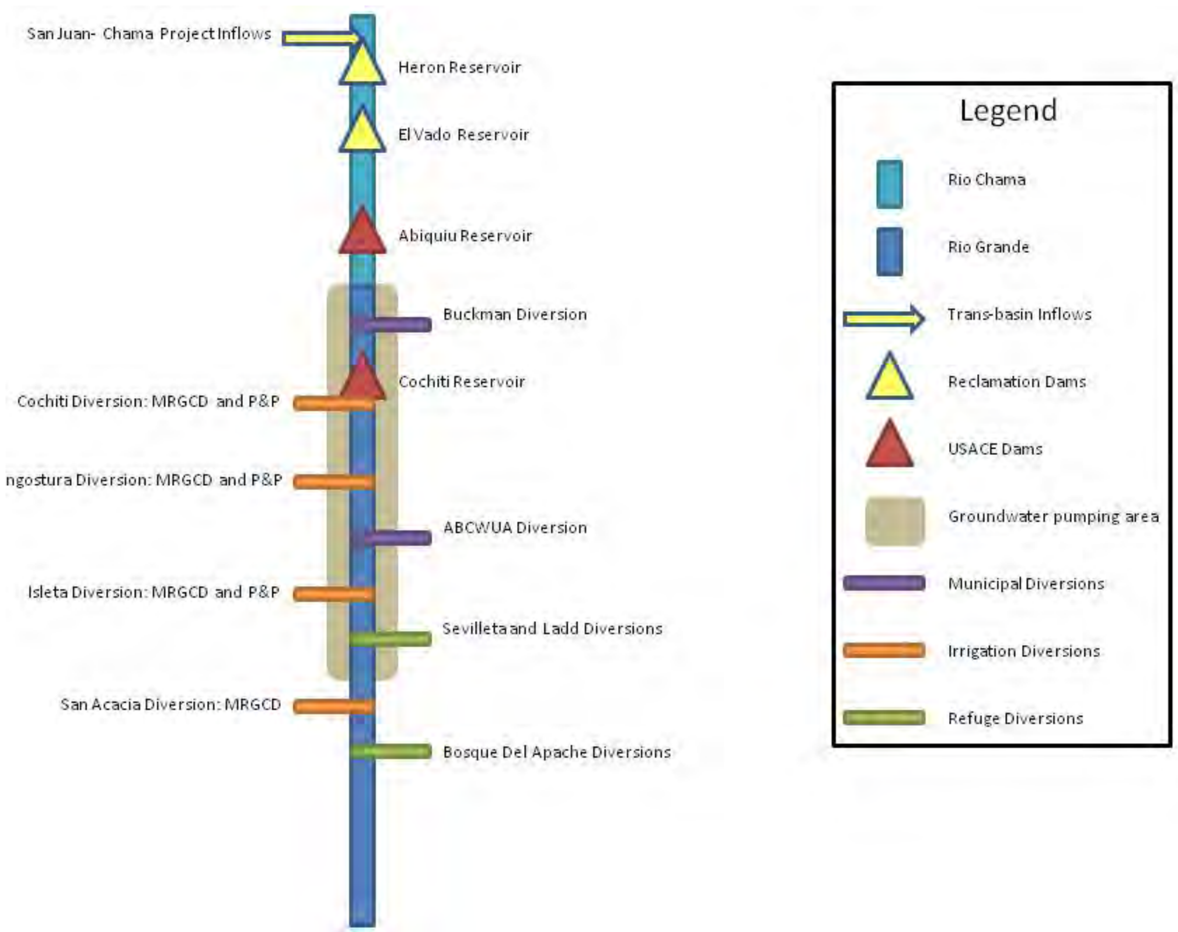

Figure 22. Schematic representation of major water facilities impacting river flows in the Middle Rio Grande.

The major Federal reservoir facilities within the action area include the following:

- Rio Chama
  - Heron Dam Reservoir (owned and operated by Reclamation as part of the SJC Project)
  - El Vado Dam Reservoir (owned and operated by Reclamation as part of the MRG Project)
  - Abiquiu Dam and Reservoir (owned and operated by the Corps for flood control and SJC Project storage)

- Rio Grande
  - Cochiti Dam and Lake (owned and operated by the Corps for flood control)
- Off-Channel
  - Jemez Canyon Reservoir (owned and operated by the Corps for flood control)
  - Galisteo Dam (owned and operated by the Corps for flood control)

Heron Dam and Reservoir are located on Willow Creek, a tributary of the Rio Chama. Reclamation operates Heron Reservoir to manage imported SJC Project waters and passes all native Rio Grande flows. Reclamation operates El Vado Reservoir to store native Rio Grande water, when allowed by the Compact, for use in the MRG Project service area by non-Indian farmers and the Six MRG Pueblos. Reclamation stores native Rio Grande waters for prior and paramount water needs pursuant to the 1981 Agreement and discussed below. When space is available, El Vado also may store SJC Project water. Abiquiu Reservoir is authorized for flood control, sediment control, and storage of both SJC Project and native Rio Grande waters. However, storage of native Rio Grande water in Abiquiu is rare.

Very little native Rio Grande flow is actually captured and stored in the major reservoirs in this system. On average, only 100,000 AF of native Rio Grande water (less than 10% of annual average flow at Otowi gage) is historically stored (even temporarily) upstream of Elephant Butte Reservoir. The vast majority of combined storage in Heron, El Vado, Abiquiu, and Cochiti Reservoirs is imported SJC Project water (Flanigan et al. 2007).

Rio Grande flows at Otowi gage, which is located just downstream from the confluence of the Rio Chama, consist of unregulated main stem Rio Grande flows crossing the border from Colorado and discharges from reservoirs along the Rio Chama, including both native Rio Grande watershed inputs and imported SJC Project waters. Cochiti Reservoir is the sole main stem reservoir capable of regulating these native Rio Grande flood flows. Native Rio Grande spring runoff from April–June typically is allowed to pass through Cochiti Dam unregulated, with the exception of peak flows that exceed safe channel capacity. Abiquiu Reservoir is the primary flood control reservoir along the Rio Chama, and the Jemez Canyon and Galisteo provide flood control on the Jemez and Galisteo Rivers, respectively—tributaries that discharge to the MRG. Releases from the other water supply reservoirs along the Rio Chama (i.e., Heron and El Vado Reservoirs) typically occur later in the year, from May—October, depending on irrigation demand and the need for available Supplemental Water to meet environmental flow requirements.

Water management reaches differ slightly from river maintenance geomorphic reach designations and are primarily defined by locations of mainstream irrigation diversion dams (figure 23). The upper reaches are similar to the river maintenance designations. The Cochiti Reach extends from Cochiti Dam to Angostura Diversion Dam. The reach from Angostura Diversion Dam to Isleta Diversion Dam is called the Angostura Reach (this reach is interchangeably known as the Albuquerque Reach). The Isleta Reach is bounded upstream by Isleta Diversion Dam and downstream by San Acacia Diversion Dam. Water management defines only one reach below San Acacia Diversion Dam to the full reservoir pool of Elephant Butte Reservoir, known as the San Acacia Reach whereas there are several geomorphic designations within this reach.

The Low Flow Conveyance Channel is a 54-mile long riprap-lined channel that parallels the Rio Grande on the west side and originally extended from San Acacia Diversion Dam to the narrows of Elephant Butte Reservoir but now ends approximately at river mile 60. The LFCC was constructed to aid delivery of Compact water and sediment to Elephant Butte Reservoir and serves to improve drainage of irrigated lands and provide additional water for irrigation by collecting water draining from farmland. The LFCC is owned, operated, and maintained by Reclamation.

New Mexico water law follows the Doctrine of Prior Appropriation, which gives senior water users a better right than junior water users in times of shortage. Under the doctrine, priority of water rights is determined through a stream system adjudication in a court of law. Water rights in the MRG have not yet been adjudicated to determine their nature and extent, and the waters of the MRG are fully appropriated.

5.4.1.2 San Juan-Chama Water Operations

The SJC Project operations augment the Rio Grande water supplies through transbasin diversion of Colorado River water. SJC Project water must be consumptively used in New Mexico and cannot be used for deliveries under the Compact.

Figure 24 provides a summary of annual SJC Project diversions, which enter to the Rio Grande system via the Azotea Tunnel, annual inflows of SJC Project water to El Vado Reservoir, and annual amounts of water conveyed at the Otowi gage for consumption in the MRG.

During the 11-year period shown in figure 24, an annual average of about 61,550 AF of SJC Project water passed the Otowi gage in response to downstream demand by SJC Project contractor requests and Reclamation Supplemental Water Program releases. The remainder of SJC Project water remained stored in MRG reservoirs, especially El Vado and Abiquiu, as shown in figure 25.

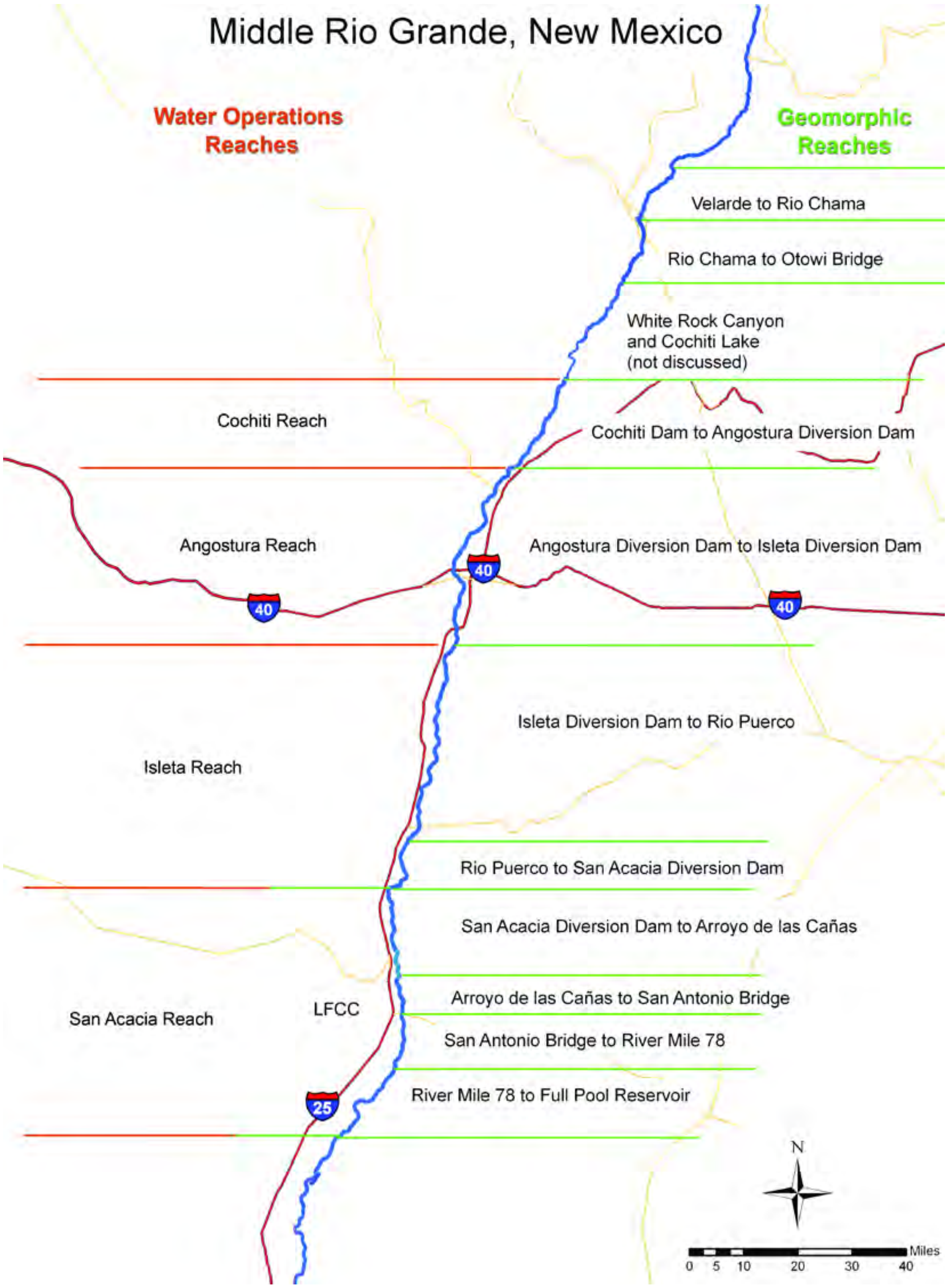

Figure 23. Geomorphic reach designation.

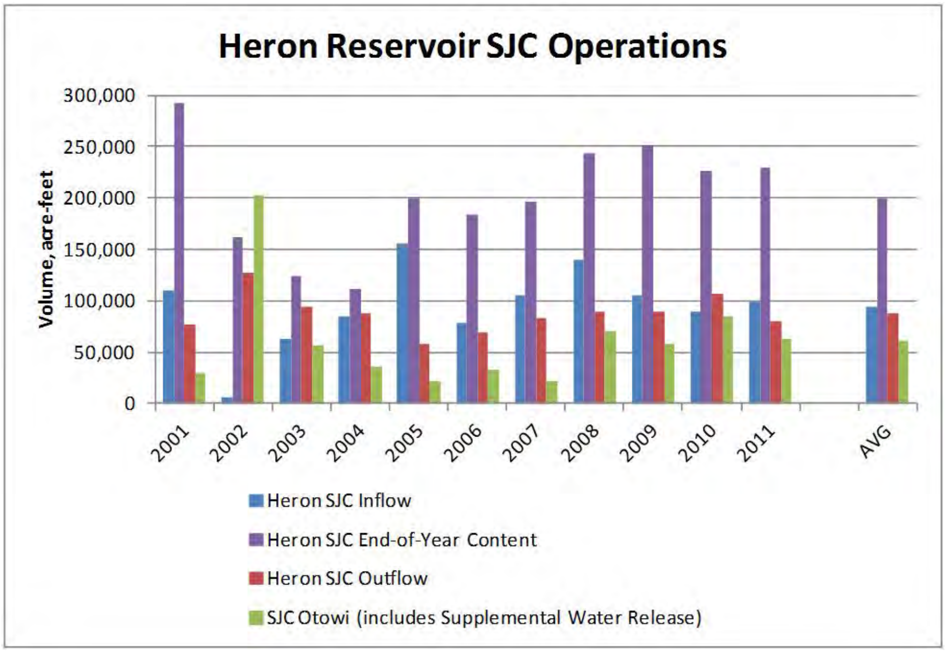

Figure 24. Summary of annual Heron Reservoir operations under the San Juan-Chama Project, including inflows, outflows, and storage of SJC Project water and annual amounts of San Juan-Chama Project water crossing the Otowi gage for consumption within the MRG.

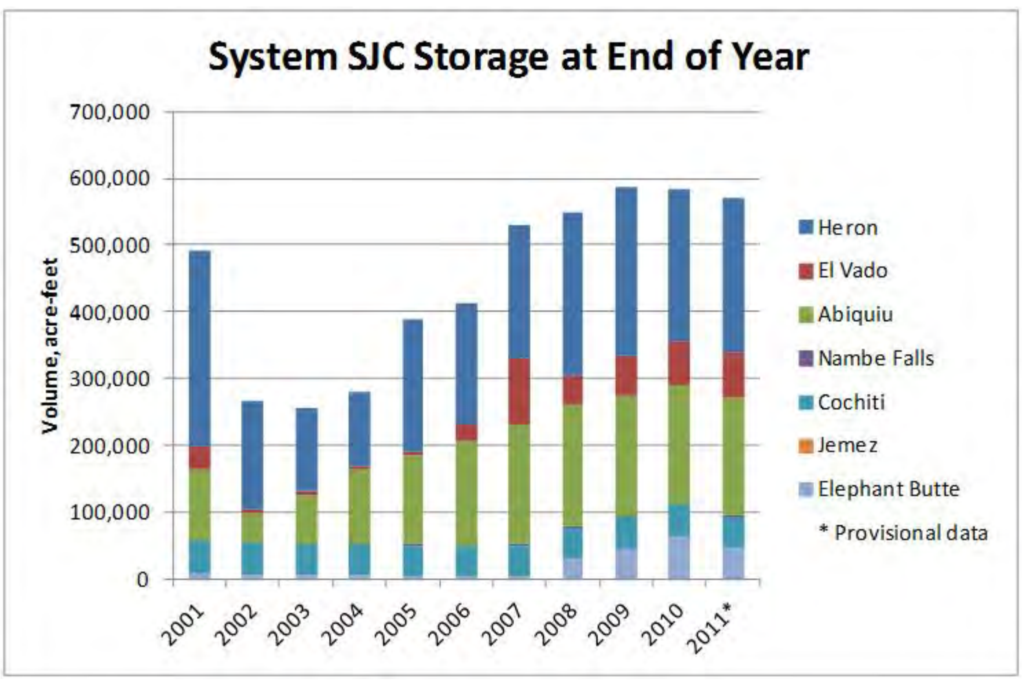

Figure 25. Summary of end-of-year storage of SJC Project water in Middle Rio Grande reservoirs.

5.4.1.3 El Vado Storage and Release Operations

Water storage dams, such as El Vado Dam, are managed to store and release water in a way that alters the spring hydrograph by scalping the peaks off the hydrographs and providing water when natural flows are lower and water needs are higher—times when the natural flows might not otherwise provide sufficient water to meet all the water needs.

Figure 26 presents a summary of storage and release activities at El Vado Reservoir over the past 11 years and visually shows the ways that El Vado Dam operations have affected the Rio Chama hydrograph. When Article VII storage restrictions under the Compact (as discussed in section 5.4.1.1) are not in effect, the peak inflows to El Vado Reservoir, shown in blue, tend to be larger than, and occur before, the peak outflows from the reservoir. In the summertime, the outflows from storage tend to exceed the inflows to the reservoir. This outflow from storage may be evident even when Article VII restrictions are in effect, due to releases of water stored earlier, when storage restrictions were not in place. Heron Dam outflows are also shown on figure 26. These flows represent San Juan-Chama water, the non-native portion of the flow that passes through El Vado.

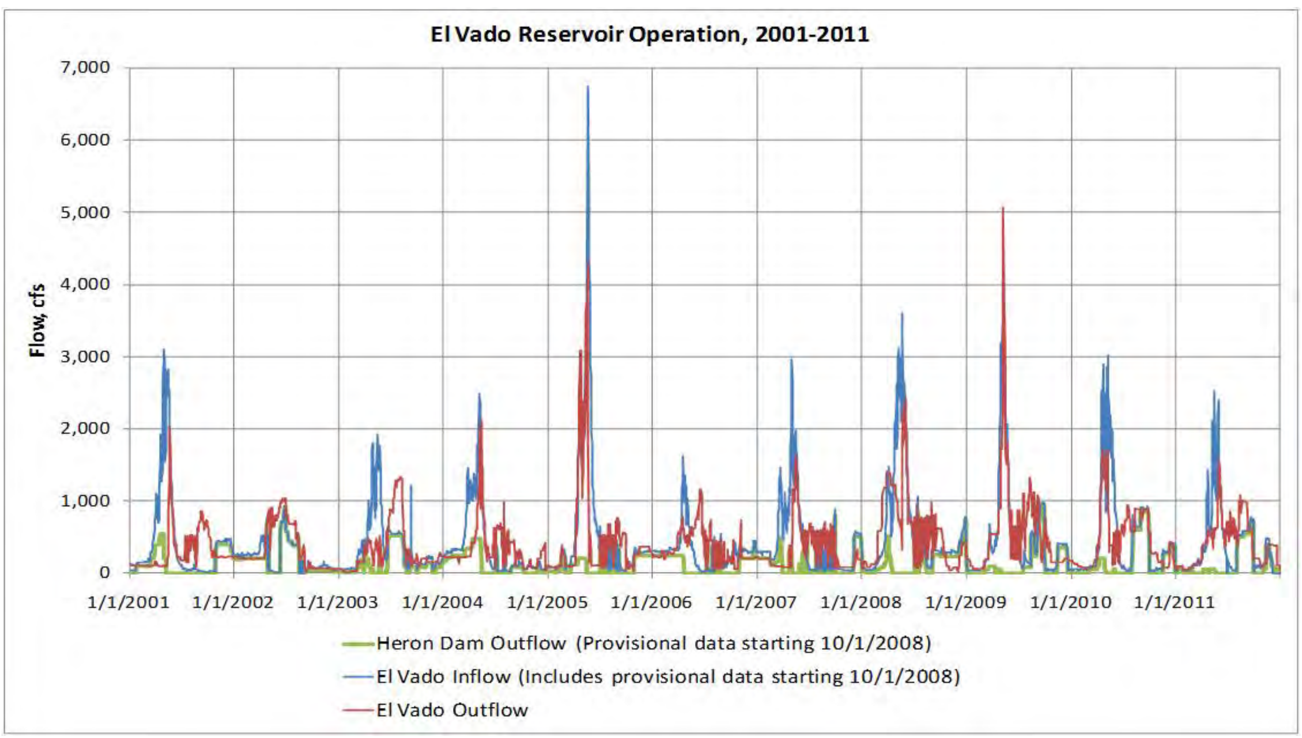

Figure 26. Hydrograph depicting El Vado Reservoir operations, 2001–2011, including a comparison of Heron Dam outflow, El Vado Reservoir inflow, and El Vado Dam outflow.

These relationships can be seen more clearly for the annual hydrograph, for 2007, an example year with a typically-shaped spring hydrograph, shown in figure 27. The difference between the Heron Dam outflow (green line) and the El Vado Reservoir inflow (blue line) represents the native inflow from the Rio Chama. The difference between the El Vado Reservoir inflow (blue line) and the El Vado Dam outflow (red line) shows the ways in which the operation of El Vado Dam affected the hydrograph of the Rio Chama.

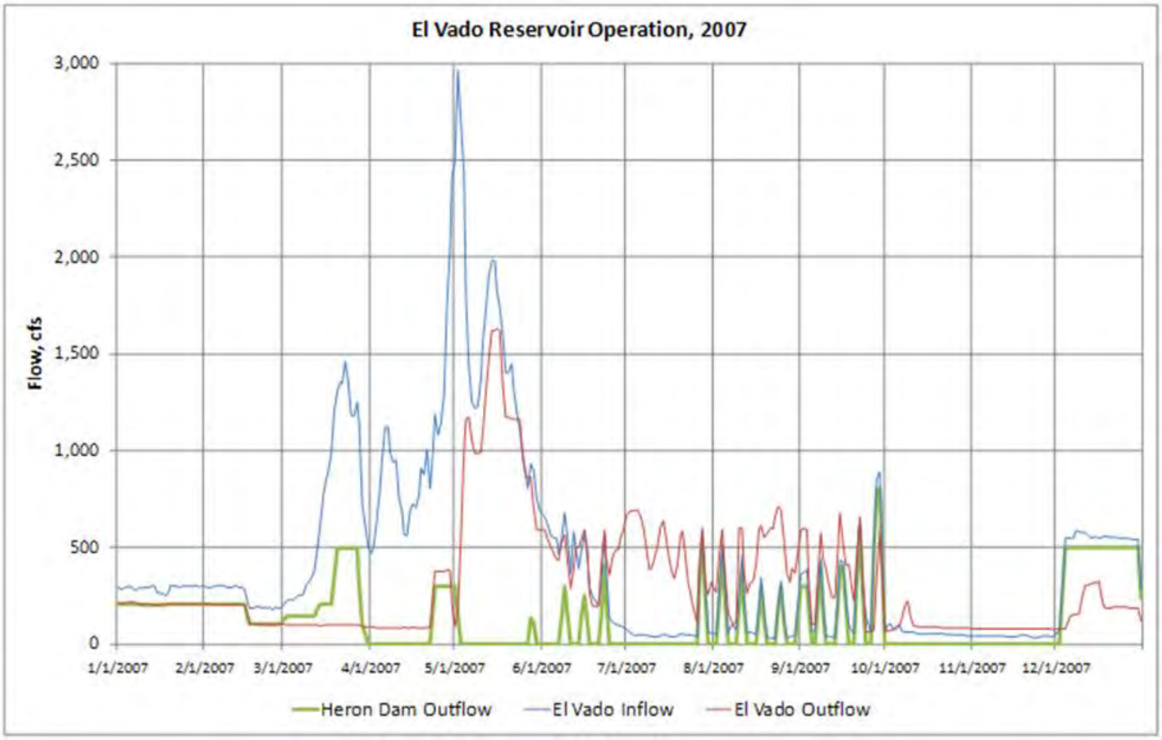

Figure 27. Comparison of Heron Dam outflow, El Vado inflow, and El Vado outflow, 2007.

Releases of stored water from El Vado are made at the request of the MRGCD, as needed to meet MRG irrigation demand, or, when the MRGCD is under shortage operations, by the Bureau of Indian Affairs as needed to meet the irrigation demand of the lands of the Six Middle Rio Grande Pueblos with prior and paramount water rights. MRGCD operations are described in more detail section 5.4.2.9 below.

5.4.1.4 Flood Control Operations

The Corps owns and operates Abiquiu and Cochiti Dams, which are primarily used for flood control, and is consulting separately on the effects of its actions. Flood control dams affect flows in the river by storing and releasing water in a manner that decreases flood peaks but does not cause significant changes in the shape of the hydrograph or in the annual total flow volume (Corps et al. 2007). The flood control dams in the Middle Rio Grande system are operated to pass all inflows except those that exceed a designated safe channel capacity downstream from the dam, currently 1,800 cfs below Abiquiu Dam and 7,000 cfs below Cochiti Dam.

Figure 28, below, displays the inflow to and outflow from Cochiti Reservoir over the past decade. The general character of each annual hydrograph is similar, indicating that the dam operations do not fundamentally change the character of the hydrograph, except in removing flows that exceed 7,000 cfs, the designated safe channel capacity in the Middle Rio Grande. When inflow exceeds this designated safe channel capacity, releases are cut to below 7,000 cfs, and the duration of the high flow event is extended until the floodwaters have been released. Such an operation can be seen in 2005 during the snowmelt runoff, but at no other time during the past decade.

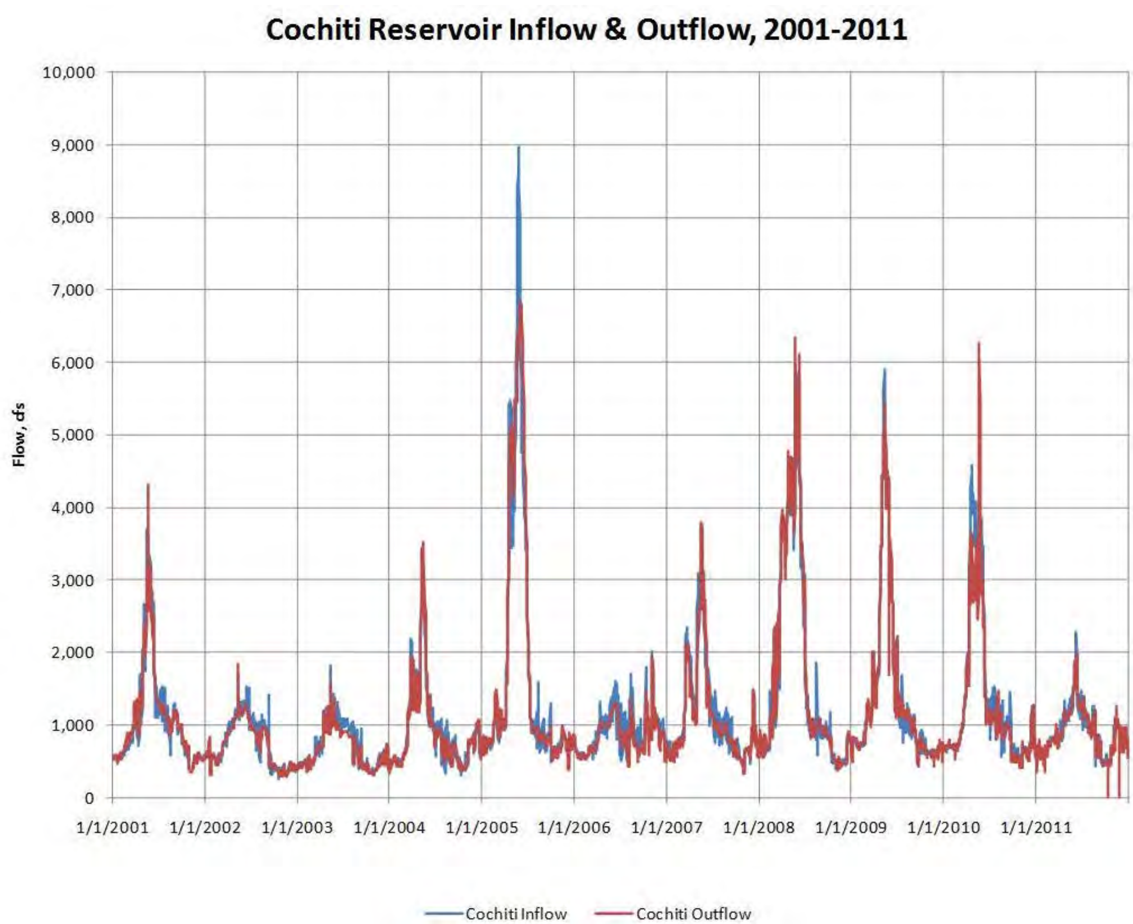

Figure 28. Comparison of inflow to and outflow from Cochiti Reservoir, 2001–2011, showing flood control operations in 2005.

Figure 29 presents a comparison of inflow and outflow hydrographs for Cochiti Reservoir for 2005 only. This comparison provides detail on the changes to the hydrograph caused by the spring 2005 flood control operations.

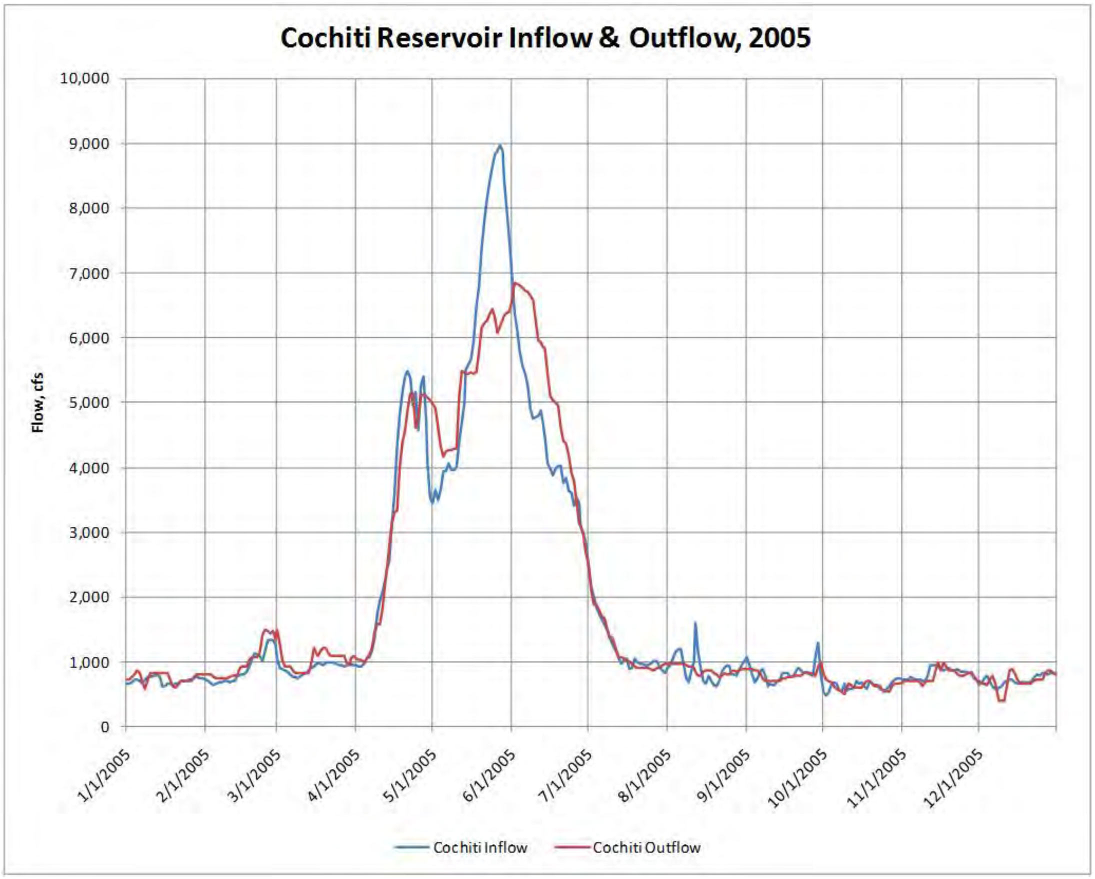

Figure 29. Comparison of inflow to and outflow from Cochiti Reservoir, 2005, showing flood control operations.

Figure 30 shows the inflow to and outflow from Abiquiu Reservoir over the past decade. The designated safe channel capacity below Abiquiu Dam is only 1,500–1,800 cfs, due to capacity restrictions in the reach directly below the dam, as well as the presence of numerous rock and brush diversions in the vicinity of Chamita (Corps 1996 [Water Control Manual]). The effects of flood operations, therefore, are more apparent on the hydrograph, and can be seen in 2001, 2004, 2005, 2008, 2009, and 2010. These flood control operations prevent the flows on the Rio Chama from significantly contributing to overbank or recruitment flows in the MRG.

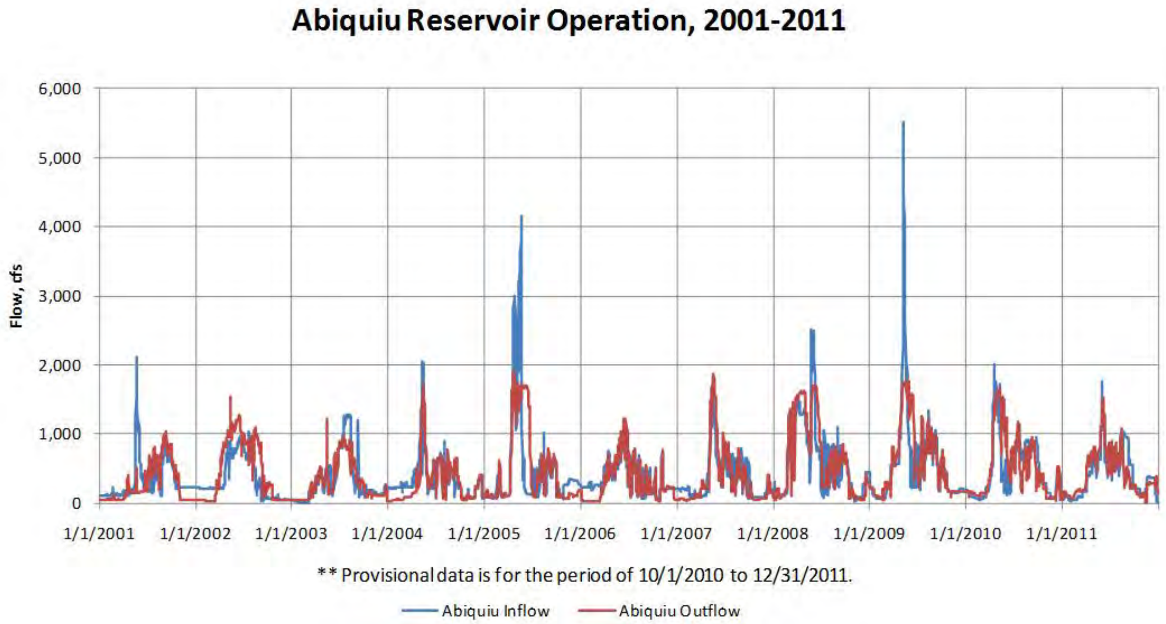

Figure 30. Comparison of inflow to and outflow from Abiquiu Reservoir, 2001–2011, showing flood control operations in 2001, 2004, 2005, 2008, 2009, and 2010.

5.4.1.5 Santa Fe's Buckman Direct Diversion

The city and county of Santa Fe use their SJC Project allotments and native Rio Grande water to support their water supply utilities through the Buckman Direct Diversion Project (Buckman Project). The Santa Fe National Forest, in concert with the city and county of Santé Fe, consulted with the Service (Consultation #22420-2006-F-0045) on the construction and operation of this project. The Service identified reasonable and prudent measures (RPM) that would minimize the incidental take resulting from this project and determined that this action, along with the proponents' environmental commitments and the Service's Reasonable and Prudent Measures, likely would not jeopardize the continued existence of the silvery minnow and will not adversely modify its designated critical habitat (Service 2007c).

The city and county of Santa Fe have initiated, under the Buckman Project, direct use of their 5,605 AFY allocation of SJC Project and native Rio Grande water to supplement their other water supplies. The partners have been diverting water to the Buckman Project from the Rio Grande since January 2011. Performance and acceptance testing was performed in April 2011, and operation was turned over from the design and construction contractor to the city, as the current project manager, for full operations in May 2011.

The current Record of Decision from the Buckman Project Environmental Impact Statement allows the Buckman Project to divert an annual average diversion of 12.06 cfs, which includes 7.75 cfs of SJC Project water and 4.31 cfs of native Rio Grande water. The Buckman Project's peak day capacity is 28.2 cfs. Additionally, up to 4 cfs of carriage water is diverted and is returned to the river, along with diverted river sediment, immediately downstream from the diversion structure. The Buckman Project is intended to divert water year-round.

Consistent with the terms of the ESA consultation, the Buckman Project will curtail diversions of native water at times when the native Rio Grande flow at Otowi gage is less than 325 cfs and will cut off all diversions of native water if the native Rio Grande flow at Otowi gage is less than 200 cfs. Curtailment when Otowi flows are between 200 and 325 cfs will be scaled by linear interpolation. Under these conditions, the project still can divert its allocation of SJC Project water. When Abiquiu Reservoir is under flood operations, the Buckman Project will not call for release of its SJC water from upstream reservoirs and instead use either native Rio Grande water or exchange and divert SJC water stored in Elephant Butte. Additional environmental commitments associated with the construction and operation of this project, which include restoration, maintenance, and monitoring of riparian and riverine habitat, are spelled out in the Record of Decision for the project, found at http://www/bddproject.org/reports.htm.

5.4.1.6 Cochiti Deviations

In 2007, the Rio Grande Compact Commission approved deviations from the Corps' normal reservoir operation schedule (as specified in its Water Control Manual) to support minnow spawning and recruitment. Such deviations from normal operations were implemented in 2007 and 2010, in coordination with the Service and Federal and non-Federal water management agencies. Such deviations from normal operations of Cochiti Dam to support overbank or recruitment flows have been approved by the Corps and, therefore, may be implemented as deemed appropriate, through 2011, with the option of a 2-year extension to 2013. The Corps has completed consultation with the Service under Section 7 of the ESA for Cochiti deviations and is operating pursuant to its biological opinion.

During a "Cochiti deviation," waters on the ascending limb of the spring runoff hydrograph are held back and temporarily stored in Cochiti Lake in an amount sufficient to allow the desired discharge volume and duration during peak flows when these waters are released. In this way, the Corps is authorized to temporarily store up to 10,000 AF of water in Cochiti Reservoir.

A deviation was implemented in 2007 to create a minnow spawning and recruitment flow of over 3,000 cfs, as measured at the Central Avenue (Albuquerque) gage, for a period of 7–10 days. The deviation operations produced an extended peak runoff flow resulting in 26 days above 2,500 cfs and

10 days above 3,000 cfs at Albuquerque. In 2010, a deviation was implemented to achieve an overbank flow of 5,800 cfs at the Central Avenue gage for 5 days. However, only a 2-day overbank flow of this magnitude was achieved. Annual hydrographs displaying the effects of the 2007 and 2010 Cochiti deviations are presented in figures 31 and 32.

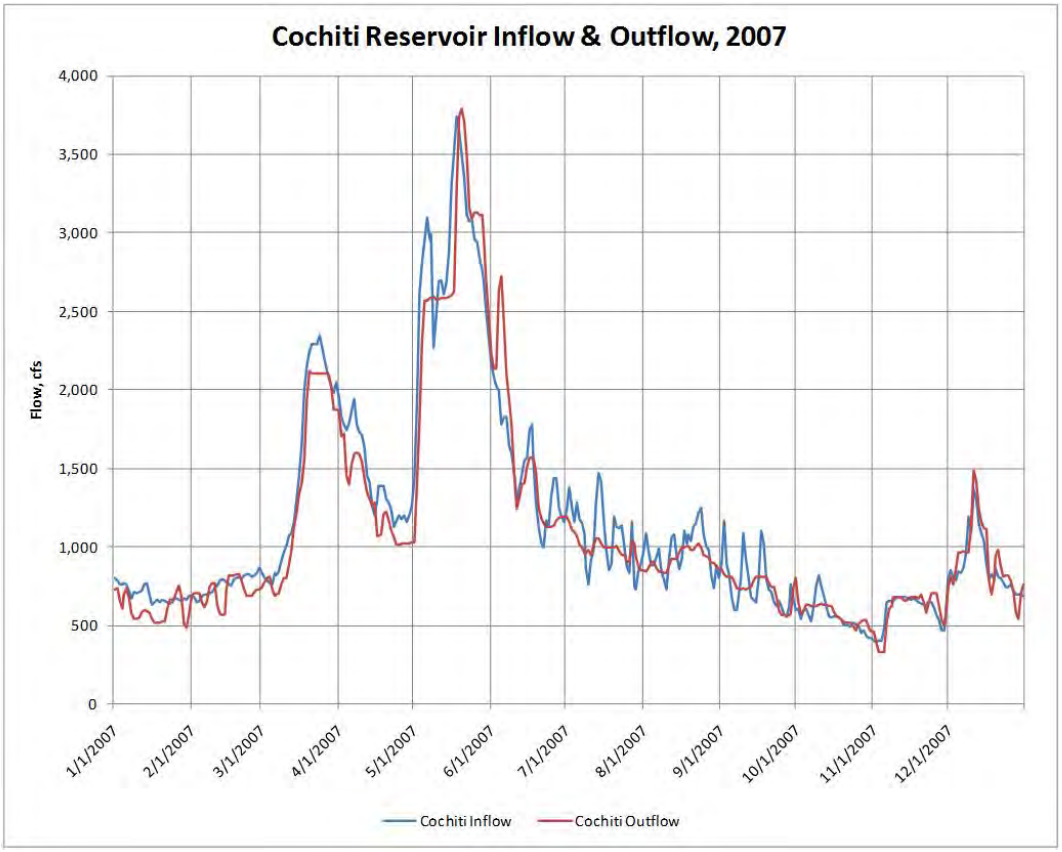

Figure 31. Comparison of inflow to and outflow from Cochiti Reservoir, 2007, showing the effects of “Cochiti deviation” operations.

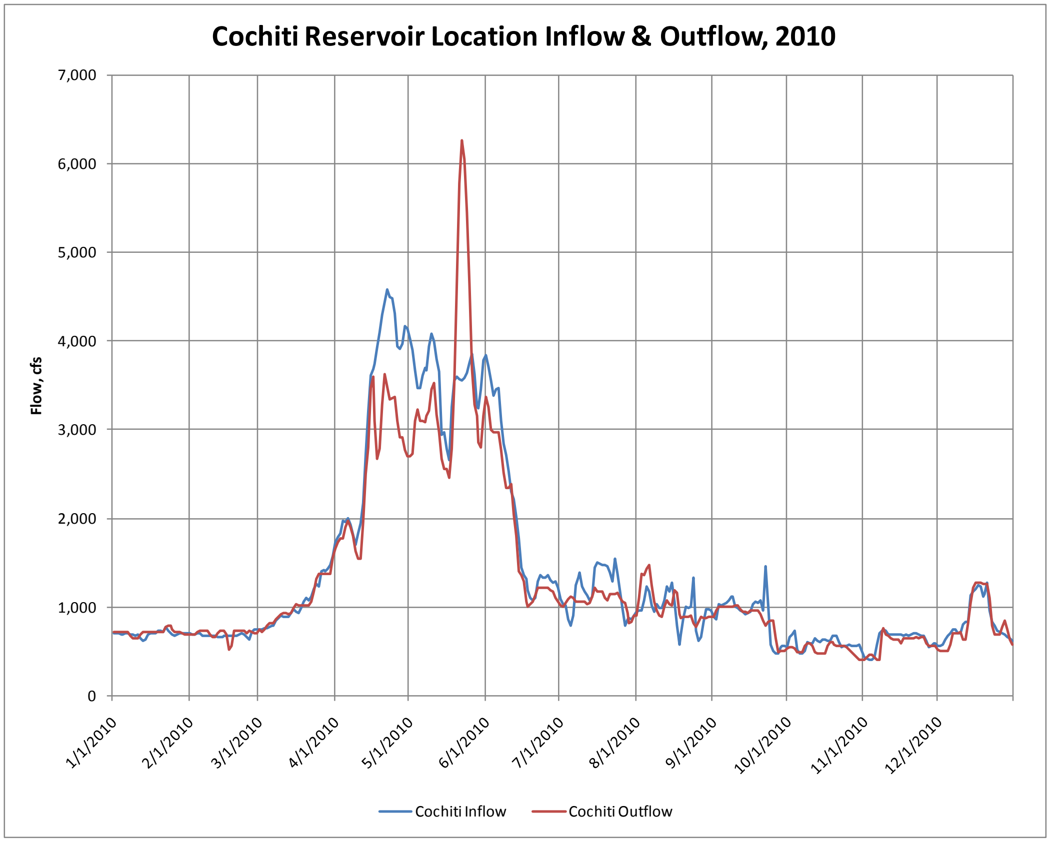

Figure 32. Comparison of inflow to and outflow from Cochiti Reservoir, 2010, showing the effects of "Cochiti deviation" operations.

5.4.1.7 Ground Water

Since the 1940s, population growth, combined with technological improvements in well drilling and pumping, have led to dramatic increases in ground water pumping in the MRG, primarily for domestic, municipal, and industrial use (McAda and Barroll 2002). As of 1999, it was estimated (Bartolini and Cole 2002, after MRG Water Assembly, 1999) that 170,000 acre-feet per year are pumped from the river-connected aquifer in the MRG, up to 110,000 of which were pumped by the ABCWUA for use in Albuquerque and Bernalillo County (ABCWUA 2010 [accessed March 2011]), although ABCWUA has now cut back that pumping to near half that amount, as it phases in use of its SJC Project water. This pumping has caused ground water drawdowns of up to 160 feet in some areas of Albuquerque (McAda and Barroll 2002). Ultimately, the water pumped is made up for by seepage from the river into the ground water system. Recharge from the river to the aquifer through the MRG was estimated in 1999 to total 295,000 acre-feet per year.

The NMOSE has calculated the depletions caused to the river by ground water pumping, and requires that the entities who do the pumping replace the water volume to the system, including the river and other affected users, through return flows, the purchase of water rights, or repayment of the water from upstream storage using SJC Project water.

The NMOSE provides Reclamation with letters describing, for each pumper, the time period of depletions from the river, the volume of water depleted from the river, and a deadline for the pumpers to release SJC Project water to replace that which was lost from the river and was not offset through the purchase of water rights or through return flows to the river. The depletions are described by the NMOSE as cumulative effects on Elephant Butte Reservoir (and, therefore, to New Mexico's deliveries under the Compact) due to depletions above and/or below the Otowi gage and cumulative effects on the Rio Grande in the MRG above and/or below the Otowi gage. Depletions that occur during the irrigation season are considered effects on the MRG and are replenished by releases to the MRGCD, which has the right to divert that flow. Depletions that occur outside of the irrigation season are considered effects on Elephant Butte Reservoir and are replenished to the Rio Grande.

The replacement SJC Project water requested by the NMOSE is released from reservoirs on the Rio Chama. If the depletion is deemed to have affected the MRGCD, the MRGCD can request to have the water stored or released to the Rio Grande for use in irrigation. If the depletion is deemed to have affected Elephant Butte Reservoir, the water is released to the Rio Grande, to be delivered to Elephant Butte Reservoir. Reclamation has received letters from the NMOSE requesting releases to replace water depleted over the current, previous, and sometimes 3 previous years. The depletions occur gradually and are replaced by an equivalent volume over a short period, typically 1–10 days. These short duration replacements typically occur months to years after the depletion. Total volumes of the depletions made up through "letter-water" deliveries of SJC Project water over the 2001–2010 period ranged from 1,000–7,000 AFY. At the end of 2010, the State Engineer requested releases for the following contractors to offset 2009 depletions: 93 AF for the city of Espanola, 161 AF for the village of Los Lunas, 13 AF for the town of Taos, 6 AF for village of Taos Ski Valley, 47 AF for the city of Belen, and 2,024 AF for the ABCWUA.

5.4.1.8 Water Right Transfers

As discussed in section 3, the NMOSE has jurisdiction over water rights administration in New Mexico, and water rights are alienable private property rights that can be conveyed like other property rights. The majority of water rights sold in the MRG have been purchased by large corporate entities, such as developers or the cities of Rio Rancho and Albuquerque. Other purchasers include some primary income farmers who purchase water rights or additional agricultural land to expand operations, as well as private entities involved in water intensive activities, such as residential developers, utilities, and technology. The transfer of land and water from agricultural to urban uses in the MRG was modeled by Sandia National Laboratory in November 2004 (Sandia Report 2004). Analyzing trends in water rights transfers is difficult because data is not readily available, accurate or up to date (Sandia Report 2004).

The aquifer in the MRG, consisting of Santa Fe Group and younger alluvial deposits, is known to be hydrologically connected to the Rio Grande surface water system. Since ground water diversions from aquifers hydrologically connected to the Rio Grande affect the fully appropriated surface flow, the NMOSE conjunctively manages the water resources within the MRG Basin. On September 13, 2000, the NMOSE established guidelines for the Middle Rio Grande Administrative Area (MRGAA);(NMOSE 2000) to ensure compliance with the Compact, to prevent impairment to existing rights, to limit the rate of decline of ground water levels so that the life of the aquifer is extended, and to minimize land subsidence.

The guidelines embody NMOSE's existing practice for evaluating applications for permits for ground water use in the MRGAA and recognize that offsetting the effects of ground water diversions is critical to the conjunctive management of water resources within the MRG stream system. Accordingly, the guidelines provide that permitted ground water diversions shall be limited to the amount of valid consumptive use surface water rights held and designated for offset purposes by the permittee plus any NMOSE-approved flow returned directly to the Rio Grande. As mentioned above, the use of offsets or return flows replaced the depleted surface water in volume but does not restore the timing of flows in the river.

5.4.1.9 Water Management to Meet the Needs of the Six Middle Rio Grande Pueblos

The Six MRG Pueblos (Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta) hold aboriginal, time immemorial, reserved, and, in some instances, contract water rights that are recognized and protected under Federal law. A certain portion of their water rights is statutorily recognized under the 1928 Act and the Act of 1935, 49 Stat. 887 (1935 Act). Water rights have been statutorily recognized for 20,242.25 acres, comprised of 8,847 acres of prior and paramount lands, 11,074.4 acres of newly reclaimed lands, and 320.65 acres of lands purchased by the United States pursuant to the Pueblo Lands Act of 1924 (43 Stat. 636). The 1928 Act also recognizes a prior and paramount right to water for domestic and stock purposes. These Acts of Congress do not establish the full extent of the water to which these Pueblos are entitled, and references to the Pueblos' "prior and paramount" rights under these Acts are not intended to suggest that the Pueblos do not have other water rights in the MRG or tributaries that are senior to other water uses in the system.

Reclamation engages in water operations to serve the water rights of the Six MRG Pueblos recognized by the 1928 Act and the 1935 Act. Each year over the past three decades, Reclamation has stored water in El Vado Reservoir to ensure an adequate supply of prior and paramount water for the Six MRG Pueblos pursuant to the 1981 Agreement. The BIA Designated Engineer and Reclamation have calculated the quantity of water to be stored at El Vado Reservoir for prior and paramount irrigation needs, based on the gap between the forecasted demand for the 8,847 acres of lands and the anticipated available supply of the river. The Coalition of the Six MRG Pueblos has then directed the Designated Engineer to request that Reclamation release the stored water according to the schedule provided by the Pueblos. This stored water has been, or is intended to be, delivered to the Pueblos by the MRGCD through downstream diversions.

A summary of the water stored for the prior and paramount rights and released annually since 2002 is provided on figure 33. During a number of the years in the past decade, water was stored for prior and paramount uses during years with Article VII storage restrictions in place under the Rio Grande Compact. Unused prior and paramount water in El Vado that was stored when Rio Grande Compact Article VII restrictions were in place was released for delivery to Elephant Butte Reservoir after the irrigation season, usually in November or December. This water is shown as released to Elephant Butte Reservoir in figure 33. Unused prior and paramount water stored in El Vado outside of Article VII storage restrictions was retagged as native Rio Grande water and is shown in figure 33 as being released to the Rio Grande account. Water shown as released to the MRGCD is water released for irrigation beyond the requirements of the prior and paramount rights.

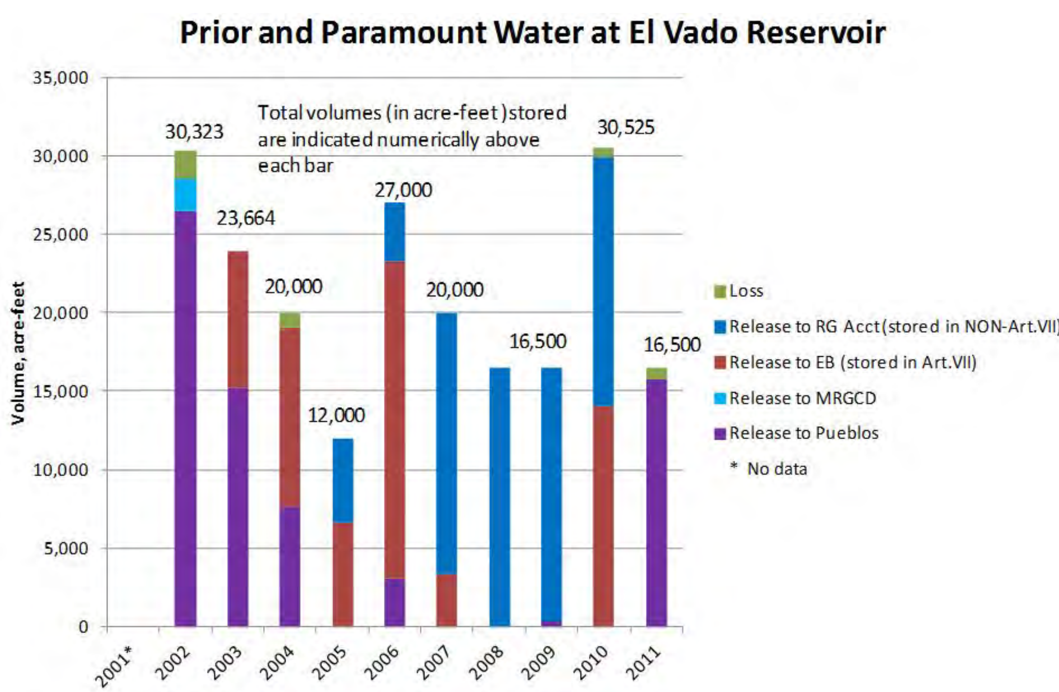

Figure 33. Summary of prior and paramount water stored in and released from El Vado Reservoir for irrigation of lands.

5.4.1.10 MRGCD Operations

Early in the decade, an extensive effort was undertaken by the NMISC, the New Mexico Water Trust Board, Reclamation, and the MRGCD to increase the MRGCD's water management efficiency and decrease the MRGCD's irrigation diversions, especially during water-short periods. Progress was made through infrastructure and metering improvements and through improvements in irrigation-system operations, such as the implementation of rotational water delivery and the development of a Decision Support System to model demand within the network and develop efficient water delivery schedules. The following figure 34 shows the effects of these improvements. Total MRGCD diversions during the 1990s were approximately 600,000 AF; but after 2001, typical total MRGCD diversions ranged from 300,000 to 400,000 AF.

These operational improvements have the effect of leaving more water in the river during periods of high native flow on the main stem. They also have the effect of extending the irrigation season during dry years by extending the availability of stored water in El Vado Reservoir. During dry times, water released from El Vado Reservoir for Middle Rio Grande irrigation supports river flows throughout the MRG, especially in the Albuquerque Reach. Therefore, extending the length of the irrigation season measurably decreases the Supplemental Water required to meet MRG ESA flow targets.

Figure 35 breaks down the diversions by MRGCD division. This breakdown shows that the largest diversions occur at the Isleta diversion structure for the Isleta division of the MRGCD. These diversions at Isleta also support the San Acacia division, which receives the tailwater from the Isleta division.

These diversions are made primarily during the summer months. The monthly average of diversions over the past decade is shown on figure 36.

MRGCD return flows are also an important part of the irrigation system and river operations. District management of return flows provides regularly wetted conditions downstream from the outlets of wasteways. MRGCD return flows can strategically release water to key reaches during low flow or drying periods in the Albuquerque or Isleta Reaches (the return flows in the San Acacia Reach return to the LFCC rather than to the river).

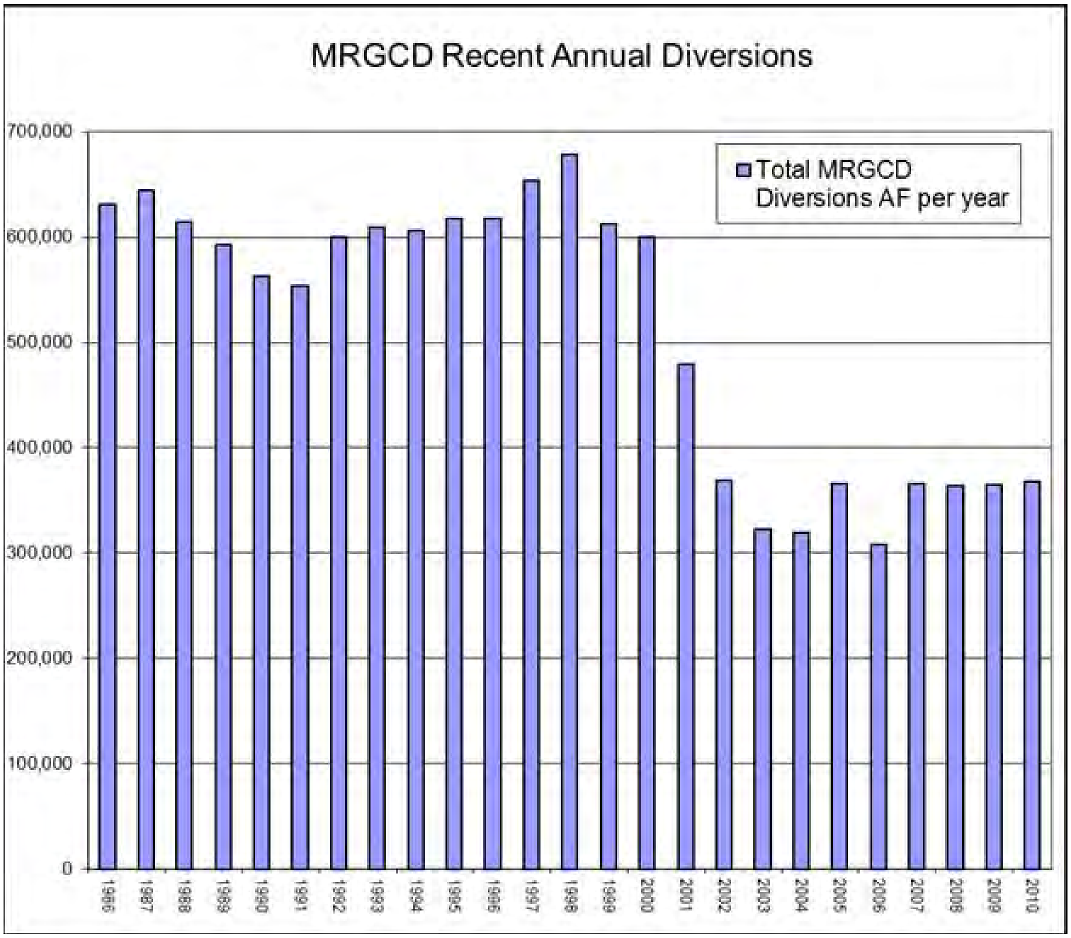

Figure 34. Summary of total water diversions by the MRGCD, 1996–2010.

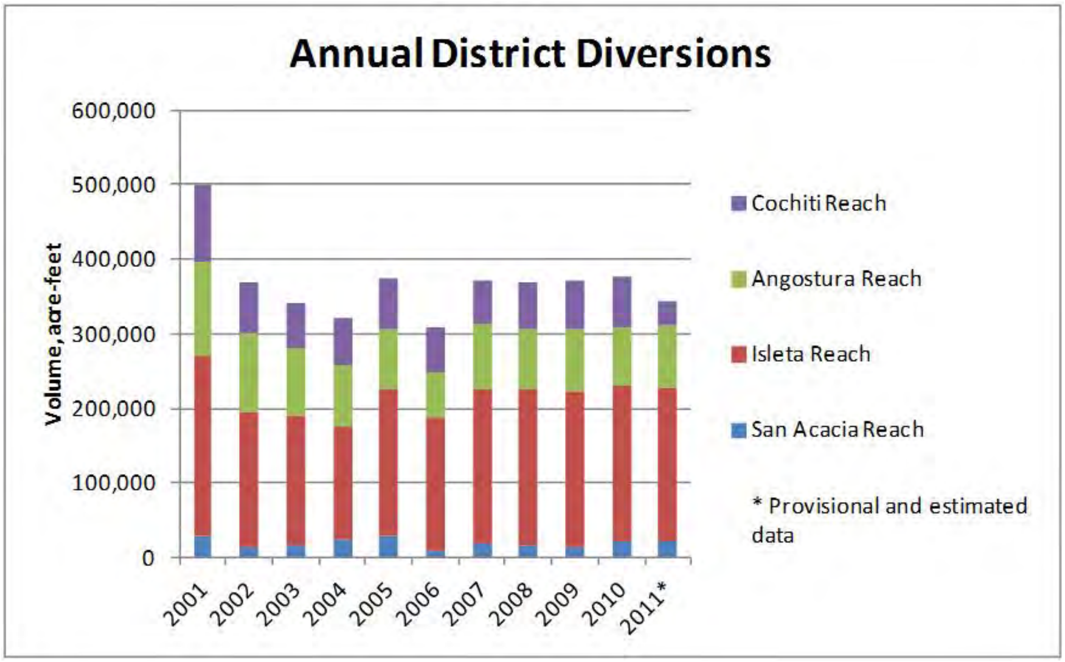

Figure 35. Summary of annual diversions from the Rio Grande to the MRGCD at the four MRG diversions structures.

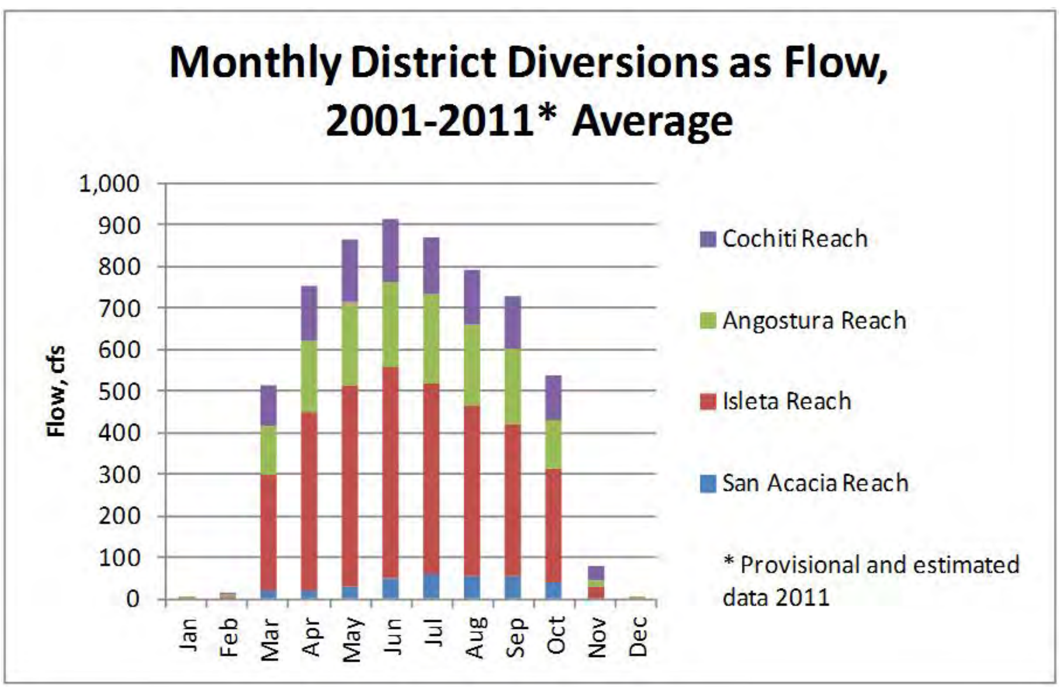

Figure 36. Monthly breakdown of average annual diversions to the MRGCD at the four MRG diversion structures, 2001–2011.

The following figures, figures 37 and 38, show the monthly average return flows from wasteways in the Albuquerque and Isleta Reaches, which enter the river from the left side (left descending bank, which is the right side as you look at a map with north at the top) or the right side (right descending bank, which is the left side as you look at a map with north at the top). It can be seen on these figures that some wasteways release water from drains, which collect ground water that is used both to supplement irrigation supplies and to return water to the river. These wasteways have higher discharge rates in the winter and lower discharge rates in the summer. Other wasteways discharge water from canals that collect tailwater from irrigation. Returns from these wasteways are lower in the winter and higher during the irrigation season.

The first graphs in each set present average wasteway and drain returns for the baseline period without 2003. The later graphs in each set present 2003 alone. 2003 stands out as the year during which the MRGCD most fully applied rotational water delivery to the laterals within its system. The difference between the graphs showing 2003 releases and those showing average releases during the other years highlights the tradeoffs between MRGCD operational efficiency, as is apparent in 2003, and the incidental benefits provided by less efficient system operation, including wasteway returns that support flows in critical reaches.

Legend for figures 37 and 38

240WW	340 Feeder Wasteway		LP1DR	Lower Peralta Drain Outfall #1
ALJWW	Alejandro Wasteway		LP2DR	Lower Peralta Drain Outfall #2
ARSDR	Albuquerque Drain Outfall		LSJDR	Lower San Juan Drain Outfall
ATRDR	Atrisco Drain Outfall		PERWW	Peralta Wasteway
BELDR	Belen Drain Outfall		SABDR	Sabinal Drain Outfall
CENWW	Central Avenue Wasteway		SANWW	Sandia Lakes Wasteway
CORWW	Corrales Wasteay		SFRDR	San Francisco Drain Outfall
FD3WW	Feeder 3 Wasteway		SILWW	Sile Main Wasteway
HAYWW	Haynes Wasteway		STYWW	Storey Wasteway
LCRDR	Lower Corrales Drain Outfall		UCRDR	Upper Corrales Drain Outfall
LJYDR	La Joya Drain Outfall		UN7WW	Unit 7 Wasteway

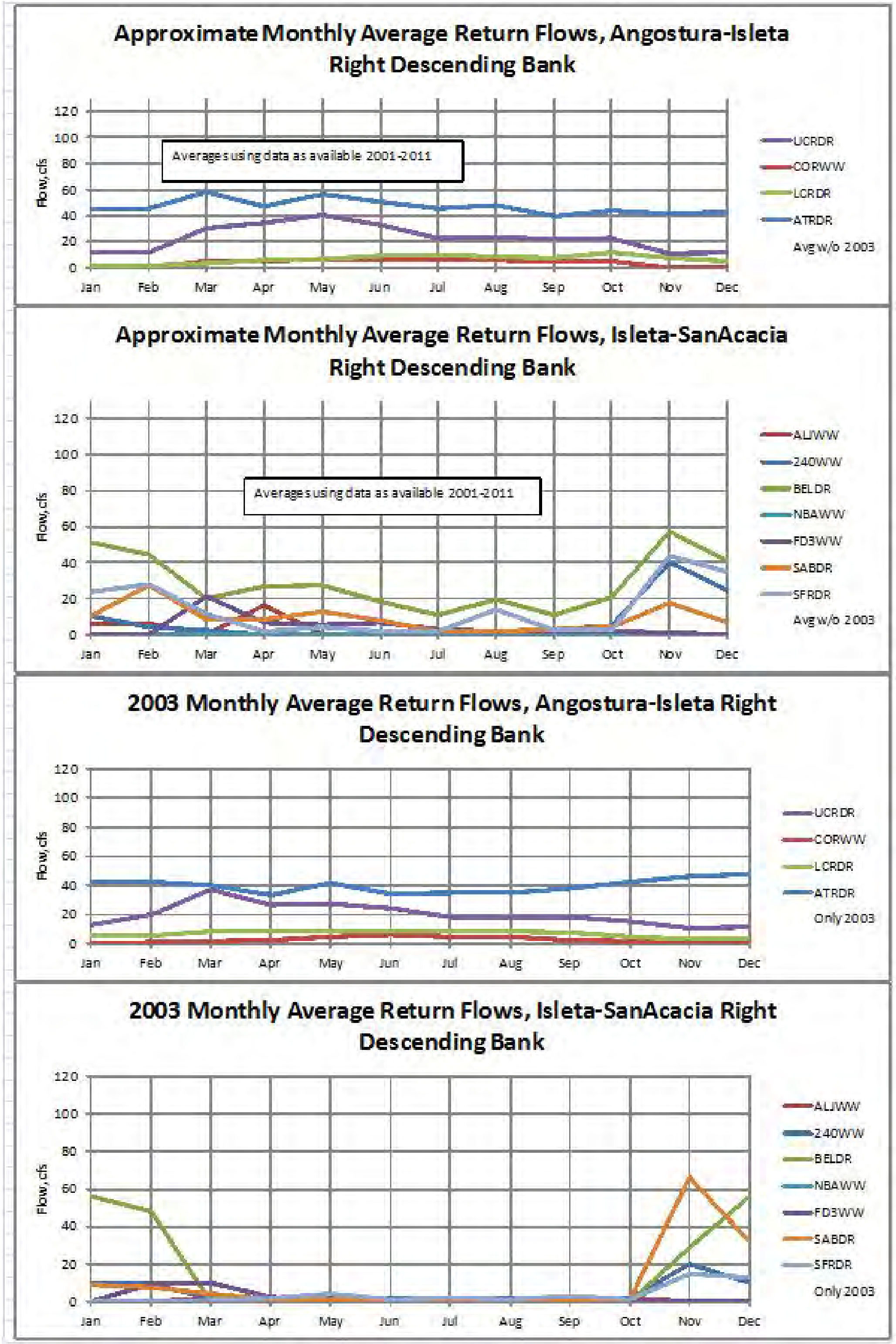

Figure 37. Summary of average district drain and tailwater returns to the Rio Grande, by month, 2001–2011, right descending bank.

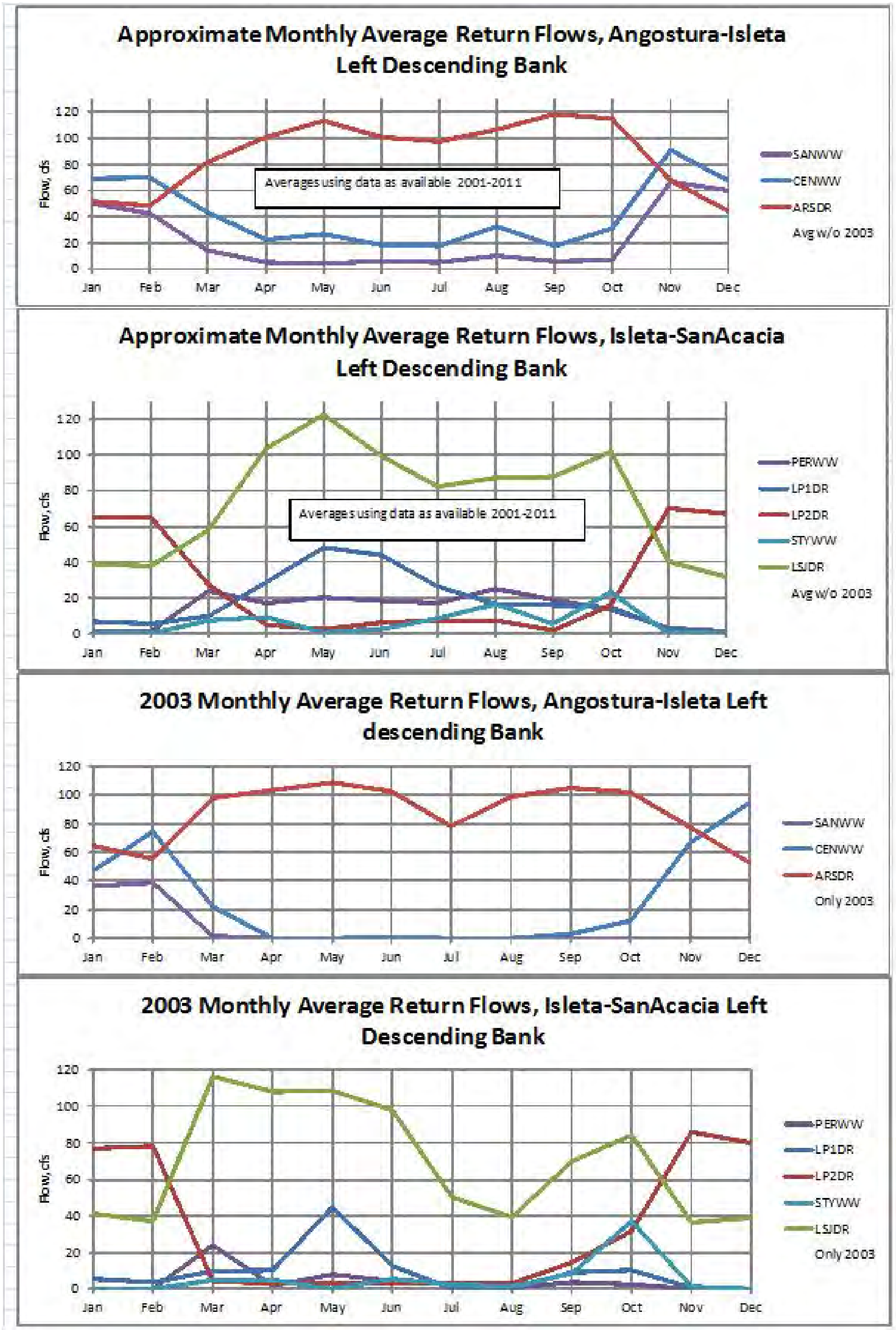

Figure 38. Summary of average district drain and tailwater returns to the Rio Grande, by month, 2001–2011, left descending bank.

5.4.1.11 *Albuquerque Bernalillo County Water Utility Authority Drinking Water Project*

The ABCWUA's primary use of SJC Project water is to support its Drinking Water Project in Albuquerque. After taking delivery of its SJC Project water from Heron Reservoir, the ABCWUA manages the majority (approximately 94%) of the 180,000 AF that can be stored at Abiquiu Reservoir for this water.

In 2004, Reclamation, in concert with ABCWUA, consulted with the Service under ESA, Section 7, on this project (Consultation #2-22-03-F-0146). The Service determined that this action, along with the proponent's environmental commitments and the RPM associated with the consultation, likely would not jeopardize the continued existence of the silvery minnow and would not adversely modify its designated critical habitat (Service 2004).

Until 2008, the city of Albuquerque's and Bernalillo County's potable water supplies were provided exclusively from ground water, which was pumped from the alluvial and colluvial aquifer filling the Albuquerque basin. The impact on the river of this extensive ground water pumping has been made up to the MRGCD and to New Mexico's delivery of water to Elephant Butte under the Compact through annual "letter-water" releases from Albuquerque's allotment of SJC Project water, as described generally above. Furthermore, the ground water pumping that is foreseen as a component of ABCWUA's Drinking Water Project is covered under the consultation for the Drinking Water Project described above.

The now-combined municipal supplier, ABCWUA recently has initiated use of its allocation of SJC Project water for urban uses and drinking water supply through implementation of its Drinking Water Project. Over the past 4 years, ABCWUA has been phasing in the diversion of surface water for municipal supply and the diversion of nonpotable water from a collection gallery beneath the river. The intent is for ABCWUA to conjunctively use ground water and surface water for its future municipal supply, and for its SJC Project allocation to make up the majority of the consumed water, which is typically about half of the total amount of water pumped or diverted. Figure 39 shows the total drinking water supply to the city and county, the total nonpotable supply over the past 10 years, and its distribution between ground water and surface water. It can be seen on this figure that the total potable water supply to the city is typically between 100,000 and 110,000 AFY. The figure further shows that use of the SJC Project water as a portion of that supply began at a testing level in 2008 and increased to over 40,000 AFY by 2010. Diversion of SJC Project water to the nonpotable water system began in 2003 and continued through the decade at up to 2,500 AFY.

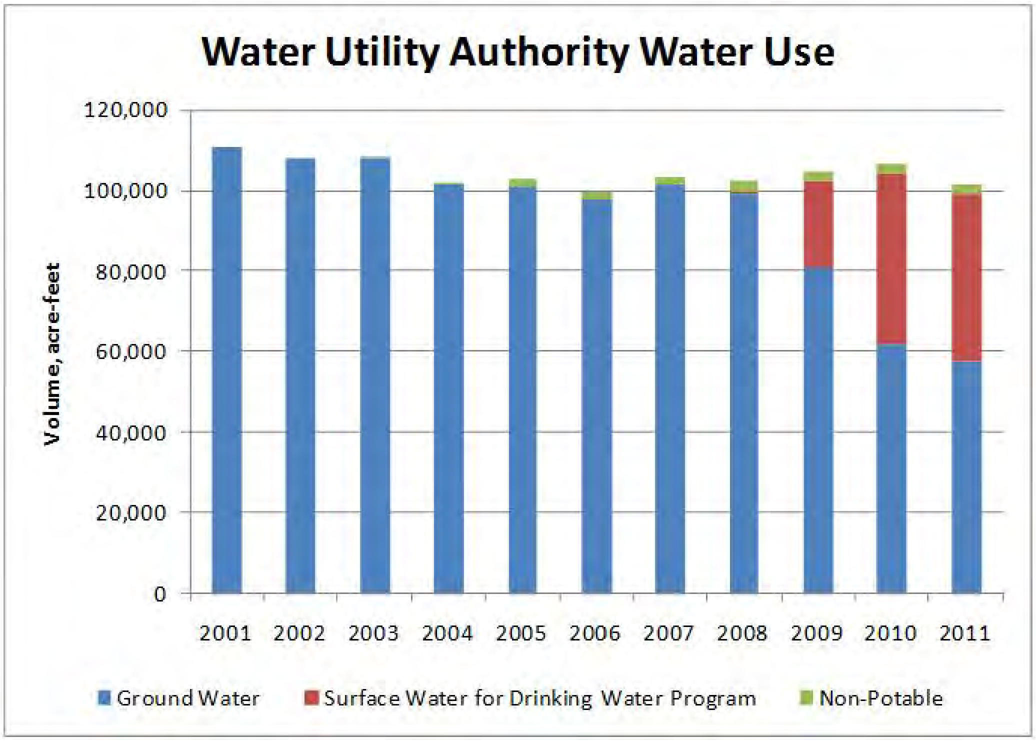

Figure 39. Gross municipal supply, including ground water and surface water contributions to the drinking water supply and nonpotable supply, to ABCWUA, 2001–2011.

Since the ABCWUA began diverting its SJC Project allotment from the Rio Grande, release of this SJC Project water from upstream storage has supplemented river flows on the Rio Chama and the Rio Grande from the Rio Chama confluence downstream to the ABCWUA's diversion structure between the Alameda Boulevard and Paseo del Norte crossings in Albuquerque. The city's diversion includes its SJC Project water allotment plus an approximately equal amount of native water, which is returned to the river downstream, at the outflow from the Albuquerque Wastewater Treatment Plant. The total amount of water returned to the river at the Albuquerque Wastewater Treatment Plant outfall, 16 river miles downstream, is summarized on figure 40.

ABCWUA's diversion of native water along with its SJC Project water decreases flows in the 16-mile reach from the diversion downstream to the wastewater treatment plant return flow. This reach includes the Albuquerque/Central Avenue gage, a key flow target location in the 2003 BiOp; therefore, operation of the drinking water project has the potential to affect how flow targets are met at this gage. For this reason, ABCWUA committed, through its ESA consultation, to curtail its diversions when native flows in the Rio Grande at the point of diversion drop below 195 cfs, and suspend diversions completely when these flows drop below 130 cfs, or when the flow at the Albuquerque gage (Central Avenue) drops below 122 cfs.

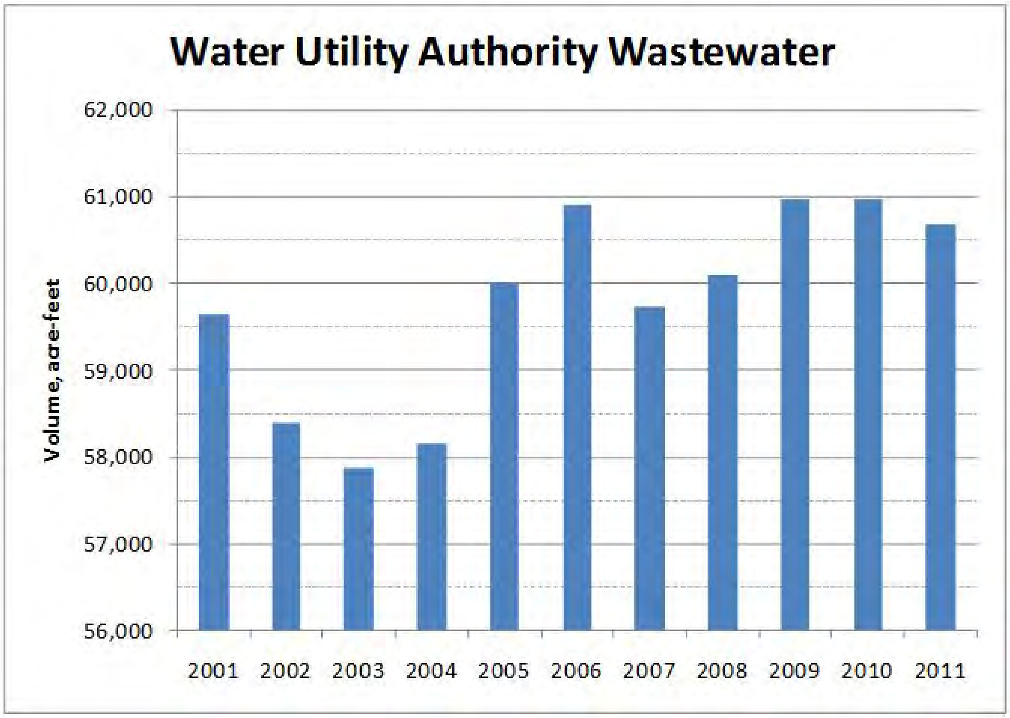

Figure 40. Summary of return flows from the Albuquerque Wastewater Treatment Plant, 2001–2011.

ABCWUA also curtails its diversions during high flows, when the turbidity gets high. As previously noted, the use of Albuquerque's supply of SJC Project water for urban uses and drinking water decreases the supply of water available to Reclamation for its Supplemental Water Program.

ABCWUA's obligation to make up for the effects on the river of past ground water pumping (discussed in section 5.4.2.6 above) continues, even if the majority of the current demand is met with surface water. For this reason, ABCWUA must continue to provide a portion of its SJC Project allotment, or native water for which it has rights, to the river for use by the MRGCD or for delivery to Elephant Butte under the Compact.

5.4.1.12 Bosque del Apache National Wildlife Refuge Operations

The Service manages the Bosque del Apache National Wildlife Refuge and is operating pursuant to a completed internal ESA consultation (Service 2001). The Service possesses 12,417 acre feet per annum of senior surface water rights to support its irrigation and wildlife (mainly bird) management activities in the lower portion of the San Acacia Reach. A portion of this water is obtained during the irrigation season from tailwater from the MRGCD irrigation network. The majority of the BDANWR's supply is from direct diversions from the LFCC at the north boundary of the refuge and at a second point in the middle of the refuge.

These diversions can decrease the availability of water to Reclamation's LFCC pumping program.

Water use for irrigation occurs mainly during the summer months. Irrigation on the refuge uses water from both MRGCD tailwater and LFCC diversions. The refuge differs from most other water users in the Middle Rio Grande Valley in that a significant portion of its diversions occurs in the winter to support ponded habitat. The water source available for these purposes in the winter is the refuges diversions from the LFCC.

Figure 41 summarizes the water consumption of the BDANWR, broken down by year and by season. The refuge also passes substantial amounts of water through its water distribution network that is returned at the south boundary of the refuge. This water is not portrayed in these consumption tallies.

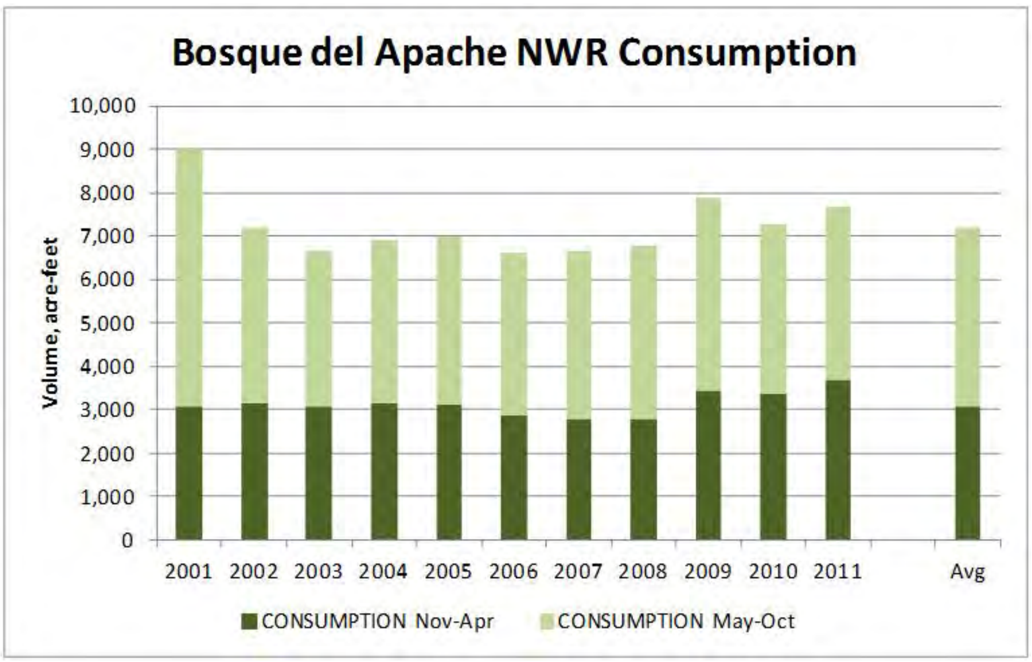

Figure 41. Seasonal breakdown of water consumption within the Bosque del Apache National Wildlife Refuge.

When water supplies are short, water from the LFCC cannot fully meet the needs of both the refuge diversion and LFCC pumping under Reclamation's Supplemental Water Program. In its ESA consultation (Service 2001), the refuge concluded that it would contribute up to 10% of its water supply to support endangered species needs when necessary. In several instances during the time period of operations under the 2003 BiOp when river conditions were in danger of violation of the flow targets in the 2003 BiOp, the refuge has decreased its diversions from the LFCC to allow more water to be available to Reclamation's

Supplemental Water Program to avoid violating the continuous flow requirements of the 2003 BiOp.

5.4.2 Current Hydrologic Conditions

This section summarizes the hydrologic and administrative (i.e., Article VII restrictions under the Compact) conditions over the past decade.

5.4.2.1 Article VII Status and Credits under the Rio Grande Compact

As described in the previous section, Article VII of the Compact restricts storage in upstream reservoirs constructed after 1929 if there is less than 400,000 AF of usable storage for the Rio Grande Project in Elephant Butte and Caballo Reservoirs. Article VII storage restrictions were in place for a majority of the period covered by the 2003 BiOp. These storage restrictions helped Reclamation achieve flow requirements since, as described above, years are classified as "dry" under the 2003 BiOp if the Article VII storage restrictions are in place at the beginning of the spring snowmelt runoff (April 1). Years classified as "dry" under the 2003 BiOp had lower flow requirements and a longer period in which drying is permitted than was authorized for years with "average" or "wet" classifications. The recent recurring periods when storage restrictions per Article VII were in place came after a long period, from 1978–2002, in which storage restrictions were never in effect. Figure 42, below, shows New Mexico's Article VII status from 1978–2010.

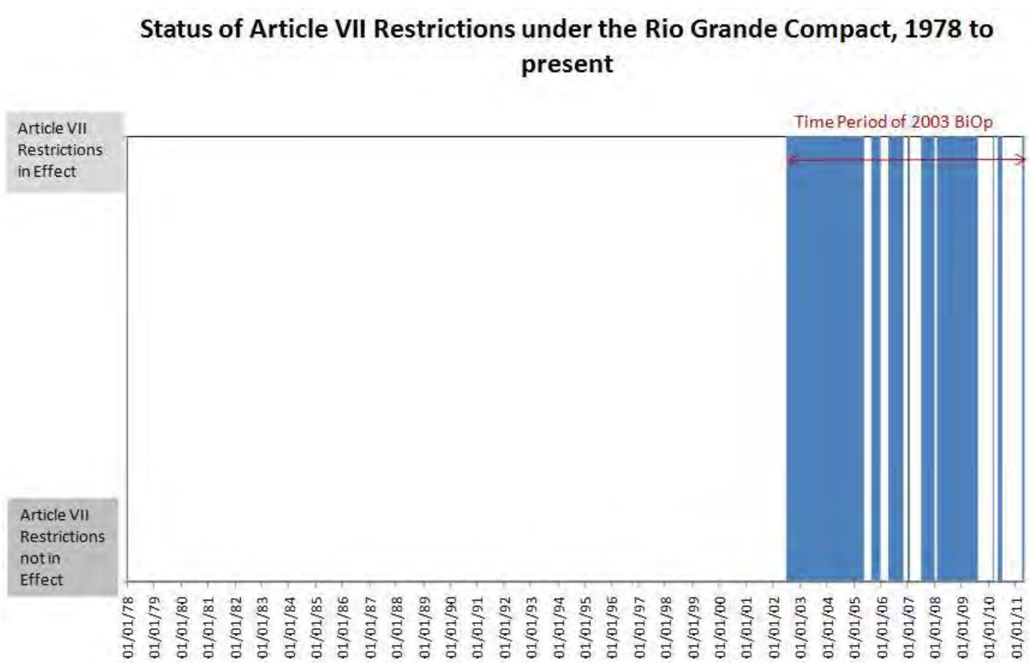

Figure 42. Article VII status under the Rio Grande Compact, 1978–2011.

During the period covered by the 2003 BiOp, New Mexico regularly accrued credits under the Compact, because this period did not include any very wet years, and also likely due to channel construction by Reclamation and the State of New Mexico in the headwaters of Elephant Butte Reservoir. In addition, it is possible that Supplemental Water released by Reclamation for ESA purposes, which has been exchanged with a like amount of native water so that it can be passed downstream, contributes to this accrual. New Mexico has relinquished credits several times during this period and has made a portion of this relinquished water available to Reclamation's Supplemental Water Program under the Conservation Water Agreement and the Emergency Drought Water Agreement.

5.4.2.2 Water Year Designation

The 2003 BiOp flow requirements are based on an annual year type designation of "dry," "average," or "wet." The following are the specifications for each of the 3 year-type designations, as described in the 2003 BiOp. "Dry years" are those for which the NRCS April 1 streamflow forecast for the Otowi gage is less than 80% of average, with average determined based on the streamflow at Otowi gage over the 30-year period from 1971–2000. "Dry year" flow requirements also can be invoked for years in which Article VII storage restrictions under the Compact are in effect on April 1. "Average years" are those for which the NRCS April 1 streamflow forecast for the Otowi gage is between 80–120% of average, and Article VII storage restrictions are not in effect. "Wet years" are those for which the NRCS April 1 streamflow forecast for the Otowi gage is greater than 120% of average, and Article VII storage restrictions are not in effect.

These designations are determined based on a combination of the April 1 hydrologic forecast for that year and the administrative conditions—specifically, whether Article VII restrictions under the Compact are in place on April 1. If Article VII storage restrictions are in effect on April 1 in a given year, that year is designated as a "dry" year regardless of the hydrologic conditions. Article VII status determined that 2003, 2004, 2005, 2006, 2007, and 2010 would be dry years, regardless of hydrologic conditions.

Figure 43, below, presents the Article VII status at the beginning of the spring runoff for each of the years in the past decade, and the corresponding water year designation. Since 2001 and 2002 were prior to the 2003 BiOp, they were not classified (another classification was in place under the 2001 BiOp). "Dry year" flow targets were in effect from 2003–2007 due to a combination of dry hydrologic conditions and Article VII Compact restrictions. The highest flow volume of the decade passed the Otowi gage in 2005; but since Article VII restrictions were in effect as a result of low reservoir levels at the end of the drought period, the less stringent "dry year" flow requirements were in place. It was not until 2008 that Article VII Compact restrictions were lifted. Therefore, the more stringent "wet year" flow requirements were in place for that year, but that was the only year in the decade for which they were. "Average year" flow requirements were in place in 2009, and Article VII restrictions returned in 2010, so "dry year" flow requirements were observed. The year 2011 was designated as a dry year based on both Article VII Compact restrictions and an extremely low snowmelt-runoff.

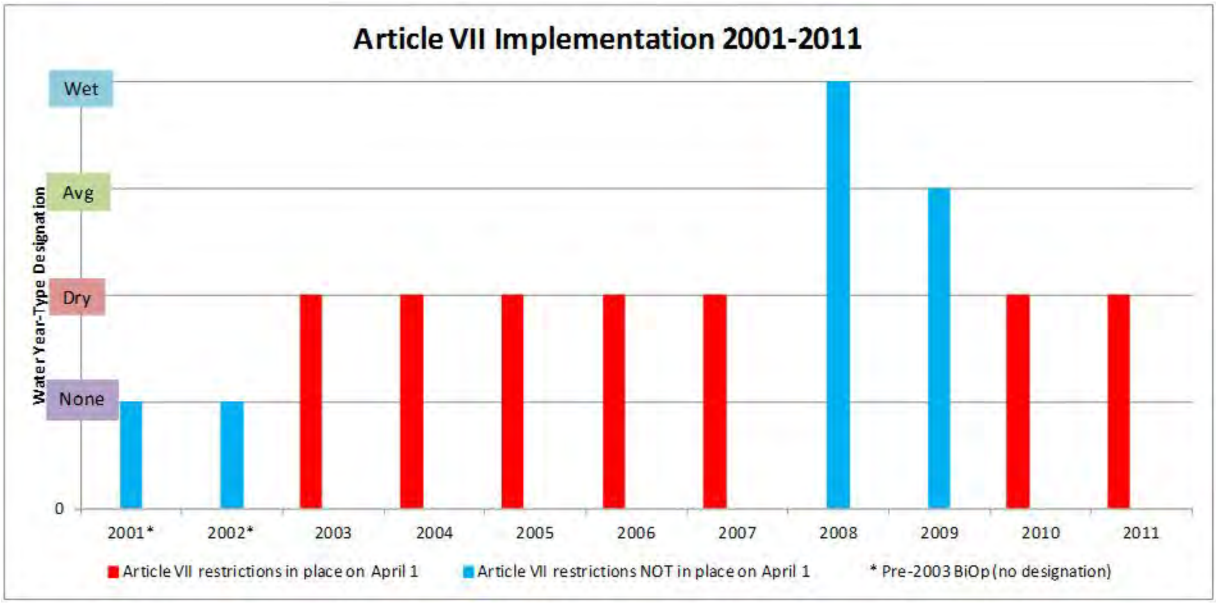

Figure 43. Article VII status under the Compact on April 1 of each year and water year-type designations under the 2003 BiOp, 2003–2011 (not applicable for 2001 and 2002).

5.4.2.3 Hydrologic Conditions Over the Baseline Period.

The first decade of the 21st century began with high reservoir levels at Elephant Butte Reservoir due to a number of high water years in the 1980s and 1990s. The first half of the decade (2000–2004) was characterized by record drought, which diminished those reservoir levels. Beginning in 2005, hydrologic conditions became wetter; however, Article VII storage restrictions, resulting from low Elephant Butte Reservoir levels due to the drought, persisted until 2006 and then recurred several times through the remainder of the decade.

For purposes of this analysis, we have divided the past decade into high volume years and low volume years, based on the total flow passing the Otowi gage that year. The high volume years are defined as those with a total flow past Otowi gage of 800,000 AF or more and include 2005, 2007, 2008, 2009, and 2010. Figure 44, which presents the hydrographs at Otowi gage for these years, reveals a pattern of snowmelt driven hydrographs, with spring pulses between April and June, which are typically bimodal, representing the smaller runoff from the Rio Chama followed by the larger runoff from the Rio Grande main stem, These hydrographs also are characterized by low summertime flows, interspersed with occasional monsoonal spikes.

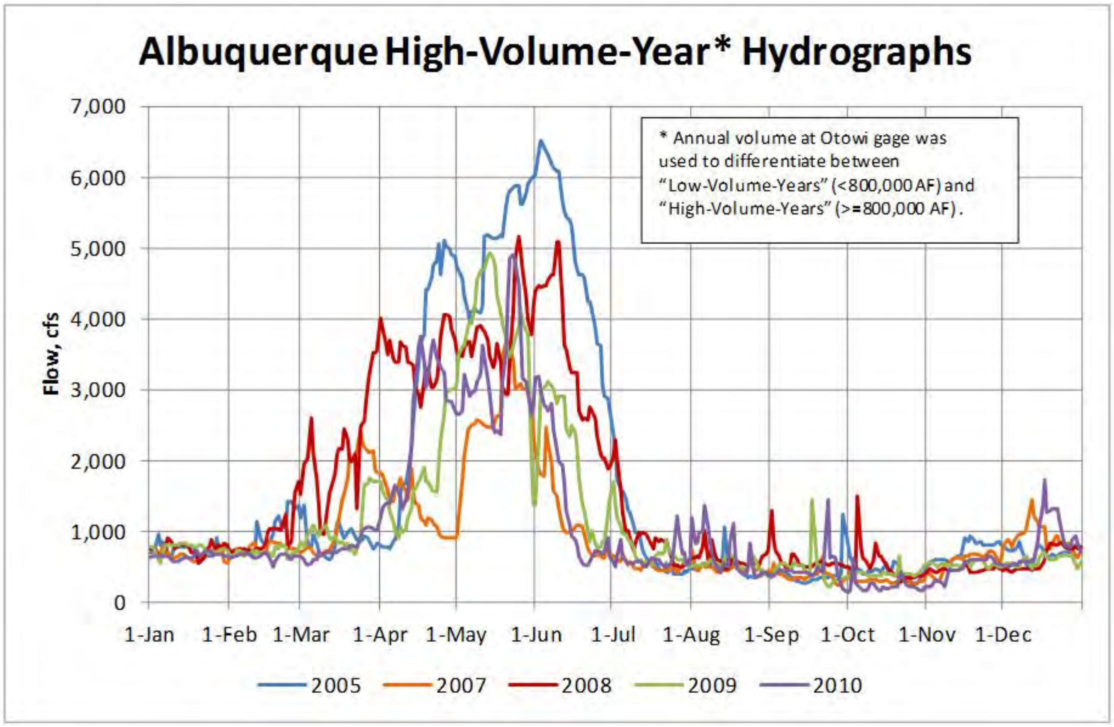

Figure 44. Hydrographs of flows at Otowi gage for the higher volume years during the past decade (2001–2011).

The highest-volume year of the decade was 2005. That year had a very large and long duration spring snowmelt runoff. Starting in mid-July, it had similar flows to the other years and, therefore, would have required significant quantities of Supplemental Waters if it had been designated as a wet year under the 2003 BiOp. However, it was designated as a dry year, since Article VII restrictions under the Compact were in place at the start of the runoff. The years 2008, 2009, and 2010 also had flows in Albuquerque of over 3,000 cfs for a significant period of time. The year 2008 was designated as wet year, and significant Supplemental Water was released to maintain higher summer flows in the Isleta and San Acacia Reaches. In 2007 and 2010, authorized deviations from normal Cochiti Dam operations were used to engineer flow spikes. In 2007, a flow spike of over 3,500 cfs was created in late May. In 2010, a flow spike of 5,800 cfs out of Cochiti Reservoir was created but maintained for only 2 days.

Figure 45 presents the hydrographs at Otowi gage for the lower volume years of the past decade, those years with a total flow past Otowi gage of less than 800,000 AE. These years include 2001, 2002, 2003, 2004, 2006, and 2011. Among these lower volume years, 2006 stands out, both for its lack of a spring runoff (springtime flows never exceeded 800 cfs) and for its significant monsoon flows, including numerous spikes with daily-average flows over 1,000 cfs. These conditions led to a considerable accumulation of New Mexico credits under the Compact. The years 2002 and 2003 were dry throughout the year, with poor snowmelt runoffs and low volume monsoons. The other years shown, 2001, 2004, and 2011 exhibit more traditional hydrographs, with bimodal spring snowmelt runoffs (representing the Rio Chama runoff followed by the main stem runoff), and low summertime flows, punctuated by occasional monsoon spikes.

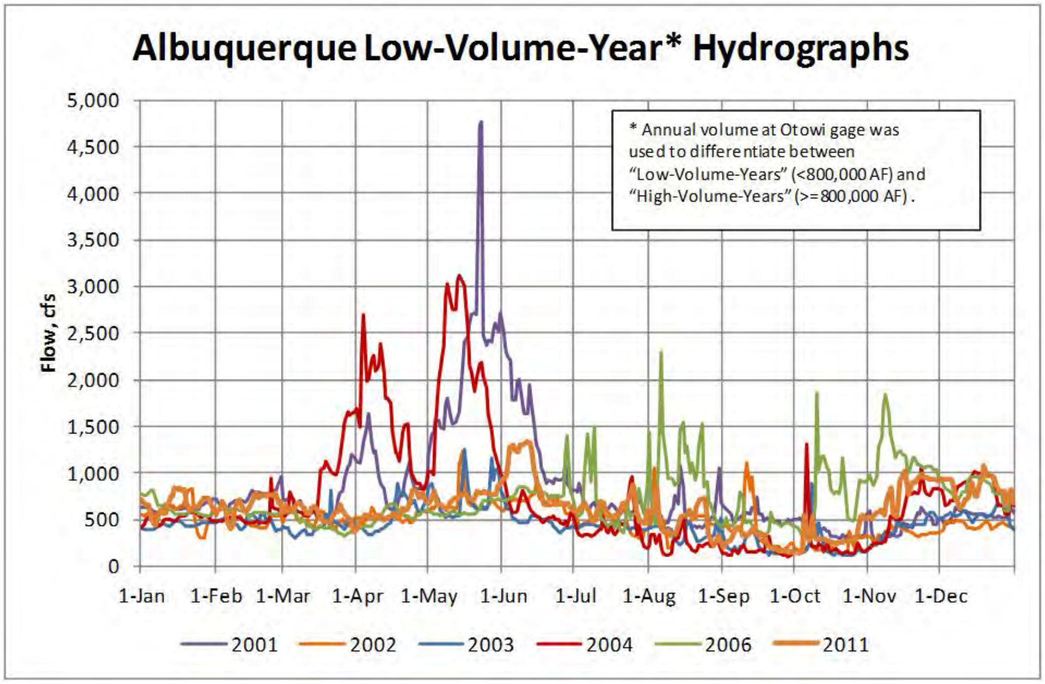

Figure 45. Hydrographs of flows at Otowi gage for the lower volume years during the past decade (2001–2011).

Dry years and, to some degree, the years following dry years tend to exhibit higher losses from the river to the ground water system and to evapotranspiration. This, in turn, affects river drying, as described in the following section.

5.4.2.4 River Drying

As discussed in the Water Operations section in section 2, RiverEyes data have been used to deduce trends in river drying, and threshold flows below which river intermittency should be expected. For example, river observations suggest that whenever gaged flows drop below 150 cfs at the Bosque Farms or below 200 cfs at the San Acacia gage, downstream drying is likely. The timing of drying is highly variable, affected in part by antecedent hydrologic conditions (whether the previous year was wet or dry), local weather (which affects the rates of evaporation and evapotranspiration), the degree and nature of the wetted sands, the magnitude of local return flows, the timing and nature of tributary inflows from the Rio Puerco and Rio Salado, and the degree of flood plain connectivity.

As can be seen in table 4, since implementation of the 2003 BiOp flow targets, river conditions have ranged from the rather extreme drying that occurred in 2003 to a continuous flowing river throughout 2008. The extreme river drying in 2003 occurred in response to low snowmelt runoff and a poor monsoon season that year, in combination with extremely dry antecedent conditions, which resulted in lower reservoir levels and high loss rates from the river. The MRGCD storage in El Vado was depleted, and, therefore, non-Indian irrigators were in "run-of-the-river" operations from late August through the end of the irrigation season. Therefore, irrigation water released from storage for delivery to downstream irrigation structures was not available to supplement river flow. Over 72% of the Isleta Reach and 95% of the San Acacia Reach experienced river drying, and an estimated 57% of total silvery minnow critical habitat dried in 2003. The 2006 spring runoff was also well below average because of lower than normal snowpack. In May 2006, year-to-date precipitation was well below average; and the snow pack was at 20% of average in the Rio Grande Basin. Fortunately, a strong monsoon season led to the wettest July and August within our period of monitoring. Consequently, only 26.5 miles of river dried in the summer of 2006 in the Isleta and San Acacia Reach. Fortunately, a succession of higher runoff years followed. In 2008, the river was continuous throughout the entire year. In 2011, however, dry conditions returned to the MRG, with total drying in the Isleta and San Acacia Reaches of over 40 miles.

Table 4. River drying by reach and by percent of critical habitat that dried (2001–2011)

Year	Information Source	Total Critical Habitat Dry (of_163_mi)	Albuquerque Reach Dry	Isleta Reach Dry	San Acacia Reach Dry	Maximum Combined Drying	Maximum Drying Isleta Reach (of_53_mi)	Maximum Drying San Acacia Reach (of_58.5_mi)
		%	%	%	%	miles	miles	miles
2001	FWS	6%	0%	0%	17%	10	0 **	10
2002	RE, Anec	31%	0%	0%	43%	50.2	18.2	25
2003	RE Sum	57%	0%	72%	95%	93.5	38	55.5
2004	RE GIS	30%	0%	36%	50%	48.5	19	29.5
2005	RE GIS	26%	0%	11%	63%	43	6	37
2006	RE GIS	15%	0%	11%	31%	24	6	18
2007	RE, ExpAct	21%	0%	18%	42%	34	9.5	24.5
2008*	RE	0%	0%	0%	0%	0	0	0
2009	RE	9%	0%	0%	26%	15	0	15
2010	RE	18%	0%	17%	36%	30	9	21
2011	RE	25%	0%	25%	47%	40.5	13	27.5

Notes:
Anec = Anecdotal Information
ExpAct = 2007 Experimental Activities
FWS = U.S. Fish & Wildlife Service
GIS = Geographic Information System data
RE = RiverEyes
Sum = Summary Information
* 2008 was designated as a wet year; BiOp did not permit drying
** zero assumed at Isleta, 2001

Figures 46 and 47 summarize the extent of river drying over the past decade, in terms of both the total number of river miles dried each year and in terms of the days of drying per year in the Isleta and San Acacia Reaches.

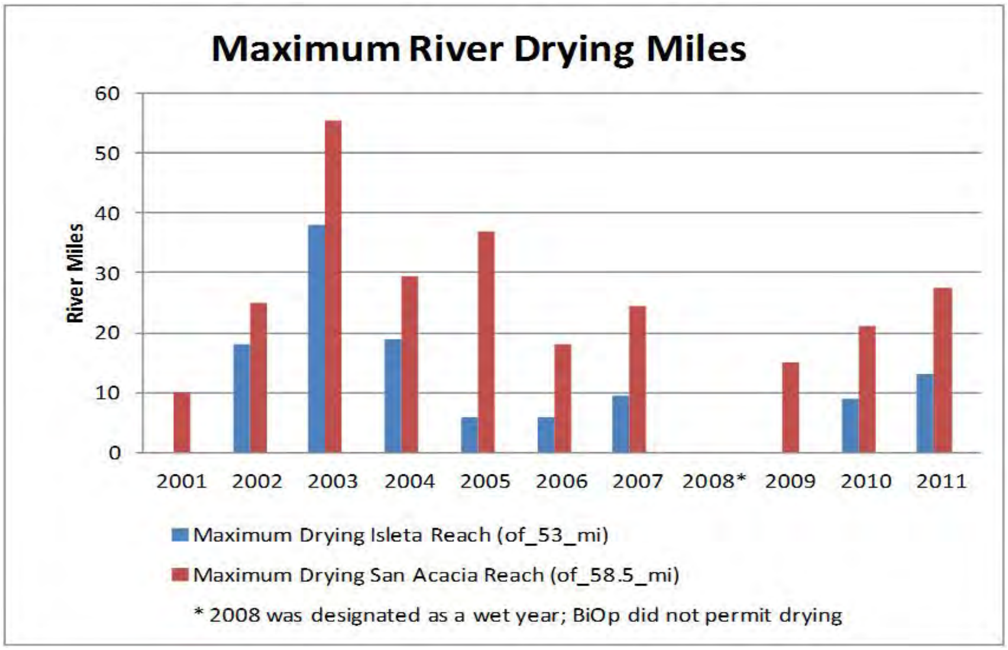

Figure 46. Summary of river miles that dried in the Isleta and San Acacia Reaches. (2001–2011).

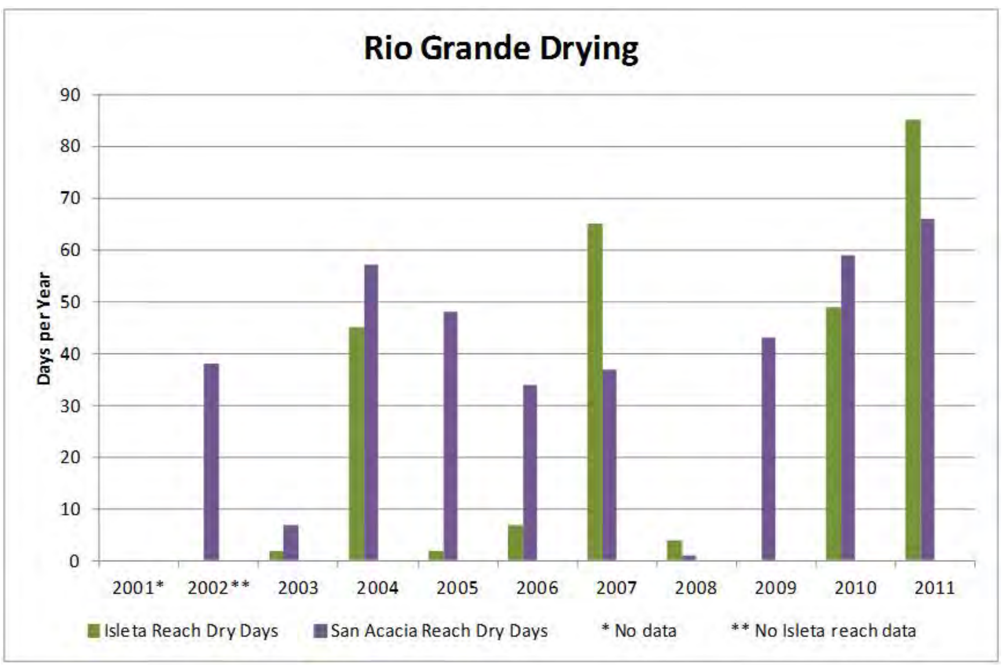

Figure 47. Number of days per year of river drying in the Isleta and San Acacia Reaches, 2001–2011.

Drying did not occur in the Cochiti Dam and Albuquerque Reaches during this time period. River operations in 2001 and 2002 were subject to different criteria, drying restrictions, and flow targets than were the years covered by the 2003 BiOp.

Figures 48 and 49 depict the timing of this river drying from 2001–2011, in the Isleta and San Acacia Reaches, by depicting the first and last day of reported drying in each reach. The years 2002, 2006, and 2011 are noteworthy for experiencing drying in the San Acacia Reach prior to June 15.

5.4.2.5 Meeting the 2003 BiOp Flow Targets

Reclamation consistently achieved compliance with flow targets established in the 2001 and 2003 BiOps due to a combination of factors:

- High reservoir levels in the drier years and low reservoir levels in the wetter years.
- A sequence of hydrologic years that was favorable under the flow target calculations.
- Lease agreements with SJC Project contractors who had not yet developed the capacity to use that water for its intended purpose.
- Agreements for water with the State of New Mexico (the Conservation Water Agreement and the Emergency Drought Water Agreement).

Because conditions were dry during the first half of the decade and became significantly wetter during the second half of the decade, Article VII restrictions under the Compact were put in place early in the decade and remained in place, or returned, for several of the later, wetter years. The Article VII storage restrictions allowed the later, wetter years to have “dry year” flow targets under the 2003 BiOp; so the water requirements to meet those targets were lower than they otherwise would have been.

Additionally, a larger amount of water has been available for Reclamation’s Supplemental Water Program than Reclamation can rely on in the future. Direct diversion projects for municipal use of SJC Project water by the city and county of Santa Fe and ABCWUA have decreased the amount of SJC Project water available for lease to Reclamation. Also, Reclamation has had the benefit of leased water from the State under the Emergency Drought Water Agreement (EDWA)/Conservation Water Agreement (CWA), which it cannot count on in the future. It is estimated that gains to Elephant Butte Reservoir were fairly high in recent years as compared to historical conditions, partially due to the lower reservoir level during much of the period but also due to extensive river maintenance activities in the Elephant Butte delta. The resulting gains in

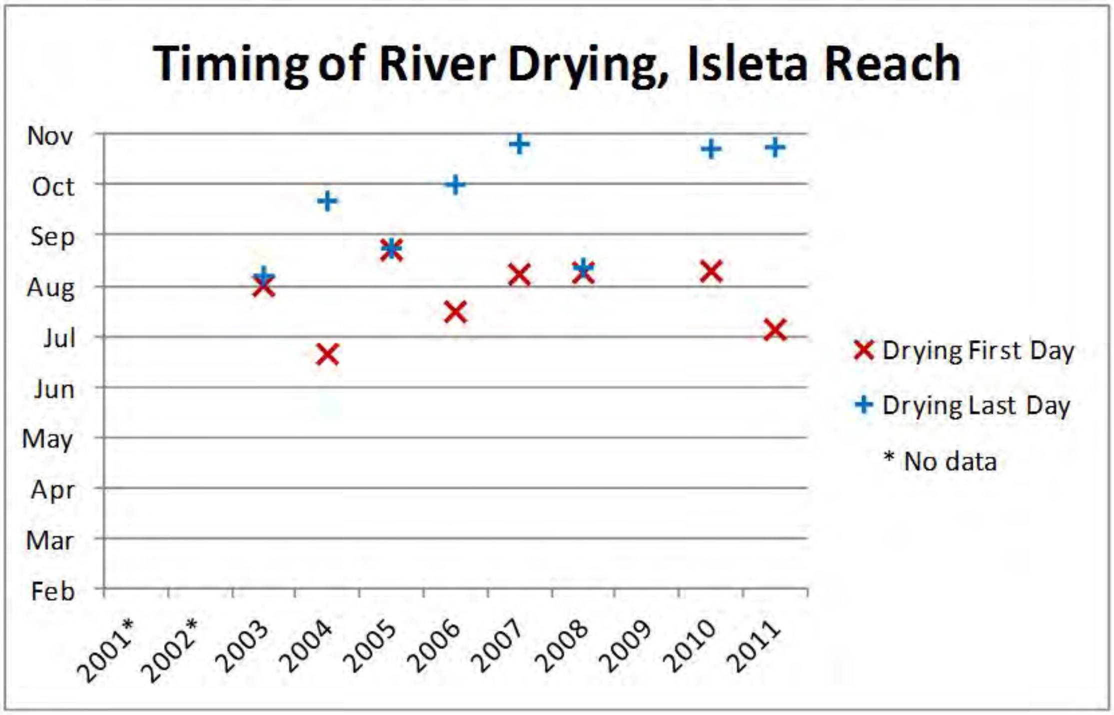

Figure 48. First and last calendar days of river drying in the Isleta Reach, 2001–2011.

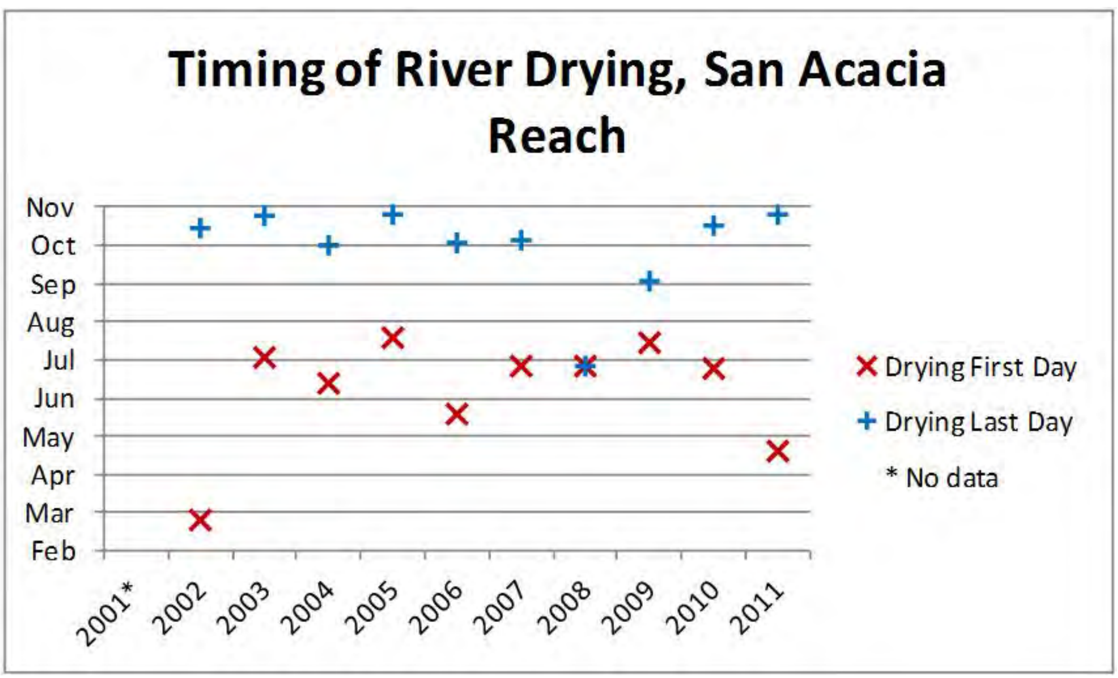

Figure 49. First and last calendar days of river drying in the San Acacia Reach, 2001–2011.

Elephant Butte deliveries resulted in greater Compact credits for New Mexico. The State was then able to relinquish an appreciable quantity of Compact credits and subsequently allow for Emergency Drought Water to be stored at El Vado Reservoir and be used for meeting the flow targets of the 2003 BiOp.

5.5 Channel Conditions and Dynamics

The following discussion is summarized from the 2012 report titled Channel Conditions and Dynamics of the Middle Rio Grande by Makar and AuBuchon. The channel conditions of a river are the integrated outcome of physical processes such as weathering, erosion, transport, and deposition of sediment and the natural and anthropogenic influences on those processes. Knowledge of the history of changes, both natural and anthropogenic, and the adjustment sequence within the alluvial watershed and channel provides a better understanding of this complexity to help interpret significant trends and estimate future conditions (Schumm et al. 1984, Kondolf and Piegay 2003).. The interrelationship between the flow of water, the movement of sediment, and the variable character and composition of the channel boundaries over time and space essentially determines the current channel morphology that is observed (Schumm 1977, Leopold et al. 1964). This channel morphology can be constantly changing as the river seeks to balance the movement of sediment (sediment supply) with the power available from the flow of water (sediment transport capacity) (Schumm et al. 1984, Reclamation 2005c). It is the imbalance between sediment transport capacity and sediment supply which is a key cause of most channel and flood plain adjustments (Lane 1955, Schumm 1977, Biedenharn et al. 2008).

Climatic changes, flood and sediment control, regulation of flows for irrigation, land use, vegetation changes, and channelization have altered the water and sediment supplied to the MRG over time. Factors affecting the imbalance between sediment transport capacity and sediment supply can be categorized as drivers of adjustment and controls on adjustment. Both drivers and controls can be modified through natural or anthropogenic means.

Important drivers on the MRG include flow frequency, magnitude and duration, and sediment supply. Changes in these drivers that have resulted in recent geomorphic channel changes on the MRG include decreased flow peaks, increased low flows of longer durations, and decreased sediment supply. Decreased peak flows result in the existing channel not being reworked on as large a scale as it was historically. Increased low flows of longer durations provide more water during dry periods. The flows can sustain vegetation but also aid encroachment of vegetation into the active channel that narrows it. Increased low flows of longer durations occur as a result of anthropogenic regulation of the flows in the water system. This includes holding back flood flows that naturally would occur during the snow melt runoff and monsoonal events and releasing that water during nonflood periods, such as during the summer and winter months. Increased low flows of longer durations also occur as a result of moving water, beyond the native flow, to keep the river wet and to facilitate the transfer of water downstream. Decreases in sediment supply, such as those due to land use changes in the watershed or the storage of sediment behind dams and diversion structures or stabilized banks and bars, can cause an increase in the likelihood of channel erosion.

There are several factors that can limit or control the effects of the drivers on channel adjustment and the observed reach characteristics. Controls of channel adjustment such as bank stability, bed stability, base level, flood plain lateral confinement, and flood plain connectivity influence the extent of effect that the drivers have on the observed characteristics of a reach. Bank stability can be affected by natural (e.g., riparian vegetation) or mechanical (e.g., riprap) means. Similarly, bed stability can come from channel armoring through bed material coarsening or from cross channel facilities. An example of a base level control is a change in pool elevation of a reservoir. The change can result in an upstream channel response, such as channel degradation or aggradation. Levees and geologic outcrops can create lateral confinement of the flood plain and limit channel migration. A well-connected flood plain dissipates the energy of flood flows, reducing the sediment transport capacity.

The fact that many changes, both natural and anthropogenic, occurred contemporaneously on the MRG greatly complicates interpreting the drivers and controls of the observed trends of channel and flood plain adjustments and also the prediction of future trends. Figure 10, in the introduction of this section, Environmental Baseline, illustrates the timing of many of these events and dates of significant floods. A more detailed history of events affecting the morphology of the MRG can be found in the report, titled Channel Conditions and Dynamics of the Middle Rio Grande (Makar and AuBuchon, 2012).

5.5.1 MRG Reach Geomorphic Parameters and Current Trends

The field of geomorphology uses certain parameters to better understand the observed trends and to help predict how a river self-adjusts to move toward a balance between sediment transport capacity and sediment supply. These geomorphic parameters help identify and document changes in the drivers and controls of channel adjustment. Geomorphic parameters currently evaluated on the MRG, from both direct measurement and/or analysis, include the following:

- Discharge magnitude and frequency
- Sediment supply
- Channel width
- Channel planform and location

- Slope
- Sinuosity
- Bed material size and type
- Channel and floodway topography

These parameters and their applicability to the MRG are further described in the report titled Channel Conditions and Dynamics of the Middle Rio Grande (Makar and AuBuchon 2012). For the ensuing discussions, reach designations follow geomorphic breaks described in the same report. Most of the discussion in this document focuses on the reaches between Cochiti Dam to the Elephant Butte Full Pool Reservoir. The majority of Reclamation's investigations have been in this historically more geomorphically active reach and, thus, more data is available. This area also corresponds to the section of the river occupied by silvery minnow.

The first two geomorphic parameters, discharge magnitude and frequency and sediment supply are geomorphic drivers. Changes in flow and sediment supply continue to impact the morphology of the MRG. The decreased annual peak flows, which are now typically less than 5000 cfs, and the reduced sediment supply are documented changes in the drivers that are correlated in time with observations of channel narrowing, vegetation encroachment, and incision; which in turn influence bank height, bed material size and generally lead to a more uniform channel. These observations are much more noticeable upstream of Albuquerque, where significant changes to the drivers have occurred. South of Albuquerque, especially south of the Rio Puerco, the effects of the changes to the drivers is less consequential because of the influence on the morphology from the tributary flows and sediment supply. These less-altered tributaries allow for a higher variability in both flow and sediment supply, which dampens the effects of the upstream changes to the drivers. These tributaries can also bring in coarser material that influences bed stability at lower flows.

The next six parameters (channel width, channel planform and location, slope, sinuosity, bed material size and type, and channel and floodway topography) are characteristics that help describe conditions of a reach. Controls on channel adjustment such as bank stability, bed stability, base level, flood plain lateral confinement, and flood plain connectivity interact with the drivers and influence the extent of effect that the drivers have on the observed characteristics of a reach. A lower bank and bed stability may have the potential to add to the sediment supply, whereas increases in the stability (bed and/or bank) or flood plain connectivity (which may cause lower velocity areas) can reduce the sediment supply.

The influence of drivers and controls along the MRG is variable, but commonalities have been identified. It is the commonalities in the river's responses to drivers and controls present that help identify and separate the MRG into reaches with similar trends. The analysis of the geomorphic parameters, beyond identifying current trends on the MRG, also provides a summary of traits or characteristics for these reaches and a trajectory of expected changes. A summary of these six geomorphic parameters that influence the drivers and currently observed trends is provided in table 5. Additional information and discussions on reach specific details are provided in the report titled Channel Conditions and Dynamics of the Middle Rio Grande (Makar and AuBuchon 2012).

The major current trends observed on the MRG, although not every trend on every reach, are listed below.

- Channel narrowing
- Vegetation encroachment
- Increased bank height
- Incision or channel bed degradation
- Bank erosion
- Coarsening of bed material
- Aggradation (river bed rising due to sediment accumulation)
- Channel plugging with sediment
- Perched channel conditions (river channel higher than adjoining riparian areas in the floodway or land outside the levee)
- Increased channel uniformity

These trends and their applicability to the MRG are discussed in the sections below. The relationship between sediment transport capacity and sediment supply is also identified for each trend. This relationship is key to anticipating future changes in reach trends and the direction of river responses, which helps determine potentially more sustainable corrective actions. Additional details supporting these trends and the relationship between sediment transport capacity and sediment supply are provided in the report titled Channel Conditions and Dynamics of the Middle Rio Grande (Makar and AuBuchon 2012).

5.5.1.1 Channel Narrowing (Sediment Transport Capacity Can Be Either Greater or Less than Sediment Supply)

The channel narrowing that has occurred since 1949 is likely the result of some combination of decreased peak flows, increased low flows of longer duration, decreased sediment supply, increased bank stability, increased flood plain lateral confinement, and decreased flood plain connectivity. The particular combination is dependent on reach-specific conditions.

When sediment transport capacity is greater than sediment supply, bed degradation or channel incision can occur. More bed degradation occurs in the channel thalweg (deepest area of the channel) than in shallower areas resulting in channel narrowing. For the case where the sediment transport capacity is less than the sediment supply, channel narrowing can occur as a result of sediment deposition in the form of medial or bank attached bars during high flows (lateral accretion). When subsequent flows are lower, these bars may not remobilize and so result in channel narrowing. Based on historical accounts and survey data, the MRG has narrowed significantly over the last century (Makar et al. 2006). For both cases, the resulting more confined, uniform sections offer little diversity of instream habitats for silvery minnow and low flood plain connectivity. Narrow, confined channels have less low velocity habitats for silvery minnow and often require higher flows to inundate riparian vegetation, which is important for flycatcher.

5.5.1.2 Vegetation Encroachment (Sediment Transport Capacity Can Be Either Greater or Less than Sediment Supply)

Significant vegetation encroachment into the active channel has occurred historically and again during the recent drought cycle as documented by historical photography and in Scurlock (1998), Lagasse, (1980) Makar et al. (2006), and Makar (2010). This is likely the result of decreased peak flows and increased low flows of longer duration. Increased low flows of longer duration provide water more consistently and encourage vegetation growth near the channel. At the same time, the decreased peak flows have insufficient shear stresses to uproot the established vegetation. Existing hydrology and flood control operations for safe channel capacity make an event large enough to destabilize the current vegetation extremely unlikely on the MRG. Thus, it is likely that, on a reach scale, bank erosion and subsequent bank migration will be restricted, provided the bed elevation does not degrade below the root zone of established riparian vegetation. These channel resetting events maintained a diversity of habitats, backwaters, and side channels within the river channel for silvery minnow and a variety of successional stages of vegetation with riparian zone for flycatchers.

Conditions where the sediment transport capacity is greater than the sediment supply can lead to bed degradation or channel incision, as described above in the section on channel narrowing. The channel incises more along the thalweg than in other portions of the river bed; therefore, adjoining, higher areas of the river bed are inundated and mobilized less frequently, which creates a condition conducive to vegetation growth. This vegetation growth then reduces the width of the active channel.

Conditions in which the sediment transport capacity is less than the sediment supply can result in sediment deposition. These deposits can become vegetated if they are not remobilized by high flows, thereby narrowing the channel. These more confined, uniform sections offer little diversity of instream habitats for silvery minnow and low flood plain connectivity. The mature vegetation associated with this encroachment is valuable habitat for flycatchers but has a limited lifespan of suitability. Habitat diversity both in the riparian zone and within the channel has decreased due to lack of channel resetting events.

5.5.1.3 Increased Bank Height (Sediment Transport Capacity Can Be Either Greater or Less than Sediment Supply):

The increase in bank height that has occurred is likely the result of some combination of decreased sediment supply, increased bank stability, low bed stability, lowered base level (e.g. Elephant Butte reservoir pool elevation), increased flood plain lateral confinement, and flood plain connectivity (lower velocities in flood plain cause sediment to settle and result in vertical accretion in flood plain). The particular combination is dependent on reach-specific conditions.

If the sediment transport capacity is greater than the sediment supply, bank height increases can occur as a consequence of channel degradation or incision, which can reduce flood plain connectivity as well. When sediment transport capacity is less than sediment supply, bank height can increase due to sediment deposition in the flood plain (vertical accretion). This is primarily due to the lower sediment transport capacity of the flood plain when flows go overbank. An example of vertical accretion on the MRG is the observation of surface deposits during the high flows in the spring of 2005 on vegetated bars and islands within the Albuquerque area (Meyer and Hepler 2007). Similarly after the 2005 spring runoff ended, field observations indicated significant vertical accretion occurred on the bars, islands, and flood plains in the Isleta to Rio Puerco Reach, especially near areas of flowing water (Bauer 2007). These higher features subsequently require larger magnitude runoff events to inundate. These more confined, uniform sections offer little diversity of instream habitats for silvery minnow and low flood plain connectivity.

5.5.1.4 Incision or Channel Bed Degradation (Sediment Transport Capacity Is Greater than Sediment Supply)

When banks are more resistant than the bed, the river seeks to increase its sediment supply by transporting additional sediment from the bed. The incision that has occurred is likely the result of some combination of decreased sediment supply, increased bank stability, low bed stability, lowered base level (e.g., Elephant Butte Reservoir pool elevation), increased flood plain lateral confinement, and decreased flood plain connectivity. The last three factors all contribute to higher flow energy, which adds to the river's need to self-adjust through channel bed degradation. The particular combination of factors is dependent on reach-specific conditions.

Incision on the MRG between Cochiti and Isleta has been impacted most strongly by construction of Cochiti and Jemez Canyon Dams, and these effects appear to be continuing to extend downstream. The lack of upstream sediment supply exacerbated the combined effects from the placed jetty fields of the more efficient channel and the reduction of bank material as a sediment source and resulted in degradation of the river channel and disconnection from the adjacent flood plain. Another example of this trend in the lower reaches of the MRG is due to the recent low elevation of Elephant Butte Reservoir. The low reservoir elevation is one of the causes of erosion of the upstream channel and delta deposits that has led to channel degradation from the southern BDANWR to the pool. Due to these changes, the channel has become disconnected from the surrounding flood plain in some areas. The extent (depth and length) of degradation depends on the extent of the base level lowering and the duration that the reservoir pool is lower.

The incision throughout the MRG also has the effect of lowering the water table in the vicinity of the active channel, which diminishes the ability of the river to recharge perennial and ephemeral wetland areas. These more confined, uniform sections offer little diversity of instream habitats for silvery minnow and low flood plain connectivity.

5.5.1.5 Bank Erosion (Sediment Transport Capacity Is Greater than Sediment Supply):

The bank erosion that has occurred is likely the result of some combination of decreased sediment supply, low bank stability, higher bed stability, lowered base level (e.g., Elephant Butte Reservoir pool elevation), increased flood plain lateral confinement, and decreased flood plain connectivity. The last three all contribute to higher flow energy that adds to the river's ability to self-adjust through bank erosion. The particular combination of factors contributing to bank erosion is dependent on reach-specific conditions. When the bank stability is less than the bed stability, the channel responds to unmet sediment transport capacity by bank erosion and lengthening of the channel, thereby increasing sinuosity. An overly-lengthened channel may reduce sinuosity when a more hydraulically efficient cutoff channel develops and straightens that bend. These dynamic processes can form side channels and other features that may contribute to habitat diversity within the reach. Higher sinuosity areas are more likely to contain features such as backwaters and low velocity side channels that are important to all life stages of silvery minnow and overbank wetted vegetation used by flycatchers. It should be noted, however, that on the reach scale, the MRG is classified as having low sinuosity.

Bed material coarsening (discussed below) can make the bed more resistant to erosion than the banks. Channel degradation or incision leads to taller banks that are often less stable, again resulting in bank erosion. At present, the bank heights in several reaches of the MRG are generally tall enough for the river's thalweg to intersect the banks beneath the root zone of the riparian vegetation, creating conditions in which the banks are more easily eroded. This, coupled with a single-channel planform and a thalweg that alternates between the banks, has led to the development of a series of migrating bends in those reaches.

5.5.1.6 Coarsening Bed Material (Sediment Transport Capacity Is Greater than Sediment Supply

As the channel bed degrades or incises, bed sediment of finer sizes, which are more easily transported, are removed from the bed while coarser sizes remain. Figure 50 presents the median size of the bed material over time in the MRG and shows the coarsening trend. Coarsening of bed material is likely the result of some combination of decreased sediment supply, increased bank stability, low bed stability that allows transport of finer bed particles, lowered base level (e.g., Elephant Butte Reservoir pool elevation), increased flood plain lateral confinement, and decreased flood plain connectivity. The first three factors may contribute to channel narrowing, which may lead to or be coupled with channel bed degradation. The last three of these factors all contribute to higher flow energy, which adds to the river's ability to move bed material. Under all of these conditions, the bed material may potentially coarsen further. Since the amount of energy to move a particle is proportional to its size, only the very coarsest materials remain. The particular combination of factors contributing to coarsening of bed material is dependent on reach-specific conditions.

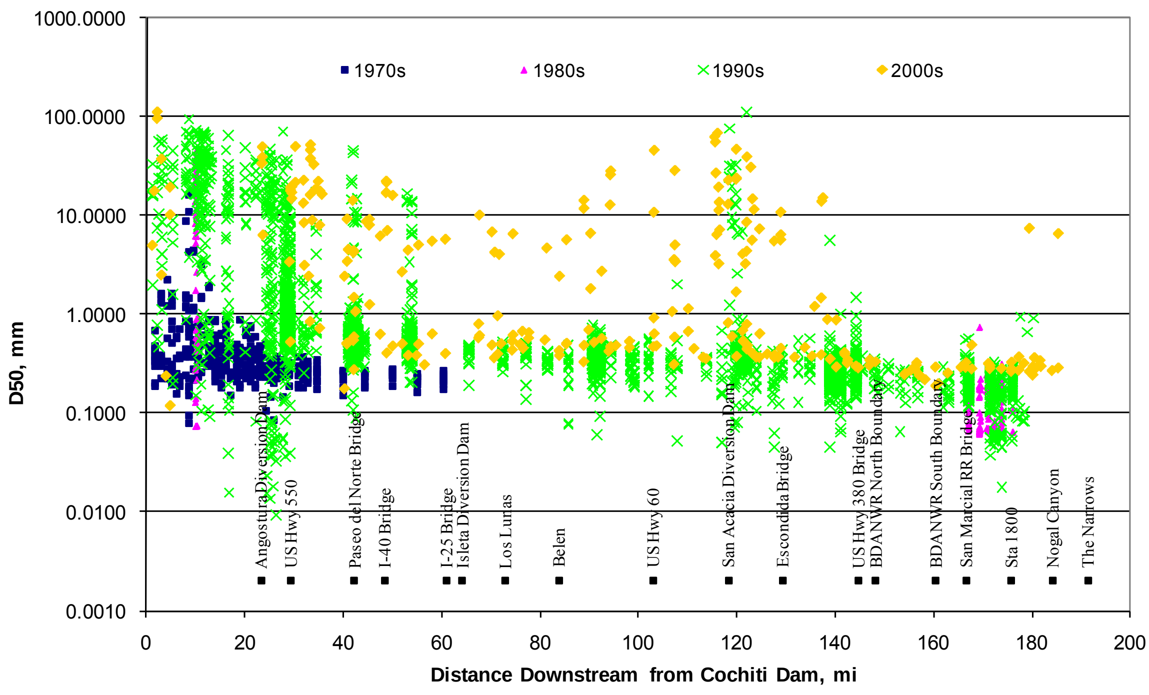

Figure 50. Median bed material size on the MRG over time (Bauer 2009).

5.5.1.7 Aggradation (River Bed Rising Due to Sediment Accumulation – Sediment Transport Capacity Is Less than Sediment Supply)

Aggradation is likely the result of some combination of high sediment supply, increased bank stability, higher base level (e.g., Elephant Butte Reservoir pool elevation rising that causes flatter slopes and increased flow resistance upstream, which tend to decrease the channel's sediment transport capacity), increased flood plain lateral confinement (which causes increased aggradation, due to limitation of the available area for deposition), and increased flood plain connectivity. The particular combination of factors contributing to aggradation is dependent on reach-specific conditions.

When sediment deposition occurs, it raises the bed elevation in both the main channel and the adjoining riparian zone. The extents and amounts are dependent upon the magnitude of the sediment transport imbalance; the greater the imbalance, the greater the deposition. The aggradation rate in the San Marcial area has been historically greater than any other reach. From 1900–1937, the riverbed aggraded more than 16 feet at the San Marcial Railroad Bridge. It has aggraded almost 13 more feet through 1999 (Makar 2009). The railroad bridge has been raised three times for a total of 22 feet (Van Citters 2000). Aggradation is currently a significant long-term concern from San Antonio south. There is some mild aggradation upstream of San Antonio. These reaches are strongly influenced by the pool elevation of Elephant Butte Reservoir (Elephant Butte Dam was closed in 1916) as well as sediment and water discharge magnitude, duration, and frequency (Levish 2010). During wetter periods with a full reservoir, these reaches continue to experience high levels of aggradation, alternating with degradation influenced by recession of the reservoir during drier periods and lower incoming sediment load.

The aggradation of the active channel provides water to a broader area of riparian vegetation that is used by flycatchers as well as lower velocity habitats for silvery minnow.

5.5.1.8 Channel Plugging with Sediment (Sediment Transport Capacity Is Less than Sediment Supply)

Channel plugging is likely the result of some combination of high sediment supply, increased bank stability, higher base level (e.g., Elephant Butte Reservoir pool elevation), increased flood plain lateral confinement, and increased flood plain connectivity. A higher base level and an increase in flood plain connectivity can reduce the sediment transport capacity of the river, which over time builds conditions that support the formation of sediment plugs. The particular combination of factors that lead to plugs is dependent on reach-specific conditions.

As sediment deposits in the main channel, flow from the top of the water column can go overbank at lower discharges. Because there is a lower concentration of sediment being transported at the top of the column, the overbank flow removes a higher percentage of water volume than sediment load. As a result, the main channel sediment transport capacity is reduced, but the sediment supply decreases by a smaller percentage. This results in additional deposition in the main channel. Continued overbank flows with sediment accumulation in the main channel further reduces main channel flow capacity. This process can continue until sediment completely fills the main channel. The River Mile 78 to River Mile 62 Reach has a history of sediment plug formation near RM 70, approximately 1.5 miles upstream of the San Marcial Railroad Bridge. Three plugs have formed at this location in the last 20 years, in 1991, 1995, and 2005. The 1991 plug caused a breach of the Tiffany Levee on the west side of the river. The 1995 plug grew to a length of approximately 5 miles, and the 2005 plug grew to a length of approximately 3 miles. During the 2008 spring runoff, a sediment plug formed in the main channel of the river within the San Antonio Bridge to River Mile 78 Reach, just downstream from RM 81. The main channel was completely plugged with sediment for a length of a half mile and partially plugged upstream of that for a distance of over 1 mile.

The plugging of the active channel provides water to a broader area of riparian vegetation that is used by flycatchers as well as lower velocity habitats for silvery minnow. A connected flood plain provides important larval and rearing habitats for silvery minnow as well as inundated riparian vegetation for flycatcher.

5.5.1.9 Perched Channel Conditions (River Channel Higher than Adjoining Riparian Areas in the Floodway or Land Outside the Levee – Sediment Transport Capacity Is Less than Sediment Supply)

Perched channel conditions are likely the result of some combination of high sediment supply, increased bank stability, higher base level (e.g., Elephant Butte Reservoir pool elevation), increased floodway lateral confinement, and increased flood plain connectivity.

As a riverbed raises and sediment-laden waters flow overbank into the riparian zone, flow velocity decreases, which causes sediment deposition that, in turn, raises the river bank height. Continued bed raising and overbank deposition results in a channel bed, bordered by natural levees, which is significantly higher than the adjoining areas between manmade levees or geologic formations. This condition is known as a perched channel. A river corridor also can become higher than land areas outside the levee when sediment deposition occurs across the entire flood plain between the levees. The historical valley flood plain accessible by the MRG has been significantly reduced by levees paralleling much of the river. Subsequent aggradation between the levees has rendered that area higher than the adjoining valley for most of the MRG between Angostura Diversion Dam and Elephant Butte Dam. This process is most pronounced on the Rio Grande downstream from San Antonio. Perched channel conditions can be a factor in channel plugging.

The perching of the active channel provides water at a larger variety of flows to a broader area of riparian vegetation that is used by flycatchers as well as lower velocity habitats for silvery minnow. A connected flood plain provides important larval and rearing habitats for silvery minnow as well as inundated riparian vegetation for flycatcher.

5.5.1.10 Increased Channel Uniformity (Sediment Transport Capacity Can Be Either Greater or Lesser than Sediment Supply)

On a reach scale in the MRG, morphological features (width, depth, velocity, flood plain connection, backwater features, etc.) that were once significantly variable are becoming more uniform. This increase in channel uniformity results primarily from a decreased variability in flows and sediment supply. This decreased variability is a result of flow control, which causes lower peaks and more constant low flows. Lower peaks mean less energy is available to rework the channel and flood plain. The channel banks and flood plain do not erode as much, and sediment remains stored in the banks. More constant low flow means vegetation can grow more easily (see vegetation encroachment section above), further reinforcing the existing bank line and perhaps storing even more sediment.

In the MRG, storage of sediment behind dams in both the main stem and tributaries, less watershed erosion due to land use changes, and bank and bed stabilization have so reduced the sediment supply that, even with lower peaks, the sediment transport capacity is greater than the sediment supply for most of the MRG. SWCA (2010b) found that after the 1930s the channel dynamics in the Angostura to Isleta Reach of the MRG were diminished to the point that the riparian environment diversity became static and no longer changed as it once did.

Conditions in which the sediment transport capacity is greater than the sediment supply lead to river bed degradation or channel incision, as previously described. As the channel incises and narrows, the active channel planform moves from a wide braided channel with extensive mobile bars to a narrow single channel with few mobile bars. The wetted channel at higher flows changes from being wide and shallow with significant topographic and hydraulic variations, to narrow and deep with limited space for topography and hydraulic variations. These changes contribute to increased channel uniformity locally and also on a reach basis as the irregularities of the natural channel become more and more alike. The end result is a channel with more uniform slope and width, high, steep banks, lower suspended sediment load, and coarser bed material.

Conditions in which the sediment transport capacity is less than the sediment supply lead to channel aggradation, as previously described. Since the majority of the MRG has lateral constraints, as the channel aggrades, the space between the constraints becomes elevated. This, in turn, raises the bed elevation of the main channel, creating greater opportunities for flooding and diminishing the topographical elevation variations between the main channel and the flood plain.

Vegetation growth, as described in the section on vegetation encroachment, is encouraged by the smaller in-channel forces created by lower peak flows and the greater connectivity between the main channel and the flood plain. Bars often attach to the bank as the channels fill in, decreasing bar mobility. Under these conditions, the active channel planform moves towards a narrow active channel with a more consistent width and limited sediment mobility.

Figure 51 illustrates one aspect of channel uniformity, the variability of the channel width within a reach. The narrowing of the gap between the maximum and minimum measured widths and the decrease in the standard deviation are an indication that widths are becoming increasingly uniform.

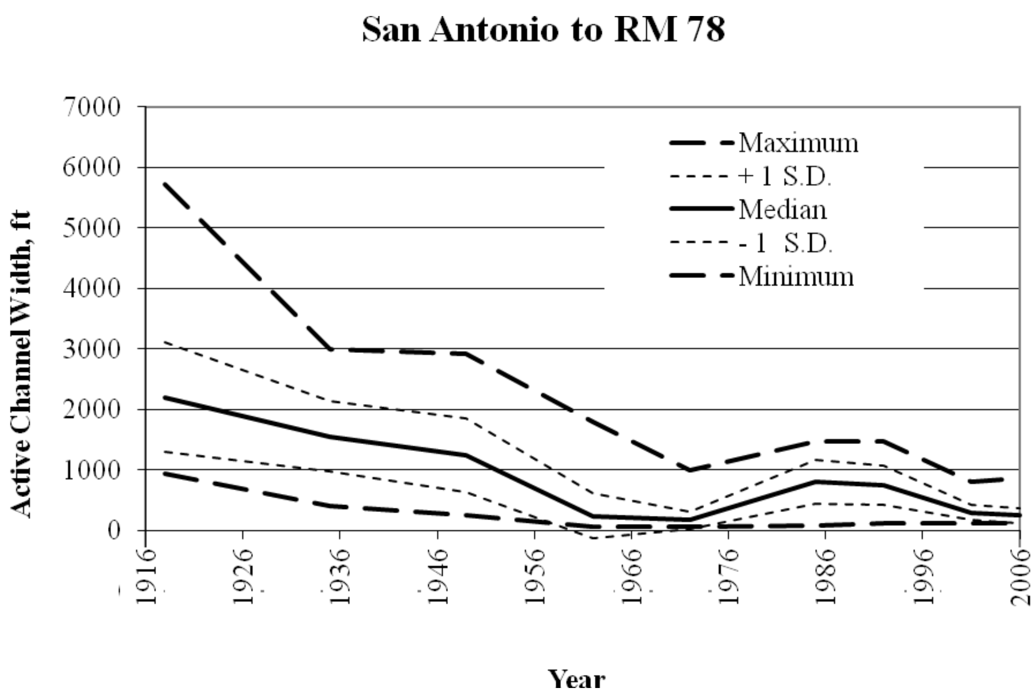

Figure 51. Channel mean width change over time with standard deviation for San Antonio (RM 87.1 to RM 78).

5.6 Actions to Avoid, Minimize, or Mitigate

This environmental baseline is also affected by many ongoing activities that the Service prescribed in biological opinions issued over the last 10 years, as well as other activities that have had positive effects on the status and knowledge of the species. Many of these activities have been carried out by the Collaborative Program, which focuses on improving the status of the listed endangered species in the MRG including the silvery minnow and the flycatcher. These activities serve as a tool to conserve listed species, assist with species recovery, and help protect critical habitat.

The following is a brief discussion of the activities carried out, including elements in the RPA, RPM, and conservation recommendations in the 2003 BiOp as well as other measures that may improve the status and knowledge of the species.

5.6.1 Environmental Water Management

Over the past decade, Federal, State and local agencies have engaged in efforts to coordinate water and river operations to improve system operations and achieve ESA compliance. Environmental water operations are triggered by 2003 BiOp flow criteria. RPA Element C mandates that reconnaissance of portions of the Middle Rio Grande be performed to:

1. Provide current information on river flows that allow Reclamation and the other agencies to react quickly to rapidly changing conditions on the river,
2. Facilitate coordination among the agencies to prevent unexpected drying.
3. Prepare for silvery minnow rescues.

Daily coordination of water operations between Federal and non-Federal partners has been especially critical during periods of limited water availability and river drying. For example, coordination with the MRGCD allowed the maintenance of short lengths of wet river during extremely dry periods through small, targeted return flows from irrigation system drains, outfalls, and wasteways. Also, coordination of the RiverEyes program with the Service's minnow salvage program allowed targeting of salvage efforts to the locations at which they would be most effective. Information provided by the RiverEyes program also allowed optimal use of pumping from the LFCC to the river as needed to limit the extent of drying, manage recession and avoid excessive stranding, and to support silvery minnow rescue operations.

Many of the RPA elements (A to O, RPMs 1.1, 3.1, and 3.2) involve water management thresholds, targets, and requirements. Element A calls for a spike release to induce silvery minnow spawning. A natural spike flow occurred in 2003 and was followed in 2009 by a spike flow resulting from an experimental deviation in the operation of Cochiti Reservoir. A deviation of Cochiti Reservoir operations also occurred in 2010, but that deviation resulted in a rapid decrease in flows following the flow spike, which may have disrupted the development of silvery minnow eggs and larvae.

Supplemental water releases have aided in maintaining the flow targets and slowing the rate of recession, which helps both minnow and flycatcher habitat (Elements A to O, RPM 3.1, 3.2). Supplemental water generally has only been used to manage the recession of spring runoff and not to augment spring peaks.

The flow requirement increases between average and wet years in the 2003 BiOp may not significantly change the condition of the river but can result in a significant increase in the required water.

As part of the Supplemental Water Program (Element O, RPM 4.1), in the San Acacia Reach, pumping from the LFCC to the river is done at four locations. The use of this water to manage river recession has been successful and has allowed many of the fish to move with the receding river. Pumping for flycatchers has not been done directly and should be assessed on a case-by-case basis where appropriate; during very dry years, it is theorized that pumping may attract predators to areas where flycatchers are nesting. In recent years, pumps have run continuously at the south boundary of BDANWR during low flow conditions though not required by the 2003 BiOp. There has been no assessment of the effectiveness of pumping to benefit the species or how effective the pumped water is at maintaining river connectivity.

5.6.1.1 Reclamation's Supplemental Water Program

Reclamation initiated its Supplemental Water Program in 1996 to support water needs of the ESA-listed species in the MRG. The program originally included acquisition, storage in upstream reservoirs, and release of water to support river flows. Since 2001, it also has included operation of a pumping network in the San Acacia Reach to pump water from the LFCC to the river. Reclamation has enhanced the flexibility of its program of leases of annual allotments of SJC Project water with a program of waivers of release dates from Heron Reservoir of contracted water. This program of release waivers has served to further enhance water releases for environmental and recreational purposes on the Rio Chama.

Through these methods, Reclamation has acquired a supply of Supplemental Water over the past decade and used this water to support river flows and manage recession to meet the needs of the endangered species and the terms of the BiOps. Since 2003, Reclamation has released an average of 28,568 AFY of Supplemental Water in the manner deemed to provide the most benefit to the listed species. An updated NEPA analysis of the current Program was completed in 2011, and a finding of no significant impact was issued.

The Program has included the following elements:

- Lease from contractors and storage of SJC Project water
- Heron Reservoir release waiver
- Acquisition and storage of relinquished credit water from the State of New Mexico;

- Release of Supplemental Water to meet the needs of listed species
- Pumping of water from the LFCC to the San Acacia Reach of the Rio Grande

These elements of the program are described in more detail in the following subsections.

5.6.1.1.1 San Juan-Chama Project Water Acquisition and Storage

Since 1997, Reclamation has acquired most of its Supplemental Water Program water by entering into temporary lease agreements with SJC Project contractors. The amounts and sources of these leases each year are summarized in table 6.

Since 2003, Reclamation has leased an average of 24,664 AF of water from SJC Project contractors annually.

Figure 52 presents a summary of the water obtained for Reclamation's Supplemental Water Program from willing SJC Project contractors since 2001. The primary source of SJC Project water to the program has been the ABCWUA. However, as previously described, ABCWUA has brought online its drinking water diversion, through which it plans to use its allocation of SJC Project water for urban supply. Therefore, the availability of this water to Reclamation's Supplemental Water Program has been significantly reduced.

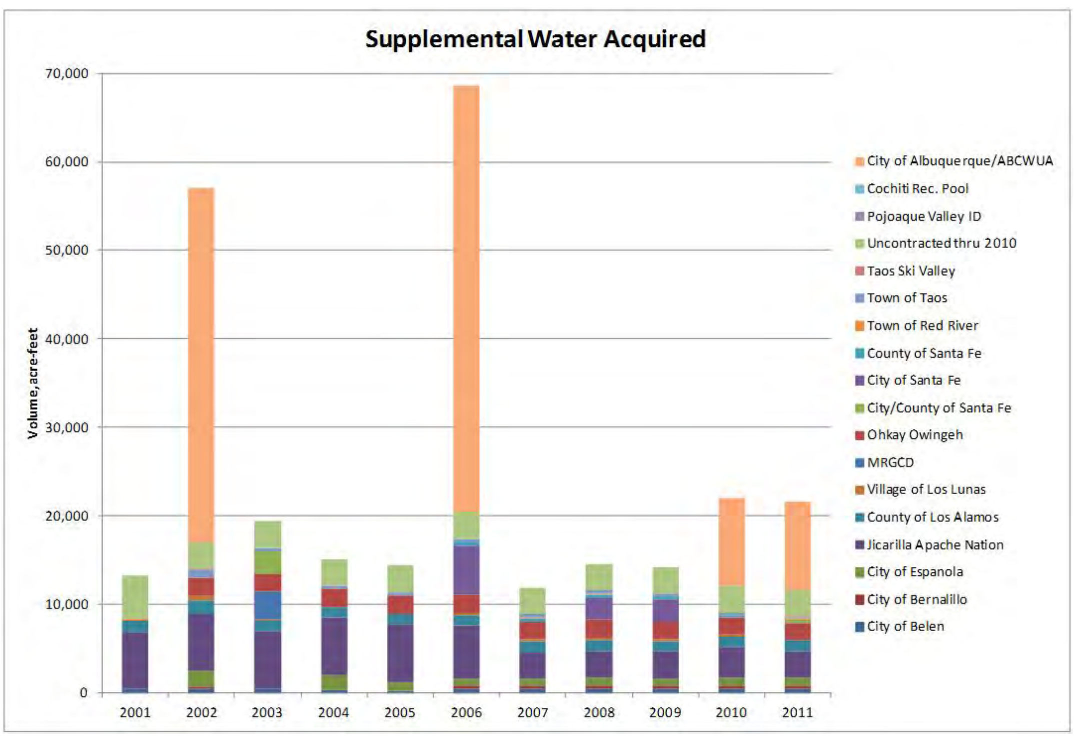

Figure 52. Summary of San Juan-Chama Project water leased to Reclamation's Supplemental Water Program.

Table 6. Leased supplemental San Juan-Chama Project water (1997–2011)

CONTRACTOR	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Albuquerque	10,000	10,000	10,000	64,500		40,000				48,200				10,000	10,000	202,700
City of Belen			800	700	400	470	504	354	242	450	470	470	400	450	450	6,160
City of Bernalillo						300				400	320	400	400	400	400	2,620
City of Espanola		2,000	2,000	5,000		1,687		1,650	1,000	800	856	850	850	850	900	18,443
Jicarilla Apache Nation			6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,000	2,948	3,000	3,000	3,500	3,000	66,948
County of Los Alamos		3,650	3,600	5,000	1,200	1,529	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	25,779
Village of Los Lunas		500	500	300	200	500	100			256	293	331	200	200		3,380
MRGCD							3,132									3,132
Ohkay Owingeh						2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	20,000
City of Santa Fe		10,000	10,000	10,000			2,500			5,500		2,500	2,500		375	43,375
County of Santa Fe										375	375	375	375	175		1,675
Town of Red River			60	60	60	60	60	60	60	60	60	60	60	60	60	780
Town of Taos			400	400		937	419	400	400	400	400	400	200	245	225	4,826
Taos Ski Valley			50	50		53					15	15	15	8	8	214
Uncontracted		4,990	4,990	4,990	4,990	2,990	2,990	2,990	2,990	2,990	2,990	2,990	2,990	2,990	2,990	49,860
Total	10,000	31,140	38,900	97,500	13,350	57,026	19,405	15,154	14,392	68,631	11,927	14,591	14,190	22,078	21,608	**449,892**

Reclamation has entered into agreements with the MRGCD and ABCWUA to store the leased SJC Project water that Reclamation acquires for the Program. Under an MRGCD storage agreement, which expired at the end of 2009, Reclamation stored up to 30,000 AF of SJC Project water in El Vado Reservoir. The ABCWUA storage agreement authorizes Reclamation to store 10,000 AFY of SJC Project water in Abiquiu Reservoir through 2012, with options to extend.

5.6.1.1.2 Heron Reservoir Release Waivers

As discussed above, SJC Project contractors must take delivery of their annual allocation of SJC Project water prior to December 31 of each year; otherwise their water reverts to the SJC Project pool at Heron Reservoir. However, Reclamation regularly authorizes extension of that date, in cases for which such an extension benefits the United States. Waivers generally allow SJC Project water to remain in Heron Reservoir through April 30 of the year following the one in which the water was allocated to the contractor. Reclamation has authorized waivers even later in the year, but only under unusual circumstances.

Reclamation has authorized waivers at times when maintaining water in Heron will allow use of such water at a later date to facilitate downstream storage or when changes to the timing of deliveries help maintain fishery flows and support recreation on the Rio Chama. Reclamation also has authorized waivers to contractors who have agreed to lease their allocated water to Reclamation's Supplemental Water Program.

From 2003–2011, Reclamation acquired over 201,601 AF of San Juan-Chama Supplemental Water at a cost of approximately $17,679,696.

5.6.1.1.3 Conservation Water Agreement and Emergency Drought Water Agreement

Reclamation also includes in its Supplemental Water supplies water leased from the State of New Mexico of water obtained through relinquishment of New Mexico credits under the Rio Grande Compact. Lease of this water to Reclamation's Supplemental Water Program was made possible through the Emergency Drought Water Agreement[26] and the Conservation Water Agreement (CWA) with the State of New Mexico. CWA and EDWA water has been stored, and made available to Reclamation, consistent with the relevant interstate compacts and with State and Federal law as a conservation pool upstream of Elephant Butte Reservoir. Pursuant to the amended EDWA agreement (2003–2013), Reclamation may release up to 20,000 AF of its allocated water in any one calendar year. This water is authorized for storage while Article VII storage

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[26] In 2003, Reclamation, the MRGCD, the Service, BIA, and the Corps entered into the Emergency Drought Water Management Agreement to coordinate the use of EDWA water, to provide an additional source of stored water for routine MRGCD operations, and to manage EDWA water in a manner that optimizes operations for meeting needs of both irrigators and species as set out in the 2003 BiOp.

restrictions under the Compact are in effect; and, therefore, this supply has significantly contributed to the availability of Supplemental Water during low-water years.

In 2003, New Mexico offered to relinquish up to 217,500 AF of accrued credit waters in Elephant Butte Reservoir. In April 2003, New Mexico relinquished 122,500 AF of credit water held in Elephant Butte Reservoir, and Texas accepted that water in project storage. It was further agreed that Texas would accept the balance of 95,000 AF if available. In 2004, Texas accepted an additional 53,000 AF. These agreements allowed Reclamation to store in El Vado Reservoir a maximum of 169,448 of the 175,500 AF relinquished to date while under Article VII restrictions. Approximately one-third of the relinquishment storage could be used by Reclamation on behalf of federally listed endangered species, while two-thirds of the relinquishment was assigned to the MRGCD supplies. Releases related to the EDWA storage for endangered species compliance averaged 7,620 AF over the 6-year period from 2003–2008. Credit relinquishments for 125,000 AF in 2008 enabled Article VII restrictions to be lifted. Approximately 62,500 AF of water was allocated for species needs, but EDWA waters were not actually stored in 2008. An unallocated balance of 62,500 AF of water was reserved for future as yet undefined needs. As of the end of 2011, there was 19,196 AF of EDWA water in storage at El Vado, and Reclamation has an additional unused allocation of 19,500 AF.

Reclamation also sought to maximize storage for Supplemental Water obtained either from EDWA or SJC Project water leases. Storage agreements for conservation water storage at Abiquiu Reservoir were secured, contingent on the availability of space. In 2005 and 2006, 20,000 AF of storage at Abiquiu was designated for conservation storage. A new agreement signed in 2007 identified 10,000 AF of conservation storage space. Since ABCWUA has brought its SJC Drinking Water Project online, the amount of potentially available conservation storage space available at Abiquiu is increasing and is expected to ultimately increase to about 30,000 AF.

From 2003–2011, Reclamation acquired over 64,509 AF of Supplemental Water under the Emergency Drought Water Agreement at a cost of approximately $6,450,900.

5.6.1.1.4 Release of Supplemental Water

Supplemental water acquired as described in the sections above has been released from storage by Reclamation as needed to meet the needs of listed species. Since SJC Project waters are not authorized to be used for delivery compliance under the Compact, Reclamation has exchanged the leased SJC Project water with MRGCD for native Rio Grande flows. The SJC Project water leased each year by Reclamation has, therefore, been used beneficially in New Mexico for irrigation, while native waters have augmented stream flow and provided benefits to the listed species. The MRGCD has used the exchanged Supplemental Water for irrigation once it has passed the downstream-most flow target.

The following figure 53 shows the total water released under the Supplemental Water Program for ESA purposes over the past decade. It is evident from this figure that CWA and EDWA water were a significant source of water released to benefit listed species during the drought years of the early part of the past decade. Please note that in 2001 and 2002, water was released according to different criteria and flow targets than in the years covered by the 2003 BiOp. In 2000, 171,000 AF was released that was related to a court order to keep the Rio Grande wet pending re-consultation with the Service over the minnow. This process resulted in the 2001 BiOp. In 2002, 73,000 AF was released under the 2001BiOp.

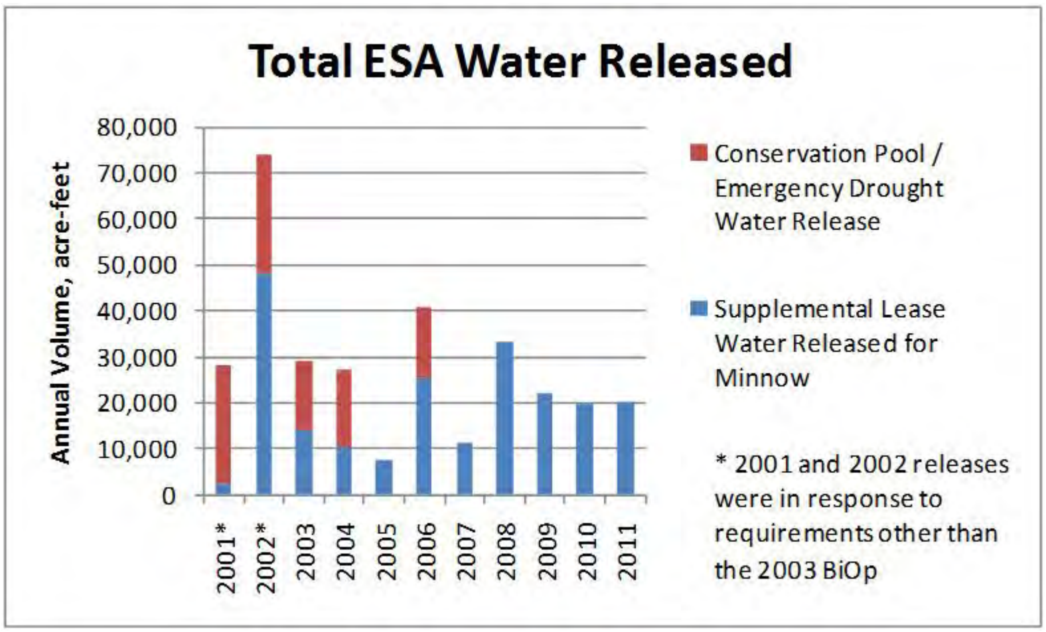

Figure 53. Summary of water released annually to meet the needs of listed species under Reclamation's Supplemental Water Program.

A new Biological Opinion was implemented as of March 13, 2003, and the remaining releases were made to meet the requirements of that BiOp. The annual average release of water for ESA purposes under the 2003 BiOp was 28.568 AF, of which 19,593 AF was leased SJC water, and 8,975 AF was conservation pool/emergency drought water.

About one-third of Supplemental Water released was used to support continuous flow requirements, spring spawning and recruitment flows, and to manage recession (March–June) while the remaining two-thirds of Supplemental Water supplies were released to meet late season flow targets (July–October) or manage recession after rewetting.

The date of first release of Supplemental Water has varied widely, from early March to early August. These variations, which are graphed in figures 54 and 55, are dependent on hydrologic conditions (the earliest dates are from the drought years of 2002–2004) and BiOp requirements for a given year. The last release date for Supplemental Water each year was in October, the last month of the irrigation season for non-Pueblo irrigators, except in 2006, in which it was in early November, during the final period of Pueblo irrigation. In figures 54 and 55, these dates of ESA water release are compared to the dates of reported river drying in the Isleta Reach and the San Acacia Reach. As can be seen on these graphs, ESA water release typically has been initiated in anticipation of river drying in these reaches.

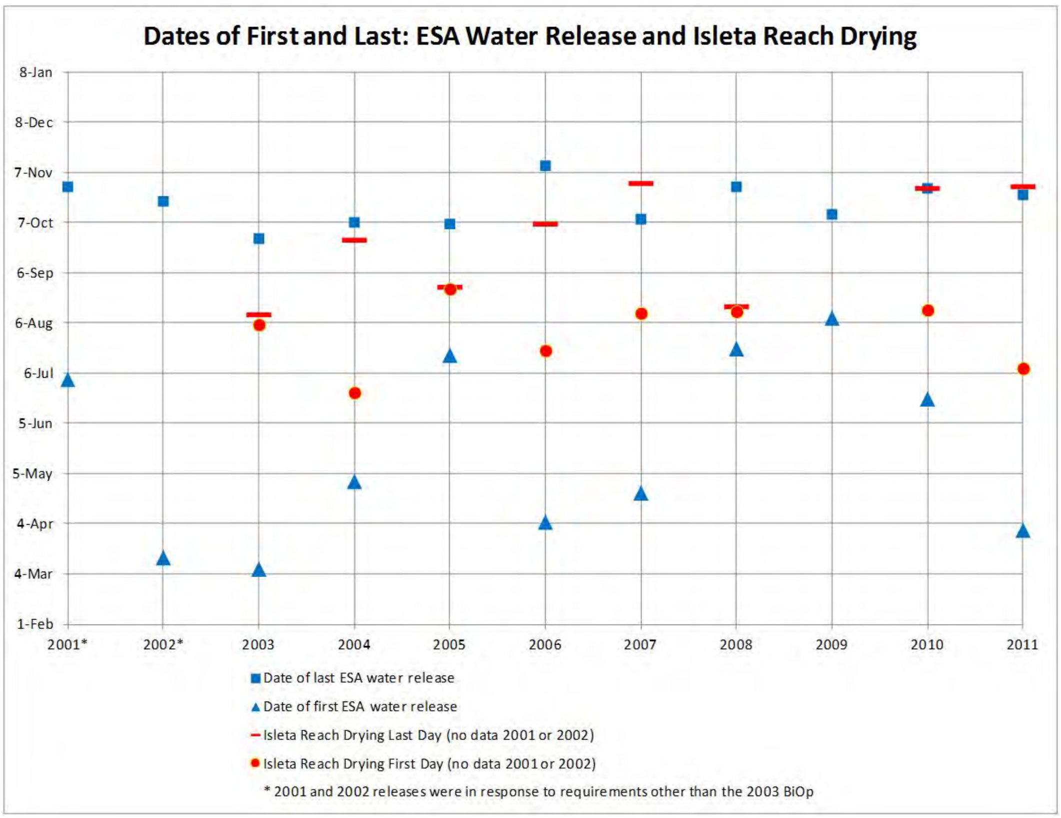

Figure 54. Comparison of dates of first and last release of water from Reclamation's Supplemental Water Program to dates of reported river drying in the Isleta Reach, 2001–2011.

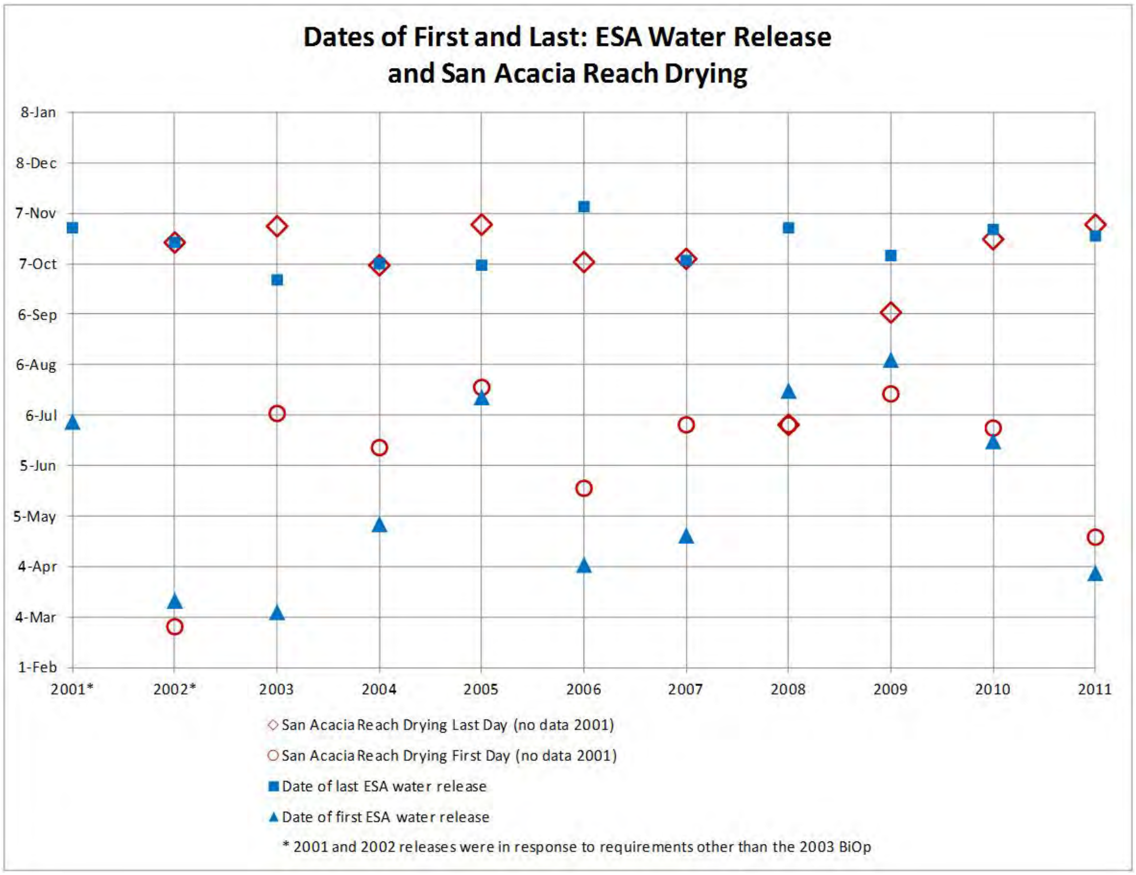

Figure 55. Comparison of dates of first and last release of water from Reclamation's Supplemental Water Program to dates of reported river drying in the San Acacia Reach, 2001–2011.

The data presented demonstrate that Reclamation has met the flow requirements of the 2001 and 2003 BiOps over the past decade, but that Reclamation's ability to do so was dependent on the following conditions and events:

- The availability of water to be leased to Reclamation's Supplemental Water Program, including both SJC Project water leased from willing sellers and water relinquished and leased to Reclamation by the State of New Mexico.
- Conservations measures and other helpful water management actions performed by Reclamation's water management partners, including the Corps, the Service /BDA National Wildlife Refuge, the State of New Mexico, and the MRGCD.
- No years with small, early snowmelt runoffs, such that Supplemental Water is required to maintain continuous flow throughout the MRG.

5.6.1.1.5 *Pumping from the Low Flow Conveyance Channel*

Due to the long travel times for Supplemental Water stored in Rio Chama reservoirs, various types of diversion and river losses, and difficulties in meeting downstream flow targets during dry periods, Reclamation implemented a local water management alternative in the reach below San Acacia Diversion Dam, in which water, collected from seepage into the LFCC, is pumped from LFCC to the river. From 2001–2010, pumping of water from the LFCC to the river in the San Acacia Reach has been used to limit the extent of river drying from Neil Cupp south to Fort Craig and to assist in managing river recession and silvery minnow rescue. LFCC pumping was identified in the 2003 BiOp as a beneficial action that helps sustain habitat for both the silvery minnow and Southwestern willow flycatcher. Accordingly, Reclamation has performed this action as part of its Supplemental Water Program. As such, it does not preclude river drying when drying is allowed under the 2003 BiOp.

In 2000, Reclamation installed and operated temporary pumps at Neil Cupp, Mid-Bosque, South Boundary, and Ft. Craig to alleviate drying in the Rio Grande to benefit the RGSM and SWWF. Subsequently, Reclamation relocated the Mid-Bosque pumps to North Boundary. In June 2005 Reclamation produced an appraisal design study on installing permanent, electrically operated pumps at the four historical sites. Due to monetary concerns, the permanent-pump alternative was not pursued. At present, sites are located at both the northern and southern boundaries of Bosque del Apache Wildlife Refuge (North Boundary, South Boundary), Neil Cupp and Fort Craig.

Although not required by the 2003 BiOp, Reclamation has continuously pumped water from the LFCC to the river at South Boundary during each of the summer drying seasons except 2008, to maintain river flows south of BDANWR for the benefit of the minnow. Other stations are used as needed and, as water is available, to assist in managing river recession (generally before the end of June) and to support RGSM salvage and rescue operations. The pumps at North Boundary and at Neil Cupp have been operated intermittently, primarily due to the need to balance the use of the available water in the LFCC between the Supplemental Water Program, the MRGCD (which has an LFCC diversion structure at Neil Cupp) and the BDANWR (which has an LFCC diversion structure at the north boundary of the refuge).

Figure 56 shows the total amount of pumping from all of the LFCC pump stations since 2001 on an annual basis. LFCC pumping volumes ranged from 30 (2008) to 32,481 (2002) AFY. As this figure shows, total pumping was highest during the early 21st century drought years and has declined considerably since. A typical distribution of volume pumped at each site is given in figure 57, which was representative of the 2006 pumping season.

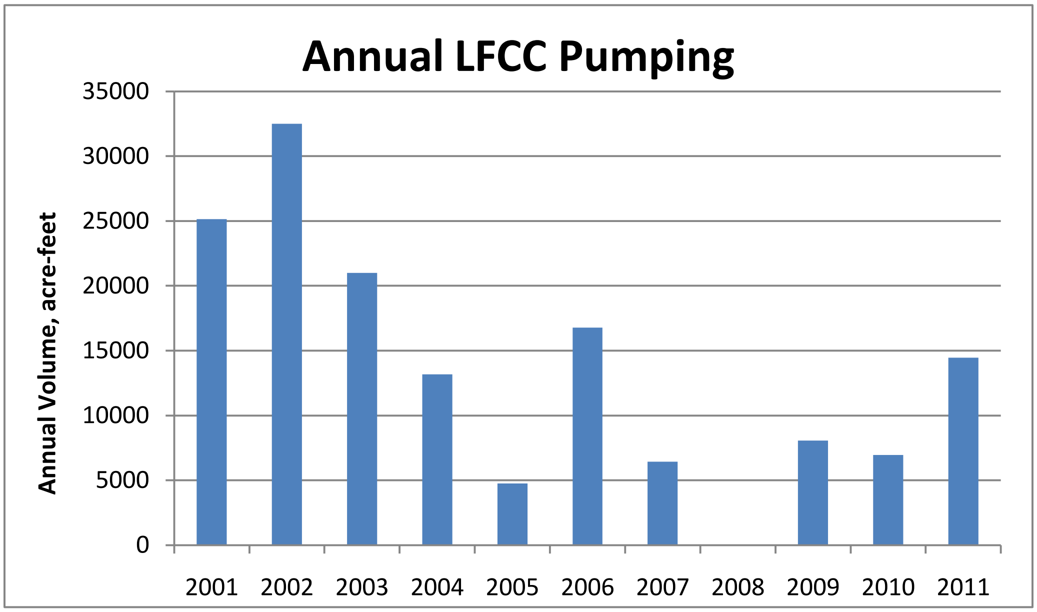

Figure 56. Summary of water pumped annually from the LFCC to the San Acacia Reach of the Rio Grande, as part of Reclamation's Supplemental Water Program.

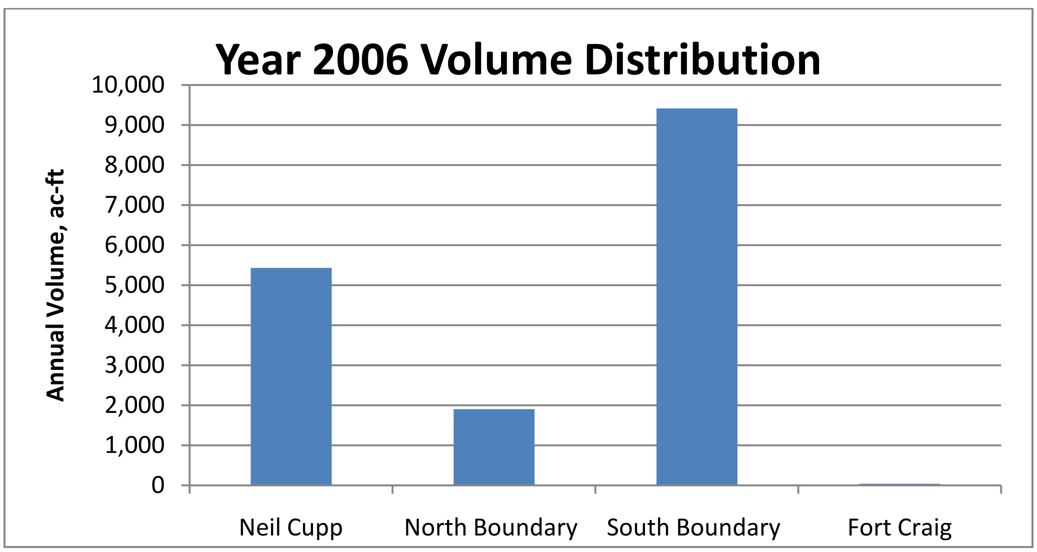

Figure 57. 2006 distribution of annual volume pumped from the LFCC across the four pumping sites used during the baseline period.

Figure 58 provides a comparison of the time period during each calendar year in which Reclamation has pumped water from the LFCC to the San Acacia Reach of the river to the time period in which drying was reported in this reach. In most of these years, pumping has been initiated in anticipation of river drying and has helped to ameliorate the effects of that drying on the species by providing refugial wetted habitat at key locations.

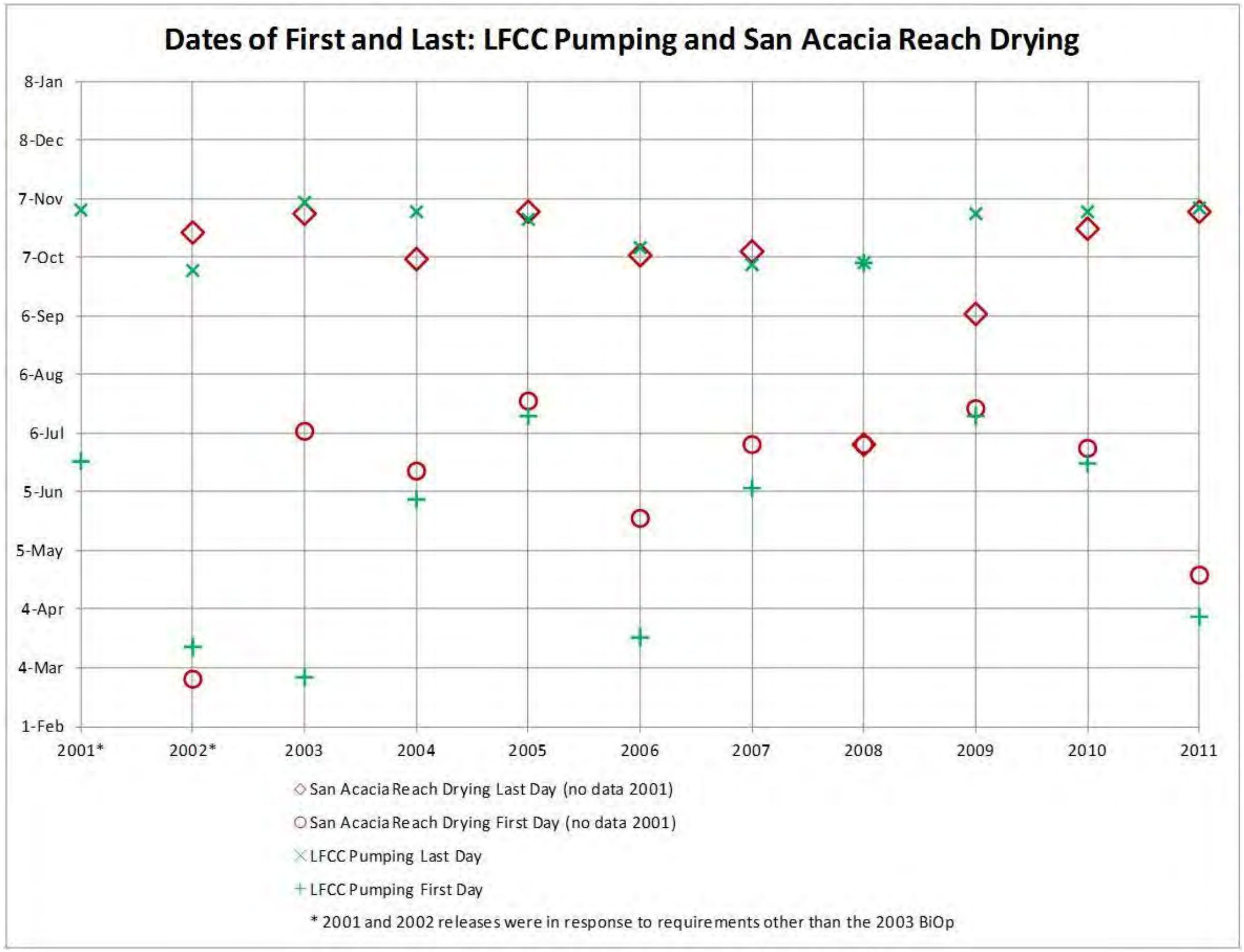

Figure 58. Comparison of the calendar days of supplemental water release to the calendar days of pumping from the Low Flow Convevance Channel.

5.6.1.2 MRGCD's Conservation Activities.

The MRGCD takes the below-described measures to support listed species. Additionally, the MRGCD participates in and shares the cost of the Collaborative Program, and funds PVA model development (full funding for one of the two models under development).

5.6.1.2.1 MRGCD's Enhanced Coordination for Environmental Water Operations

The MRGCD's enhanced coordination for environmental water operations have included the following timeframe:

- Participation in the regular management of water operations throughout the MRG, in conjunction with Reclamation, the Corps, NMISC, the ABCWUA, and the Service with the goal of providing efficient water management, meeting the needs of all State of New Mexico permitted water uses, remaining in compliance with the Compact, and benefitting the species to the greatest extent practical.

- Provision of access to MRGCD managed lands for operational and scientific purposes involving species (including guides, keys, etc.), including activities related to habitat restoration projects, fish monitoring, and fish salvage.

- Operation and maintenance of measurement stations, telemetry equipment, computer processing, and data exchange networks to collect and distribute information on MRGCD water operations to other water management entities and the general public.

- Expansion and refinement, with funding and cooperation from the State of New Mexico, Reclamation, and the Program, of the network of MRGCD measurement stations to contribute to a more thorough scientific understanding of water movement, distribution, and use throughout the MRG.

- Support for efforts by Reclamation and NMISC to fully understand Rio Grande depletions from all sources through participation in river measurements made by various entities.

- Support for management of Supplemental Water by Reclamation, and species salvage by the Service, through participation in river measurements during critical periods.

5.6.1.2.2 MRGCD Operations to Support Instream Habitat and Flow Management

The primary purpose of the MRGCD's operational measures described below has been to benefit listed species.

- MRGCD requested that Reclamation release from El Vado only the amount of irrigation water necessary to sufficiently augment native supplies to meet agricultural demands. This operational efficiency has the goal of increasing annual carryover of stored water, minimizing both Reclamation's need for Supplemental Water for the species and impacts of subsequent storage operations on flows. This allowed the MRGCD to minimize the rate of diversion at the Diversion Dams during critical times, most significantly Angostura Diversion Dam, and to continue to use the layout of the four MRGCD divisions to efficiently re-use return flows.

- The MRGCD has managed releases of return flows from drain outfalls and wasteways to better meet the needs of RGSM. These releases, which have been coordinated with Reclamation's Supplemental Water Program, have increased the consistency of return flows and have provided discrete wetted sections that have served as refugia for RGSM, with possible SWFL benefit. On occasion, the MRGCD managed these releases to assist the Service with its RGSM rescue efforts.

- The MRGCD has exchanged Reclamation's Supplemental Water, as necessary, for an equal amount of native water. This exchange has ensured that all SJC Project water that was released under the Supplemental Water Program was beneficially consumed within the MRG.

- The MRGCD has borne all losses to Reclamation Supplemental Water through Cochiti Dam and Albuquerque Reaches. As a result, Supplemental Water has been conveyed through the Cochiti and Albuquerque Reaches without incurring any loss. In exchange, the MRGCD has diverted the remaining Supplemental Water once it has passed the downsteam-most flow target specified in the 2003 BiOp.

- During periods with a continuous flow requirement through the MRG, the MRGCD has borne a variable portion of losses to Reclamations' Supplemental Water, to ensure that 50% of the Supplemental Water arriving at Isleta Diversion Dam is passed through the Isleta Reach to the San Acacia Diversion Dam.

- During its shortage/conservation operations in the fall of 2011, the MRGCD reduced diversions at Angostura Diversion Dam to the minimum practical rate of flow required to meet irrigation demand within the Albuquerque division.

- The MRGCD has exchanged water with Reclamation's Supplemental Water Program to allow the program to achieve intended rates of flow below diversion dams without accounting for travel time between the reservoir from which the water was released and the river reach of concern (that is, when Reclamation has begun releasing Supplemental Water, the MRGCD has bypassed water through its diversion dams to support critical reaches downstream, even though the Supplemental Water had not yet reached the diversion dam). The MRGCD has taken actions to avoid the sealing of gates in the Isleta Diversion Dam, such that the normal gate leakage of approximately 8 cfs is maintained throughout the irrigation season. This water has provided critical refugial habitat for the minnow downstream from the dam.

- The MRGCD has taken actions to avoid the sealing of gates in the San Acacia Diversion Dam, such that the normal gate leakage of a approximately 8 cfs is maintained throughout the irrigation season. This water has provided critical refugial habitat for the minnow downstream from the dam.

5.6.1.2.3 The MRGCD's Operation to Support Spring Peak Flows

- The MRGCD has minimized or temporarily suspended diversions during periods of peak silvery minnow egg production to minimize incidental entrainment of eggs and larvae into irrigation canals; this action has been subject to rates of flow, agricultural needs, and coordination with the Service.

- The MRGCD has coordinated its storage requests with Reclamation, NMISC, and the Corps with the goal of maximizing peak discharge and/or duration of the spring runoff through the MRG to benefit the species.

5.6.2 Habitat Improvement

Habitat restoration elements in the 2003 BiOp include various components meant to benefit the species. Some elements are basically coordination efforts to utilize the best available methods to minimize take. For example, any project that may potentially affect flycatcher or minnow habitat is coordinated with the Service including maintenance of LFCC pumps (Element P). This includes vegetation clearing and other activities that surround the pump sites. Water is a key element within the Rio Grande, and many gages in the river and within MRGCD (Element Q) have helped to ascertain the accurate accounting of water use. Other elements are more specific to improving conditions for endangered species and may be specifically tied to the recovery plan.

5.6.2.1 Fish Passage

Fish passage (Element R) has been delayed due to needed additional assessments. An external peer review process, initiated through the Collaborative Program, was completed in 2011. This peer review of the science surrounding the need for fish passage found that there was much uncertainty surrounding what the goals for fish passage are, and how many silvery minnow would need to use it to accomplish these goals (PBS&J 2011). The peer review panel recommended that more research into the relationship between genetic diversity and dam fragmentation as well as the influence of habitat mitigation within reaches on movement, growth, survival, and reproductive success of the silvery minnow be conducted before fish passage at San Acacia Diversion Dam is attempted.

5.6.2.2 Habitat Restoration

Habitat improvement projects (Elements S, T, and X) and efforts by other parties in coordination with the Collaborative Program, yielded over 2,500 acres of habitat restoration work in the MRG at a cost of $16,487,092. This amount includes Reclamation and Collaborative Program amounts for actual construction. Additional funding was provided for planning, design, and monitoring costs (not included in the $16.4 million).

The initial focus of these restoration efforts was in the more degraded upstream reaches between Cochiti Dam and Isleta Diversion Dam. However, more recently the emphasis has expanded to include significant restoration efforts in the Isleta Reach. Funded through the Collaborative Program, the Corps, Reclamation, the Service's Management of Exotics for Recovery of Endangered Species program, ABCWUA, the Pueblos, city of Albuquerque, and others have provided localized changes to improve riverine and riparian conditions along the MRG.

The projects have used techniques including creating/opening secondary high flow channels, lowering/clearing bank lines, islands, and adjacent bars, creating overbank flooded habitat, clearing non-native vegetation, planting native vegetation, building gradient reduction facilities, widening the river channel, placing large woody debris, building embayments and backwater areas, and removing lateral constraints. Further descriptions of the methods, the most likely geomorphic and biological response, as well as habitat characteristics of the habitat restoration techniques commonly used on the MRG over the last decade is included in Appendix 1. Because the MRG is actively self-regulating to balance its sediment transport capacity and sediment supply, exact geomorphic and biological responses to a particular method after implementation are more difficult than for rivers that are closer to a sediment balance. Caveats on the use of the geomorphic responses are described in the Channel Conditions and Dynamics section.

The objective of many of the projects has been to provide additional low velocity habitats during high flows and increase retention of eggs and larvae within the upper reaches of the river when inundation targets are met for these projects. Habitat restoration techniques that have been used for improving habitat at lower flow conditions include creation of refugial habitat at drains and placement of cottonwood snags or large woody debris that create pool habitat. Specific projects for flycatchers also have been completed, which replace monotypic stands of saltcedar with dense native vegetation and provide greater flood plain connectivity.

Monitoring is ongoing to evaluate if restoration is producing positive results for minnows and flycatchers and to evaluate effectiveness of techniques used. Generally, most projects have had positive results and use by minnow. For silvery minnow, it is considered to be a success if more low velocity habitat is available at the sites than was available prior to restoration. Large numbers of silvery minnow have been collected on inundated sites (Collaborative Program 2011, SWCA 2010a&b). Creation of suitable flycatcher habitat is predicted to take several years postconstruction for mature vegetation to establish. No suitable habitat was identified in the 2008 flycatcher habitat suitability model. At this time, no flycatcher nesting has been verified on any program habitat restoration sites.

Hydrologic monitoring on NMISC restoration sites indicates that these sites provide fish habitat that is lower velocity and shallower than the adjacent river channel. Monitoring efforts also have been analyzed to understand the potential differences in hydrological conditions produced by different general restoration techniques. For this effort, four broad categories of habitat restoration techniques were used: high flow channels, backwaters, and lowering of bank shelves and islands (table 7). While all techniques produced hydrologic habitat conditions that fall within the suitable habitat range, backwaters generally produced the lowest velocity and the second highest depths. High-flow channels resulted in both the highest depth and highest velocity conditions. Shelves and islands were the only two techniques that had conditions within the suitable habitat range recorded in each measured transect (ISC 2011 DRAFT).

The amount of restored habitats that inundate annually varies depending on discharge. Most features have been designed to inundate at flows between 1,500 and 3,500 cfs at the site location. The amount of restored acreage that inundates annually increases with the amount of flow, though all features do not function equally at flows greater than their designed inundation level. For example, a feature designed to inundate at 1,500 cfs may not provide low velocity habitat at 3,500cfs. Since the year 2000, 4 years had spring discharge levels that fully inundated restored sites in the Albuquerque Reach (> 3,500 cfs) for more than 10 days, while 5 years failed to inundate any sites designed for 1,500 cfs or more for at least 10 days (table 8). Available data for the Bosque Farms and 346 Bridge Gage show that the inundation targets for restoration sites in the Isleta Reach are met less often. Table 9 provides a brief description of habitat restoration projects and the listed acreage of that work. Information was compiled from three sources: The Middle Rio Grande Endangered Species Collaborative Program's (MRGESCP) annual reports and Reclamation's annual Biological Opinion Accomplishment Reports sent to the Service.

Table 7. Average depth and velocity conditions on categorized habitat restoration sites (ISC 2011 Draft)

Technique Categories	Sample Number (n)	Mean Depth (ft)	Mean Velocity (ft/sec)
High Flow Channels	24	1.23	1.24
Backwaters	15	1.18	0.23
Bank Shelves	33	0.76	0.35
Island	24	0.67	0.32

Table 8. Maximum consecutive days of discharge exceeding habitat restoration inundation targets at Albuquerque Gage from 2000–2011 (USGS8330000), Bosque Farms Gage from 2006–2011 (USGS 08331160), and Highway 346 Gage from 2006–2011 (USGS 08331510). Dark shading indicates no days with average discharge greater than inundation targets. Lighter shading indicates inundation less than 10 consecutive days.

Albuquerque Reach			
Albuquerque Gage	**Inundation Targets (cfs)**		
Year	**3,500**	**2,500**	**1,500**
2000			
2001	2	6	37
2002			
2003			
2004		1	13
2005	71	78	88
2006			1
2007	3	15	37
2008	22	92	103
2009	20	34	47
2010	12	31	62
2011			

Isleta Reach			
Bosque Farms Gage	**Inundation Targets (cfs)**		
Year	**3,500**	**2,500**	**1,500**
2006		1	2
2007		4	28
2008	11	27	92
2009	13	28	35
2010	4	6	31
2011			
346 Bridge			
2006			
2007		4	27
2008	12	26	93
2009	15	33	35
2010	5	7	32
2011			

Table 9. Summary of habitat restoration activity on the Rio Grande, sorted by geomorphic reach

Year	Type of Work	Project Lead/ Project Name	Total Work Done
	Rio Chama to Otowi Bridge		
2004	Non-native vegetation removal and native vegetation planting	Ohkay Owingeh Pueblo	40 acres vegetative removal,75 acres native planted
	Removal of approximately 40 acres of Russian olive and other exotic vegetation. In addition, willows and native wetland plants were planted in two areas.	Ohkay Owingeh Pueblo	75 acres
2005	SWFL habitat created at Ohkay Owingeh Pueblo creation of high flow channels, removal of non-native trees, and planting of native tree species	Ohkay Owingeh Pueblo	10 acres
2007	Ohkay Owingeh Pueblo installed habitat within restored bosque, also included exotic vegetation removal	Ohkay Owingeh Pueblo	10 acres
2007	Buried Bendway weirs at San Ildefonso	Reclamation	
2008	Ohkay Owingeh Pueblo installed habitat within restored bosque, also included exotic vegetation removal	Ohkay Owingeh Pueblo	38 acres removed, replanted
2010	Ohkay Owingeh Pueblo invasive species removal and native vegetation planting• 15,000 herbaceous wetland plants, 3500 coyote and Gooding's willows, and 148 box elder.	Ohkay Owingeh Pueblo	279 acres replanted
	Total Rio Chama to Otowi		**487 acres of habitat work**
	Cochiti Dam Reach		
2005	Bank lowering at Santa Fe River confluence1.6 acres re-connected to river and planted with native vegetation	Reclamation	1.6 acres reconnected
2006	Modification of side channel to connect with main stem, creation of embayments and backwater, non-native vegetation removal.	Santo Domingo	114 acres non-native removed, 2 acres side channel, embayment
2007	Santo Domingo Pueblo reconnected an old oxbow to the main channel, created embayments, and installed large woody debris to the main channel	Santo Domingo	23 acres, oxbow recreation
2008	Removal of non-native vegetation at San Felipe Pueblo	San Felipe Pueblo	10 acres non-native removed
2008	Riparian and backwater area creation; bioengineering at the Pueblo de Cochiti	Reclamation	7 acres backwater
2009	Santo Domingo Pueblo - removal of invasive species and channel restoration over three areas	Santo Domingo	58 acres combined non-native removal and channel
2010	Santo Domingo Endangered Species Habitat Improvement Project Phase IV– reconstruction of a historic side channel	Santo Domingo	9 acres historic side channel
2011	Revegetation and construction at two Santo Domingo sites	Santo Domingo	30 acres
	Vegetation clearing, riparian and backwater area creation, bioengineering at the Pueblo of San Felipe	Reclamation	18 acres of non-native vegetation removal, 5 acres of habitat restoration; bioengineering planted with native vegetation
	Total Cochiti to Angostura		**272.6 acres habitat work**

	Angostura Reach		

Table 9. Summary of habitat restoration activity on the Rio Grande, sorted by geomorphic reach

2003	Habitat restoration at the Pueblo of Sandia	Sandia Pueblo	40 acres restored
2003	Clearing non-native vegetation, installation of willow swales and Gradient Restoration Facilities.	Santa Ana	Cleared 500 acres of bosque, 100 acres of willow swale, 4 GRFs
2003-2004	Perennial pools created using cottonwood large woody debris through Albuquerque reach	MRGCD	3 Cottonwood Snags
2004	Willow swale installation at Santa Ana Pueblo	Santa Ana Pueblo	10 acres willow swale
2004	Wetland creation and bosque restoration at Tingley Beach	City of Albuquerque	48 acres restoration, wetland creation (Tingley)
2005	Island and bank destabilization through the Albuquerque reach	ISC/Reclamation	12 acres bar destabilization
2005	Pond reconstruction, bosque restoration, and wetland creation at Tingley Beach	City of Albuquerque	9 acres wetlands construction, 15 acres pond reconstruction
2005	Removal of non-native vegetation throughout the Albuquerque reach		200 acres non-native removal and replanting
2006	ISC performed bank lowering, island lowering, and ephemeral channel excavation north of Alameda bridge through the Albuquerque reach	ISC	74 acres, bank, island lowering
2006	Habitat creation at the Rio Grande Nature Center	Corps/Rio Grande Nature Center	15 acres various riparian
2006	Flood plain lowering and formation of riparian habitat near Bernalillo	ISC	6 acres high flow channel
2007	Excavation of ephemeral channels and removed non-native vegetation at the Rio Bravo south site	City of Albuquerque	26 acres non-native removal near channel
2007	U.S. Highway 550, Paseo del Norte to Montano Road, in the vicinity of the I-40 bridge and in the vicinity of the South Diversion Channel. Restoration techniques included vegetated island modification, bar habitat modification, placement of large woody debris, bank scouring, bank lowering, and the establishment of ephemeral channels.	ISC	87 acres, various methods
2007	Riparian and variable flow aquatic habitat created on the Pueblo of Sandia , construction of bendway weirs and placement of rootwads	Reclamation	35 acres, mostly riparian near aquatic
2008	Habitat restoration at north Rio Bravo site	City of Albuquerque	1.3 acre Rio Bravo
2008	Rio Grande Nature Center bosque reconnection with the Rio Grande	Corps/Rio Grande Nature Center	10 acres non-native, 3 acres high flow channel
2009	Bank lowering project/habitat restoration	Corps	27 acres of habitat restored, 62 acres of banks and islands were lowered
2009	Construction of backwater and other bank lowering activities	City of Albuquerque	20 acres of bank and bar lowering; 5 acres of habitat was created by the backwater construction
2009	Removal of jetty jacks and created habitat north of Rio Bravo by reshaping of the bank	City of Albuquerque	140 jetty jacks, re-treated 20 acres of re-sprouting non-native vegetation, and planted 40 cottonwoods, 250 black willows, and 4,000 sedges and rushes. 58.3 acres of habitat were created .
2009	Route 66 bosque restoration, 121 acres of riparian restoration, 5 willow swales, and 3 high-flow channels	Corps	121 acres of habitat restored
2009	Sediment spoil pile removal	Santa Ana/ Reclamation	20 acres of overbank improved
2009	Construction of a 5-acre backwater and refugial habitat	ISC	25 Acres

Table 9. Summary of habitat restoration activity on the Rio Grande, sorted by geomorphic reach

	at an old irrigation diversion structure, named the Atrisco Diversion. Also, 20 acres of river bankline, islands, and bank-attached bars were modified by lowering and sculpting to create new flood plain habitats that inundate during spring runoff		
2009	Re-connection of flood plain at the Pueblo of Santa Ana	Pueblo of Santa Ana/Corps	62 acres of bank-lowering to increase the extent and frequency of inundation in the Pueblo's reach of the Rio Grande
2010	Project features include island and bar vegetation removal and destabilization, bank lowering, and backwater embayments	Sandia Pueblo	24 acres bar lowering, backwater
2011	Project features include island and bar vegetation removal and destabilization, bank lowering, and backwater embayments	Sandia Pueblo	30 acres, backwaters, destabilization
	Total Angostura Diversion Dam to Isleta Diversion Dam		**1,530 acres habitat work**
	Isleta Reach		
2003	Riverbank was lowered and bank features constructed at Los Lunas Habitat Restoration Project	Reclamation	50 acres bank lowering, etc.
2005	Pole planting of native vegetation at 2002 Los Lunas restoration site	Reclamation	16 acres replanted
2007	MRGCD, Reclamation, and Habitech collaborated in the anchoring of enhancement structures comprised of large cottonwood snags in the Middle Rio Grande channel at the outfalls of the three drains located upstream of Highway 308 near Belen, New Mexico in the Isleta Reach	MRGCD	Structures installed on three drains.
2008	Isleta Pueblo – Island destabilization project funded by New Mexico Water Trust Board.	Isleta Pueblo	
2009	Modification along banklines, islands, and bank-attached bars to create new flood plain habitat. The new habitat features include a large off-channel backwater in a low-lying area of the Bosque.	ISC/Isleta Phase I	24 acres, island modification and bank lowering, 5.8 acre backwater
2010	Habitat modification includes nonnative species removal, high flow channels, and bank lowering.	ISC-Reclamation/ Isleta Phase II	56 acres, various techniques
2011	Habitat modification includes nonnative species removal, high flow channels, and bank lowering.	ISC-Reclamation/ Isleta Phase II	45 acres, various
	Total Isleta Reach		**196.8 acres habitat work**
	San Acacia Reach		
2003	Helicopter spraying of dense saltcedar groves south of Socorro.		230 acres sprayed, vegetation control
2005	Setback of lateral constraints around RM 113/114	Reclamation	187 acres to readjust
2005	Removal of monotypic saltcedar and the mechanical control of non-native vegetation river bars and jetty jacks removal.	BDANWR	51 acres non-native removal
2006	Removal of monotypic saltcedar and the mechanical control of non-native vegetation river bars and jetty jacks removal.	BDANWR	76 acres non-native removal
2009	Setback of lateral constraints around RM 111, additional space provided for river to self adjust	Reclamation	59 acres setback
	Total San Acacia Reach		603 acres habitat work
	Total habitat work (all reaches)		**3,089 acres**

5.6.2.3 Railroad Bridge Relocation

The relocation of the railroad bridge at San Marcial (Element U) has not been implemented due to cost and lack of agency authorization. With the steady lowering of Elephant Butte Reservoir levels since 2001, the headcut that has resulted has contributed to increasing the flow capability under the bridge, which was the original reason for the relocation.

5.6.2.4 Overbank Flooding and Sediment Transport

The Corps has stored and later released floodwater to increase the number of days of flood plain inundation downstream from Cochiti Dam. With a degraded river channel and the very established vegetation along much of the river, the maximum flow allowed from Cochiti Dam (7,000 cfs) has limited ability to create new backwater habitats for silvery minnow and flycatcher within the upper reaches (Element V). Habitat restoration projects have increased the area that inundates at lower discharge levels. Increased sediment transport out of Cochiti, Jemez, and Galisteo Dams, (Element W) has not fully been implemented but is ongoing. In addition to this possible source of sediment into the overall sediment starved MRG, and indirect benefit from all the ongoing habitat restoration work is that approximately 2–3 million cubic yards of sediment have been reintroduced into the river. This number is derived from a summation of Clean Water Act 404 permits and environmental assessments submitted for the projects.

5.6.3 Salvage and Captive Propagation and Actions to Minimize Take of Silvery Minnow

Propagation of silvery minnow has been very successful; in most years, there are more minnows available at propagation facilities than are needed for MRG augmentation activities (Element Y, Z, AA). Dexter National Fish Hatchery and Technology Center has been able to supply more than enough minnows than are required annually for the MRG. Hatchery fish also are maintained in two other facilities (Albuquerque Biopark and NMISC Los Lunas Refugium). Minnows also were held at the New Mexico State University A-Mountain Facility for research purposes. That program was discontinued in 2009. Genetic testing so far indicates that the captive fish are representative of the wild population, and augmentation has aided in maintaining genetic diversity between reaches (Osborne and Turner 2012). A fourth recently constructed Minnow Sanctuary within the Angostura Reach will also eventually contribute towards minnow management. If negative impacts to minnow population occur in the river, these propagation facilities can provide minnows back to the river. Reclamation and the Collaborative Program exceeded the monetary support requirements for these propagation facilities with a total of $6,644,970 provided to the Service, the Albuquerque Biopark, the ISC Refugium, and the Minnow Sanctuary for expansion (at Dexter) and O&M to date.

The 10j experimental population in the Big Bend area (Element BB) is now in its third year, and recruitment has occurred. Hatchery produced minnows were provided for this reintroduction from MRG propagation facilities. The population needs to be monitored for several more years, but the results are encouraging. Lessons learned from this activity can be used when the next population is established (Element CC). Reclamation and the Collaborative Program exceeded the monetary support requirements for this activity with a total of $1,120,00 provided to the Service to date.

Silvery minnow have been salvaged from drying reaches each year except 2008 (RPM 1.2, 1.3). To determine the extent of drying and facilitate salvage of silvery minnow, RiverEyes contractors monitor the river daily (Element C). It has been difficult to determine how salvage benefits (RPM 1.3) the silvery minnow population, since it likely depends on the duration and magnitude of drying; but relocating fish into flowing habitat does reduce the amount of mortality due to drying. Protocols for salvage were adjusted in 2007 in an effort to increase the likelihood that salvaged fish are fit enough to survive when released (Remshardt 2010, Caldwell et al. 2010). River flows are ramped down slowly using Supplemental Water in coordination with the Service. Pumping from the LFCC aids the ramp down process.

During the spawning period for the silvery minnow, egg monitoring in irrigation canals and entrainment have been assessed, and egg monitoring and collection occurs within the river channel (RPM 2.1 and 2.2). Egg monitoring has occurred each year except 2005. The Service monitors eggs within the canals and more indepth analysis of the egg entrainment data is underway by the Service. ABCWUA also conduct egg monitoring activities upstream of the Paseo del Norte diversion, near the water intake point, to estimate and reduce the amount of silvery minnow eggs entrained in the diversion structure. Egg collection activities are coordinated between the city of Albuquerque and the Service.

5.6.4 Water Quality

Since 2001, there are many general water quality assessments and specific studies that have been completed or are in process (Element DD, EE). Much of the data collected by these studies has not been clear and definitive on the effects of various water quality parameters on the silvery minnow population. The current status of information is presented in section 5.3.1.4.

5.6.5 Monitor Cowbird Paritism

A cowbird control program was conducted along the MRG from 1996–2001. This program involved trapping and removing cowbirds in an effort to reduce brood parasitism on flycatchers. In 1998, a telemetry study was initiated to determine the daily and seasonal movements of cowbirds to evaluate the effectiveness of localized cowbird trapping efforts (Sechrist and Ahlers 2003). An Assessment of the Brown-Headed Cowbird Control Program in the Middle Rio Grande, New Mexico, was prepared in 2003 by Moore and Ahlers to monitor the success of the cowbird trapping and removal effort. To complete this assessment, a nest monitoring and point count study was conducted targeting neotropical avian species. The end result concluded that, although cowbird trapping was effective on a local level by reducing cowbird abundance and parasitism rates, it is an ineffective method for increasing overall nesting success.

In 2006, a report titled Riparian Obligate Nesting Success as Related to Cowbird Abundance and Vegetation Characteristics Along the Middle Rio Grande, New Mexico, by Dave Moore concluded that habitat quality is the most important factor to neotropical migrant nesting success. Similar to the report from 2003, it was found that when parasitism rates were locally reduced, other factors came into play (such as predation for example), that inevitably kept nesting success at the same level.

In addition to studies focused on cowbird parasitism, all nests monitored since 1999 have indicated whether or not parasitism was present. Further analysis on nest parasitism versus nesting substrate, territory dominance, and hydrology immediately under the nest is completed annually.

5.6.6 Conservation Recommendations

Many of the 25 conservation recommendations in the 2003 BiOp have been implemented and/or are ongoing studies. Results from some of the studies indicate the need for additional work or refinements of the original hypothesis. The following table 10 is a list of the conservation recommendation with their current status.

Table 10. Synopsis of activities for conservation recommendations as defined in the 2003 BiOp

	Conservation Recommendations and Studies	Studies to Date
1	Effects of turbidity and suspended sediment on silvery minnow	The Service was funded by the Collaborative Program to investigate fish health including effects of suspended sediment. This project is still ongoing; initial findings indicate that high suspended sediment may affect the amount of food available to silvery minnow (Lusk PowerPoint 2011), which concurs with findings by Magana 2009 and Bixby and Burdett 2011.
2	Effects of sediment toxicity on silvery minnow	NMED 2009 review of current information found that chemical concentrations in sediment may have some impacts to fish and aquatic life. Based on the data collected in 2006–2007, the concentrations are not at levels where fish kills would be expected due to any one chemical; however, several chemicals were found above levels where adverse effects are expected to occur only rarely.
3	Silvery minnow diet and sediment ingestion	Diet studies have been conducted on hatchery fish (Magana 2009, Watson et al. 2009) that indicate that silvery minnow are primarily algavores but may use other food items such as macroinvertebrates depending on their availability. There are upcoming projects to determine diet and habitat use of larval fish.
4	How effluents from waste water treatment plants mix with Rio Grande at various discharges	Not completed.
5	Water pollution education; effects and prevention	Not completed specifically for MRG.
6	Voluntary water quality monitoring by citizens	Not completed.
7	Agricultural water forbearance program	A water management decision support system was developed in 2007 by NMISC. MRGCD would be the lead agency to implement a forbearance program.
8	Program for conversion of high to low water use crops	ISC's Middle Rio Grande Water Plan www.waterassembly.org/waterplan.htm describes the benefits and tradeoffs associated with converting to low water use crops. Further development of these ideas would need to be developed with MRGCD, NMDA and others.

Table 10. Synopsis of activities for conservation recommendations as defined in the 2003 BiOp

9	Monitor/study silvery minnow spawning	Ongoing activity, spawning mentoring in the river and canals is funded each year by Reclamation. Studies indicate few eggs are currently entrained in canals (Service Data). River monitoring provides information on the timing and conditions surrounding spawning events in the river.
10	Develop and implement long-term plan	Ongoing in Collaborative Program
11	Annually survey and report willow flycatcher habitats to FWS	Surveys began in 1994 in a more concentrated area but have expanded to the southern boundary of Isleta Pueblo to Elephant Butte Reservoir since 2002. Areas near Velarde and Frijoles Canyon also have been surveyed periodically.
12	Fund willow flycatcher habitat requirements study	A nest monitoring effort supplies information on habitat requirements (i.e., distance to water, nest substrate species, major plant community, etc.) and compares nesting components to nest success. A nest quantification study from 2004–2006 provided insight to habitat requirements such as stem densities and percent canopy cover for example. A mapping effort and subsequent habitat suitability model was completed in 2008 from Bernardo to Elephant Butte. Previous mapping efforts took place using the modified Hink and Ohmart approach in 2002 and 2005.
13	Contingency plan for fire in willow flycatcher habitat	Not formally completed. In a recent fire within the Elephant Butte Reservoir pool, coordination among fire crew and Reclamation and Bureau of Land Management staff took place to focus on protecting occupied flycatcher habitat from destruction.
14	Study ground/surface water relationship	This study is very site specific and dependant on soil composition, vegetation composition, and other factors. A ground water model was developed by USGS. Also, a study using data loggers to document the ground water levels and comparing that information to flows in the river was initiated in the BDANWR in 2010.

Table 10. Synopsis of activities for conservation recommendations as defined in the 2003 BiOp

15	Implement water efficiencies and apply savings to silvery minnow and willow flycatcher conservation	There are many informal water conservation contributions that MRGCD has implemented. ABCWUA routinely evaluates and improves/ monitors the water conservation program.
16	Encourage adaptive management of flows and conservation of water for ESA species	A formal Adaptive Management Program is being developed for the Middle Rio Grande. This process will be more completely discussed in the conservation actions section.
17	Secure storage rights and water for ESA species	Not completed; studies needed
18	Fund habitat preference studies for silvery minnow	Habitat use studies were done by Platania in 1997 based on the population monitoring information. Studies to understand habitat availability at various flow conditions were completed at several sites by Bovee et al. 2008. Their model indicated that greater amounts of suitable habitat (as defined by the recovery plan) at discharges between 100 and 200 cfs. Additionally, the Corps is currently funding USGS to conduct a habitat availability study.
19	Study saltcedar control and ensure no impacts to willow flycatcher and seek funding for habitat restoration	A study was initiated in 2002 to analyze revegetation strategies and restoration of saltcedar infested sites. This study used mechanical treatments, growth amendments, herbicide applications, and seeding mixtures in an effort to restore the site. A final report was not completed; but upon visiting the site, it appeared that not many native species developed. Young saltcedar and kochia revegetated the area instead. Goats were released within a study plot in 2004 to study their impacts on saltcedar resprouts. After 2 years of treatment, less than 10% of saltcedar plants were killed. However, duff and leaf area index was reduced by 27% and plants were damaged/stressed. Saltcedar leaf beetles have been recently detected within the MRG. Monitoring is underway to determine the effects of this species on the MRG bosque.

Table 10. Synopsis of activities for conservation recommendations as defined in the 2003 BiOp

20	Prevent unauthorized use of silvery minnow water	River discharge is monitored at several locations. The MRGCD has an ongoing process to identify water rights and leases within their district boundaries.
21	Assess willow flycatcher population at Elephant Butte Reservoir	Multiple studies on hydrologic and vegetation parameters as well as annual surveys and nest monitoring have taken place within the Elephant Butte Reservoir and associated population of flycatchers. A flycatcher management plan is currently in place to focusing on developing suitable habitat outside of the reservoir pool.
22	Use drains for silvery minnow refugia	Low densities of silvery minnow likely persist within the permanently watered canals such as the LFCC and drains (Cowley et al. 2007, Lang and Altenbach 1994, Reclamation 2010). Buhl 2011 conducted in situ studies in drains to inform refugia development. Woody structures were installed at the outflow of several drains to provide habitat. Results of these projects have been mixed.
23	NMGF monitor silvery minnow at Angostura Reach	Not conducted routinely; Angostura monitoring is covered in Population Monitoring Program.
24	Limit encroachment into 10,000 cfs flood plain	Houses build adjacent to the bankline has already restricted flows below the Highway 550 Bridge near Bernalillo to 7,000 cfs. Isleta Reach has very limited encroachment between the levees on both sides of the river. The collaborative program San Acacia Reach group has proposed a reach assessment be accomplished in 2013.
25	Investigate effects of predation and competition on silvery minnow	There is little information on the effects of predation and competition on silvery minnow within the MRG. Discussions of extirpation of silvery minnow within the Pecos watershed cite competition with introduced plains minnow as a primary factor (Hoagstom et al. 2010).

5.7 Summary of Baseline Conditions for Listed Species

There has been a multitude of recent activities in the MRG aimed at improving the status of the currently listed species, especially the silvery minnow and flycatcher. Silvery minnow and flycatcher population levels have both increased since the initiation of the 2003 BiOp. The following evaluates the status of baseline conditions in each reach. In addition, tables are developed for each major period in the life history of the listed species presenting the current knowledge of status of each critical habitat PCE.

5.7.1 Summary of Habitat Condition, Species Status, and Restoration by Reach

The following information is a short summary of habitat conditions and habitat restoration projects on the Rio Grande, sorted by geomorphic reach, as well as information on silvery minnow and willow flycatcher status in the area.

5.7.1.1 State Line to Otowi (State Line–RM258)

Along the Rio Grande from the State Line to Otowi, 18 flycatcher territories were documented in 2000 (table 2). In 2004 and 2005, 12 territories were detected (NM Rangewide Database). In 2009, the population increased to 34 territories. Twenty-one territories were identified in 2010 (NM Rangewide Database). As of 2011, 452 acres of habitat restoration was funded for habitat restoration within this reach. These projects have targeted improving the health of the river for flycatchers, and the reach continues to be occupied by flycatcher. Flycatcher critical habitat exists in this reach from Taos Junction Bridge to the upstream boundary of Ohkay Owingeh Pueblo. The proposed critical habitat extends to Otowi Bridge. Though there are historic records of silvery minnow from this reach, it was likely never abundant (Bestgen and Platania 1991). Silvery minnow have not been documented in this reach for over 30 years; the last silvery minnow was captured near Velarde 5 years after the closing of Cochiti Dam in 1973 (Bestgen and Platania 1991).

5.7.1.2 Chama River (State Line to Confluence)

Along the Rio Chama from the State line to the confluence of the Rio Grande, flycatcher surveys have been recorded in the NM Rangewide Database since 1993 (table 2). In 1993, two flycatcher territories were observed. The largest population detected in this reach was in 1994, 1997, and 2001 with four territories. There are few early fish sampling records in the Chama. There is some historic information from tribal sources that silvery minnow may have occupied the Chama up to approximately Abiquiu (Parametrix 2010). There is no critical habitat designated in this reach of the river. No habitat restoration projects have been done on this reach for silvery minnow or flycatchers.

5.7.1.3 Otowi Bridge to Cochiti Dam (RM 258–RM 233)

Formal surveys for flycatcher were not conducted within this reach until 2008. Since that time, territory totals have ranged between one and twp territories mainly in an area just south of Frijoles Canyon. The type specimens of silvery minnow were likely collected near Otowi Bridge (Bestgen and Platania 1991). Silvery minnow have not been collected in this reach for over 40 years. The current potential to support silvery minnow in this reach (if they were repatriated) is limited by the entrenched channel and loss of flood plain connectivity, cold water temperatures, channel fragmentation, substrate size, and competition with non-native fish species. The lack of low velocity habitats for larvae and young-of-year and the lack of contiguous sections of river to allow silvery minnow to complete its lifecycle within the reach would limit the ability for the species to successfully complete its life cycle (Bunjer and Remshardt 2005). There is no critical habitat designated in this reach of the river. No habitat restoration projects have been done on this reach for silvery minnow or flycatchers.

5.7.2 Cochiti Dam Reach

5.7.2.1 Cochiti Dam to Angostura Diversion Dam (RM 233–RM 210)

This reach has not been formally surveyed for flycatcher and is not known to have any suitable habitat. Silvery minnow egg monitoring has been conducted in the Angostura Canal from 2002 to present. During this time, only three eggs have been reported (in 2003), and those were not preserved for confirmation. The lack of eggs in the Angostura Canal suggests that silvery minnow density upstream of Angostura Diversion Dam is extremely low if present (Service 2009). No publicly available surveys were conducted in the last decade. Limiting factors in this reach for silvery minnow are likely cool water conditions from the operations of Cochiti Dam, lack of low velocity habitat, and a generally degrading river channel (Service 2008). The land base encompassing the Cochiti Dam Reach is primarily tribal-owned and requires partnership with the Pueblos. Funding has been provided to Cochiti, Santo Domingo, and San Felipe Pueblos through the Collaborative Program from 2002 through present for habitat restoration and maintenance including nonnative vegetation control, bank lowering, and side channel formation. In total, over 277 acres have been restored to date (table 9).

5.7.3 Angostura Reach

5.7.3.1 Angostura Diversion Dam to Isleta Diversion Dam (RM 210-RM 169)

As shown in table 2, three to four flycatcher territories were known to occur in a small area in 1994 and 1995 within this reach (Mund et al. 1994, Mehlman et al. 1995). In 2000, surveys in all suitable nesting habitats within this reach found 14 territories (Johnson and Smith 2000). In 2003, only four territories were found (Smith and Johnson 2005). Seven territories were located in 2004 (Smith and Johnson 2005), six territories were identified in 2005 (Smith and Johnson 2006), and sixteen territories in 2008 (NM Rangewide Database). In 2009 and 2010, there were no territories located in this reach (NM Rangewide Database).

Silvery minnow have been commonly collected throughout this reach since 2004. This reach has not dried in recent years. Flood plain connectivity is minimal in many portions of this reach. Lack of habitat diversity and amount of low velocity habitats above Highway 550 likely was cited as a limiting factor for silvery minnow (SWCA 2008). A habitat mapping technical report was developed to supplement the ABCWUA ongoing conservation measures to include opportunities for additional aquatic and riparian projects in the Albuquerque Reach of the river. This report included extensive field surveys, mapping, and ranking of potential sites within the Middle Rio Grande. Field efforts for this project were conducted in cooperation with the Service during February 2002.

Several projects have taken place on the Sandia Pueblo and around the city of Albuquerque to improve riparian conditions with the assistance of Collaborative Program funding. To date, over 900 acres have been restored. Many of the restoration projects have concentrated on projects that provide a greater connectivity with the river at lower discharge levels than previous conditions. Other strategies have included creating side channels and installing woody vegetation to create pools during low flows. Initial results of monitoring silvery minnow at these sites indicate that large numbers of silvery minnow do use the created overbank habitats during inundation (Collaborative Program 2011, SWCA 2010). Initial monitoring of the installed large woody debris found that silvery minnow were present both during winter and summer sampling but higher numbers were collected during the summer (Wesche et al. 2006).

5.7.4 Isleta Reach

5.7.4.1 Isleta Diversion Dam to Rio Puerco (RM169–RM 127)

The majority of flycatchers detected within this reach are typically migratory flycatchers, late migrants, or occasional lone male territories. The first nesting pair was located just north of the Rio Puerco in 2005 (table 2). Over the last several years, this same area typically has about one to four territories detected. In 2010, this area supported four territories composed of three pairs and one additional pair about three-fourths of a mile upstream. In 2011, the population expanded to 10 territories, mainly near the Rio Puerco, but also farther north in the area from Los Lunas to Bernardo. Silvery minnow abundance is highly variable in this reach (Dudley and Platania 2010, Reclamation 2010). Prior to 2004, recruitment was low in this reach. Silvery minnow distribution and abundance patterns show the importance of base flows within the reach to maintain population numbers (Parametrix 2008).

Habitat restoration work throughout this reach has cleared vegetation and increased the potential for channel movement. Techniques include creation of backwaters, secondary channels, as well as bankline benches and terracing. Monitoring of these habitats indicates use of these habitats during inundation by adult silvery minnow and larval fishes as well as egg retention (SWCA 2010a, Collaborative Program 2011). Cottonwood snags also were installed at drain outfalls in this reach. Initial monitoring shows use by silvery minnow during inundation, but the intended purpose of scouring and maintaining wetted pools over a range of flow conditions had mixed results due to sedimentation issues (Wesche et al. 2010).

5.7.4.2 Rio Puerco to San Acacia Diversion Dam (RM127–RM116.2)

Flycatchers on the Sevilleta NWR and La Joya WMA were initially discovered in 1999 with four territories (table 2). All flycatchers within this reach have been found along the banks of the Rio Grande. Surveys have continued in this area since 1999, with seven territories detected in 2000 and eleven territories in 2001 and 2002. The highest numbers to date for this site, 31 territories, were detected in 2008. Over the last 3 years, there has been a decrease in territories. In 2009, there were 18 territories detected; in 2010, there were 13 territories detected; and 9 territories were detected in 2011.

This reach has lower propensity for drying than the upstream portions of Isleta Reach (Parametrix 2008). Increases in channel complexity could increase the habitat diversity required to maintain silvery minnow within the reach. There are some areas that have been perennially wet in this section due to return flow from the San Juan drain. This is likely important to silvery minnow within this reach. Habitat assessment of these flows was modeled by USGS (Bovee 2008). No habitat restoration projects have been done on this reach for silvery minnow or flycatchers.

5.7.5 San Acacia Reach

5.7.5.1 San Acacia Diversion Dam to Arroyo de las Cañas (RM 116.2–RM 95)

This area has been surveyed for flycatchers since 1997 and has had intermittent territory establishment through the years (table 2). There has never been a nesting flycatcher pair detected within this reach. Silvery minnow in this reach are seasonally concentrated in the spring and summer below the diversion dam where water is generally perennial (Dudley and Platania 2010). It is unknown if there is seasonal upstream movement behavior that would cause minnows to accumulate below the diversion dam, which blocks upstream movement. Rescue operations rarely occurred in this reach. Salvaged fish from other portions of the San Acacia Reach are stocked here where water is perennial (Service 2001 through 2010). Little potential for overbank flooding exists in this reach (Parmetrix 2008). There have been river maintenance projects within this reach, which have focused on moving back the levee and relocating the LFCC to allow the river greater area to migrate (Reclamation 2008).

5.7.5.1.1 Arroyo de las Cañas to San Antonio Bridge (RM 95–RM 87.1)

This reach is very similar to the San Acacia to Arroyo de las Cañas Reach and has been surveyed for flycatchers since 1998. Within the last 13 years, there have been minimal territories, with the exception of summer 2011 (table 2). During the breeding season of 2011, a total of seven territories were detected within this reach, most of which were detected within close proximity of the BDANWR. Silvery minnow densities in this reach are highly variable, October densities increased from 2006–2009 (Dudley and Platania 2010). Rescue efforts have occurred most years in portions of this reach. River pumps are installed in this reach to aid in slowing the rate of river drying using water supplied from the LFCC. No habitat restoration projects have been done on this reach for silvery minnow or flycatchers.

5.7.5.2 San Antonio Bridge to River Mile 60 (RM 87.1–RM 60)

The upper portion of the BDANWR within the active flood plain have been surveyed for flycatchers annually since 1998. From 1998–2008, there were less than five territories detected annually. In 2009, there was a large population increase to 19 territories and another large increase in 2010 with 37 territories. In 2011, the largest population in this section was recorded with a total of 44 territories.

In lower portions of the reach, from 1994–1996, the majority of detections within this reach were located between the south boundary of the BDANWR to the railroad trestle near Black Mesa. Since 1994, the population within this entire reach has increased and decreased responding to vegetation and hydrological changes. Peak years within this section include 1994 with 11 territories, 2004 with 16 territories, and 2006 with 14 territories. Since 2006, territory numbers range from 7–11, with 11 territories detected in 2011.

Silvery minnows generally are collected in surveys within this reach, and occasionally densities are high. Reclamation surveys and population monitoring surveys found high winter densities in 2010 following high 2009 October numbers (Dudley and Platania 2010, Reclamation 2010). Generally, this reach is very prone to river drying, and salvage generally occurs early in the year. River pumps from the LFCC supply water to the river from the northern and southern boundary of the refuge and near Fort Craig and aid in slowing the rate of river drying. Due to the perched condition of the channel, high flow events may go out of the channel and into the lower elevation overbank areas. There have been sediment plugs that have formed within the channel.

5.7.6 Summary of Baseline Conditions Affecting Silvery Minnow Life History and Critical Habitat Elements.

In this section, baseline biology information and status of critical habitat elements (PCEs) are described in table 11. The life history of the minnow is subdivided into spawning, egg, larval, juvenile, and adult stages; and current information on how those stages are functioning is described.

Even though there is some uncertainty surrounding the preferential spawning locations for the minnow, it is evident that the minnow likely will spawn in the spring with any slight increase in discharge in whatever habitat is available.

Table 11. Status and information of life history elements and critical habitat PCEs for silvery minnow. Grey cells indicate that life history stage is generally not present during that season or affected by the PCE.

Life History Element	Spawning	Eggs	Larval	Juvenile	Adult
Spring (April–June)	Spawning has been detected each year. Very small flow spikes are necessary for fish to spawn. Properly functioning in baseline.	The carrying capacity of recruitment is set by spring flows. Eggs and larvae that are retained upstream in low velocity habitats are more likely to recruit into the adult population. Higher spring flows allow more overbank habitats to be inundated. Recruitment success is likely the driver for genetic diversity and effective size of the population. Function is tied to spring runoff. Habitat restoration has increased available habitat at lower discharge levels in Angostura Reach.			Large numbers of adult silvery minnow are collected on overbank habitats during spring flows. It appears that population levels must be very low before the numbers of adult spawners has a detectable effect on numbers of offspring measured in next fall.
Summer (June–September)			Delayed onset of low flow conditions and increased summer flow correlates with higher October densities. Increased turbidity from various flow events may decrease the available food base. Refugial habitats may decrease take and maintain higher numbers of silvery minnows during dry periods. Refugial habitats were constructed at some return drains and may reduce the impact of drying on the population.		
Fall (September–November)				Generally steady base flows during this time period is positive for October population densities. Drying has occurred within this timeframe.	

Table 11. Status and information of life history elements and critical habitat PCEs for silvery minnow. Grey cells indicate that life history stage is generally not present during that season or affected by the PCE.

Life History Element	Spawning	Eggs	Larval	Juvenile	Adult
Winter (December–March)					Silvery minnow are known to use habitats with some type of cover. Relatively constant winter flows are positive. Habitat restoration activities have installed large woody debris in both the Angostura and Isleta Reach.
Summary of baseline population trend and indicators.	Baseline conditions 4 years of 10 had negative population growth. However, catch rates have increased substantially since the low in 2003. Discharge of at least 3000 cfs in Angostura Reach and delayed onset of low flow increase likelihood of mean October CPUE > 10 fish per 100 square meters.				
Critical Habitat PCEs					
Hydrologic Regime					
Low to moderate currents	Determined by sediment transport, reach slope, sinuosity, which all contribute to habitat complexity. Current trend is toward channel simplification. Habitat restoration has improved condition in Angostura Reach and Isleta Reach.				
Diversity of habitats for all life history stages		Egg and larval development habitat is greater when overbank habitats are inundated. Depending on river, reach occurs when spring flows are greater than 1,500 cfs. Flows reached this level at the Albuquerque gage for at least 10 days in 7 of the last 12 years. Habitat restoration activities have provided more low velocity habitats in the 1,500- to 3,500-cfs range.		Juvenile and adult silvery minnow use wetted habitats with moderate depths and low velocity during nonwinter times. Winter habitat use is concentrated in deeper areas with available cover (debris piles, tumbleweeds). Bovee et al. (2008) modeled the availability of habitat at various flow regimes. Habitat in their model was maximized at flows between 40 and 150–200 cfs depending on the availability of woody debris. Similar studies of availability are currently underway.	
Spawning trigger	Spawning has occurred each year of baseline, even in years with minimal spring flow spike.				
No increased low flow	River drying is predicted when flows drop below 100 cfs at San Acacia gage. Number of low flow days at San Acacia gage is significantly different in baseline timeframe (2003–2011) and listing timeframe (1993–2002) ($t = [2.1]$, $p<0.05$). Mean # days <100 cfs 1993–2002=17 (SE 10), 2003–2011=52 (SE 12).				

Table 11. Status and information of life history elements and critical habitat PCEs for silvery minnow. Grey cells indicate that life history stage is generally not present during that season or affected by the PCE.

Life History Element	Spawning	Eggs	Larval	Juvenile	Adult
Constant winter flow				Irrigation seasons generally end up and down the basin. Water deliveries are often made in November and December, which may increase base flows.	
Unimpounded stretches of river with a diversity of habitats and low velocity refuge areas					
River reach length	Reach length in Middle Rio Grande has not changed since time of listing. The only new cross channel structure is the ABCWUA diversion that was mitigated with a fish passage structure. The pit tag study shows that silvery minnow do use the passage.				
Habitat "Quality" in each reach and refugial habitats.	Each reach has positive and negative habitat attributes. Channel trends throughout the MRG are towards a more simplified channel due to vegetation encroachment. Cochiti Dam and Angostura Reaches are not as susceptible to drying but have limited connection with overbank areas. Isleta Diversion Dam and San Acacia Reaches are prone to drying in areas but have low overbank thresholds and a greater diversity of meso-habitats than the upper reaches due to the more dynamic nature of the channel than the upper reaches. Habitat restoration activities have provided more low velocity habitats in the 1,500- to 3,500-cfs range. Low velocity refuge areas are important during summer drying and overwinter habitat. Channel trend throughout the MRG is towards a more simplified channel due to vegetation encroachment.				
Substrate of sand or silt					
Substrate size		Substrate size is dependent on water velocity and sediment transport within the reach. The lower reaches of the river are dominated by sand/silt substrates. Reaches that have a low sediment supply (Cochiti and Angostura) are trending towards larger substrates.			
Water quality					
Temp >1˚ - <30˚C.	Warmer temperatures speed the rate of egg development and larval growth. This is generally considered positive for fish since they spend less time in this vulnerable stage. A notable difference between water temperatures in high flow years versus low flow years is the minimization of diel variation in high flow years, thus a more constant temperature. Overbank habitat has been shown to provide warmer daytime temperatures but may also experience greater fluctuations corresponding to air temperatures then main channel habitats.		NMED monitoring has shown little evidence of temperatures exceedences within the main channel of the river. Isolated pools often exceed 30 ˚C. Pools >34 ˚C are not salvaged due to the poor condition of fish within the pools. Low temperatures have not been a concern within the occupied portion of the MRG except in extreme weather events. Ice flows were present within the channel in February 2011 following extreme low temperatures.		

Table 11. Status and information of life history elements and critical habitat PCEs for silvery minnow. Grey cells indicate that life history stage is generally not present during that season or affected by the PCE.

Life History Element	Spawning	Eggs	Larval	Juvenile	Adult
DO > 5 mg/L	There have been records of low dissolved oxygen within the main stem of the MRG. Many of these are associated with rain events and storm water entering the system. The duration of these low DO events are generally less than a few hours. There were localized conditions that deviated from the main stem conditions due to low flow conditions and isolated pools. From salvage data, it appears that many isolated pools have DO that falls below the optimal level. These pools are not considered for salvage. Additionally, low DO was detected in 2005 on inundated flood plain areas that have high levels of organic materials.				
pH (6.6-9.0)	No exceedences of the 6.6 to 9.9 (s.u.) criterion were documented from deployed data loggers at any locations except for one sample in 2007 at NM Highway 550 Bridge. Isolated pools may experience high pH levels. Pools greater than 9.0 are not considered for salvage.				
Other Contaminants	Short-term water quality issues due to chlorine releases from waste water quality treatment plants have occurred infrequently in the MRG. Initial studies of fish tissue indicate elevated levels of zinc in some samples. Other studies have not indicated specific water quality issues that may be affecting silvery minnow.				

It does appear that the spring hydrograph has a substantial influence on the recruitment of silvery minnow into the population (section 5.3.1.2). This is indicated by the relationship of fall catch rates and the spring hydrograph. Spring flows that inundate the flood plain create large amounts of low velocity habitat that aids in the retention of eggs and larvae in upstream reaches and provides an area of highly productive low velocity habitat, which promotes larval development. The lack of recruitment in 2010 provides some indication that management of recession may be an important management consideration.

The current measure of the population is based on October catch rates, which gives an indication of annual recruitment into the population. October catch rates of silvery minnow have varied widely since the inception of the monitoring program in 1993. This variation is similar to abundance measures of many species of fish that have high reproductive potential. Though there is large variation, mean catch rates from 2004–2011 are over 10 times higher than the lowest recorded catch rates in 2002 and 2003. Mean catch rates in 2005 were roughly 1,000 times the mean catch rate recorded in 2003.

Juvenile silvery minnow utilize low velocity habitats, similar to larval stages; however, they are able to actively swim at this stage. Little is known about the full range of factors that influence survival of juvenile and adult silvery minnow. Food availability is varied due to hydrology and storm events. Studies indicate that the main source of periphyton, which is one of the main foods of silvery minnow, exists in a “bathtub ring” in the shallow sections of the river. Storm events or other flow changes may affect periphyton availability by scour events, inundation which places existing colonies out of optimal light areas, or desiccation.

Drying also causes direct take of silvery minnow. Drying has occurred each year since 2003 except for 2008 in some portion of critical habitat. There is some evidence that a portion of silvery minnow are able to move with the water as the river begins to dry, and some fish can survive for long periods in the isolated pools that may persist in disconnected sections of the river. However, there is documented take of minnows that has occurred each year associated with drying. Other unquantified sources of take that occur with river drying include predation from birds and other species, as well as mortality due to poor water quality and disease that is exacerbated when fish are isolated in pools.

At least some amount of river drying is predicted when San Acacia flows drop below 100 cfs. On average, from 2003–2011, there were 52 days annually when San Acacia was below 100 cfs compared to the previous timeframe (1993–2002) when the annual average was 17 days. There is a significant negative correlation to October catch rates and the number of days with low flow conditions at the San Marcial gage (figure 17).

There is little known about winter survival of silvery minnow. Studies indicate that they are most often found in backwaters and other habitats with cover in the winter (Dudley and Platania 1996, Dudley and Platania 1997). As with other fish species, they seek out low velocity habitats that limit the amount of energy they must expend during cold water temperatures. It is hypothesized that stable water levels may be positive since stability of individual habitats is related to stability of water levels in the MRG. Generally, flow is higher early in the winter when letter water is being released as well as other activities to move stored water. Winter storm flows occur periodically.

With the current condition of the river, mechanical means are needed to substantially change geomorphology. Water management alone cannot provide flows of high enough discharge and duration to remove established vegetation and reset river banks. Habitat restoration activities since 2003 have increased the amount of habitat that inundates at lower flow levels, especially in the Angostura Reach. These areas show use by silvery minnow each year of inundation.

5.7.7 Summary Baseline Conditions Affecting Willow Flycatcher Life History and Critical Habitat Elements

The flycatcher population within the MRG has increased over the last decade. Habitat availability appears to not be a limiting factor since not all suitable habitat is occupied. High flow events and overbank flooding conditions tend to attract flycatchers and lead to new territory establishment. These localized events aid in providing the successional aged structure in riparian stands that flycatchers depend on. Suitable habitat areas are temporary because vegetation senescence occurs relatively quickly.

Temporary overbank flooding or close proximity to water also contribute to vegetation health and insect prey base abundance. This is particularly important during territory establishment to attract and retain territories. As flycatchers move through the chronology of the season and put forth an increasing amount of energy towards nesting (first territory establishment, then pairing, nest building, egg laying, incubating, feeding nestlings, and taking care of fledglings), they are less and less likely to abandon a territory. Nest success is dependent on vegetative health to provide the canopy cover required for protection from predators and other environmental stressors such as weather. Conversely, prolonged flooding prohibits seed establishment and can have a long-term negative effect on vegetative health. Nest success has remained relatively high within the MRG over the last decade with a slight decline this past summer of 2011.

The proposed critical habitat designation for flycatchers (76 CFR 50542) indicates riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal, and shelter. This habitat can include trees and shrubs such as Gooddings willow, coyote willow, tamarisk, or Russian. Vegetation must be dense, with a canopy cover of about 50–100%. Vegetation can range in height from about 6–98 feet tall depending on elevation (within the project area, vegetation height is typically about 9–26 feet tall [Moore 2007]). Patches also must include small openings of open water or marsh areas to create a variety of habitat that is not uniformly dense. Vegetation patch size can range from 0.25–175 acres.

A variety of insect prey populations are also essential for flycatchers. The abundance of insects typically associated with riparian flood plains or moist environments is likely related to the proximity of water to the habitat patch and density of vegetation within the canopy. Flooded sites provide for higher relative humidity and likely greater insect abundance (Reclamation 2009). No surveys have been done to estimate prey availability within various types of habitats within the MRG. Insects that are considered to be flycatcher prey include flying ants, wasps, and bees (Hymenoptera); dragonflies (Odonata); flies (Diptera); true bugs (Hemiptera); beetles (Coleoptera); butterflies, moths, and caterpillars (Lepidoptera); and spittlebugs (Homoptera). See table 12.

Table 12. Status and information of life history elements and critical habitat PCEs for willow flycatcher. Grey cells indicate that life history stage is generally not present during that season or affected by the PCE

Life History Element	Migration (April–June and July–September)	Arrival to Territories/ Territory Establishment/Nest Building (May–July)	Egg Laying/ Incubation/ Nestling/ Fledgling (June–August)
Breeding Season (April–September)	Flycatchers may use less suitable habitat as stopover locations (i.e., narrow vegetated areas such as LFCC or areas a greater distance from water).	Flycatchers are attracted to areas within 50 m of slow moving water, particularly flooded areas, or areas with saturated soils and dense vegetative canopy cover. Higher spring flows allow more overbank habitats to be inundated, thus attracting flycatchers, improving vegetative health, and likely increasing abundance in prey.	At this point, flycatchers are more invested in their established territories and less likely to abandon nests should conditions dry or decline in value. However, if vegetation does not have adequate water resources, canopy cover will likely decrease, and predation and/or parasitism would likely be more prevalent. Prey abundance may decrease with decreased water availability.
Summary of baseline population trend and indicators.	Baseline conditions since 1993 have indicated mainly positive population growth. The most recent increase in territory numbers within the project area can be attributed to an event within the BDANWR in which overbank flows increased in combination with the large population within Elephant Butte Reservoir beginning to disperse and defend territories in other locations.		
Critical Habitat PCEs			
Riparian Vegetation		Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal, and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. The 2008 habitat suitability study mapped out suitable habitat in Isleta Diversion Dam and San Acacia Reaches. Habitat mapping occurs every 2–4 years and documents changes within the riparian area. Currently, flycatcher only occupy a portion of suitable habitats; thus, amount of habitat is not considered to be limiting factor.	
Insect Prey Populations	The abundance of insect prey populations in a given habitat patch is likely related to the proximity of the patch to riparian flood plains or moist environments. There is no data indicating that insect prey is a limiting factor within suitable habitat areas.		

5.7.8 Summary Baseline Conditions Affecting Pecos Sunflower.

Pecos sunflower (*Helianthus paradoxus)* is currently only located in two locations within the MRG action area, La Joya Wildlife Management Area and a private location. There is no designated Pecos sunflower critical habitat for the species within the action area. *Helianthus paradoxus* is an annual species that must re-establish populations of adult plants each year from seed produced during previous years' reproductive efforts. Populations tend to grow in crowded patches of dozens or even thousands of individuals. Solitary individuals may be found around the periphery of the wetland, but dense, well-defined stands within suitable habitats are more typical. NMDGF developed a habitat conservation plan to support conservation of the species on the La Joya Wildlife Management Area by:

1. Annually controlling invasive species.
2. Protecting the natural spring in Unit 5 from motorized vehicles and heavy equipment.
3. Monitoring core populations by digitizing these areas annually.
4. Conserving *H. paradoxus* by adjusting invasive species treatment area boundaries.
5. Restoring native habitat through re-vegetation.

The acreage of Pecos sunflower on La Joya has varied but has remained greater than 200 acres since 2008. Water supply for this population is provided through existing drains that supply La Joya WMA.

6. Effects Analysis

"Effects of the action" refers to the direct and indirect effects of the Proposed Action on listed species or critical habitat together with the effects of other activities that are interrelated or interdependent with that action. These effects are considered along with the environmental baseline to determine the overall effects on the species (50 CFR Part 402.02). For purposes of this BA, effects on listed species and designated critical habitat are analyzed for the full suite of Proposed Water Management Actions as well as individually, where possible, for the discrete actions.

This section presents an evaluation of the hydrologic effects of the Proposed Water Management Actions and the predicted effects that those would have on the listed species. Reclamation and its non-Federal partners propose to continue water operations as described in section 3. Reclamation has deemed that the effects of these Proposed Water Management Actions can best be presented through a combination of analyses.

These include:

- Assessment of the composition (in terms of the source of water, and whether the water has been stored in a reservoir) of the flows that provide supply to the MRG; as well as the distribution of uses of that water;

- Evaluation of the total, aggregate impacts of Reclamation and non-Federal Proposed Water Management Actions without the use of Supplemental Water (Proposed Water Management Action). The model runs used assume operation of the facilities to meet the flow targets as defined by the 2003 BiOp. These actions are not part of the Proposed Action but were necessary to define the operations for the model.

- Action-by-action analysis of the relative effects of individual components of the Proposed Water Management Actions, to the extent practical, through the comparison of a simulation with those actions to a simulation in which those actions did not occur. Individual components of the Proposed Water Management Actions that were evaluated in the action-by-action analysis include:

    - Reclamation's operations at Heron Dam.

    - Actions by Reclamation and the MRGCD related to the operation of El Vado Dam.

- MRGCD's surface water diversions and associated water management actions.

- An assessment of the effectiveness of proposed conservation measures of Reclamation and the MRGCD in offsetting the aggregate impacts.

6.1 Approach, Tools, and Methods for Hydrologic Analysis

Reclamation performed the hydrologic analyses that support this effects analysis using a combination of hydrologic modeling and analytical computations. The URGWOM was used for the majority of the analyses. URGWOM is, a computational, rule-based, water operations computer model that simulates physical processes and operations of facilities in the Rio Grande Basin in New Mexico. URGWOM has been developed through an interagency effort and is constantly being refined. It is the only model available that can perform the needed analyses at a daily time-step and can make computational estimates of river drying. URGWOM individually tracks water allocated for specific uses, and Reclamation has used this capability to isolate the effects of individual actions evaluated in the action-by-action portion of this effects analysis.

Reclamation completed the simulations, as well as the analytical computations that support the modeling, using five 10-year synthetic hydrologic sequences developed with reference to paleo-climate data to represent the range of past hydrologic variability in the MRG Basin. The hydrologic sequences represent hydrologic conditions for which total annual flow at Otowi gage has a 10, 30, 50, 70, and 90% chance of being exceeded (higher exceedence curve represents drier conditions). Reclamation, in cooperation with the Population and Habitat Viability Assessment workgroup of the Collaborative Program, developed these sequences to capture the full range of variability in the hydrology and climate that have been experienced over the past 604 years, as captured in tree-ring records (Roach 2009; Appendix 1). These sequences represent a range of hydrologic conditions that might reasonably be expected to occur during the time period associated with this BA.

The sequences were developed through a statistical sorting of the hydrologic years contained in the 604-year reconstruction (Gangopadhyay and Harding 2008, Appendix 1). From the years within the reconstruction, 1,000 10-year sequences were constructed. The sequences of years were corrected to ensure that the year-to-year transitions were consistent with those in the hydrologic record but were otherwise randomly composed. For each of these sequences, the total flow past Otowi gage over the 10 years was calculated and compared to the range of 10-year total flows for the full set of 1,000 sequences. The five sequences for which the total flow past Otowi gage over the 10-year period was closest to having a 10, 30, 50, 70, and 90% chance of exceedence among the full suite of sequences (i.e., for the 90% sequence, 90% of the sequences had more water flowing past Otowi gage over the 10-year period than flowed past the gage in this sequence) were selected as the sequences for which Reclamation would analyze the impacts of the Proposed Water Management Actions in this BA. Each year in a selected sequence was then matched to the actual year in the URGWOM record (1975–2007) with the most similar total flow past Otowi gage, and that year's daily hydrologic record was used to distribute the total annual flow to daily flow for the modeled year.

It should be noted that these sequences were developed based on the total flow past Otowi gage, which is upstream of the MRG. The flow past Otowi gage is a good indicator of the total snowmelt runoff in a given year but does not fully reflect the strength of the summer monsoons, particularly in years for which summer moisture is distributed disproportionately downstream of Otowi gage. However, the years contained in the URGWOM record reflect a range of monsoon conditions. Since actual years in the 1975–2007 period are used in the simulations as representations for hypothetical years in the sequences, the monsoon volumes in the sequences are paired with flows past Otowi gage as they have been in recent years.

Figure 59, below, provides a comparison of the hydrologic conditions, as depicted by the distribution of flows at Otowi Bridge, in the five synthetic hydrologic sequences against the mean of those experienced under baseline conditions for this BA.

The distribution of flows at Otowi Bridge experienced during the baseline period (2001–2011) is within the envelope of flows defined by the five hydrologic sequences. Except among the very lowest flows (percent chance of exceedence 95–100%, for which the baseline and synthetic sequences are all in approximate alignment), baseline conditions fall between the two driest synthetic sequences, those with a respective 70 and 90% chance of exceedence.

The modeling analyses presented in this section do not consider the potential impacts of climate change on water resources and on Reclamation's water operations, since Reclamation's work evaluating the likely future impacts of climate change in the MRG Basin is not yet complete. However, the inclusion of the range of hydrologic variability, as determined from the 604-year tree ring analysis, serves as a proxy for quantitative climate-change analysis, in that it allows for consideration of a wider range of hydrologic variability than has been experienced during the period for which flows have been monitored. Past and current climatic conditions are described in Section 5, Environmental Baseline. A more detailed discussion of the current and potential impacts of climate change is contained in Section 7, Cumulative Effects Analysis.

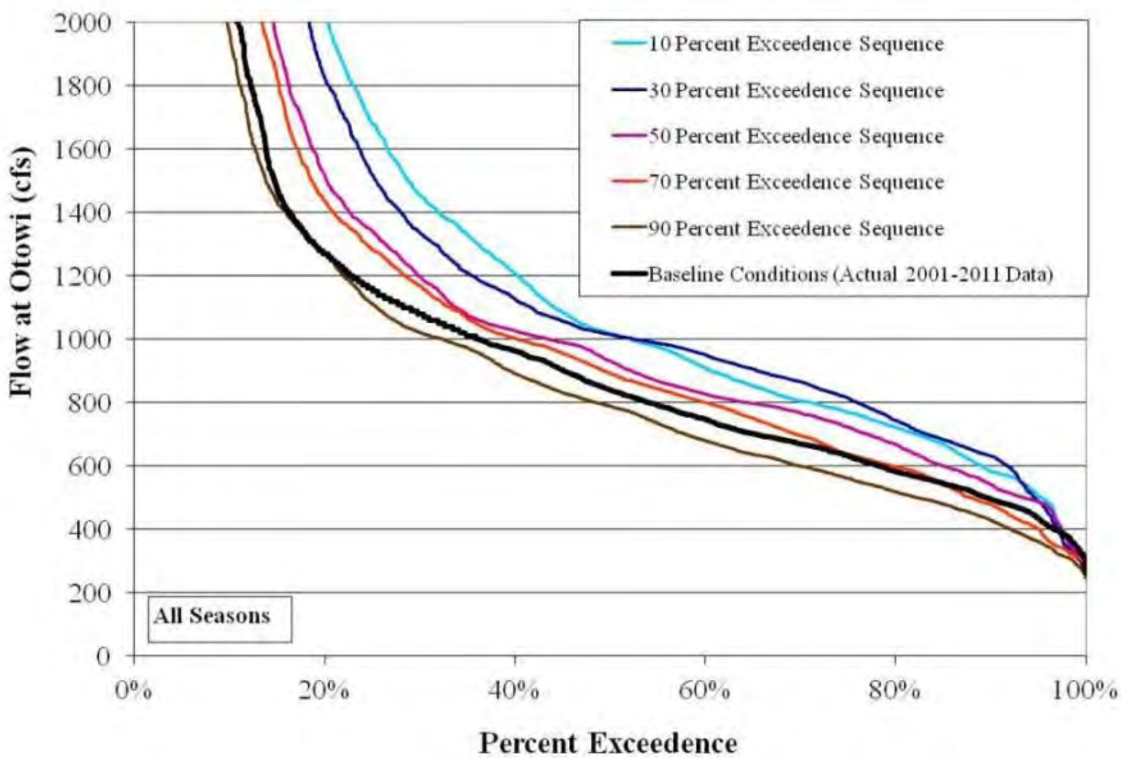

Figure 59. Comparison of flows at the Otowi Bridge for the Proposed Water Management Actions under the five hydrologic sequences against baseline conditions.

In the action-by-action analysis, Reclamation analyzed the discrete impacts of individual actions by utilizing model runs for the Proposed Water Management Actions, and sequentially turning off specific actions, so that the model runs without a particular action could be compared to model runs with that action, and the difference between the two could be assessed. Please note that the Proposed Action model runs also include the interrelated and interdependent actions of the Corps and State Letter Water releases as described in 3.2.1.

The combined impacts on river flows of the Proposed Water Management Actions and the impacts of individual actions in the action-by-action analysis are presented through several graphical methods, including box-and-whisker plots, which characterize ranges of variation in flows as the result of particular actions, and flow exceedence curves, which present flows, or differences in flows, that result from particular actions against total flow. The flow exceedence curves represent the percentage of time that a given river flow is equaled or exceeded. The majority of the curves were assembled using the results for all of the five hydrologic sequences, so they represent 50 years of simulation results and a broad range of historic hydrologic variability. They can be used to interpret the chance of occurrence of overbank flows as well as the chance of river drying.

6.1.1 Model Uncertainty and Refinements to Support Hydrologic Analysis

The URGWOM model realistically simulates water management scenarios through the Rio Grande/Rio Chama system to Cochiti Reservoir based on past gage data, expected runoff volumes, and reservoir operating rules. However, the outputs from the URGWOM model become appreciably less certain for locations downstream from Cochiti Dam. This is due to a highly complex interaction of consumptive uses and ground water exchange into and out of the river. In recent years, significant effort has gone into calibrating the URGWOM model to better reflect MRG conditions, and it is improved. Still, calibration has only been possible against observed conditions, and the No Action condition, in which none of the Proposed Water Management Actions are being performed, has not occurred since before flow monitoring began. Because of this lack of knowledge about the No Action condition, the model is unlikely to accurately reflect the extent and duration of river drying. Therefore, the extent of river drying under the No Action condition has been assessed and compared to the extent of river drying under the Proposed Water Management Actions using an analytical spreadsheet model developed by the MRGCD.

Because of the uncertainty in the degree of river drying under the No Action condition, graphs are provided in this effects analysis that present the difference in flows between model runs. These graphs depict the effects of proposed actions in terms of relative changes to flow rather than the absolute flows. Also, additional analyses have been performed using a spreadsheet model developed by the MRGCD to compare the drying, as well as high flows, under the Proposed Water Management Actions relative to the No Action condition. The results of these computations are provided in tabular form. The PHVA workgroup of the Collaborative Program and Reclamation, in coordination with the URGWOM Technical Team (an interagency team of modelers who have been working together to create and refine the URGWOM model), have made significant enhancements to URGWOM the planning module and to URGWOM’s representation of the rules that govern operational policy in this basin to support the modeling efforts presented in this BA. These include refinements and corrections to the model as well as the incorporation of new processes, such as the ABCWUA drinking water project and the Buckman Direct Diversion. A full data management interface (DMI) was established in URGWOM to allow model inputs to be set efficiently for all simulations, and spreadsheet tools were set up to facilitate postprocessing and review of results from all the completed model runs. These enhancements were made both prior to and during the modeling efforts to support this BA. The list includes enhancements made in response to comments received on the first draft of this BA, which was distributed to members of the water management community on August 18, 2011. The current configuration of the URGWOM planning model and the refinements made to it as part of this process are summarized in the URGWOM modeling report presented in Appendix 7.

An analysis has been completed to develop appropriate initial conditions for reservoir storage and account status to use in BA model runs. These initial conditions reflect conditions as of December 31, 2011, and are described in Appendix 4.

6.1.2 Approach for Analysis of Effects to Listed Species

URGWOM hydrologic modeling represents Reclamation's best understanding of the hydrologic effects that may occur due to the Proposed Water Management Actions. Effects to the species are evaluated using this modeling and species information presented in the baseline. Additional modeling is presented in this section as needed to better understand conditions that may affect listed species.

Environmental conditions and water management decisions within the MRG are correlated both spatially and temporally and, thus, are not independent of each other. Several levels of effects to the listed species are considered in this BA. Any action that may cause mortality of an individual is considered "likely to adversely affect" even if the long-term indirect effects are likely to be beneficial. Population level effects are more difficult to predict and are presented using the best available information for each species. It is anticipated that a silvery minnow population viability model (PVA) may be available to develop the biological opinion that can give a better resolution of the management actions effects on long-term viability of silvery minnow in the MRG.

The only currently viable population of Rio Grande silvery minnow exists within the project area described within this document. Due to the lack of any interaction with other populations of silvery minnow, actions that occur within this area have direct ramification to the species existence. Timing and magnitude of discharge and geomorphic trends through the MRG are key factors driving population levels. Proposed Water Management Actions may affect spring runoff, magnitude, and duration of summer drying as well as winter flows. These hydrologic parameters affect each life stage of silvery minnow (spawning, larval development, juvenile, and adult survival), as well as habitat availability and quality and water quality. There is evidence presented both by population monitoring and preliminary PVA analysis that suggests that successful recruitment of silvery minnow is strongly linked to the magnitude and duration of spring runoff, with population increases coinciding with the inundation of overbank habitats supporting larval development. Drying of the river, which occurs mainly during summer and fall months, causes mortality for silvery minnow.

The MRG currently supports a large proportion of the total population of the endangered flycatcher when compared range wide. Water operations can have both positive and negative effects on flycatchers and the vegetative habitat they find suitable. In general, actions that promote overbank flooding or maintain moist soil conditions during territory establishment (approximately May 10–June 15) are beneficial for flycatchers and vegetative health. Suitable flycatcher habitat typically only remains suitable for a short amount of time (5 to 15 years depending on environmental conditions) when vegetation composition and structure are within a certain age class. For this reason, flycatchers depend on an ever changing environment where vegetation has the opportunity to continuously over mature in some areas and regenerate and reach maturity in other areas.

There are currently two populations of Pecos sunflower in the MRG. The La Joya population is mainly affected by actions that would change the delivery of water to the La Joya SWA. The Rhodes population is in the flood plain of the river and would be affected by actions that change the incidence of overbank flows in the San Acacia Reach. There is no critical habitat associated with the MRG for Pecos sunflower. Pecos sunflower effects are consolidated in section 6.3.3, while silvery minnow and flycatcher effects are presented with each action.

As previously mentioned in the Status and Distribution section of this analysis, the interior least tern can be considered a vagrant on the MRG, and no interior least tern nesting has been recently documented (Service 1995). According to the Recovery Plan from the Service in 1990, the only documented breeding along the Rio Grande takes place in Texas, and the only documented breeding within the State of New Mexico can be found on the Pecos River (Service 1990); similar conclusions are drawn in the complete range-wide survey collected in 2005 (Lott 2006). Due to the low potential for occurrence and that the interior least tern likely only would be present infrequently and/or temporarily (i.e., during migration), the interior least tern likely would not be affected by the project; and no further analysis will be completed on behalf of the species.

6.1.3 Continuation of Geomorphic Trends

The reductions in peaks, increased low flow duration due to water use within the basin, and reduced sediment supply from in place dams has altered the geomorphology of the MRG from a wide, active channel to a narrow, stabilized system. The historic pattern was characterized by large, high energy flows, which reworked sections of the river and flood plain, removed vegetation, supplied sediment, and may have relocated the main channel laterally to lower elevations. This pattern resulted in a wide, braided, sandy channel that was well connected to the flood plain.

The current condition, with lower peak discharges, allows vegetation to establish that, in turn, causes the channel to narrow and become more simplified with little within-channel habitat diversity. In reaches where sediment supply is low, the river has become disconnected from the flood plain and is less likely to inundate the flood plain than in the historical condition. Generally, areas that have high sediment load and low sediment transport have a greater connectivity to the flood plain and provide more complex habitat at all flows; however, these sections are also more prone to intermittency due to the perched nature of the channel causing the flow to go subsurface.

The Proposed Water Management Actions are not anticipated to have trend-reversing effects on the geomorphology within the MRG. The river is expected to continue to trend towards a narrower, more simplified channel. Channel degradation downstream from Cochiti Dam is expected to continue and to extend further downstream. Currently, the designated safe discharge from Cochiti Dam is 7,000 cfs; and significantly larger discharges would be needed to reverse the geomorphic trends. Habitat restoration and river maintenance activities have had some impact on this trend but have not been performed on a large enough scale to return the river to predevelopment conditions. These restoration projects also will require periodic maintenance to function as designed.

6.2 The Composition of Middle Rio Grande Flows

This section breaks down sources of water providing flows to the MRG at Cochiti Dam as well as of water used to meet the MRGCD diversion demand for the Six MRG Pueblos, the MRGCD's non-Indian irrigators, and the BDANWR. These breakdowns indicate the original sources of the water (native versus. non-native), whether or not the water has been stored (natural flow versus released from storage), and the use or fate of the water (diverted for beneficial use or delivered to Elephant Butte). These breakdowns were developed from URGWOM simulations performed for this BA and present these water sources and fates for each of the five synthetic hydrologic sequences.

The breakdowns of the sources and fates of water that are presented in this section represent the range of 10-year average hydrologic conditions that are likely to be encountered under stable climatic conditions as well as the degree of variability of these conditions in individual years. These breakdowns provide an indication of the scale of the effect of upstream water management actions presented in this BA as well as the degree to which changes to these actions can affect flow conditions in the MRG.

Natural flow, which constitutes the majority of MRG flows, is comprised of natural flow from the main stem, unregulated tributary inflows, and native water from the Rio Chama that has been bypassed from storage at El Vado Dam. The natural flow bypassed at El Vado may be regulated at Abiquiu or Cochiti Dams and still maintains its designation as natural flow for this analysis.

The analysis also shows native water released from storage at El Vado Reservoir and non-native SJC Project water. Native water released from storage at El Vado Reservoir includes:

- Water stored during times in which native inflow to El Vado exceeded irrigation demand, and in which Article VII restrictions under the Rio Grande Compact are not in effect.
- Water stored in El Vado during times in which Article VII restrictions under the Rio Grande Compact are in effect to meet the irrigation requirements of the lands of the Six MRG Pueblos with prior and paramount water rights.
- Water stored in El Vado during times in which Article VII restrictions under the Rio Grande Compact are in effect, but storage is allowed in equal exchange for delivery credits by New Mexico to Texas that have been relinquished under the terms of the Rio Grande Compact. Water has been stored at El Vado under this process in the past decade by agreement (i.e., EDWA) between the State of New Mexico, the MRGCD, Reclamation (for its Supplemental Water Program), and New Mexico municipalities. The EDWA s only a result of initial conditions, not additional relinquishments or allocations.

SJC Project water includes water released from Heron Reservoir to meet the needs of 16 SJC project contractors, including ABCWUA and the MRGCD, as well as water leased by Reclamation under its Supplemental Water Program. SJC Project water may be released to meet contractors' needs or may be released as "Letter Water," to offset the impacts of ground water pumping. SJC Project water released from Heron may be temporarily stored or reregulated at El Vado, Abiquiu, or Cochiti Reservoir and still be presented as SJC Project Water for this analysis. SJC Project water maintains its identity until it is fully depleted within the State of New Mexico.

6.2.1 The Composition of River Flow at Cochiti Dam

To better understand water management in the MRG. it is important to first understand the composition of water under various conditions. This section shows the average percentage contributed by each source of water that provides flows at Cochiti Dam (table 13) and the average uses or fates of that water over a calendar year for the five hydrologic sequences used in this effects analysis. The first three rows of this table (shown in blue) indicate that, on average, about 90% of the water in the MRG is composed of the natural flow in the Rio Grande system, consisting of native water of the Rio Grande and its tributaries that has not been stored for beneficial use at a Reclamation reservoir. Of that 90%, over 32% is used to meet MRGCD's irrigation demand, and the rest is conveyed to Elephant Butte Reservoir to support New Mexico's compliance under the Compact. Releases of native water from El Vado (shown in green, in the second block of rows) total an average across the calendar year of only 3% of the flow out of Cochiti Dam, including native storage, storage for irrigation of lands with prior and paramount water rights, and relinquished credit water under the Rio Grande Compact ("EDWA water"). SJC Project water (shown in purple, in the third block of rows) makes up an average of just over 7% of the flow out of Cochiti Dam. Table 14 presents the percentage of the total flow that goes to the major SJC Project contractors—MRGCD and ABCWUA—as well the portion that is used to supplement river flows under Reclamation's Supplemental Water Program. Flow to other contractors that do not lease their contracted water to the Supplemental Water Program is negligibly small.

Table 13. Composition of river flows below Cochiti Dam as percent: calendar year

Wetter ⟶ *Drier*

WATER SOURCE OR USE	10%-Exceedence Sequence		30%-Exceedence Sequence		50%-Exceedence Sequence		70%-Exceedence Sequence		90%-Exceedence Sequence		Avg
Natural Flow of Rio Grande System	**90.8**		**89.6**		**90.5**		**90.1**		**89.2**		**89.8**
Diverted to meet MRGCD and BDA Demand		23.4		27.0		31.0		33.5		37.5	32.3
Delivered to Elephant Butte		67.4		62.6		59.5		56.6		51.7	57.6
El Vado Releases	**4.3**		**4.1**		**2.7**		**2.7**		**2.4**		**3.0**
Native Storage		3.5		3.2		1.1		0.8		0.1	1.3
Prior and Paramount, for demand		0.1		0.1		0.2		0.2		0.4	0.2
Prior and Paramount, unused, evacuated		0.2		0.2		0.7		0.9		1.0	0.7
EDWA (MRGCD)		0.3		0.3		0.4		0.4		0.5	0.4
EDWA (Reclamation)		0.2		0.3		0.3		0.3		0.4	0.3
SJC Project Water	**4.9**		**6.4**		**6.9**		**7.2**		**8.4**		**7.2**
MRGCD		1.4		2.4		2.6		2.5		3.4	2.7
ABCWUA Diversion		2.7		3.1		3.5		3.7		3.8	3.5
Supplemental Water Program		0.8		0.8		0.8		1.1		1.1	1.0

Table 14 depicts the composition of flows, by percentage, which makes up the supply used to meet the MRGCD diversion demand over the calendar year. The water diverted by the MRGCD is used to meet the needs of the Six Middle Rio Grande Pueblos as well as the MRGCD's non-Indian irrigators. Diverted water that remains at the end of the MRGCD's system is delivered to the BDANWR. The MRGCD estimates this delivery to be 40,000–60,000 acre-feet per year, most of which is passed through the refuge and returned to the LFCC. The actual volumes associated with the MRGCD's diversion demand are provided in Appendix 5, by month and by diversion structure.

The composition of the water that is used to meet the diversion demand of the MRGCD differs somewhat from the composition of water at Cochiti Dam but shows the same general character in which most the water is supplied by the natural flow of the Rio Grande and its tributaries. Additionally, 79% of the diversion requirement at the MRGCD's four main stem diversions (Cochiti Dam and Angostura, Isleta, and San Acacia Diversion Dams, but not the LFCC diversions) is met by natural flows of the Rio Grande system, consisting of native flows not stored at El Vado Reservoir and over which Reclamation has no control. Only 5.9% of water diverted at these four main stem MRGCD diversions is composed of Reclamation's releases of Rio Grande water from storage at El Vado Reservoir. Reclamation's SJC Project releases account for approximately 6.7% of the MRGCD's irrigation demand. The remainder of the MRGCD's irrigation demand (as defined by the irrigation demand curves used in the URGWOM model (Appendix 5) remains unmet.

Table 14. Composition of the diversion demand of the MRGCD, as percent: calendar year

Wetter → *Drier*

WATER SOURCE OR USE	10%-Exceedence Sequence		30%-Exceedence Sequence		50%-Exceedence Sequence		70%-Exceedence Sequence		90%-Exceedence Sequence		Avg
Natural Flow of Rio Grande System	**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**
Native Storage		10.1		6.5		2.9		1.3		0.1	2.7
Prior & Paramount, for demand		0.3		0.3		0.5		0.4		0.8	0.5
Prior & Paramount, unused, evacuated		0.6		0.6		1.9		2.1		2.1	1.7
EDWA (MRGCD)		1.0		1.0		1.0		1.0		1.0	1.0
MRGCD SJC Project Water	**4.8**		**7.2**		**6.8**		**5.9**		**6.8**		**6.7**
Deficit	**4.4**		**3.5**		**4.9**		**9.9**		**14.7**		**8.2**

Table 15 shows sources of flow and uses or fates of water for the five hydrologic sequences during the snowmelt runoff season (March–July). A comparison of table 14 to table 16 shows that the proportion of the flow out of Cochiti that consists of the natural flow of the Rio Grande system is higher during the snowmelt runoff season than in the year overall. This is because, during the snowmelt runoff season, natural flow typically provides more than sufficient water to meet the irrigation demand; and, therefore, releases of native water in storage or SJC Project water are usually not needed to meet demand (native water is usually being stored in El Vado during this period). Some releases of native water from El Vado and SJC Project water occur during this period, particularly in the later part of this period in years for which the runoff ends before July, but the amount is lower than during the year overall.

Table 16 shows the composition of flows out of Cochiti Dam during the later part of the irrigation season, after the snowmelt runoff is complete (August–October). During this period, the use of stored native water and SJC Project water is at its maximum. However, even during this period, over 79% percent of the flow is composed of natural flow.

Table 15. Composition of River Flows below Cochiti Dam as percent: runoff season (March–July)

Wetter ⟶ *Drier*

WATER SOURCE OR USE	10%-Exceedence Sequence		30%-Exceedence Sequence		50%-Exceedence Sequence		70%-Exceedence Sequence		90%-Exceedenc e Sequence		Avg
Natural Flow of Rio Grande System	**94.1**		**92.8**		**93.3**		**91.6**		**89.7**		**91.8**
Diverted to meet MRGCD and BDA Demand		24.8		28.2		32.9		36.1		43.1	35.1
Delivered to Elephant Butte		69.3		64.6		60.3		55.5		46.6	56.8
El Vado Releases	**2.2**		**1.6**		**2.1**		**1.8**		**2.4**		**2.0**
Native Storage		1.6		0.9		0.8		0.4		0.1	0.5
Prior and Paramount, for demand		0.1		0.1		0.2		0.3		0.5	0.3
Prior and Paramount, unused, evacuated		0.0		0.0		0.2		0.1		0.5	0.2
EDWA (MRGCD)		0.3		0.1		0.5		0.5		0.7	0.5
EDWA (Reclamation)		0.3		0.4		0.4		0.5		0.6	0.5
SJC Project Water	**3.7**		**5.7**		**4.7**		**6.6**		**7.9**		**6.2**
MRGCD		1.2		2.8		1.5		2.7		3.7	2.7
ABCWUA Diversion		1.4		1.9		2.2		2.2		2.6	2.2
Supplemental Water Program		1.1		0.9		1.1		1.7		1.6	1.3

Table 16. Composition of river flows below Cochiti Dam as percent: late (postrunoff) irrigation season (August–October)

Wetter ⟶ *Drier*

WATER SOURCE OR USE	10%-Exceedence Sequence		30%-Exceedence Sequence		50%-Exceedence Sequence		70%-Exceedence Sequence		90%-Exceedence Sequence		Avg
Natural Flow of Rio Grande System	**72.1**		**77.2**		**75.6**		**81.9**		**82.5**		**79.3**
Diverted to meet MRGCD and BDA Demand		51.2		54.3		59.7		69.4		67.2	62.7
Delivered to Elephant Butte		20.9		23.0		15.8		12.5		15.3	16.6
El Vado Releases	**17.3**		**12.7**		**8.3**		**8.0**		**5.5**		**8.6**
Native Storage		14.5		9.7		3.9		2.1		0.0	3.9
Prior and Paramount, for demand		0.1		0.1		02		0.1		0.5	0.2
Prior and Paramount, unused, evacuated		1.2		1.2		3.7		5.2		4.3	3.6
EDWA (MRGCD)		0.9		1.7		0.5		0.7		0.7	0.9
EDWA (Reclamation)		0.5		0.0		0.0		0.0		0.0	0.0
SJC Project Water	**10.7**		**10.1**		**16.1**		**10.0**		**12.0**		**12.1**
MRGCD		4.6		3.5		10.3		5.0		7.1	6.5
ABCWUA Diversion		5.4		5.2		5.0		4.9		3.9	4.8
Supplemental Water Program		0.7		1.4		0.8		0.1		1.0	0.9

The tables presented thus far in this section depict average conditions over 10-year periods for a variety of hydrologic conditions. Table 17 displays the degree to which these conditions can vary in individual years, based on the volume of the natural flow and the availability of water stored in reservoirs from previous years. The largest component of natural flow would occur in a year for which the initial reservoir storage is small and the natural flow is large. In the modeled year for which these conditions are most extreme, the percentage of MRG flows made up of natural flow of the Rio Grande system is 95.2%. In this high-natural-flow year, the component of MRG flow that is made up of water that had been stored in El Vado is 3.0%, and the component made up of SJC Project water is 1.8%. The largest contribution of stored and non-native water would be in a year with large initial reservoir storage and a small natural flow. In the modeled year for which these conditions are the most extreme, the percentage of MRG flows made up of natural flow is only 74.0%. In this low-natural-flow year, the component of MRG flow that is made up of water that had been stored in El Vado is 9.8%, and the component made up of SJC Project water is 16.2%.

Table 17. Composition of river flows below Cochiti Dam, as percent: range of variability for individual years

WATER SOURCE OR USE	Individual Year with Small Reservoir Storage and Large Natural Flow	Individual Year with Large Reservoir Storage and Small Natural Flow
Natural Flow of Rio Grande System	95.2	74.0
Diverted to meet MRGCD & BDA Demand	17.1	38.8
Delivered to Elephant Butte	78.1	35.2
El Vado Releases	3.0	9.8
Native Storage	1.8	6.5
Prior & Paramount	0.0	2.4
EDWA (MRGCD)	0.8	0.0
EDWA (Reclamation)	0.4	0.9
SJC Project Water	1.8	16.2
MRGCD	0.1	5.8
ABCWUA Diversion	1.7	6.9
Supplemental Water Program	0.0	3.6

6.3 Comparison of Hydrologic Conditions with and Without the Proposed Water Management Actions

This section compares modeled hydrologic conditions under the Proposed Water Management Actions to modeled hydrologic conditions in the absence of those actions (referred to as the "No Action" condition in this section, for convenience). The Proposed Water Management Actions do not include Reclamation's Supplemental Water Program, which is evaluated separately as a conservation measure in section 6.5. Both conditions have been modeled and evaluated using the five synthetic hydrologic sequences described in section 6,1. In the simulations of the Proposed Water Management Actions, Reclamation operates Heron Dam to provide SJC Project water to its contractors. Reclamation, in coordination with the MRGCD, stores native water in El Vado Dam and releases that water as needed to meet MRGCD diversion demand, and the MRGCD operates its MRG diversions. In the simulation of the No Action condition, these operations are turned off in the model. However, MRGCD irrigation demand is not turned off. Therefore, if water is available to the irrigation network, such as from interior and riverside drains, that water will be used to meet irrigation demand if it can be delivered to the turnout without being diverted from the river. The flow targets set by the 2003 BiOp are used as operating rules for all model runs. Additionally, through 2013, the Corps can deviate its operations of Cochiti Dam to enhance the timing and shape of the spring hydrograph in the MRG, an interrelated and interdependent action to this BA, which is turned on in all model runs (see table 30).

There are effects to both high flow and low flow conditions within the MRG from the Proposed Water Management Action when compared to a No Action scenario. Figure 60 presents a comparison of the modeled duration of continuous high flows at Central Avenue under the Proposed Water Management Actions, relative to the No Action condition. This figure shows that, on average, the Proposed Water Management Actions decrease the length of time that the spring snowmelt runoff peaks persist in the MRG. For example, there is a 4-day difference between the duration of flows exceeding 3,000 cfs and a 10-day difference in the duration of flows exceeding 1,000 cfs under the Proposed Water Management Actions relative to the No Action condition. This change is due to both diversion of flows and storage of water at El Vado. The difference is more pronounced in the Isleta Reach decreasing the duration at 3,000 cfs by 6 days and 1,000 cfs by over 20 days. The COE deviation program is included through 2013 in the model runs for both Proposed Action and No Action scenarios. The deviation is not likely to change the total flow volume but may extend the number of days that flow remains above a threshold level.

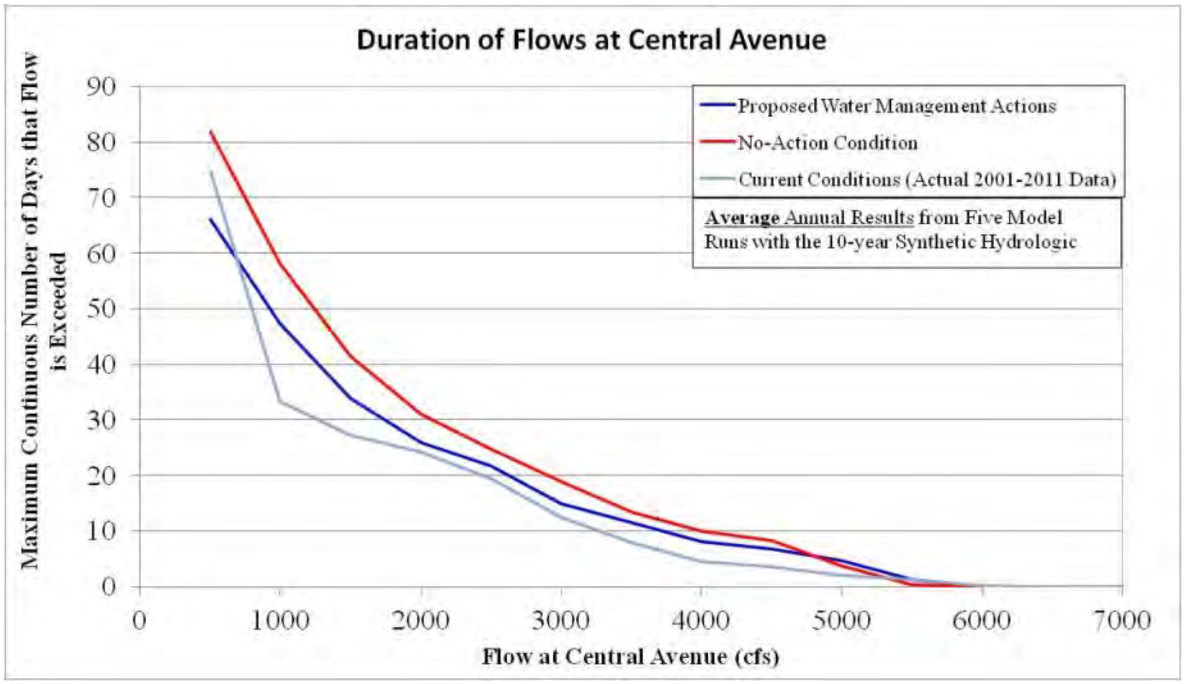

Figure 60. Comparison of the duration of continuous days of high flow under the Proposed Water Management Actions, relative to the No Action condition, at Central Avenue gage, Rio Grande, New Mexico, in the 500- to 7,000-cfs range.

The effect is more pronounced during lower flows. Figure 61 provides a summary of the impact of the Proposed Water Management Actions on flows in the MRG, relative to the No Action condition, at key locations within the MRG, including the Albuquerque/Central Avenue gage, downstream from Isleta Diversion Dam, downstream from San Acacia Diversion Dam, and at San Marcial, from July 1 to October 31. Each colored bar shows the combined effects on flows of both Federal and non-Federal actions in the Proposed Water Management Actions, including operation of Heron Dam under the SJC Project, Operation of El Vado Dam, and MRGCD diversions, at these key locations. It shows that the Proposed Water Management Actions result in lower flows across the normal range of flows at this location.

This effect is concentrated in the irrigation season. The difference between the Proposed Water Management Actions and the No Action condition during the nonirrigation season is very small. The model runs and the spreadsheet analysis presented here indicate that Proposed Water Management Actions likely will result in additional days of river drying. The relative differences between modeled flows under the Proposed Water Management Actions and the No Action persist downstream through the remaining reach of the MRG.

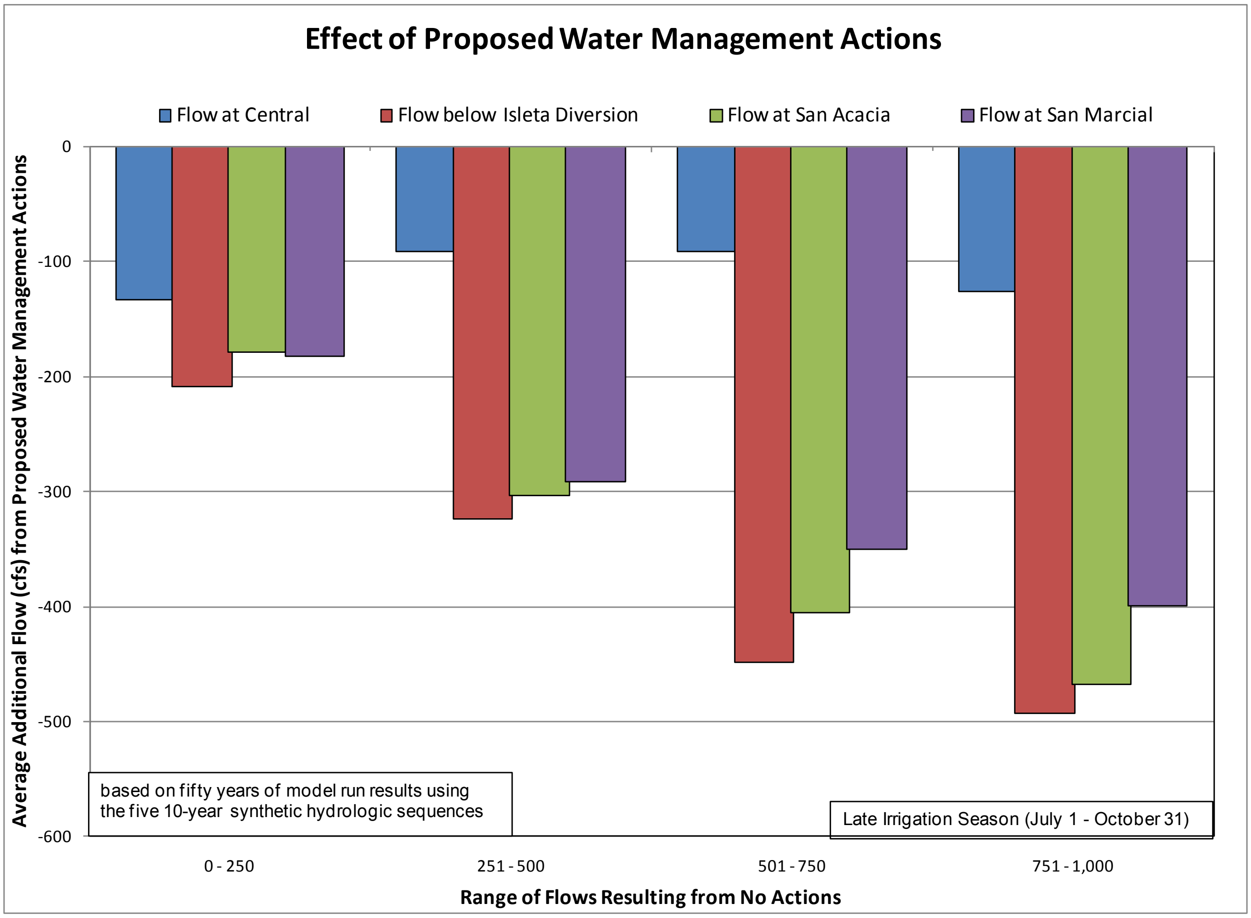

Figure 61. Change in modeled flow under the Proposed Water Management Actions to flow modeled under the No Action condition over the calendar year.

As explained in section 6.1.1, the portrayal of the No Action condition in URGWOM is subject to considerable uncertainty, since this condition has not been monitored in the MRG, and, therefore, the model has not been calibrated to this condition. Therefore, an additional computational tool, a mass-balance-based spreadsheet model developed in MS Excel by the MRGCD (described in Appendix 9) has been employed for evaluation of the No Action condition and comparison of this condition to the flow conditions under the Proposed Water Management Actions.

The premise of the spreadsheet model is that a certain flow enters each reach, and the amount leaving that reach is determined by subtracting the known depletions in that reach from that inflow. The outflow from that reach then becomes the inflow for the next reach. There are complicating factors, primarily the interaction of water into and out of the drainage system. As noted above, some reaches are aggregated for consideration, which eases the difficulty in accounting for these complicating factors. The spreadsheet model depends on an input of the flow expected to enter the MRG from the outlet works of Cochiti Reservoir. This input value is derived from the previous URGWOM modeling for various conditions.

The spreadsheet model then uses estimates of agricultural, riparian, and open water depletions from Reclamation's "ET Toolbox," plus a ground water component in the Albuquerque area, to estimate flows arriving at four key points in the MRG; Central Avenue gage in Albuquerque, below Isleta Dam, San Acacia Gage, and San Marcial Gage. Flows at these points are evaluated in terms of number of years of successful spawn/recruitment condition during each run (Central Avenue only), days of major drying over the course of the run, days of intermittency over the course of the run, number of years during the run in which major drying occurs, and number of years during the run in which some intermittency occurs (table 18).

Table 18. The following thresholds were specified as output criteria for table 19

	Spawn Flow/Duration	Major Drying	Intermittency
Central Avenue	3,000 cfs/7 days	10 cfs	100 cfs
Below Isleta Dam		30 cfs	100 cfs
San Acacia Gage		10 cfs	200 cfs
San Marcial Gage		10 cfs	50 cfs

The spreadsheet model also includes a user-adjustable factor that specifies agricultural consumption. This allows for full agricultural consumptive use to occur in the model under the Proposed Water Management Actions, where it should be set to 1. However, for No Action runs, agricultural consumption may still occur in some areas even when no diversion for that purpose is occurring, due to ground water accretion in MRGCD drains. The factor specified for a given reach is dependent on whether the drain flows in that reach can be used for irrigation, or must return to the river.

Table 19 presents a summary of the days of minnow spawning flows, intermittency, and river drying that are projected under the five hydrologic sequences used for this effects analysis for the Proposed Water Management Actions and the No Action condition. The third column of tables compares the two conditions and, therefore, presents an assessment of the impact of the Proposed Water Management Actions on these conditions, based on the spreadsheet model. Please note that the column headers for the Central Avenue location differ from those for the other key locations.

No Action

Central Ave.	Sequence	Less than 100 cfs Days	Less than 100 cfs Years	Spawn (YRS) 3000cfs/7dys
Wetter ↑	10%	31	4	8
	30%	23	4	6
	50%	16	3	6
↓	70%	34	4	6
Drier	90%	47	3	3
	All (50 yrs)	151	18	29

Below Isleta Dam Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	39	5	127	6
30%	25	4	68	4
50%	16	3	71	3
70%	40	4	141	4
90%	64	3	261	8
All (50 yrs)	184	19	668	25

Blw SanAcaciaDam Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	276	7	668	9
30%	175	6	460	8
50%	186	5	597	9
70%	277	4	640	10
90%	447	6	831	10
All (50 yrs)	1361	28	3096	46

Blw SanMarcial Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	683	10	765	10
30%	547	8	618	9
50%	670	10	730	10
70%	723	10	787	10
90%	824	10	900	10
All (50 yrs)	3447	48	3800	49

Proposed Action

Central Ave.	Sequence	Less than 100 cfs Days	Less than 100 cfs Years	Spawn (YRS) 3000cfs/7dys
Wetter ↑	10%	122	2	8
	30%	95	3	6
	50%	139	3	5
↓	70%	258	4	6
Drier	90%	411	5	3
	All (50 yrs)	1025	17	28

Below Isleta Dam Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	779	9	985	9
30%	673	9	880	10
50%	907	10	1127	10
70%	1008	10	1208	10
90%	1187	10	1373	10
All (50 yrs)	4554	49	5573	49

Blw SanAcaciaDam Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	705	9	1092	10
30%	656	9	1046	10
50%	818	10	1266	10
70%	944	10	1391	10
90%	1097	10	1486	10
All (50 yrs)	4220	48	6281	50

Blw SanMarcial Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	907	10	980	10
30%	853	10	914	9
50%	1030	10	1122	10
70%	1155	10	1228	10
90%	1224	10	1296	10
All (50 yrs)	5169	50	5540	49

Impact (Proposed Action minus No Action)

Central Ave.	Sequence	Less than 100 cfs Days	Less than 100 cfs Years	Spawn (YRS) 3000cfs/7dys
Wetter ↑	10%	91	-2	0
	30%	72	-1	0
	50%	123	0	-1
↓	70%	224	0	0
Drier	90%	364	2	0
	All (50 yrs)	874	-1	-1

Below Isleta Dam Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	740	4	858	3
30%	648	5	812	6
50%	891	7	1056	7
70%	968	6	1067	6
90%	1123	7	1112	2
All (50 yrs)	4370	30	4905	24

Blw SanAcaciaDam Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	429	2	424	1
30%	481	3	586	2
50%	632	5	669	1
70%	667	6	751	0
90%	650	4	655	0
All (50 yrs)	2859	20	3185	4

Blw SanMarcial Sequence	Drying Days	Drying Years	Intermittency Days	Intermittency Years
10%	224	0	215	0
30%	306	2	296	0
50%	360	0	392	0
70%	432	0	441	0
90%	400	0	396	0
All (50 yrs)	1722	2	1740	0

Table 19. Comparison of the occurrence of spawning flows, river intermittency, and river drying under the Proposed Action relative to the No Action Condition over 10-year period. Criteria for this table are outlined in table 18.

The analysis at the Central Avenue Gage location includes an assessment of the number of years in which silvery minnow spawning flows are achieved, which is designated for purposes of this analysis as 3,000 cfs for 7 consecutive days. This analysis shows that, as has been indicated previously in this analysis, the Proposed Water Management Actions have a negligible impact on the spawning flows. The spreadsheet model projects a difference of one year in fifty for the achievement of spawning flows, from 29 out of 50 years under the No Action condition to 28 out of 50 years under the Proposed Water Management Action.

The spreadsheet model projects a significantly larger difference in the number of years in which intermittency and drying occur with and without the proposed action. This is as expected, since the Proposed Water Management Actions include irrigation diversions from the river. The Proposed Water Management Action results in a change in the number of days with flows below 100 cfs at Central Avenue is projected to be about 5% of the total number of days. This translates to over 75% of intermittency at Central Avenue being attributable to the Proposed Water Management Action (table 20). The larger impact is downstream of Isleta Diversion Dam where the Proposed Water Management Actions cause over 90% of the drying, a change from drying several days per year to drying about 25% of days.

Table 20. Proportion of predicted river drying and intermittency attributable to Proposed Water Management Action downstream from various gages on the Rio Grande

	Upstream River Gage			
Sequence	Central	Isleta	San Acacia	San Marcial
Major Drying		<10 cfs	<30 cfs	<10 cfs
10%		95.0%	60.9%	24.7%
30%		96.3%	73.3%	35.9%
50%		98.2%	77.3%	35.0%
70%		96.0%	70.7%	37.4%
90%		94.6%	59.3%	32.7%
Intermittency	<100 cfs	<100 cfs	<200 cfs	<50 cfs
10%	74.6%	87.1%	38.8%	21.9%
30%	75.8%	92.3%	56.0%	32.4%
50%	88.5%	93.7%	52.8%	34.9%
70%	86.8%	88.3%	54.0%	35.9%
90%	88.6%	81.0%	44.1%	30.6%

6.3.1 Effect of Proposed Water Management Actions on Silvery Minnow

The Proposed Water Management Actions can decrease the length of time that spring snowmelt runoff peaks persist in the MRG. This indicates that the Proposed Action may have a negative effect on the development of silvery minnow eggs and larvae by reducing the time in which high flows inundate overbank habitat. The difference in the mean number of days that would be expected at each discharge level increases as the peak flow decreases. Thus, in years with high overbank potential (flows greater than 3,000 cfs at Albuquerque) there is a less noticeable decrease in high flows than in those years with minimal snowmelt. The relationship of October catch rates of silvery minnow and number of days greater than 3,000 cfs (figure 16), revealed that, since 1993, only 1 year with fewer than 30 days with discharge greater than 3,000 cfs had a mean October catch rate greater than five fish per 100 square meters (m^2). A linear regression of this relationship indicates an approximate change in mean October CUPE by two fish per 100 m^2 for every 5 days change in spring discharge > 3,000 cfs.

Table 21. Relationship of mean October CPUE with number of days with discharge greater than 3,000 cfs in May and June from figure 17

Yr	Mean October CPUE (#/100 m^2)	# Days Discharge >3,000 cfs (May and June)	Graph Value (Figure 16)
1993	11.8	59	1.9
1994	12.6	60	2.0
1995	26.8	61	2.3
1996	1.4	0	0.7
1997	13.6	43	2.2
1999	6.3	30	1.3
2000	0.4	0	0.3
2001	0.9	2	0.4
2002	0.1	0	0.1
2003	0.0	0	0.0
2004	0.9	0	0.4
2005	37.3	57	2.9
2006	1.3	0	0.6
2007	10.8	10	1.7
2008	8.3	46	1.6
2009	15.5	34	2.2
2010	1.2	19	0.6
2011	1.2	0	0.5

The Corps deviation program is included through 2013 in the model runs for both Proposed Action and No Action scenarios. The deviation is not likely to change the total flow volume but may extend the number of days that flow remains above a threshold level, which could benefit silvery minnow. There is little difference between the Proposed Water Management Actions and the No Action condition for the duration of flows over 5,000 cfs, which are the flows that are high enough to alter the channel; so the Proposed Water Management Actions have little direct effect on current silvery minnow habitat features within the MRG. However, the Proposed Water Management Actions do provide low summertime flows, which allow vegetation growth and, therefore, contribute to channel narrowing and simplification. This indirect effect is compounded by the lack of channel-resetting high flow events due to flood control operations by the Corps at Cochiti Dam. There is a complex relationship between sediment transport and silvery minnow habitat. Generally, areas that have high sediment load and low sediment transport have a greater connectivity to the flood plain and provide more complex habitat at all flows; however, these sections are also more prone to intermittency due to the perched nature of the channel causing the flow to go subsurface. These processes are described in detail in the River Maintenance Part II. Depending on their operation, diversion dams may interrupt sediment downstream transport and cause degradation within the channel.

In addition to the high flow duration, October catch rates are related to the onset of low flow conditions (figure 17). The early onset of low flows is negatively related to the recruitment of silvery minnow. Modeling predicts that the Proposed Action increases the likelihood that low flow conditions begin earlier in the year (indicated by 200 cfs at San Marcial) (figure 62). Modeling runs of the Proposed Action also indicate that the duration of low flow conditions and drying are increased under the Proposed Action as compared to the No Action scenario (table 19). In the modeled scenarios, there is increased probability of drying in all reaches with the Proposed Action as compared to the No Action scenario. Increased drying is likely to adversely affect silvery minnow, especially juvenile and adults during summer and fall timeframes.

The Proposed Action may increase winter flows during the transfer of water to Elephant Butte after the irrigation season. This is considered to have little effect on silvery minnow since the flow levels tend to be sufficient and stable during winter. Stable water conditions should allow minnow to remain in a single overwinter habitat without having to expend energy seeking out new suitable habitats as flows change. Higher flows also may provide some amount of thermal stability during times of extremely low air temperatures. A summary of the effects of the Proposed Water Management Actions on silvery minnow is presented in table 22.

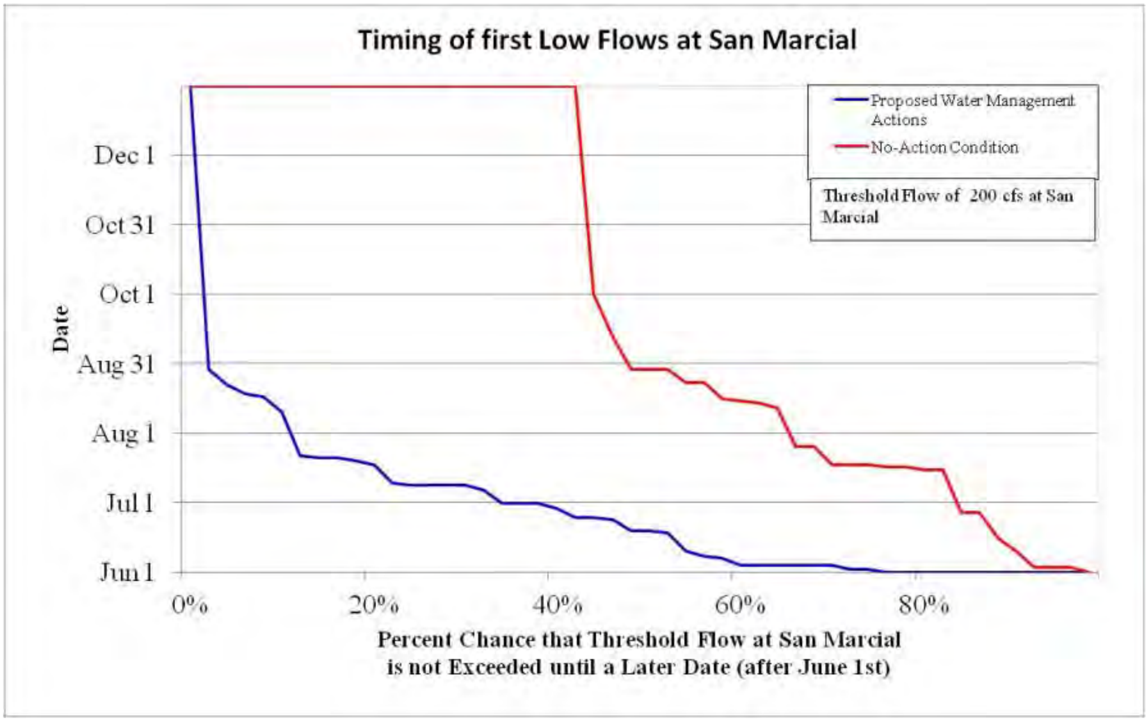

Figure 62. Comparison of the timing of the first low flows at San Marcial under the Proposed Water Management Actions to flows under the No Action condition, after June 1.

Table 22. Summary of the effect of the full Proposed Water Management Actions on the life history elements and critical habitat PCEs of silvery minnow. Table 19. Effect of Proposed Water Management Actions (3.2 and 3.3) on life history elements and PCEs of silvery minnow

	Spawning	Eggs	Larval	Juvenile	Adult
Spring (March–June)	The Proposed Action will cause a small decrease in the magnitude and duration of runoff in the MRG. This decrease is anticipated to be minor. The duration of inundation of overbank habitats is related to spawning and recruitment of silvery minnow. **Direct and Indirect – *The Proposed Water Management Actions are likely to adversely affect silvery minnow*** recruitment due to the decreased magnitude and duration of spring runoff.				There is little information on how spring flows are related to adult survival of silvery minnow. The anticipated minor changes in the spring hydro-graph from the Proposed Water Management Actions ***are not likely to directly or indirectly adversely affect adult silvery minnow.***

Table 22. Summary of the effect of the full Proposed Water Management Actions on the life history elements and critical habitat PCEs of silvery minnow. Table 19. Effect of Proposed Water Management Actions (3.2 and 3.3) on life history elements and PCEs of silvery minnow (continued)

<table>
<tr><th></th><th>Spawning</th><th>Eggs</th><th>Larval</th><th>Juvenile</th><th>Adult</th></tr>
<tr><td>Summer (June–Sept)</td><td></td><td></td><td colspan="3" rowspan="2">The Proposed Water Management Actions are anticipated to cause decreased summer and fall flows and drying as compared to the No Action scenario. Both low flows and drying are likely to cause mortality of silvery minnow. Thus, Direct and Indirect – The Proposed Water Management Actions are likely to adversely affect silvery minnow during summer and fall periods.</td></tr>
<tr><td>Fall (Sept–Nov)</td><td></td><td></td></tr>
<tr><td>Winter (Dec–Feb)</td><td></td><td></td><td></td><td></td><td>Water releases for SJC Project contractors generally occur in November and December. These releases provide higher flows through the MRG, which are of sufficient amount and generally stable. Direct and Indirect – The Proposed Water Management Actions are not likely to adversely affect winter survival of adult silvery minnow.</td></tr>
<tr><td colspan="6">Critical Habitat PCE’s</td></tr>
<tr><td colspan="6">Hydrologic Regime</td></tr>
<tr><td>A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats.</td><td colspan="5" rowspan="2">The Proposed Action has no effect on the duration of channel resetting, habitat forming flows (> 5,000cfs) but does set the base flow levels that also continues the long-term geomorphic trends within the MRG, which is trending towards a narrower, more simplified channel due to vegetation encroachment. There are indirect as well as interrelated and interdependent effects on silvery minnow critical habitat from the storage and release of water from reservoirs which changes sediment transport capacity and disrupts of peak flows.

There is no direct effect to silvery minnow critical habitat but indirect effects include long-term vegetation encroachment within the channel, which may adversely affect silvery minnow critical habitat.</td></tr>
<tr><td>Presence of a diversity of habitats for all life history stages</td></tr>
</table>

Table 22. Summary of the effect of the full Proposed Water Management Actions on the life history elements and critical habitat PCEs of silvery minnow. Table 19. Effect of Proposed Water Management Actions (3.2 and 3.3) on life history elements and PCEs of silvery minnow (continued)

	Spawning	Eggs	Larval	Juvenile	Adult
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	Silvery minnow are known to spawn with very small flow increases. However, the Proposed Action may result in a minor decrease in high flows especially in years with limited spring runoff; ***this may have direct and indirect effects but is not likely to adversely affect critical habitat for spawning of silvery minnow.***				
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow		The Proposed Action increases the likelihood of low flow periods and drying in the MRG as compared to No Action. **Direct and Indirect –** ***The Proposed Action is likely to adversely affect silvery minnow critical habitat by increasing the duration of low flow and drying within the MRG.***			
Constant winter flow				Water releases for SJC Project contractors generally occur in November and December. These releases provide higher flows through the MRG that are of sufficient amount and generally stable. **Direct and Indirect –** ***Actions are not likely to adversely affect winter critical habitat.***	

Table 22. Summary of the effect of the full Proposed Water Management Actions on the life history elements and critical habitat PCEs of silvery minnow. Table 19. Effect of Proposed Water Management Actions (3.2 and 3.3) on life history elements and PCEs of silvery minnow (continued)

	Spawning	Eggs	Larval	Juvenile	Adult
Unimpounded stretches of river with a diversity of habitats and low velocity refuge areas					
River reach length	Currently, diversion dams are in place; no new cross channel structures are proposed. The actual length of wetted river within each reach changes depending on channel sinuosity. Sinuosity changes depending on geomorphology and discharge levels. Sinuosity of the thalweg may increase during low flows that increase the length of the river but also may promote vegetation growth on point bars within the river channel. The lack of flood stage flows also changes the potential that the river will move outside its current channel. The Proposed Action ***is not likely to adversely river reach length.***				
Habitat "Quality" in each reach and refugial habitats.	Habitat quality in each reach is dependent on the structure and diversity of available habitat. Channel trends throughout the MRG are towards a more simplified channel due to vegetation encroachment. Base flow levels from the proposed actions drive the vegetation encroachment within the channel. The quantity of suitable habitat within each reach also changes at different flows, this relationship is not linear in most sections of the river and is dependent on channel shape. The Proposed Action ***may have indirect effects that adversely affect silvery minnow critical habitat***.				
Substrate of sand or silt					
Substrates of predominantly sand or silt	The Proposed Action is not likely to affect the current trend of substrate coarsening in the Cochiti Dam and Angostura Reaches or deposition within the lower reaches. Much of the sediment in the MRG is introduced from tributary flows that are largely unregulated. The presence and operation of diversion dams within critical habitat interrupts sediment transport and may affect the substrate size downstream from the structures. Direct and Indirect – The Proposed Action ***is likely to adversely affect substrate composition within silvery minnow critical habitat.***				
Water quality					
Temp >1˚ - <30˚C. DO > 5 mg/L pH (6.6-9.0)	Water temperature, DO, and pH within the MRG may be affected during low flow conditions, especially in intermittent areas. ***Direct and Indirect – The Proposed Action is likely to adversely affect water quality due to increased low flow periods.***				
Other Contaminants	Drain and irrigation return water has the potential to have poor water quality, but recent studies (Buhl 2011) found no biologically significant levels of contaminants in the tested wasteway water. The Proposed Action reduces the amount of water that is available to dilute contaminants that are introduced to the river from outside sources. This lack of dilution may have ***indirect effects but is not likely to adversely affect silvery minnow***.				

6.3.2 Effect of Proposed Action on flycatcher.

Currently, the suitable habitat within the project area that would be affected by the Proposed Action include areas in the upper end of Cochiti Reservoir in the Otowi to Cochiti Dam Reach; from just south of Albuquerque to the Isleta Diversion Dam, Isleta Diversion Dam to Rio Puerco, and Rio Puerco to San Acacia Reaches; and from the BDANWR to RM 73 (just south of the BDANWR) in the Arroyo de las Cañas to San Antonio Bridge, San Antonio Bridge to River Mile 78 and River Mile 78 to River Mile 62 Reaches (reach boundaries are described in the River Maintenance section). Areas that are not on the list likely will not reach suitability in at least the next 10 years based on vegetation trends in the last 10 years and/or the depth to ground water is likely too deep to encourage new growth of native-dominated vegetation communities. An extensive effort beyond water operations would be required to establish flycatcher suitable habitat in those areas.

Above Cochiti Reservoir, other factors influence hydrology and flycatcher habitat such as water coming in from tributaries, reservoir storage, and beaver activity that maintains ponded areas of water within the Cochiti Reservoir delta. Into the future, flycatcher habitat in this area is predicted to remain well within the 50 meter distance to water and have saturated soils associated with flycatcher preference to establish territories and conditions suitable for vegetation health and recruitment. This prediction is based on historic flows observed at the Otowi Bridge gage over the last 10 years.

The area from the confluence of the Rio Grande and the Rio Chama to Otowi Bridge is proposed critical habitat for flycatchers; however, that area would not be affected by the Proposed Action because MRGCD's water diversions do not take place this far north. Additionally, due to the 1,800-cfs channel capacity on the Rio Chama below Abiquiu Reservoir, flows from the Chama alone would make little impact on the occurrence of recruitment or overbank flows in the MRG.

Overbank flooding events tend to attract flycatchers and lead to territory establishment. These events also contribute to vegetation health, seedling establishment, and insect prey base abundance. The methodology described in the following paragraphs was used in an effort to determine the relative change in the potential for overbank flooding due to the decrease in high flow periods from the Proposed Water Management action.

The one-dimensional modeling from the River Maintenance Part 2, Most Likely Strategies and Methods by Reach Attachment uses the a value of 4,700 cfs as an indicator for predicting overbank flows. The 2-year return rate of 4,700 cfs was modeled to predict the frequency of when an overbank flooding event would occur. For example, a value is over 1 signifies a higher frequency of overbank flows at lower discharge than 4,700 cfs. Values under 1 signify lower frequency of overbank flows. This modeling effort does not include overbank flows on islands; therefore, it is likely an overestimate of the flows required to inundate those areas. Table 23 describes the modeling value for overbank flows in each reach related to a discharge of 4,700 cfs.

Overbank discharge values were less than 1 in most reaches, signifying that more than 4,700 cfs would be needed for overbank flows with the exception of areas in the BDANWR. Because the Arroyo del las Cañas to San Antonio Bridge and San Antonio Bridge to River Mile 78 Reaches had overbank discharge values over 1, flows less than 4,700 cfs would trigger an overbank flooding event. A recent Colorado State University study determined actual overbank flows occur at a discharge of 1,400 cfs for that reach.

Table 23. Modeled predictions of overbank flooding at 2-year return rate of 4,700 cfs

Reach	Inundation Value
Angostura Diversion Dam to Isleta Diversion Dam	0.76
Isleta Diversion Dam to Rio Puerco	0.70
Rio Puerco to San Acacia Diversion Dam	0.53
Arroyo del las Cañas to San Antonio Bridge	1.74
San Antonio Bridge to River Mile	3.36
River Mile 78 to River Mile 62	0.53

Hydraulic modeling indicates a small change in the overbank flooding potential in all reaches due to the Proposed Action (figures 63, 64, and 65) using the Proposed Action with no Supplemental Water sequence and during the early irrigation season that covers the period of flycatcher territory establishment. There would be a difference of between 1 to 3 days of overbank flows in all reaches from Albuquerque to RM 62 with the exception of the area from Arroyo del las Cañas to River Mile 78 when comparing the Proposed Action to No Action (table 24). This difference is likely inconsequential for flycatcher, considering that these areas often require more than the 4,700 cfs for flooding, and areas where flycatchers occupy are typically along the rivers' edge and within the 50-meter distance to water where 94% of flycatcher nests are located.

Table 24. Effects of the Proposed Water Management Action compared to No Action and the difference in potential days of overbank flooding events during early irrigation season and flycatcher territory establishment. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with Proposed Action	Number of days flows reach 4,700 cfs with Proposed Action	Percent of the time flows reach 4,700 cfs with No Actions	Number of days flows reach 4,700 cfs with No Actions
Central	10.20%	12	11.30%	14
San Acacia	7.10%	9	10.00%	12
San Marcial	3.10%	4	4.40%	5

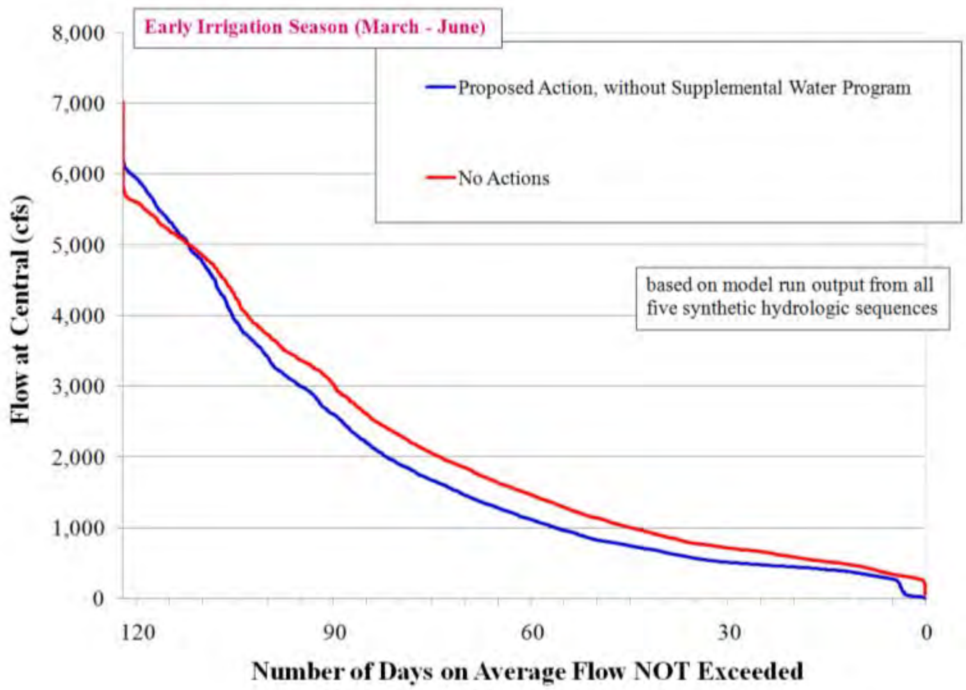

Figure 63. Relative comparison of modeled flows at Central gage considered Proposed Action with no Supplemental Water Program compared to No Action during the flycatcher territory establishment period.

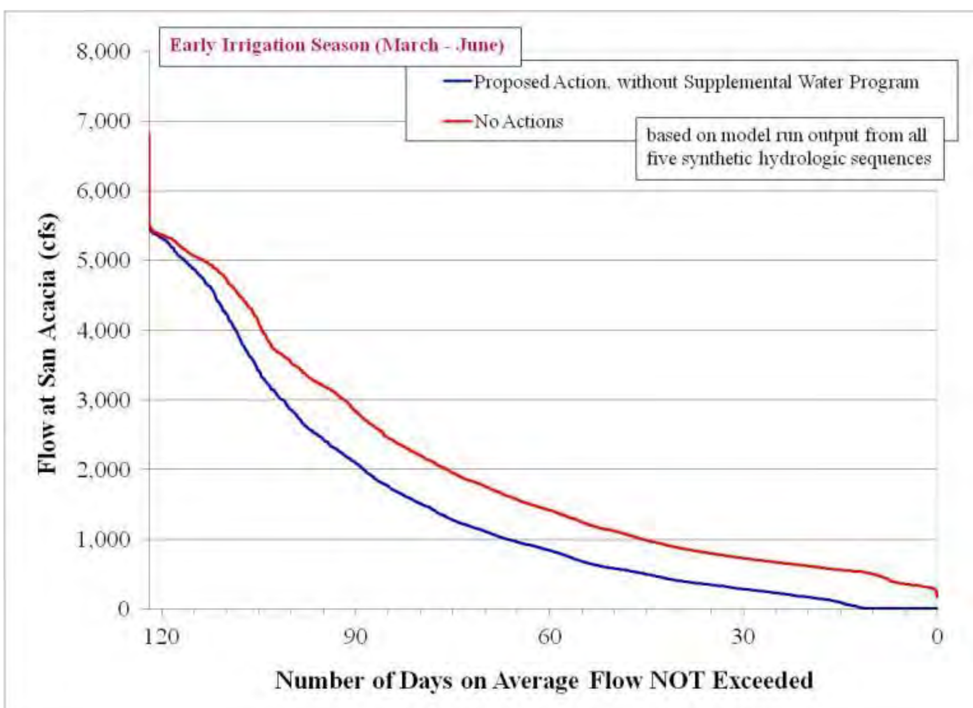

Figure 64. Relative comparison of modeled flows at San Acacia gage considered Proposed Action with no supplemental water program compared to No Action during the flycatcher territory establishment period.

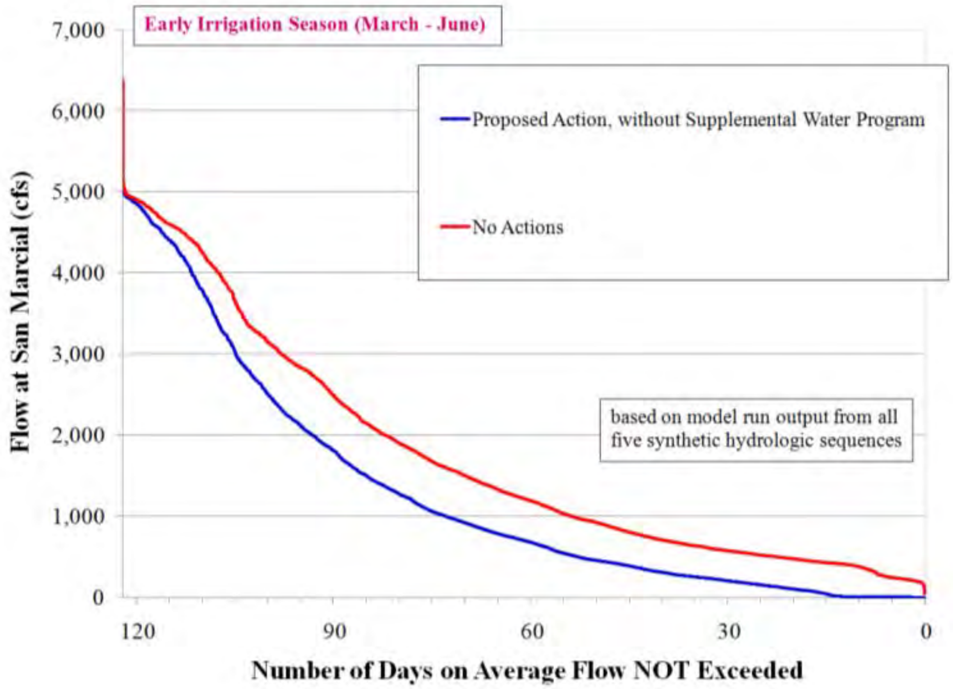

Figure 65. Relative comparison of modeled flows at San Marcial gage considered Proposed Action with no Supplemental Water Program compared to No Action during the flycatcher territory establishment period.

Hydrologic modeling for the late irrigation season from July to October indicate a small decrease in water but relatively minor differences between the No Action versus Proposed Action scenarios (table 25).

Table 25. Effects of the Proposed Water Management Action compared to No Action and the difference in potential days of overbank flooding events during late irrigation season and flycatcher nesting period. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with Proposed Action	Number of days flows reach 4,700 cfs with Proposed Action	Percent of the time flows reach 4,700 cfs with No Actions	Number of days flows reach 4,700 cfs with No Actions
Central	1.8%	2	2.2%	3
San Acacia	1.8%	2	2.4%	3
San Marcial	1.7%	2	2.3%	3

For the Arroyo del las Cañas to RM 78 reach, modeled flow at the San Acacia gage was analyzed with the Proposed Action at the 1,400 cfs required for inundation within the BDANWR area. According to calculations, this area would meet overbank flows 45.0% of the time in the No Action sequence and 36.3% or

44 days in the Proposed Action sequence (table 26). This 10-day difference would be more substantial when compared to the other reaches but territories within this area are found along the river and are typically within 50 m of water as long as the river is wet which would be the majority of time in the March-to-June time period.

Table 26. Effects of the Proposed Water Management Action compared to No Action and the difference in potential days of overbank flooding events during early irrigation season and flycatcher territory establishment in the reaches from Arroyo del las Cañas to RM 78.

Gage Location	Percent of the time flows reach 1,400 cfs with Proposed Action	Number of days flows reach 1,400 cfs with Proposed Action	Percent of the time flows reach 1,400 cfs with No Actions	Number of days flows reach 1,400 cfs with No Actions
San Acacia	36.30%	44	45.00%	55

The modeling results for the late irrigation season from July–October at the San Acacia gage results indicate a 5-day difference in potential overbank flooding during that time period (table 27). Though this time period is less important in regard to territory establishment, it is important for vegetative health and nest success during July and August. If vegetation declines in value for flycatchers during this time period, their nests would be more visible and subject to predation due to decreased foliage cover. Table 28 presents a summary of the effects of Heron and El Vado Dam operations and MRGCD diversions on flycatchers in the MRG.

Table 27. Effects of the Proposed Water Management Action compared to No Action and the difference in potential days of overbank flooding events during late irrigation season and flycatcher nesting period in the reaches from Arroyo del las Cañas to RM 78.

Gage Location	Percent of the time flows reach 1,400 cfs with Proposed Action	Number of days flows reach 1,400 cfs with Proposed Action	Percent of the time flows reach 1,400 cfs with No Actions	Number of days flows reach 1,400 cfs with No Actions
San Acacia	6.2%	8	10.5%	13

Table 28. Effect of Proposed Action on life history elements and PCEs of flycatchers

Life History Element	**Migration** (April–June and July–September)	**Arrival to Territories/ Territory Establishment/Nest Building** (May–July)	**Egg Laying/ Incubation/ Nestling/ Fledgling** (June–August)
Breeding Season (April–September)	The Proposed Action would ***not likely adversely affect*** flycatcher stopover locations during migration because flycatchers will use habitat that is less suitable during this time and farther away from water sources.	The Proposed Action may ***indirectly affect flycatcher habitat on a negligible level***. Because the Proposed Action, when compared to No Action, would ***decrease the potential of overbank flooding and decrease the overall water available for vegetation***, this could cause a decline in territory recruitment and canopy cover/plant health/seed establishment and ***could potentially adversely affect flycatcher habitat,*** particularly in periods of drought. However, it should be noted that the decrease in water between the two scenarios is a relatively small amount.	Territory recruitment at this stage is no longer an issue as flycatchers are more invested in their territories and less likely to abandon nests should conditions dry or decline in value. However, if vegetation does not have adequate water resources, canopy cover likely will decrease, and predation and/or parasitism likely would be more prevalent. Because the Proposed Action would result in less water in the system, there would be an increased possibility of vegetation not having adequate water to maintain health and, thus, ***would adversely affect flycatcher habitat and potential nest success*****,** again particularly in times of drought.
Critical Habitat PCES			
Riparian Vegetation	Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal, and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. With a decrease in the water amount reaching flycatcher suitable habitat patches, the Proposed Action could ***potentially adversely affect flycatcher riparian vegetation****.*		
Insect Prey Populations	A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the No Action and the Proposed Action ***may affect, not likely to adversely affect the insect prey populations***. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

6.3.3 Effect of Proposed Action on Pecos Sunflower

In the Middle Rio Grande, the Pecos sunflower is presently known to exist within the La Joya Waterfowl Area of the NMDGF Ladd S. Gordon Waterfowl Complex. This is one of the largest populations of *H. paradoxus*, consisting of 100,000 to 1,000,000 plants. This unit is 854 acres (346 ha) in Socorro County, New Mexico. This population is located about 7 mi (11 km) south of Bernardo within Socorro County near the confluence of the Rio Grande and the Rio Puerco. The La Joya population is bounded to the west by I-25 and to the east by the Unit 7 Drain. The plants exist entirely within the managed area of the NMDGF wildlife area. Ponds, springs, and wetted soils are features within the La Joya Unit that strongly influence the presence and distribution of Pecos sunflower. Both ground water and managed water create these wet features where Pecos sunflower is found. The interaction between these is complex and not well understood (NMDGF 2007). One or all three may be a source of water for the Pecos sunflower, possibly to varying degrees at different times of the year. Water is delivered to this area via the Unit 7 Drain and the La Joya drain which is part of the "former state drain system."

In recent years, the maintenance of the drains has been limited. In the past, Reclamation performed maintenance on portions of the drains that was largely funded by the State. Currently, the responsibility for O&M of the drains is under consideration. Effects of maintenance are discussed in the River Maintenance section. Reclamation's Water Management actions (operation of Heron and El Vado) mainly extend the supply of water available for diversion during irrigation season and have little or no effect on the Pecos sunflower in the Middle Rio Grande (table 29). Water delivered through the MRGCD system to manage the Ladd S. Gordon Waterfowl Complex for migratory waterfowl habitat is beneficial to preserve wetland habitat for *H. paradoxus*. Parts of the riverside drains also function as conveyance channels during the irrigation season, causing drain stage to be above the water table. Therefore, riverside drains either can lose or gain water from the aquifer system depending on the drain stage and drain bed altitude relative to the water table. The ground water modeling by USGS (Bartolini and Cole 2002, McAda and Barroll 2002) indicate that ground water elevation in the region near the sunflower population has been generally steady in recent history. There is no designated critical habitat for Pecos sunflower in the Middle Rio Grande.

Infestations of exotic plant species continue to destroy or degrade desert wetlands and riparian areas. High densities of saltcedar (*Tamarix* sp.), Russian olive (*Elaeagnus angustifolia*), and perennial pepperweed (*Lepidium latifolium*) can have adverse impacts to cienegas. Saltcedar and Russian olive trees transpire considerable amounts of water from shallow water tables, which could reduce water available for Pecos sunflower. These invasive species also create an over story canopy that reduces light in the understory and further degrades Pecos sunflower habitat. Perennial pepperweed reduces species diversity in cienegas and space otherwise available for Pecos sunflowers. The Pecos sunflower habitat management plan identifies their strategy to control exotic plants within the wildlife area (NMDGF 2007).

The newly established Rhodes population is likely to be inundated only during high flow conditions. The area did inundate during the winter of 2011 due to an ice dam forming in the area. However, stream flow levels in the winter are typically sufficient to prevent ice dams, and an unusual, extreme cold period in winter 2011 allowed the ice dam to form. There are no effects to the population during base flow conditions. The effects of water operations on the inundation of the population would be relative to those described in the flycatcher section for this reach. Frequent inundation is not necessary for this population as springs and groundwater maintain the wetland conditions and frequent inundation may possibly be detrimental, bringing in non-native species and affecting the salinity.

Table 29. Effects of Proposed Water Management Actions on Pecos sunflower within the Middle Rio Grande, New Mexico

Proposed Actions	Effect on Pecos Sunflower
	Direct and Indirect – Flow from drains and return channels provide water to maintain wetland conditions suitable for Pecos sunflower and, therefore, is beneficial to the species. ***The delivery of water is beneficial to Pecos sunflower.*** Actions that decrease the potential for overbank flooding in the area of the Rhodes population have an insignificant effect and ***may indirectly affect but are not likely to adversely affect Pecos sunflower***.
Reclamation's Proposed Actions	**Effect on Pecos Sunflower**
Heron Dam and Reservoir	The sunflower population is supported from MRGCD drain and return water. The operation of Heron Dam and SJC Project water only provides roughly 7% of the total water diverted by MRGCD. Therefore, the difference in the hydrograph is insignificant and Heron Dam operations have an insignificant effect on the high flows that would be needed to inundate the Rhodes population. **Direct and Indirect** – ***Not likely to adversely affect Pecos sunflower***.
El Vado Dam and Reservoir	The sunflower population is supported from MRGCD drain and return water. Storage and release of water from El Vado does not have a significant impact on the amount of water available to the Pecos sunflower population. El Vado operations may decrease the potential for overbank flooding on an insignificant level; the effect on flows is only noticeable during years that main stem Rio Grande flows are low and overbank flows are not present anyway. **Direct and Indirect** – ***Not likely to adversely affect Pecos sunflower***.

Non-Federal Proposed Actions	**Effect on Pecos Sunflower**
MRGCD Diversion Operations	
Operation of Diversion Dams and Returns	**Direct and Indirect** – Flow from drains and return channels provide water to maintain wetland conditions suitable for Pecos sunflower and, therefore, is beneficial to the species. ***The delivery of water through MRGCD drains is beneficial to Pecos sunflower at La Joya SWA.*** MRGCD diversions decrease the water within the River and the frequency of overbank flows. This decrease in frequency is insignificant and ***may affect but is not likely to adversely affect Pecos sunflower*** within the flood plain of the Rio Grande.

6.4 Action-by-Action Analysis of Effects of Components of the Proposed Water Management Actions

6.4.1 Approach to Action-by-Action Analysis

In the action-by-action portion of this hydrologic effects analysis, effects of individual actions are parsed out from the overall effect of the Proposed Water Management Actions to identify the relative effect of each discrete action, to the extent practical. The effect of each action is evaluated by comparing a condition in which that action does not occur. The analyses presented in this section distinguish the relative impacts of the discrete actions and, therefore, can contribute to developing and evaluating potential mitigative alternatives and additional conservation measures.

Reclamation's action-by-action analysis differentiates the effects of the following management actions:

- Reclamation's releases from Heron Reservoir at the request of project contractors, under the SJC Project.
- Storage of water in and release of water from El Vado Reservoir, by Reclamation and in coordination the MRGCD.
- MRGCD operations of the MRG diversion structures to provide flows to MRGCD irrigators, including the Six MRG Pueblos, and tail water to the Bosque del Apache National Wildlife Refuge.

The simulations included in the action-by-action analysis are summarized in table 30. The second row in this table explains how the comparisons between runs are used to determine the impact of each discrete action. The runs are compared sequentially in a step down approach, from the full suite of actions on the right to the No Action condition on the left. The effects of Reclamation's Heron Dam operations under the SJC Project are simulated by comparing the Proposed Water Management Actions to a run that simulates only Reclamation's El Vado Dam operations and MRGCD diversions. The effects of El Vado Dam operations under the MRG Project are determined by comparing simulations of El Vado Dam operations and MRGCD diversions to a set of simulations of MRGCD diversions of the natural flow, but no El Vado Dam operations.

Table 30. Summary of water operations included in each action-by-action model run

Across: Action-by-Action Model Runs Down: Modeled Operations	No Actions	MRGCD Diversions only	El Vado Dam Operations and MRGCD Diversions (No SJC Project Operations)	Proposed Water Management Actions	Proposed Water Management Actions and Reclamation's Supplemental Water Program
	Compare with next scenario to evaluate impact of MRGCD diversions; compare with 4th column to evaluate impact of all actions	Compare with next scenario to evaluate impact of El Vado Dam operations	Compare with Proposed Action to evaluate impact of Heron Dam operation	Compare with next scenario to evaluate impact of Reclamation's Supplemental Water Program	Conservation measure evaluation
Heron Dam Operations					
Reclamation leases					X
LFCC Pumping					X
San Juan-Chama Project diversions				X	X
Heron waivers				X	X
MRGCD SJC Project storage at El Vado				X	X
ABCWUA storage at Abiquiu, diversions, and Letter Water delivery				X	X
SJC Combined-account storage at Abiquiu, and Letter Water delivery				X	X
Refilling of Cochiti Recreation Pool				X	X
Maintenance of target flows				X	X
El Vado Dam Operations					
Prior and paramount water storage at El Vado			X	X	X
Release of prior and paramount water according to daily demand schedule			X	X	X
Storage of unused allocation of Emergency Drought Water (MRGCD and Supplemental Water Program)			X	X	X

Rio Grande Storage at El Vado			X	X	X
Release Rio Grande water from El Vado for the MRGCD demand			X	X	X
El Vado reregulation for the channel capacity below El Vado			X	X	X

Table 30. Summary of water operations included in each action-by-action model run (continued)

Across: Action-by-Action Model Runs Down: Modeled Operations	No Actions	MRGCD Diversions Only	El Vado Dam Operations and MRGCD Diversions (No SJC Project Operations)	Proposed Water Management Actions	Proposed Water Management Actions and Reclamation's Supplemental Water Program
MRGCD Diversions					
Diversions for MRGCD non-Indian irrigators		X	X	X	X
Diversions for Pueblos		X	X	X	X
Other Operations					
Cochiti Deviations (years one and two)	X	X	X	X	X

And finally, the effects of the MRGCD diversions are determined by comparing the simulation of the MRGCD diversions only to a run that includes none of the Federal or non-Federal Proposed Actions. The effects of the Proposed Water-Management Actions, in total, are evaluated by comparing the Proposed Water-Management Actions simulation to the simulation of the "No Action" condition.

Figures 66 through 69 summarize of the range of impacts of the discrete actions evaluated in this action-by-action analysis under low flow conditions during the late irrigation season, the period most likely to have river intermittency and drying. As discussed above, in these graphs, the impacts of discrete actions are evaluated through comparing sequential steps in the stepped-down sequence of URGWOM simulations presented in table 30. The vertical axis on these plots depicts the difference in flow that results from the action being evaluated, in comparison to a situation in which that action is not performed. The gray boxes on these "box and whisker plots" show the middle 50% of impacts.

These plots show that, during low flow conditions in the late irrigation season, Heron and El Vado Dam operations each provide a small, but occasionally significant, increase in flow. The impacts are largest at Central Avenue, and progressively smaller at Isleta, San Acacia, and San Marcial. MRGCD diversions decrease flows in times of low flow conditions, which increases with distance downstream, due to the cumulative effects of diversions on river flows. The impact of the combined Proposed Water Management Actions, shown in the final box and whisker, represents the impact of the discrete actions combined. The combined Proposed Water Management Actions have a consistently negative impact on low flows.

At Central Avenue (figure 66), the positive impacts of Heron Dam operations on low flows during the late irrigation season are typically (the middle 50%) between zero and 60 cfs, and the impacts of El Vado Dam operations are typically between zero and 240 cfs. The downward impacts on flows of MRGCD diversions are typically between 200 and 300 cfs at Central Avenue, and the total impact of the Proposed Action typically ranges from 180–240 cfs.

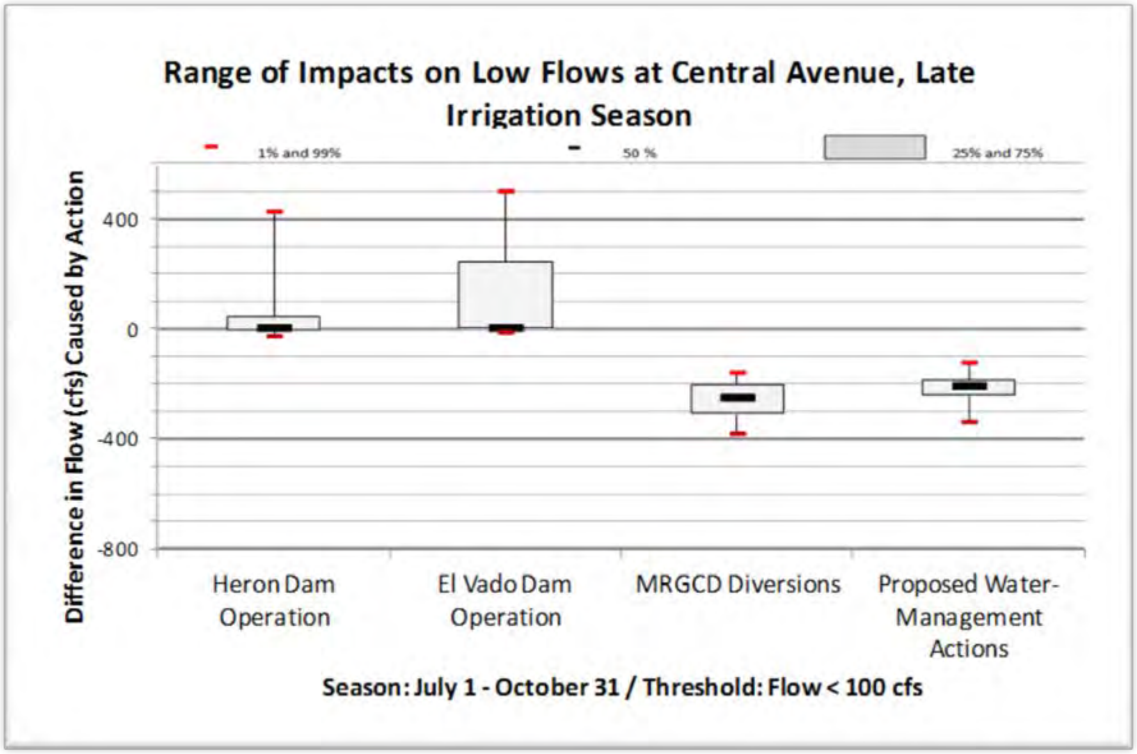

Figure 66. Range of impacts for the step down comparison of discrete actions on low flows at the Central Avenue Gage in Albuquerque during the post-runoff season.

Downstream of Isleta Diversion (figure 67), model results show a smaller positive impact from Heron and El Vado Dam operations on low flows during the late irrigation season and a larger negative impact from MRGCD diversions, typically between 380–520 cfs. Therefore, the combined effects of discrete actions, represented by the Proposed Water Management Actions, also cause a negative effect during low flows.

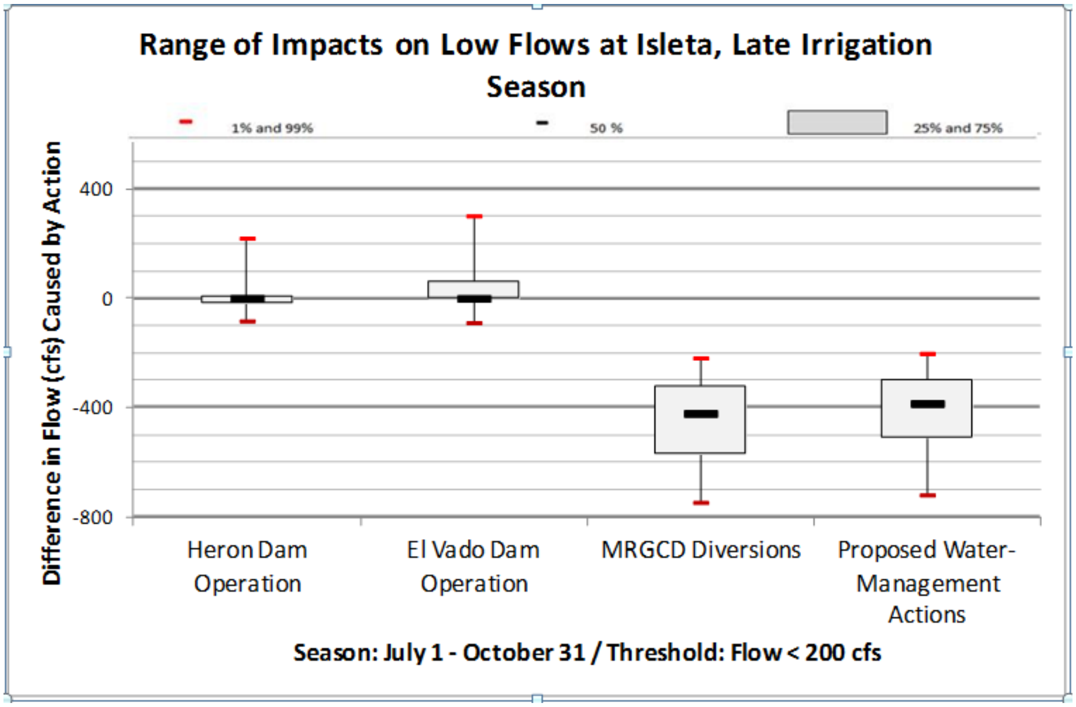

Figure 67. Range of impacts for the step down comparison of discrete actions on low flows downstream of the Isleta Diversion Dam during the post-runoff season.

Downstream of San Acacia Diversion (figure 68), this trend, in which the positive impact of Heron and El Vado Dams on flow is lessened, and the negative impact on flows of MRGCD diversions is increased due to the cumulative effect of upstream diversions, continues. However, the differences between the effects downstream of Isleta Diversion and those downstream of San Acacia Diversion are small because there is relatively little water diverted at San Acacia.

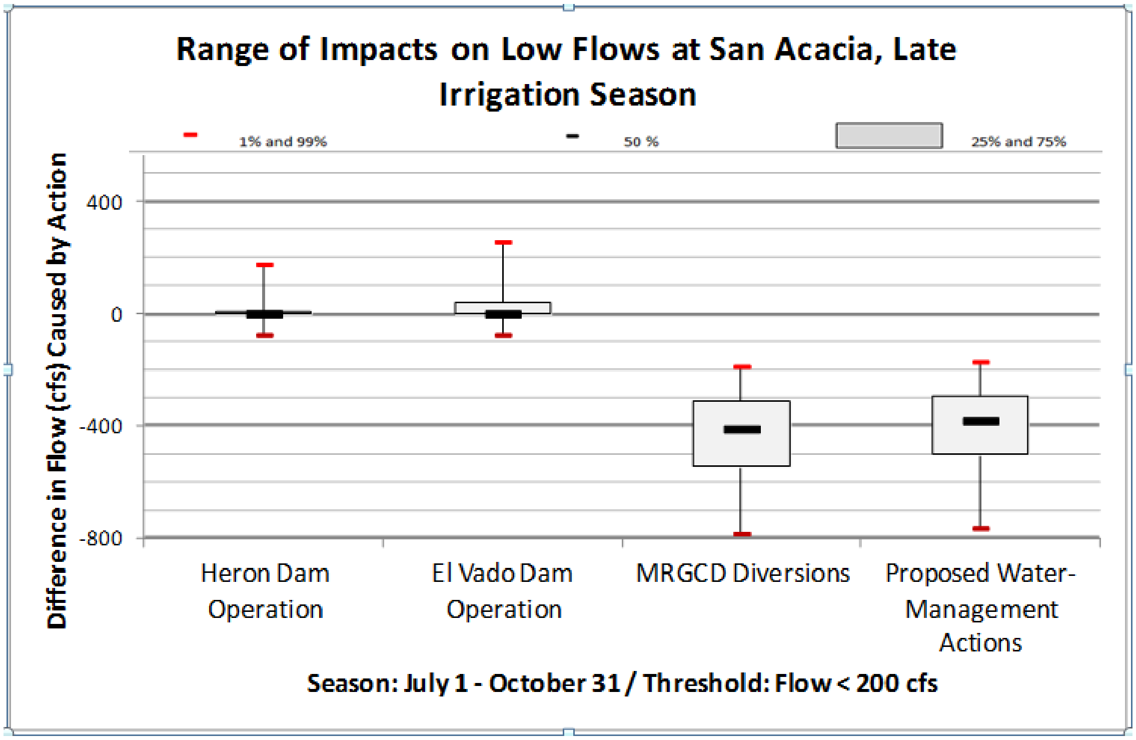

Figure 68. Range of impacts for the step down comparison of discrete actions on low flows downstream of the San Acacia Diversion Dam during the postrunoff season.

At San Marcial, which is downstream of the MRGCD and the BDANWR (Figure 68), the positive impact on flows of Heron and El Vado Dam operations is very small. The negative impact of diversions is also decreased, due to return flows, especially from the BDANWR. At this location, the cumulative negative impact on low flows of the Proposed Water Management Actions is 200 to 400 cfs.

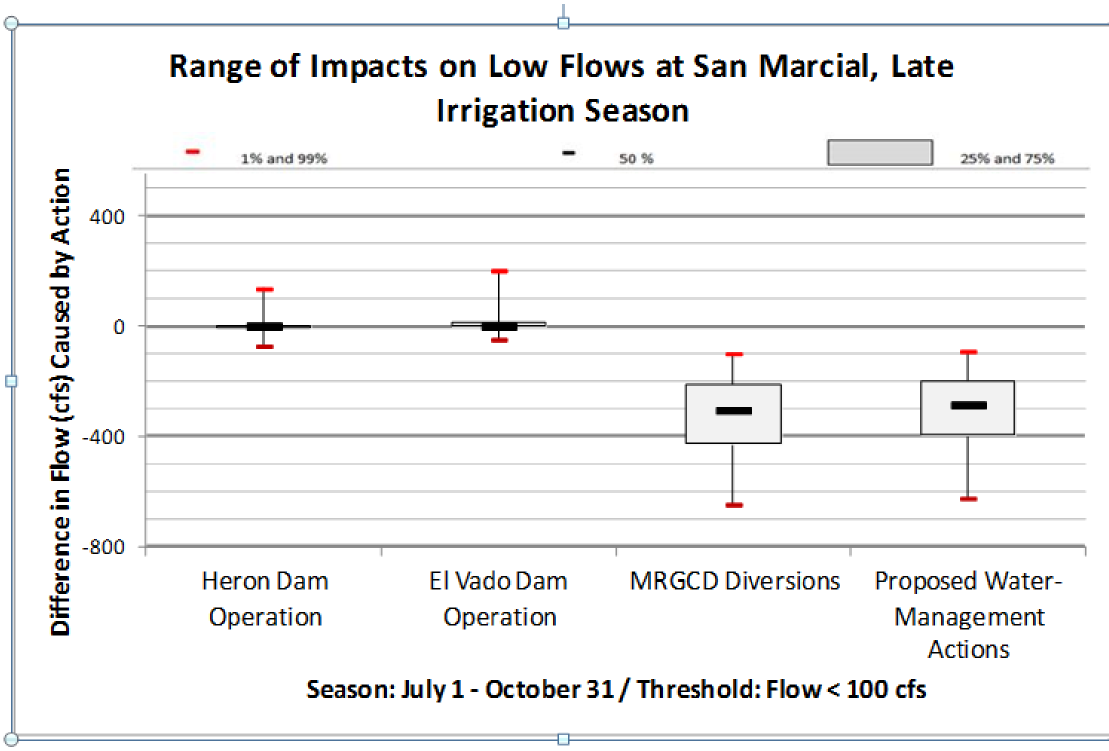

Figure 69. Range of impacts for the step down comparison of discrete actions on low flows at San Marcial during the postrunoff season.

Table 31 summarizes the average impacts of the discrete actions at the key locations presented in the plots. In this table, the impacts are depicted as positive (increasing flows in the low flow range) or negative (decreasing flows when flows are already low), and near zero (less than 20 cfs), minor (20 cfs to less than 50 cfs), or major (greater than 50 cfs). The patterns of impact are essentially the same as has been described for the “box and whisker” plots. However, the average impact of Supplemental Water on low flows downstream from Isleta has been characterized as “major” due to the influence of Supplemental Water released to comply with continuous flow requirements.

Table 31. Qualitative assessment of average impact on low flows in the Middle Rio Grande.

Location	Season	Supplemental Water	Heron Dam Operation	El Vado Dam Operation	MRGCD Diversions	Proposed Water-Management Actions	Threshold Flow (cfs)
Central Avenue Gauge	Early Irrigation	minor (+)	major (+)	major (+)	major (-)	major (-)	100
Downstream of Isleta Diversion Dam		major (+)	~0	~0	major (-)	major (-)	200
Downstream of San Acacia Diversion Dam		minor (+)	~0	~0	major (-)	major (-)	200
San Marcial Floodway Gauge		major (+)	~0	~0	major (-)	major (-)	100
Central Avenue Gauge	Late Irrigation	~0	major (+)	major (+)	major (-)	major (-)	100
Downstream of Isleta Diversion Dam		~0	~0	minor (+)	major (-)	major (-)	200
Downstream of San Acacia Diversion Dam		~0	~0	minor (+)	major (-)	major (-)	200
San Marcial Floodway Gauge		~0	~0	~0	major (-)	major (-)	100

Legend				
	50	to	1000	major (+)
	20	to	49.99	minor (+)
	-19.99	to	19.99	~0
	-49.99	to	-20	minor (-)
	-1000	to	-50	major (-)

Further details on the impacts of each of the discrete actions are provided in the following sections.

6.4.2 Effects of Heron Dam Operations under the SJC Project

6.4.2.1 Approach to the Analysis of Reclamation's Actions under the SJC Project

URGWOM runs were used to evaluate Reclamation's Heron Dam operations under the SJC Project. In this analysis, Reclamation's Heron Dam operations include deliveries to all contractors, whether or not those contractors have completed ESA consultations for the delivery and use of their SJC Project water. Entities that have separate ESA consultations for their use of SJC Project water include the city of Santa Fe and Santé Fe County (for the Buckman Direct Diversion Project) and ABCWUA (for the Albuquerque Drinking Water Project).

Without Reclamation's release of SJC Project water from Heron Reservoir, the MRGCD would not have access to its annual allocations of SJC Project water, and the ABCWUA would not have supplies for its drinking-water diversion project. Also, no deliveries would be made to offset evaporative losses from the Cochiti Recreation Pool, and there would be no "Letter Water" deliveries to offset impacts of ground water pumping on MRGCD irrigators and the Compact.

As shown on table 32 (shown later in this discussion) and described above, the effects of Reclamation's Heron Dam operations are evaluated by comparing a simulation of the Proposed Water Management Actions to a simulation of when the only aspects of the Proposed Water Management Actions that are included are El Vado Dam operations and MRGCD diversions (i.e., Heron Dam operations are turned off). The simulations when Heron Dam operations are turned off specify no importation of water from the San Juan Basin, no new allocations of SJC Project water to contractors, and no releases of SJC Project Water at Heron Dam.

Note that under the initial conditions for these model runs, some SJC Project water is already in storage by the MRGCD, the ABCWUA, and other contractors at El Vado and Abiquiu Reservoirs. For the analysis, these stored waters are used to meet standard demands, but no new SJC Project water is available once these supplies are depleted. All SJC Project water initially in Heron Reservoir is retained and gradually evaporates. In general, these runs do not include the Supplemental Water Program that is evaluated as a conservation measure. Supplemental Water available under initial conditions is used as long as supply lasts, but no additional SJC Project water is made available for lease to the Supplemental Water Program.

6.4.2.2 Effects of Reclamation's Heron Dam Operations under the San Juan-Chama Project

Reclamation's operations of Heron Dam under the SJC Project result in augmented flows below Cochiti Dam as a result of ABCWUA deliveries to its surface-water diversion and MRGCD deliveries of its SJC Project water allocation to irrigators in the MRG. While increased flows are evident below Cochiti Dam and at Central Avenue, much of the additional flow is diverted at the ABCWUA diversion or at MRGCD diversions at Cochiti, Angostura, or Isleta.

Figure 70 compares flows below Cochiti Dam and the Cochiti diversions with and without Reclamation's operations of Heron Dam. Both curves summarize hydrologic conditions compiled from all of the synthetic hydrologic sequences. This comparison indicates that Heron Dam operations increase flows during low flow periods downstream from Cochiti Dam as a result of the additional supply for ABCWUA and MRGCD irrigators.

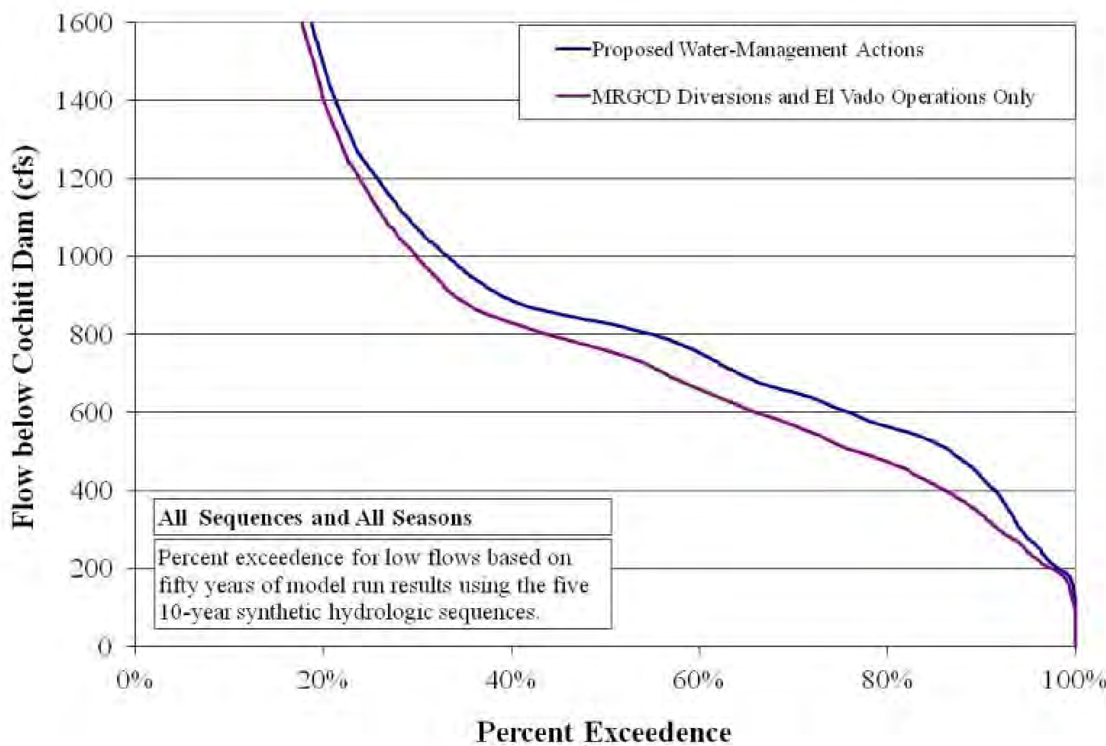

Figure 70. Relative effect of the Heron Dam operations on flows downstream from Cochiti Dam and Diversion.

Figure 71 shows that the benefit of flow augmentation by SJC Project water is less pronounced at the Central Avenue gage, since this gage is located downstream from the ABCWUA's diversion for its drinking water project and, therefore, does not get the benefit of flows of SJC Project water to that diversion. The benefit of Reclamation's Heron Dam operations at Central Avenue is due to the MRGCD's SJC Project water deliveries to Isleta diversion. This graph does not indicate a significant incidence of drying at the Central Avenue gage with or without Reclamation's Heron Dam operations.

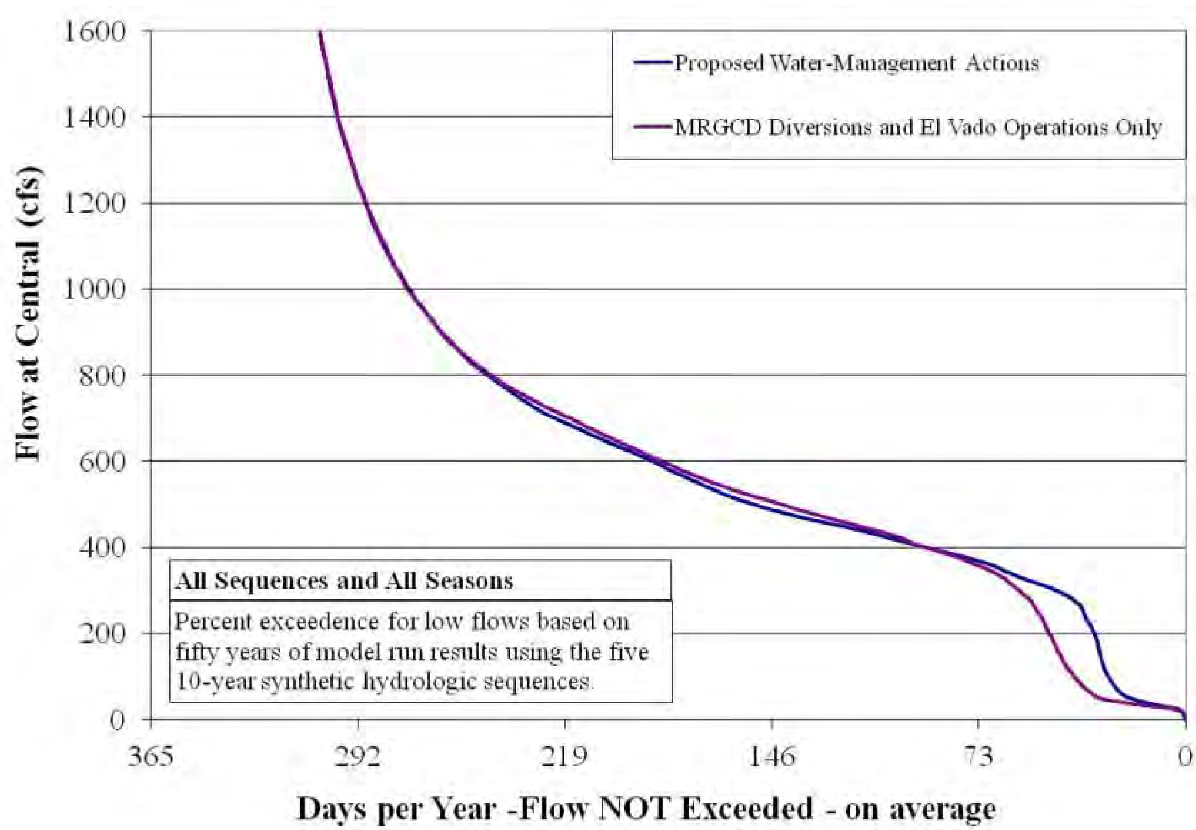

Figure 71. Relative impact of the Heron Dam operations at the Central Avenue gage.

The positive impacts of SJC Project water are most apparent during dry conditions when the MRGCD has depleted its native supplies and is operating using SJC Project water. MRGCD's use of SJC Project water, which constitutes an average of about 7% of its diversions (including Letter Water allocated to the MRGCD), helps to reduce the amount of time that MRGCD is in shortage operations. Since there is a greater chance of critically low flows in the Albuquerque and Isleta Reaches during shortage operations, Reclamation's SJC Project operations help to maintain flows in these reaches during critical periods. Flow exceeds 300 cfs more frequently with Heron Dam operations than without. Hence, SJC Project releases increase flows at Central Avenue during times of shortage.

Other uses of SJC Project water, such as that by Santa Fe's Buckman Direct Diversion or the Cochiti Recreation Pool, are upstream of Cochiti Dam and do not affect flows in the MRG. Many contractors use their SJC Project water to provide an offset to MRGCD irrigators and the Compact for depletions caused by ground water pumping, as administered by the Office of the State Engineer's Letter Water program. Letter Water deliveries to the MRGCD typically are stored in El Vado Reservoir and used to supplement MRG irrigation along with the remainder of the MRGCD's SJC Project allocation. Letter Water deliveries to the Compact typically are released in the winter. SJC Project releases are not of sufficient magnitude to significantly impact the size of the spring snowmelt runoff peak in the MRG.

Downstream from the Isleta Diversion Dam, there is essentially no difference in flows between simulations with and without Heron Dam operations, since Isleta Diversion Dam is the furthest-downstream point of diversion for any significant amount of SJC Project water.

6.4.2.3 Effect of Heron Dam Operation on Silvery Minnow

Prior to reaching the upstream boundary of silvery minnow critical habitat, there are three major dams (El Vado, Abiquiu, and Cochiti) downstream from Heron Dam. The importation of SJC Project water provides more water to meet MRG water demands. Model results indicate that SJC Project water delivered during low flow periods of the irrigation season is detectable in the MRG until Isleta Diversion Dam and may help maintain continuous flow within the Angostura Reach. There are very few detectable geomorphic or water quality effects within silvery minnow critical habitat from the operation of Heron Dam. Table 32 presents the effects of Heron Dam operation on the life history elements and critical habitat PCEs of silvery minnow. Delivery of Letter Water to Elephant Butte may have a more noticeable effect downstream during the late fall and winter.

Figures 72 and 73 show the stepped down effects of the various components of the Proposed Water Management Actions on two of the most important elements for silvery minnow recruitment, the magnitude and duration of spring high flows and the timing of the onset of low flow conditions. There is little impact from Heron Dam operation on the magnitude and duration of high flow events. There is also little impact on the timing of the onset of low flows. The Supplemental Water Program, which is not considered in this graph, helps manage the recession of runoff.

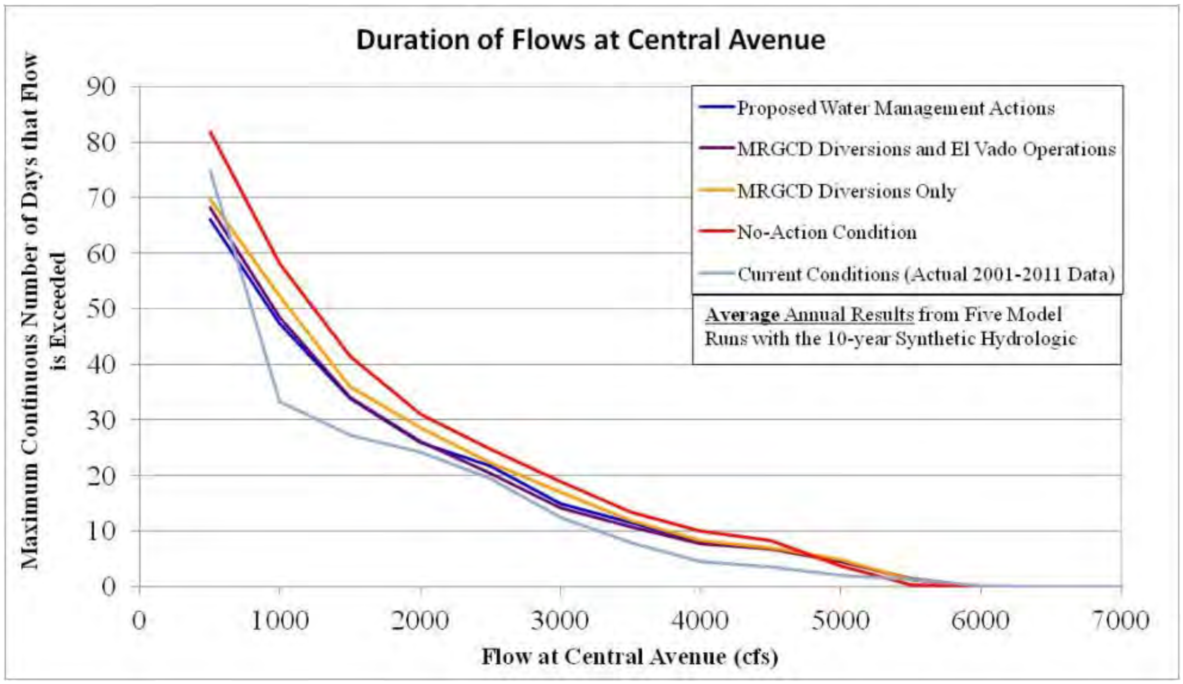

Figure 72. Modeled average annual results of maximum number of continuous high flow days from five model runs with the 10-year synthetic hydrologic sequences at San Acacia gage, Rio Grande, New Mexico.

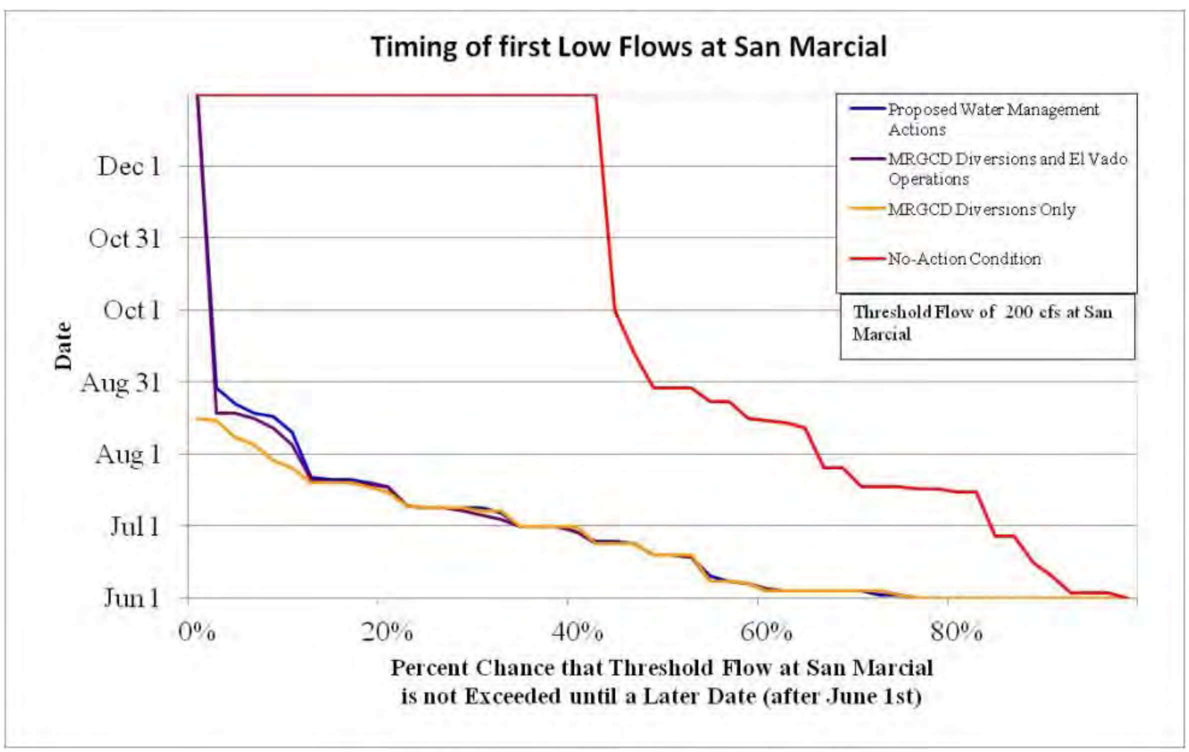

Figure 73. Modeled average annual results of the relative percentage of time low flow (< 200 cfs) begins prior to June 1 at San Marcial gage, Rio Grande, New Mexico from five model runs with the 10-year synthetic hydrologic sequences.

Table 32. Effect of Heron Dam operation (3.2.1) on life history elements and PCEs of silvery minnow

<table>
<tr><th></th><th>Spawning</th><th>Eggs</th><th>Larval</th><th>Juvenile</th><th>Adult</th></tr>
<tr><td>Spring (April–June)</td><td colspan="3">Timing of the Rio Chama peak spring runoff does not normally coincide with the Rio Grande peak. Channel capacity of the Rio Chama below Abiquiu is limited. The anticipated effect on the hydrograph within occupied habitat during spring runoff is minor. Direct and Indirect – Heron operations are not likely to adversely affect silvery minnow spawning or recruitment.</td><td></td><td>The anticipated effect on the hydrograph within occupied habitat during spring runoff is minor. Direct and Indirect – Heron operations are not likely to adversely affect adult silvery minnow.</td></tr>
<tr><td>Summer (June–Sept)</td><td></td><td></td><td colspan="3" rowspan="2">Heron Dam operations increase flows during low flow periods below Cochiti Dam till Isleta Diversion Dam. Much of this water is utilized at the ABCWUA diversion. Model runs indicate that this water helps maintain perennial flow within the Angostura Reach. Thus, Direct and Indirect – Heron Dam operations are beneficial to silvery minnow during summer and fall periods.</td></tr>
<tr><td>Fall (Sept–Nov)</td><td></td><td></td></tr>
<tr><td>Winter (Dec–March)</td><td></td><td></td><td></td><td></td><td>Water releases for contractors generally occur in November and December. These releases provide higher flows through the MRG that are of sufficient magnitude and generally stable. Direct and Indirect – Operations are not likely to adversely affect winter survival of adult silvery minnow.</td></tr>
</table>

Table 32. Effect of Heron Dam operation (3.2.1) on life history elements and PCEs of silvery minnow

	Spawning	Eggs	Larval	Juvenile	Adult
Critical Habitat PCEs					
Hydrologic Regime					
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats.	***Direct and Indirect – Heron Dam operations are not likely to adversely affect*** the hydrology and maintenance of silvery minnow habitats within the MRG. There may be some beneficial effects due to decreased chances of drying in the Angostura Reach.				
Presence of a diversity of habitats for all life history stages		There is ***not likely to be an adverse effect*** on geomorphology or silvery minnow habitats in the MRG from Heron Dam operations. Vegetation encroachment and channel narrowing caused by water delivery is anticipated to be negligible.			
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	Timing of the Rio Chama peak spring runoff does not normally coincide with the Rio Grande peak. Channel capacity of the Rio Chama below Abiquiu is limited. There is little effect on the hydrograph within occupied habitat during spring runoff. **Direct and Indirect –** ***Operations are not likely to adversely affect silvery minnow critical habitat for spawning.***				
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow	Heron Dam operations increase flows during low flow periods below Cochiti Dam. Much of this water is utilized at the ABCWUA diversion. Model runs indicate that this water helps maintain perennial flow within the Albuquerque Reach. Thus, **Direct and Indirect–** ***Heron Dam operations are beneficial to silvery minnow critical habitat during summer and fall periods*****.**				

Table 32. Effect of Heron Dam operation (3.2.1) on life history elements and PCEs of silvery minnow

	Spawning	Eggs	Larval	Juvenile	Adult
Constant winter flow				Water releases for contractors generally occur in November and December. These releases provide higher flows through the MRG that are of sufficient magnitude and generally stable. **Direct and Indirect – *Heron operations are not likely to adversely affect winter critical habitat.***	
Unimpounded stretches of river with a diversity of habitats and low velocity refuge areas					
River reach length	The actual length of wetted river within each reach changes depending on channel sinuosity. Low flow conditions are supplemented by the operation of Heron Dam. Sinuosity changes depending on geomorphology and discharge levels. Sinuosity of the thalweg may increase during low flows and increases the length of the river but also may promote vegetation growth on point bars within the river channel. The operation of Heron Dam ***is not likely to adversely river reach length.***				
Habitat "quality" in each reach and refugial habitats.	Habitat quality in each reach is dependent on the structure and diversity of available habitat. Channel trends throughout the MRG are towards a more simplified channel due to vegetation encroachment. Base flow levels from the proposed actions drive the vegetation encroachment within the channel. The quantity of suitable habitat within each reach also changes at different flows; this relationship is not linear in most sections of the river and is dependent on channel shape . The Proposed Action ***may have indirect effects that adversely affect silvery minnow critical habitat***.				
Substrate of sand or silt					
Substrates of predominantly sand or silt	Heron Dam is on Willow Creek, a small tributary of the Rio Chama. El Vado, Abiquiu, and Cochiti Dams capture sediment downstream prior to water entering critical habitat. There is ***no effect*** on sediment transport in the MRG from Heron Dam operations.				
Water quality					
Temp >1˚ - <30 ˚C DO > 5 mg/L pH (6.6-9.0)	Water temperature, DO, and pH within the reservoir are not likely to have any effect on these parameters within critical habitat. However, increased water availability in the MRG during low flow periods is likely to maintain water quality within the described range. **Direct and Indirect – *Heron Dam operations are beneficial to silvery minnow critical habitat during summer and fall periods.***				
Other contaminants	All chemical parameters were well below levels of concern in Heron; however there is a listing for mercury in fish tissue. It is unknown how contaminants in this reservoir affect water quality in critical habitat, but it is likely a minor factor. **Direct and Indirect – *Heron Dam operations are not likely to affect silvery minnow critical habitat.***				

6.4.2.4 Effect of Heron Dam Operation on Flycatcher

The effect of Heron Dam operation on flycatchers is minimal and results in an increased amount of water in the river at times of lowest flows which may help maintain and establish vegetation. However, Heron Dam operations essentially have no impact on overbank flow conditions that are essential for flycatcher recruitment. Figures 74 and 75 display those model results comparing Central to San Marcial gages during the flycatcher territory establishment period. The result of minimal difference between actions is also evident in the late irrigation season.

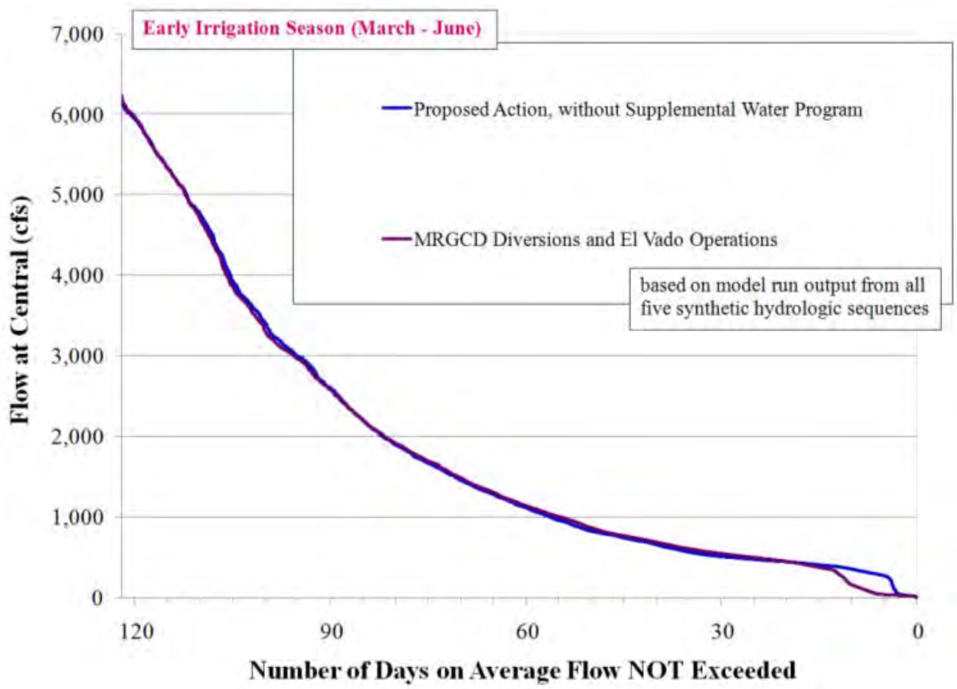

Figure 74. Relative comparison of flows at Central gage considered Proposed Action with no Supplemental Water Program compared to MRGCD diversions and El Vado Operations during the flycatcher territory establishment period.

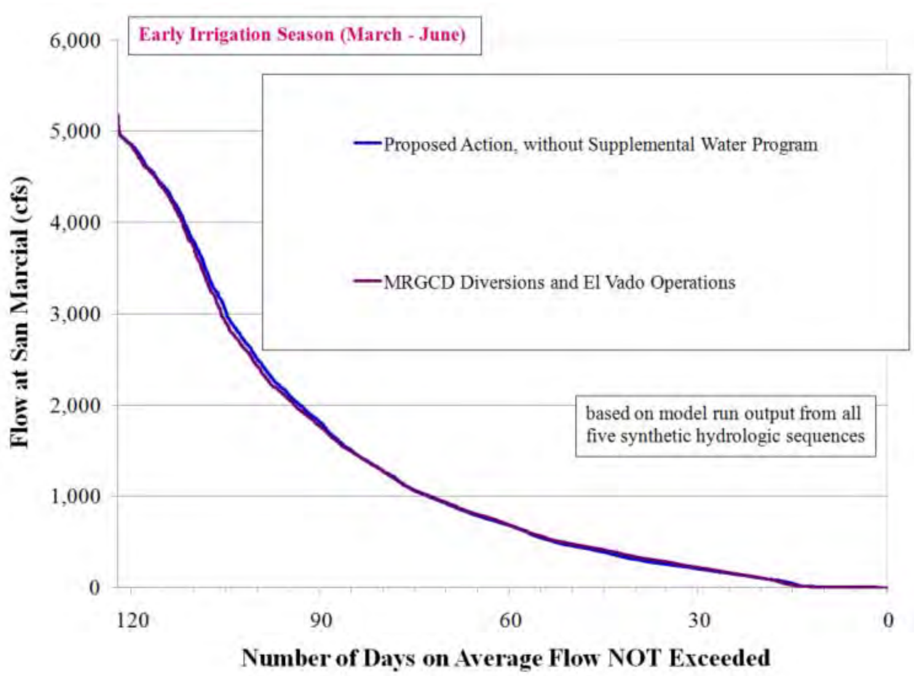

Figure 75. Relative comparison of flows at San Marcial gage considered Proposed Action with no Supplemental Water Program compared to MRGCD diversions and El Vado operations during the flycatcher territory establishment period.

It is also important to review information from the hydrological effects section. Due to the 1,800-cfs channel capacity on the Rio Chama below Abiquiu Reservoir and the normal release schedule from Heron Reservoir, Heron Dam operations for the SJC Project have essentially no impact on the occurrence of recruitment or overbank flows in the MRG.

There is a minimal difference in potential overbank flooding occurrence during early irrigation season due to the operation of Heron Dam (table 33). This difference is largely inconsequential, especially when considering that these areas often require even more than the 4,700 cfs for flooding, and areas where flycatchers occupy are typically along the rivers' edge and, thus, within the 50-meter distance to water where 94% of flycatcher nests are located. For late irrigation season, from July–October, this comparison indicates no difference in the potential days of flooding (table 34).

Table 33. Effect of Heron Dam operation on the potential days of overbank flooding events during early irrigation season and flycatcher territory establishment. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with all Proposed Actions	Number of days flows reach 4,700 cfs with all Proposed Action	Percent of the time flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions
Central	10.20%	12	9.8%	12
San Acacia	7.10%	9	6.8%	8
San Marcial	3.10%	4	2.2%	3

Table 34. Effect of Heron Dam operation on the potential days of overbank flooding events during late irrigation season and flycatcher nesting period. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with all Proposed Actions	Number of days flows reach 4,700 cfs with all Proposed Action	Percent of the time flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions
Central	1.8%	2	1.7%	2
San Acacia	1.8%	2	1.7%	2
San Marcial	1.7%	2	1.7%	2

For the reach below San Acacia gage, modeling indicates that the Proposed Action would meet the 1,400 cfs required for inundation within the BDANWR area and would meet overbank flows 36.1% of the time in the MRGCD diversions and El Vado operations sequence and 36.3% in the Proposed Action sequence. There would be no difference in potential overbank flows by Heron Dam operations (table 35). For late irrigation season, from July–October, there is a very small increase in the probability of 1,400-cfs flows at the San Acacia gage due to the operation of Heron Dam. These results indicate minimal difference in potential overbank flooding during that time period (table 36). Table 37 presents a summary of the effects of Heron Dam operations on flycatchers in the MRG.

Table 35. Effect of Heron Dam operation on the potential days of overbank flooding events during early irrigation season and flycatcher territory establishment in the reaches from Arroyo del las Cañas to RM 78

Gage Location	Percent of the time flows reach 1,400 cfs with all Proposed Actions	Number of days flows reach 1,400 cfs with all Proposed Actions	Percent of the time flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions
San Acacia	36.30%	44	36.1%	44

Table 36. Effect of Heron Dam operation on the potential days of overbank flooding events during late irrigation season and flycatcher nesting period in the reaches from Arroyo del las Cañas to RM 78

Gage Location	Percent of the time flows reach 1,400 cfs with all Proposed Actions	Number of days flows reach 1,400 cfs with all Proposed Actions	Percent of the time flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions
San Acacia	6.2%	8	5.8%	7

Table 37. Effect of Heron Dam operations on life history elements and PCEs of flycatchers

Life History Element	**Migration** (April–June and July–September)	**Arrival to Territories/ Territory Establishment/Nest Building** (May–July)	**Egg Laying/ Incubation/ Nestling/ Fledgling** (June–August)
Breeding Season (April to September)	The Proposed Action would **not likely adversely affect** flycatcher stopover locations during migration because flycatchers will use habitat that is less suitable during this time and farther away from water sources.	The Proposed Action may ***indirectly affect flycatcher habitat on a negligible level***. Because the Proposed Action when compared to MRGCD Diversion and El Vado Dam Operation would ***increase flows in the river.*** At times of lower flows, it would ***minimally increase the overall water available for vegetation*** and could cause an increase in plant health. This ***could potentially and beneficially affect flycatcher habitat,*** particularly in periods of drought. This action would not affect the potential for overbank flows and likely would have no affect on territory recruitment. However, it should be noted that the increase in water between the two scenarios is a relatively small amount.	Territory recruitment at this stage is no longer an issue as flycatchers are more invested in their territories and less likely to abandon nests should conditions dry or decline in value. However, if vegetation does not have adequate water resources, canopy cover likely will decrease and predation and/or parasitism likely would be more prevalent. Because the Proposed Action would result in a little more water in the system, there would be an decreased possibility of vegetation not having adequate water to maintain health and, thus, ***would beneficially affect flycatcher habitat and potential nest success,*** again particularly in times of drought.
Critical Habitat PCES			
Riparian Vegetation	Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. With an increase in the water amount reaching flycatcher suitable habitat patches, the Proposed Action could ***potentially beneficially affect flycatcher riparian vegetation***.		
Insect Prey Populations	A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the No Action and the Proposed Action ***would have no affect the insect prey populations***. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

6.4.3 Analysis of Effects of El Vado Dam Operations Under the Middle Rio Grande Project

6.4.3.1 Approach to Analysis of Effects of the Operation of El Vado Dam Under the Middle Rio Grande Project

Impacts of El Vado Dam operations were evaluated comparing URGWOM simulations of the Proposed Water Management Actions of when Heron Dam operations are turned off to another set of URGWOM simulations of when both Heron Dam operations and El Vado Dam operations are turned off.

In the runs for which El Vado Dam operations are shut off, native inflows are not stored for use within the MRGCD. SJC Project water is not stored for use by MRGCD water rights holders when native Rio Grande flows drop below demand. MRGCD non-Indian irrigators would have available any native and SJC Project water present in El Vado Reservoir under initial conditions, but no additional native and SJC Project water would be stored beyond that required to meet prior and paramount water needs.

6.4.3.2 Effects of El Vado Dam Operations under the Middle Rio Grande Project

Operation of El Vado Dam and Reservoir involves storage of water from the Rio Chama during springtime peak flows, and calls for and use of that stored water in the MRG in times of low flow. El Vado Dam operations, therefore, result in decreased peak flows on the Rio Chama and decreased in flows in the MRG associated with the Rio Chama runoff peak, which generally occurs prior to the main stem spring runoff peak. These actions also result in an increase in flows in the Rio Chama and the MRG during low flow periods, primarily in the summer.

Figure 76 compares flows at the Central Avenue gage for two sets of model simulations: one including El Vado Dam operations and one without these actions. The difference between the two curves on figure 76 indicates the effects on flows at Central Avenue of El Vado Dam operations. Storage at El Vado Reservoir results in a small (about 5-day-per-year) decrease in the number of days with flows above 800 cfs but also causes a minor increase in the number of days per year that flows are above 100 cfs at Central Avenue.

In most years, operation of El Vado Dam does not significantly affect the spring runoff peak in the Rio Grande, since these operations affect the flows on the Rio Chama, and the Rio Chama spring runoff peaks are typically earlier in time and smaller than those on the main stem Rio Grande. In the rare years in which the Rio Chama spring runoff peaks coincide with the main stem runoff peaks, El Vado Dam operations have a greater effect; however, the effects of the Rio Chama runoff are still limited due to the 1,800-cfs channel capacity on the Rio Chama below Abiquiu Reservoir. Therefore, El Vado Dam operations have a minimal impact on the peak spring discharges in the MRG.

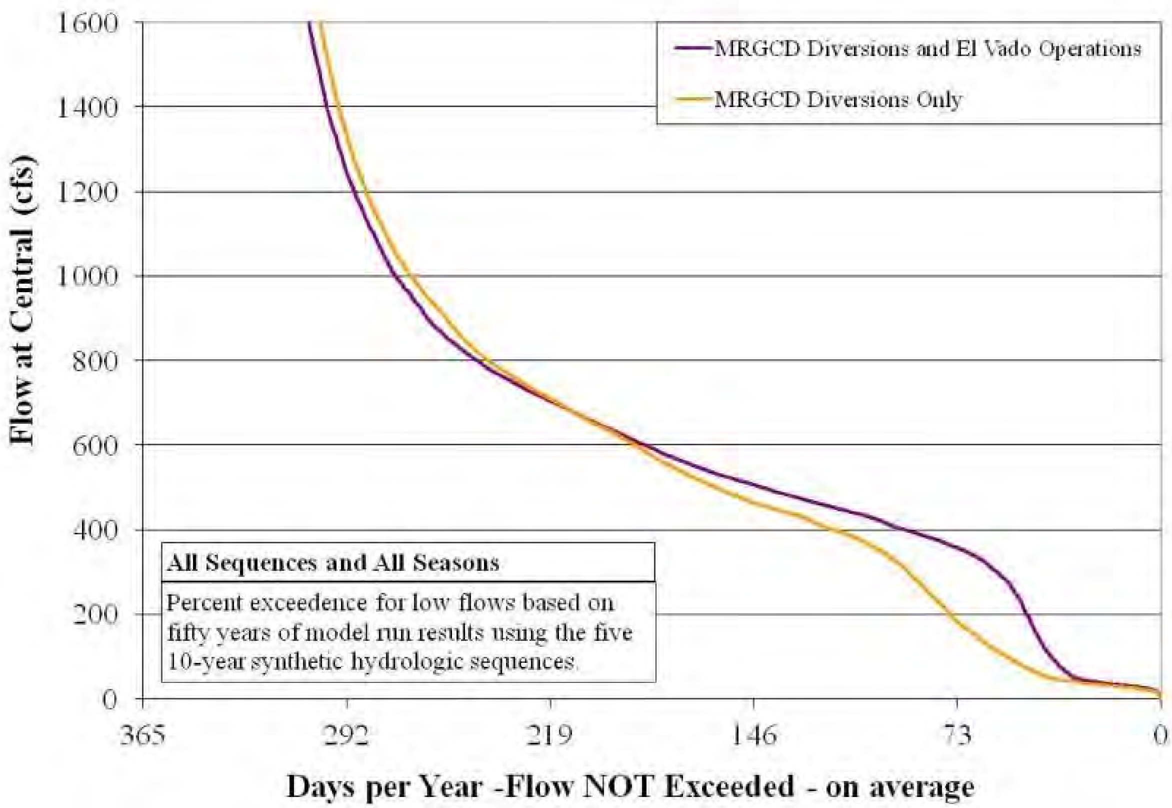

Figure 76. Relative comparison of flows at Central Avenue gage with and without El Vado operations, for the calendar year.

Reclamation releases available water from storage in El Vado Reservoir at the request of the MRGCD to meet the MRG irrigation demand during periods when the natural flow is insufficient to meet these demands. This release of stored water reduces the occurrence of critically low flows and drying, especially in the Cochiti Dam and Albuquerque Reaches, and increases river flows during those periods. This effect may be evident even when Article VII restrictions under the Compact are in effect, since under Article VII restrictions, native water that was stored at El Vado Reservoir prior to the initiation of Article VII restrictions may still be released.

Model results indicate that river drying in the reaches downstream from Isleta Diversion Dam would occur with or without El Vado Dam operations. However, without El Vado Dam operations, river drying in the MRG would be more frequent and more prolonged, especially during times when the daily MRGCD irrigation demand cannot be met by the natural flow of the river. These effects are magnified in the lower reaches of the MRG. Without the release of stored water from El Vado Reservoir, model results indicate that the MRGCD would be in shortage operations, where MRGCD has no storage water to meet demand for some portion of almost every irrigation season. During shortage operations, diversions at Angostura typically are increased to allow the limited river flow to be used as efficiently as possible and ensure that water is delivered to the Six MRG Pueblos, and to non-Indian irrigators as well if sufficient water is available. Under shortage operations, river drying could be expected in the Albuquerque Reach as well as in the Isleta and San Acacia Reaches. Without El Vado Dam operations, river drying would be expected to increase below the Isleta Diversion Dam, as shown in figure 77.

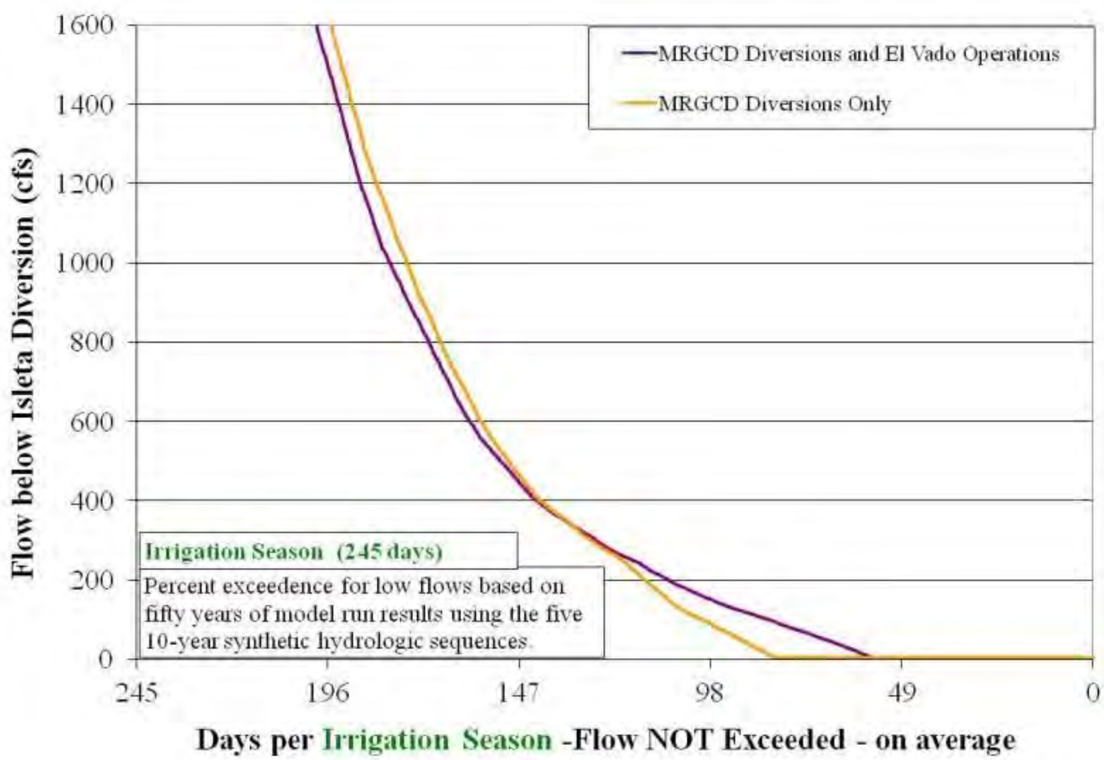

Figure 77. Relative comparison of flows below Isleta Diversion during the irrigation season with and without El Vado operations.

The effect on flows of Reclamation's El Vado Dam operations is less in the San Acacia Reach, downstream from the MRGCD's downstream-most diversion point from the Rio Grande. Still, due to return flows to the river and variations in demand, model simulations indicate that Reclamation's El Vado Dam operations decrease the duration of river drying below San Acacia Diversion, as indicated by the flow exceedence curves in figure 78.

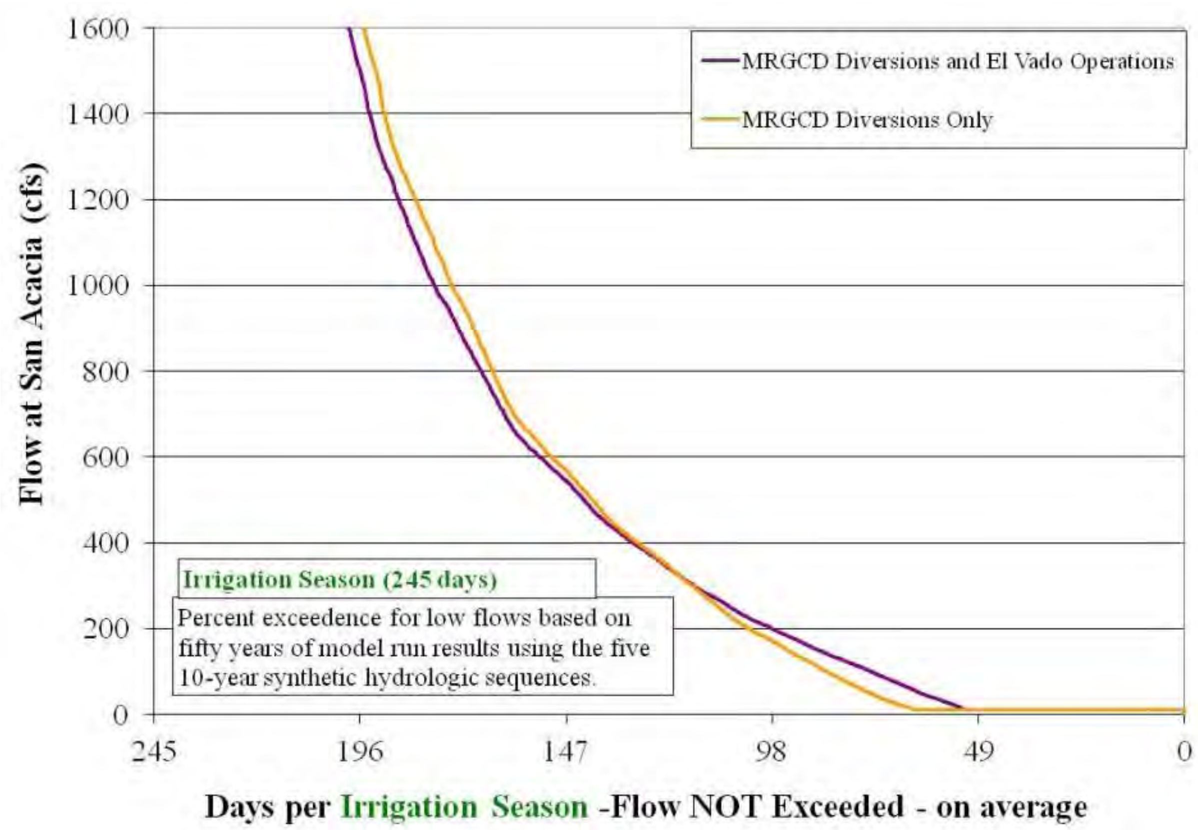

Figure 78. Relative comparison of flows downstream from San Acacia Diversion during the irrigation season, with and without El Vado operations.

6.4.3.3 Effects of El Vado Dam Operations on Silvery Minnow

The modeled effects of El Vado Dam indicate that the storage of springtime peak flows from the Rio Chama causes a slight decrease in the duration and magnitude of spring flows within silvery minnow habitat. The decrease in duration is more noticeable when springtime discharge is low to moderate (less than 4,000 cfs at Central Gage). The modeled difference in the magnitude of discharge during runoff caused by El Vado storage is less than 200 cfs. This stored water is later released for irrigation purposes. The release of this water decreases the duration of drying that would be predicted without this management action below Isleta Dam and San Acacia Dam.

There are two major dams between El Vado Dam and the upstream boundary of silvery minnow critical habitat. Any effects to sediment transport caused by operation of El Vado are masked by Abiquiu and Cochiti Dams. Additionally, the effect of operations on other geomorphic trends within occupied habitat is minor due to the limited difference in high flows from operations. Similar to Heron, El Vado water quality surveys in 2007 determined that all physical and chemical parameters were well below levels of concern except for dissolved oxygen. This report questioned the low DO readings and thought it might be due to equipment malfunction. Regardless, the low DO in El Vado is unlikely to have effects down into silvery minnow critical habitat.

El Vado has recently had positive microscopy test results for quagga mussels though the presence has not been confirmed. The long-term indirect effects downstream from potential quagga mussel establishment in El Vado are difficult to predict for the MRG. Quagga mussels do not appear to be increasing to any extent in the Ohio and Mississippi Rivers, even after being present in these rivers for over a decade. In contrast, numbers in the Colorado River system have continued to increase since the quagga mussel was first reported (Nalepa 2008). It is predicted that high levels of suspended sediment and high inorganic: organic particle ratios may limit, or possibly prevent, mussel expansion in the main stem portions of the Colorado River (Kennedy 2007). However, changes in water quality (i.e., dissolved nutrients, phytoplankton, and zooplankton) in infested reservoirs may impact food web structure or trophic linkages in the downstream riverine ecosystem. A summary of the effects of El Vado Dam on silvery minnow is presented in table 38.

Table 38. Effect of El Vado Dam operation (3.2.1) on life history elements and PCEs of silvery minnow

	Spawning	Eggs	Larval	Juvenile	Adult
Spring (April–June)	Timing of the Rio Chama peak spring runoff does not normally coincide with the Rio Grande peak. Channel capacity of the Rio Chama below Abiquiu is limited. During most years, there is limited effect on the hydrograph within occupied habitat during spring runoff. This effect is more pronounced in years with low runoff conditions in the Rio Grande drainage. Though the impact on silvery minnow spawning and recruitment is anticipated to be minor, the **Direct and Indirect effects of *El Vado operations are likely to adversely affect silvery minnow spawning and recruitment.***				There is little information on how spring flows are related to adult survival of silvery minnow. The small differences in the spring hydrograph from El Vado operations ***are not likely to (directly or indirectly) adversely affect adult silvery minnow.***
Summer (June–Sept)			El Vado Dam releases increase flows during low flow periods below Cochiti Dam to Isleta Diversion Dam. The majority of this water is diverted by MRGCD at their diversions. Model runs indicate that this water helps maintain perennial flow within the Albuquerque Reach and decreases drying in the Isleta Reach. Thus, **Direct and Indirect – *El Vado Dam operations are beneficial to silvery minnow during summer and fall periods.***		
Fall (Sept–Nov)					

Table 38. Effect of El Vado Dam operation (3.2.1) on life history elements and PCEs of silvery minnow

	Spawning	Eggs	Larval	Juvenile	Adult
Winter (Dec–March)					Water releases for contractors and Compact deliveries generally occur in November and December. These releases provide higher flows through the MRG, which are of sufficient magnitude and generally stable. **Direct and Indirect –** ***El Vado operations are not likely to adversely affect winter survival of adult silvery minnow.***
Critical Habitat PCES					
Hydrologic Regime					
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats.	***Direct and Indirect – El Vado Dam operations are not likely to adversely affect the hydrology and maintenance of silvery minnow habitats within the MRG.*** There may be some beneficial effects due to decreased chances of drying in the Angostura and Isleta Reaches during low flow periods.				
Presence of a diversity of habitats for all life history stages		There is ***no direct effect*** on geomorphology or silvery minnow habitats in the MRG from El Vado Dam operations. Water delivery with low base flow levels may have long-term impacts by encouraging vegetation encroachment and channel narrowing and ***indirectly, may likely adversely affect critical habitat***.			

Table 38. Effect of El Vado Dam operation (3.2.1) on life history elements and PCEs of silvery minnow

	Spawning	Eggs	Larval	Juvenile	Adult
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	Timing of the Rio Chama peak spring runoff does not normally coincide with the Rio Grande peak. Channel capacity of the Rio Chama below Abiquiu is limited. There is little effect on the hydrograph within occupied habitat during spring runoff. **Direct and Indirect –** ***El Vado operations are not likely to adversely affect silvery minnow critical habitat for spawning.***				
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow	El Vado Dam releases increase flows during low flow periods below Cochiti Dam. The majority of this water is diverted by MRGCD at their diversions. Model runs indicate that this water helps maintain perennial flow within the Albuquerque Reach and decreases drying in the Isleta Reach. **Direct and Indirect –** ***El Vado Dam operations are beneficial to silvery minnow critical habitat during summer and fall periods*****.**				
Constant winter flow				Water releases for contractors generally occur in November and December. These releases provide higher flows through the MRG that are of sufficient magnitude and generally stable. **Direct and Indirect –** ***El Vado operations are not likely to adversely affect winter critical habitat for silvery minnow.***	
Unimpounded stretches of river with a diversity of habitats and low velocity refuge areas					
River reach length	Currently, diversion dams are in place; no new cross channel structures are proposed. The actual length of wetted river within each reach changes depending on channel sinuosity. The sinuosity changes depending on geomorphology and discharge levels. Sinuosity of the thalweg may increase during low flows that increases the length of the river but also may promote vegetation growth on point bars within the river channel. The lack of flood stage flows also changes the potential that the river will move outside its current channel. The Proposed Action ***is not likely to adversely river reach length.***				

Table 38. Effect of El Vado Dam operation (3.2.1) on life history elements and PCEs of silvery minnow

	Spawning	Eggs	Larval	Juvenile	Adult
Habitat "quality" in each reach and refugial habitats.	Habitat quality in each reach is dependent on the structure and diversity of available habitat. Channel trends throughout the MRG are towards a more simplified channel due to vegetation encroachment. Base flow levels from the Proposed Actions drive the vegetation encroachment within the channel. The quantity of suitable habitat within each reach also changes at different flows, this relationship is not linear in most sections of the river and is dependent on channel shape. The Proposed Action ***may have indirect effects that adversely affect silvery minnow critical habitat***.				
Substrate of sand or silt					
Substrates of predominantly sand or silt	Abiquiu and Cochiti Dams capture sediment downstream from El Vado prior to delivered water reaching critical habitat. There is ***no effect*** on sediment transport in the MRG from El Vado Dam operations.				
Water quality					
Temp >1˚ - <30 ˚C DO > 5 mg/L pH (6.6-9.0)	Water temperature, DO, and pH within El Vado Reservoir are not likely to have any effect on these parameters within critical habitat. However, increased water availability in the MRG during low flow periods is likely to maintain water quality within the described range. **Direct and Indirect – *El Vado Dam operations are beneficial to silvery minnow critical habitat during summer and fall periods*.**				
Other contaminants	All chemical parameters were well below levels of concern in El Vado; however recent quagga mussel tests indicate that mussels may be present. It is unknown how quagga mussels in this reservoir may affect water quality in Critical Habitat but establishment within the main stem seems unlikely. **Direct – *El Vado Dam operations are not likely to affect silvery minnow critical habitat.* Indirect – *El Vado Dam operations are not likely to affect silvery minnow critical habitat* due to the unknown impacts from quagga mussels and unlikely establishment of mussels in the main stem.**				

6.4.3.4 Effect of El Vado Dam Operation on Flycatcher

Model results indicate a very minor change when comparing El Vado Dam operations with MRGCD diversions compared with MRGCD diversions alone. The main difference is noticed during the late irrigation season and farther north where the El Vado Dam operations maintain a more water within the channel during low flows (figure 79) and may beneficially supply additional ground water to support vegetation. Conversely, earlier in the season, by storing additional water in El Vado Reservoir when the river is experiencing higher flows, this action has a negative impact on the potential for overbank flows though El Vado operations alone have a very minimal impact on the occurrence of recruitment or overbank flows in the MRG.

Hydraulic modeling predicts on average that there is a minimal difference in potential for overbank flooding occurrence during early irrigation season for El Vado Dam operations. This difference is largely inconsequential, particularly when considering these areas often require even more than the 4,700 cfs for flooding, and areas where flycatchers occupy are typically along the rivers' edge and, thus, within the 50-meter distance to water where 94% of flycatcher nests are located (table 39). The same comparison for the late irrigation season from July–October using the MRGCD diversion and El Vado Dam operations sequence indicates no difference in the potential days of flooding (table 40).

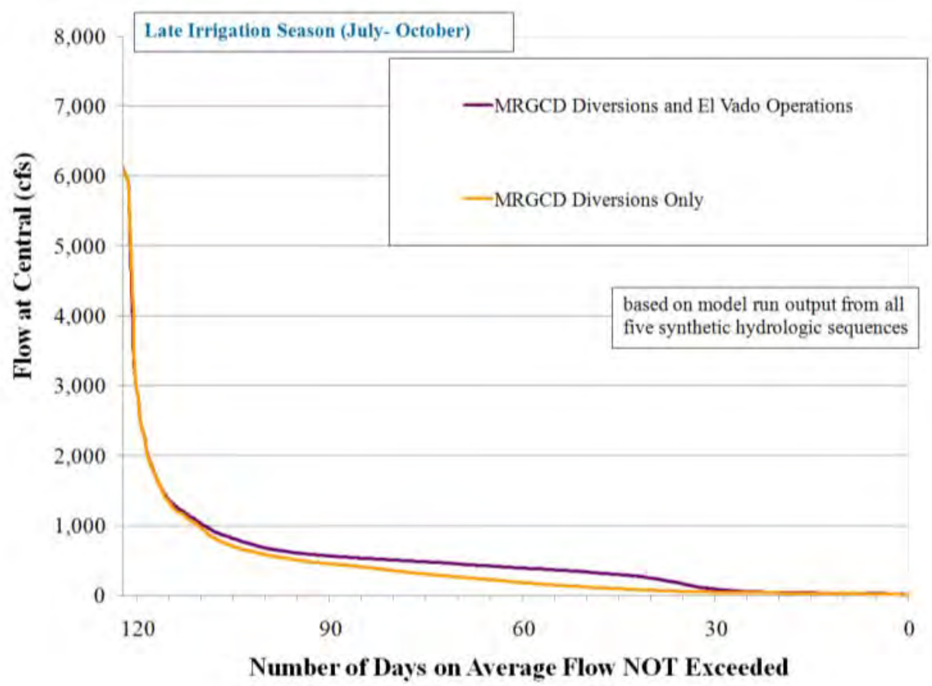

Figure 79. Relative comparison of flows at Central Avenue gage with and without El Vado operations during the flycatcher breeding period.

Table 39. Effect of El Vado Dam operation on the potential days of overbank flooding events during early irrigation season and flycatcher territory establishment. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions	Percent of the time flows reach 4,700 cfs with MRGCD diversions only	Number of days flows reach 4,700 cfs with MRGCD diversions only
Central	9.8%	12	10.4%	13
San Acacia	6.8%	8	7.2%	9
San Marcial	2.2%	3	2.9%	4

Table 40. Effect of El Vado Dam operation on the potential days of overbank flooding events during late irrigation season and flycatcher nesting period. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 4,700 cfs with only El Vado Dam operation and MRGCD diversions	Percent of the time flows reach 4,700 cfs with MRGCD diversions only	Number of days flows reach 4,700 cfs with MRGCD diversions only
Central	1.7%	2	1.8%	2
San Acacia	1.7%	2	1.7%	2
San Marcial	1.7%	2	1.7%	2

For the reach below the San Acacia gage where 1,400 cfs, required for inundation within the BDANWR area, would meet overbank flows 36.1% of the time with MRGCD diversions and El Vado operations sequence and 39.0% of the time with MRGCD diversions alone sequence (table 41). This 4-day difference would be more substantial than other reaches, but territories within this area are found along the river and are typically within 50 m of water as long as the river is wet, which would be the majority of time in the March–June time period.

Table 41. Effect of El Vado Dam operation on the potential days of overbank flooding events during early irrigation season and flycatcher territory establishment in the reaches from Arroyo del las Cañas to RM 78

Gage Location	Percent of the time flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions	Percent of the time flows reach 1,400 cfs with MRGCD diversions only	Number of days flows reach 1,400 cfs with MRGCD diversions only
San Acacia	36.10%	44	39.0%	48

From July–October at the San Acacia gage, flows would be approximately 1,400 cfs for 7 out of 123 days or 5.8% of the time in the MRGCD diversions alone sequence, or 7 days and 5.8% of the time with MRGCD diversions and El Vado Dam operations. These results indicate no difference in potential overbank flooding during that time period (table 42).

Table 42. Effect of El Vado Dam operation on the potential days of overbank flooding events during late irrigation season and flycatcher nesting period. This includes the reaches from Arroyo del las Cañas to RM 78.

Gage Location	Percent of the time flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions	Number of days flows reach 1,400 cfs with only El Vado Dam operation and MRGCD diversions	Percent of the time flows reach 1,400 cfs with MRGCD diversions only	Number of days flows reach 1,400 cfs with MRGCD diversions only
San Acacia	5.8%	7	5.8%	7

A summary of the effects of El Vado Dam on flycatchers is presented in table 43.

Table 43. Effect of El Vado Dam operations on life history elements and PCEs of flycatchers

	Migration (April–June and July–September)	**Arrival to Territories/ Territory Establishment/Nest Building** (May–July)	**Egg Laying/ Incubation/ Nestling/ Fledgling** (June–August)
Breeding Season (April–September)	The Proposed Action would **not likely adversely affect** flycatcher stopover locations during migration because flycatchers will use habitat that is less suitable during this time and farther away from water sources.	The Proposed Action may ***indirectly affect flycatcher habitat on a negligible level****.* Because the El Vado Dam operation would decrease the potential of overbank flooding but would increase the water available to vegetation at times of lower flows, overall, this would increase the potential for vegetation health, and ***could potentially beneficially affect flycatcher habitat,*** particularly in periods of drought. The benefit of maintaining the vegetative health outweighs the potential of initial territory recruitment via overbank flooding, particularly because most flycatcher habitat is along the river and within 50 meters of water anyway. However, it should be noted that the decrease in water between the two scenarios is an extremely small amount.	Territory recruitment at this stage is no longer an issue, as flycatchers are more invested in their territories and less likely to abandon nests should conditions dry or decline in value. However, if vegetation does not have adequate water resources, canopy cover will likely decrease and predation and/or parasitism would likely be more prevalent. Because the Proposed Action would result in a little more water in the system at times of low flows and increased plant stress, there would be an decreased possibility of vegetation not having adequate water to maintain health and, thus, ***would beneficially affect flycatcher habitat and potential nest success,*** again particularly in times of drought.

Table 43. Effect of El Vado Dam operations on life history elements and PCEs of flycatchers

	Migration (April–June and July–September)	**Arrival to Territories/ Territory Establishment/Nest Building** (May–July)	**Egg Laying/ Incubation/ Nestling/ Fledgling** (June–August)
Critical Habitat PCES			
Riparian Vegetation	Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. With an increase in the water amount reaching flycatcher suitable habitat patches, the Proposed Action could ***potentially beneficially affect flycatcher riparian vegetation***.		
Insect Prey Populations	A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the No Action and the Proposed Action ***would not affect the insect prey populations***. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

6.4.4 Hydrologic Effects Analysis of Non-Federal Proposed Action: MRGCD Diversions

The MRGCD diverts water for its irrigation works at Cochiti Dam and operates diversion structures at Angostura, Isleta, and San Acacia. The MRGCD typically diverts and delivers water from March 1–October 31 each year, although in recent years, delivery of irrigation water to the Six MRG Pueblos has continued through November 15. Diversions impact river flows up to the capacity of MRGCD diversions, or until the river dries. River flows are subsequently augmented, especially in the Albuquerque and Isleta Reaches, by return flows from drains and MRGCD wasteways.

Irrigation demand correlates closely with climatic conditions and the physiologic properties of agricultural crops. Demand is highest during the months of May, June, and July, tapering off in August and September. From March through mid-June, natural flows in the Rio Grande are generally greater than MRGCD consumptive needs. Therefore, during this early part of the irrigation season, much of the water diverted by the MRGCD is returned directly to the Rio Grande through wasteways and drains in the Cochiti Dam, Albuquerque, and Isleta Reaches. However, after the end of the spring snowmelt runoff, naturally occurring flows often drop precipitously and are generally less than the consumptive needs of the MRGCD. During the peak growing season, most water diverted is consumed by crops, and return flows are minimal.

At this time, the MRGCD augments the natural flow of the Rio Grande, up to its consumptive needs, with releases of stored water from El Vado Reservoir. The tail water from MRGCD diversions is delivered to the Bosque del Apache National Wildlife Refuge.

6.4.4.2 Approach for Analyzing Impacts of MRGCD Diversions

In the next step of this action-by-action analysis, MRGCD diversions for non-Indian irrigators and the Six MRG Pueblos were removed from the model, and the model was run without MRGCD diversions, El Vado Dam operations, and Heron Dam operations. The results of these runs, for the five hydrologic sequences, were then compared to the previous set of runs, in which El Vado Dam operations and Heron Dam operations were turned off, but MRGCD diversions were still operating. The comparison provides an assessment of the effects of the MRGCD diversions on river flows.

There are no historical data for years in which there were no diversions during the irrigation season; and, therefore, URGWOM is not calibrated for these conditions. For this reason, the model is not able to accurately predict river drying under these conditions. Analyses based on past river flows have suggested that river drying still would be expected during dry periods even with no diversions (Flanigan 2004). However, Reclamation's modeling analyses suggest that this drying likely is mitigated by return flows to the river from riverside and interior drains. Under the No Action condition, this water would be returned to the river and would not be diverted for irrigation further downstream. The amount of anticipated drying under the No Action scenario is presented in table 19 using an adjusted methodology.

Because of the uncertainty in the degree of river drying under the modeled No Action condition, graphs are provided in this effects analysis that present the difference in flows between model runs. These graphs depict the effects of proposed actions in terms of relative changes to flow, rather than the absolute flows. In this draft, the original graphs, which present a comparison of the flows with and without the Proposed Action being evaluated, also are presented. MRGCD diversions were simulated in the URGWOM planning model according to a set of demand curves for each diversion, which was developed by the MRGCD in cooperation with the NMISC. These demand curves are provided in Appendix 5.

6.4.4.3 Hydrologic Effects of MRGCD Diversions

Figure 80 presents a relative comparison of the flows that could be expected downstream from Cochiti Dam with and without MRGCD diversions during the irrigation season. Figure 81 presents this comparison through flow exceedence curves for the URGWOM simulation with the MRGCD diversions operating and for the No Action condition. The difference between the two lines indicates the relative impact of the diversions at Cochiti Dam. At times when the flow of the river downstream from Cochiti Dam are 200 cfs with the diversions operating, approximately 130 cfs of additional flow could be expected, on average, if the diversions were not operating. Similarly, at times when flows are above 100 cfs with irrigation diversions operating, model runs indicate approximately a 75- to 150-cfs increase could be expected below Cochiti Dam and the Cochiti diversions if the MRGCD diversions were not operating. This graph shows these differences for the irrigation season. There is essentially no impact of MRGCD diversions during the nonirrigation season.

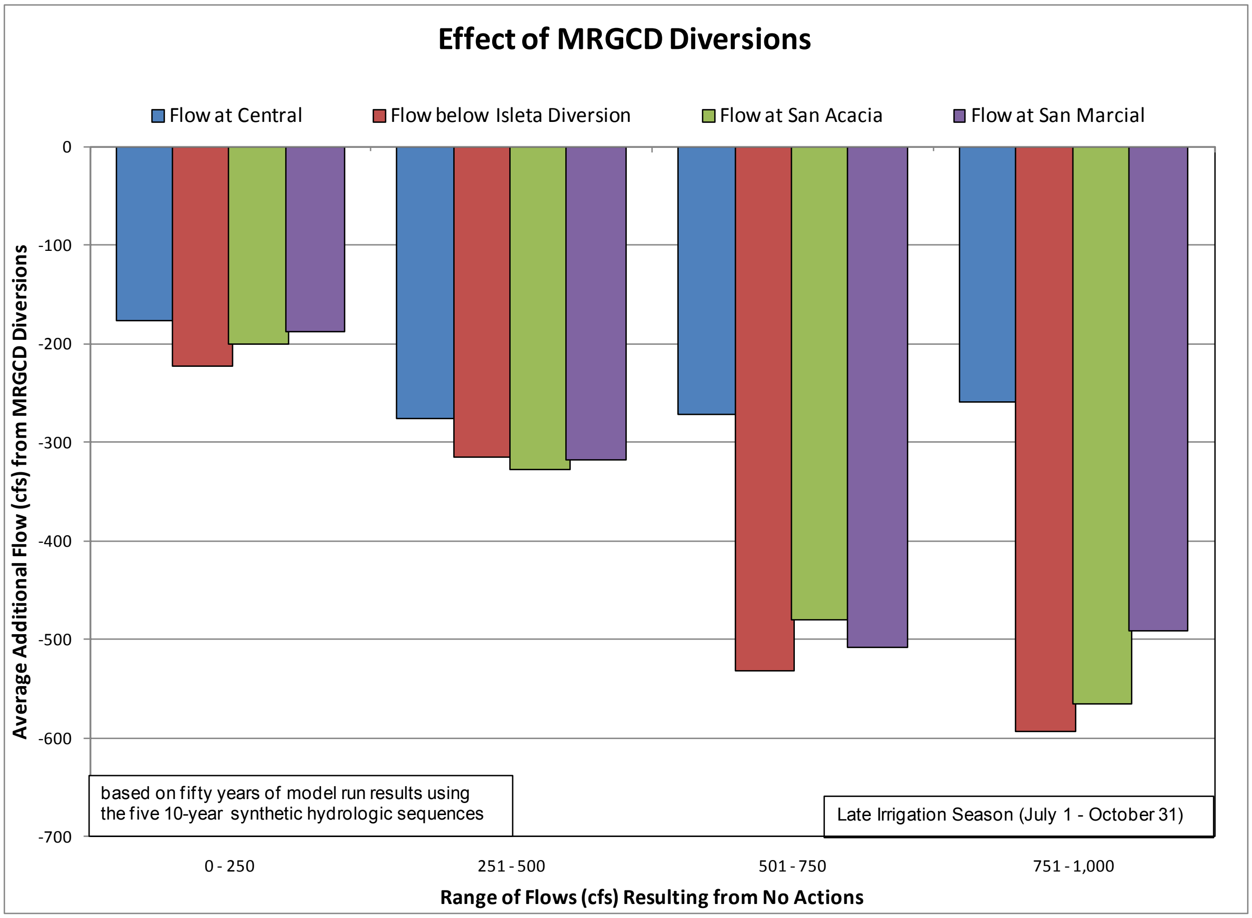

Figure 80. Flow reductions resulting from MRGCD diversions during low flow conditions, late irrigation season.

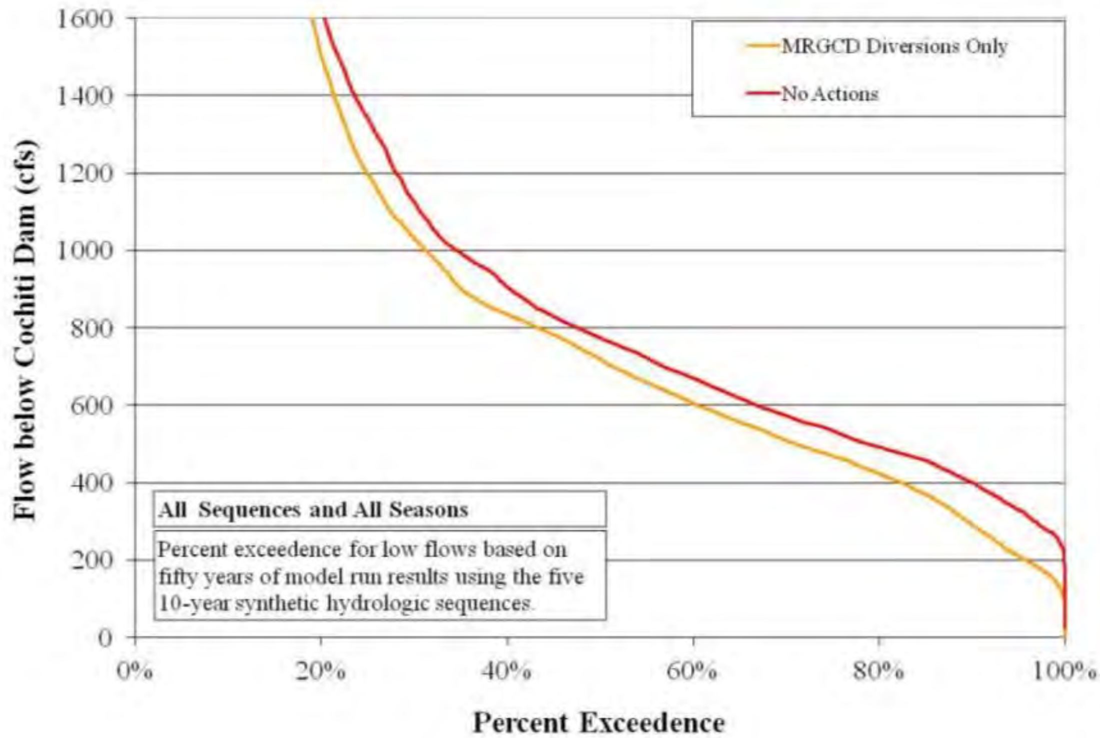

Figure 81. Relative comparison of flows downstream from Cochiti Dam with and without MRGCD diversions, for the calendar year.

Figure 82 compare the flows at the Albuquerque/Central Avenue gage with and without MRGCD diversions. The additional flows without MRGCD diversions are more significant at Central Avenue than they are downstream from Cochiti Dam and Diversion, since the river at Central Avenue is impacted by the diversions at Angostura in addition to the diversions at Cochiti. However, due to return flows from the Cochiti Division, the difference is not equal to the total of the diversions at Cochiti and Angostura. Without MRGCD diversions, flows at Central Avenue could be 200 cfs higher at most flows. When the flows with MRGCD diversions are between 100 and 500 cfs, the difference is larger—additional flows of up to 300 cfs could be expected if the Cochiti and Angostura Diversions were turned off. These conditions could reflect times in which the MRGCD is in shortage operations, and diversions at Angostura are increased to ensure delivery of water to the MRG Pueblos.

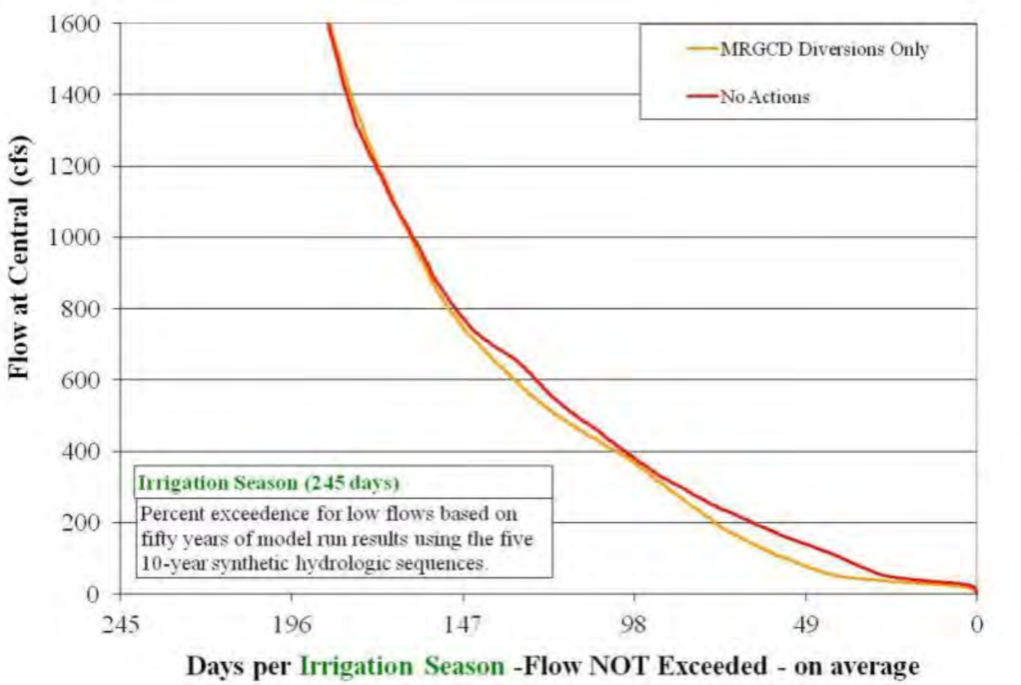

Figure 82. Relative effect of MRGCD diversions at the Central Avenue gage during the irrigation season.

Modeling indicates that additional flows are expected below San Marcial during the irrigation season if the MRGCD diversions were turned off. Below the Isleta Diversion structure, the additional river flows that could be expected without MRGCD diversions are typically in the range of 500 cfs. The additional river flow that could be expected below the San Acacia Diversion and at San Marcial would be between 400–500 cfs. The expected additional flows are lower at the locations downstream from the San Acacia Diversion due to conveyance losses. It is important to note that these differences are only apparent during the irrigation season. During the nonirrigation season, when the diversions would not be operating anyway, there is no effect from turning them off.

6.4.4.4 Qualitative Evaluation of the Effects of MRGCD's Proposed Actions

As quantified in section 6.2, the MRGCD diverts a large portion of all water moving to and through the MRG. In the process, its operations have distinct and measurable effects on water flow and distribution and, therefore, on the habitat of the listed species. MRGCD effects may be positive or negative and, in some cases, may be both depending on the timing of events.

6.4.4.4.1 MRGCD Operations

The operation of the MRGCD mimics the predevelopment pattern in which springtime floods are spread across the flood plain and a gradual drying out of the flood plain follows through the summer and fall. Though this process is now artificially controlled, and depletions have been shifted from natural vegetation to agricultural crops, water consumption occurs within the historic flood plain of the river.

The cycling (or recycling) of water throughout the MRGCD results in a pattern of dry and wet areas. Near points of diversion, the Rio Grande is typically drier. Further downstream, return flows are collected, and ground water levels generally increase. Where return flows re-enter the river, wet areas are created, often producing continuous flow downstream for several miles. Even where return flows do not directly enter the Rio Grande, increased ground water levels tend to overcome evaporative/riparian loss and produce additional wet areas in the river. This pattern simulates the predevelopment conditions in the MRG of an intermittently flowing river with scattered swamps, sloughs, and oxbows.

In the MRGCD's Socorro division, water remaining after satisfying agricultural consumptive demand finds its way, either as surface flow or ground water, to the LFCC. Reclamation then pumps this water, as required and available, from the LFCC back to the Rio Grande to support species habitat.

The MRGCD's diversions from the Rio Grande during the baseline period were about 350,000 AFY. These proposed diversions are significantly lower than the amount diverted in previous decades, and the reduced diversions help to increase flow below diversion dams at times when natural flow is greater than MRGCD demand. When natural flow is less than MRGCD demand, these reduced diversions decrease the requirement for augmentation through releases from El Vado Reservoir. This, in turn, has the effect of conserving MRGCD's supply, prolonging the time during which MRGCD is in normal operation. Normal MRGCD operation decreases the need for Supplemental Water for listed species. In addition, the reduced diversions result in smaller MRGCD releases from storage, which, in turn, results in a decreased need for water to be replaced into storage. This minimizes the impact of springtime storage in El Vado on Rio Grande flows.

As discussed in section 3, Reclamation operates El Vado Reservoir in coordination with the MRGCD. El Vado Dam operations include storage, bypass of natural flows, and release of stored water. The effect of the storage operation is to reduce the magnitude and/or duration of runoff flow on the Rio Chama. Storage may occur, and flows may be reduced, at any time of the year, but typically storage takes place between April 15–June 1. Due to the Corps' re-regulation at Abiquiu Reservoir and limited channel capacity below Abiquiu Dam, the influence of storage at El Vado on peak MRG discharge typically is minimized. Abiquiu channel capacity and the Corps' re-regulation also may moderate the impact of El Vado Reservoir storage on the duration of high spring flows in the MRG.

The release of stored water from El Vado, when requested by MRGCD, affects the Rio Grande during periods of low natural Rio Grande flow. When natural flow is insufficient to meet irrigation demand, the MRGCD relies on stored water from El Vado to augment natural flow. At times, natural flow above Cochiti Reservoir can be quite small (< 150 cfs), and virtually all water movement to and through the MRG may be due to release of stored water. The routing of this water increases flow between upstream reservoirs on the Rio Chama and MRGCD diversion structures. Typically, the increased flow extends downstream to the Isleta Diversion. At times, water is routed as far downstream as San Acacia and, therefore, keeps the Isleta Reach of the river wet. More typically, water used for irrigation in the San Acacia Reach is diverted at Isleta and routed to the San Acacia division via irrigation infrastructure rather than through the river.

While there can be exceptions when naturally occurring flow is very near or equivalent to MRGCD demands, in general, the effect of storage and release from El Vado is to moderate the MRG flows. The snowmelt runoff volumes are slightly reduced, while the extent of drying is considerably reduced. In the case of drying, the effect is not felt below San Acacia Dam, since MRGCD requests releases of water only up to its needs, and return flows from Socorro Division are delivered to the LFCC and the BDANWR instead of the Rio Grande.

Another effect of storage and release of water from El Vado is the reduced need for Supplemental Water for listed species. MRGCD's movement of water to its diversion points in the MRG increases the flow in the river to those points, so that Supplemental Water releases are not required to keep those reaches wet (although Supplemental Water still may be needed to support flows downstream from the diversion points). MRGCD may reduce diversions or cease calling for the release of water from El Vado Reservoir before the scheduled end of the irrigation season to save water for subsequent irrigation seasons, resulting in carryover storage in El Vado. Carryover storage increases the likelihood that the MRGCD will be in full operation during the subsequent irrigation season(s), decreasing Supplemental Water requirements in the future, although it may increase Supplemental Water requirements during the current season.

6.4.4.4.2 MRGCD Water Diversions and Returns

As detailed in section 6.1.3, the water that the MRGCD diverts consists of natural flows of the Rio Grande and its tributaries, native Rio Grande water released from El Vado Reservoir, and imported water from the SJC Project. The MRGCD's permit with the NMOSE, as well as the Compact, allows MRGCD to divert up to 100% of the available natural flow in the MRG.

The MRGCD's diversions from the Rio Grande have the effect of reducing river flows. During times of high flows, the effect may be slight. During times of lower flow, the effect may be significant and may lead to additional river drying.

During those low water times, Reclamation, in coordination with the MRGCD, releases stored water from El Vado Reservoir (if available) to augment the natural flow of the Rio Grande to the level required for MRGCD diversion works to function. This normally results in continuous flow in the MRG from Cochiti Dam to Isleta Diversion Dam.

The MRGCD can serve all of its irrigators downstream from the Isleta Diversion Dam at times when there is no flow in the river to the San Acacia Diversion Dam by recycling return flows from the Belen Division. Under these conditions, while the effect of MRGCD diversion is to reduce flow, it reduces flow from a rate that would be considerably less, possibly zero, in the absence of releases from El Vado (Flanigan 2004). Flows from MRGCD drains and wasteways have the positive effect of increasing Rio Grande flow in the reaches downstream from the outlets.

The MRGCD follows shortage operations at times when the natural flow is insufficient to meet the full irrigation demand, and there is not sufficient water in storage at El Vado to make up the difference, or the MRGCD chooses not to release available water in storage to make up the shortfall, but to preserve supplies for the following year. At these times, diversions occur only for the needs of the lands with prior and paramount water rights on the Six MRG Pueblos. During such times, the effect of MRGCD diversions is to reduce flow, possibly to zero, below the Diversion Dams.

MRGCD's diversions (and diversions for the BDANWR) from the LFCC may potentially conflict with Reclamation's LFCC pumping program (a component of the Supplemental Water Program) during low flow periods. As discussed in section 3, the MRGCD is comprised of four divisions, and the physical layout of the MRGCD has an effect on water movement in the MRG. Each division begins with a diversion point (the Diversion Dam). The upper three divisions return excess water directly to the Rio Grande. The lower most division returns its excess water to the BDANWR and the LFCC.

Cochiti Dam and the MRGCD's three diversion dams effectively separate the MRG into four distinct river reaches, through which water and fish can move downstream but not upstream. Cochiti and Angostura Diversion Dams form barriers to the upstream migration of fish. Isleta Diversion Dam, on the other hand, may only be a partial migration barrier depending on the elevation of the checked upstream surface and the gate settings. Channel incision directly below the San Acacia Diversion Dam has caused a more complete separation of the upstream and downstream reaches at that location.

The re-use of water into and out of MRGCD canals has the effect of reducing flow in the Rio Grande below the Diversion Dams but increases the flow where return flows are discharged. Management of the MRGCD in four distinct divisions decreases the total amount of water required by the MRGCD to operate its system significantly below the amount that would be required if the MRGCD had only a single diversion point. The recycling of carriage water adds efficiency to system operation and decreases the amount of water that Reclamation and the MRGCD must release from storage to support irrigation. Carriage water re-use can increase carryover storage, which increases the proportion of time during which MRGCD is in normal operation and, therefore, decreases the amount of time that the river must be kept wet through the release of Supplemental Water by Reclamation.

6.4.4.5 Effects of MRGCD Water Management Actions on Silvery Minnow

The main source of water for MRGCD diversions is natural flow Rio Grande water (section 6.2). Smaller amounts of the water used for MRGCD operations come from storage at Abiquiu and El Vado Reservoirs and SJC project water. The first diversion of water is taken at Cochiti Dam. In most years, the amount of water diverted at Cochiti Dam is less than or similar to the amount diverted at the Angostura Dam (figure 36). The majority of the diversions occur at Isleta Dam. Only a small fraction is taken from San Acacia Dam. In model runs, the impact of diversions is more noticeable in the downstream reaches below Isleta Diversion Dam.

During spring runoff, duration of peak flows is decreased due to MRGCD diversions. Model runs predict that operations decrease the number of continuous days that discharge exceeds 3,000 cfs on an average of 2 days at Central, 6 days below Isleta and San Acacia Dams, and 3 days at San Marcial. The difference is more pronounced at lower flow thresholds. Model runs indicate that diversions also cause low flow conditions in the lower river (i.e., < 200 cfs at San Marcial) to begin at an earlier date (figure 73). The number of high flow days and date of onset of low flow have a strong relationship to October CPUE of silvery minnow.

Similarly, the number of low flow days and drying that are predicted for each reach is increased by diversion operations. Low flow conditions that may be expected to have drying are predicted in all reaches with the MRGCD diversion only scenario. The modeled mean number of days annually that flow is less than 100 cfs in the Angostura Reach increases by over 40 days with MRGCD diversions. Drying can cause direct mortality for silvery minnow due to desiccation or being stranded into isolated pools with low water quality. There is some evidence that if flows are decreased gradually, many silvery minnow can move with the water and find refugial habitats. Low flow conditions also put silvery minnow at greater risk of predation since the amount of cover that is offered by deeper water is decreased. Sediment transport is minimal during extremely low flow periods, thus, visibility is high, and fish are concentrated. Additionally, poor water quality conditions and other stressors may reduce body condition for those fish that survive in isolated pools, which may have indirect effect to their survival later in the year.

Both the decrease in peak flow and lower base flows that are present with diversion operations have effects to the geomorphic condition of silvery minnow habitat. The current geomorphic trends of vegetation encroachment and channel simplification are driven by high flows and base flow conditions. The MRG has often developed a two-stage channel, which is large enough to reflect the common high flows and, then inside, that is a smaller channel that reflects the common low flows. This is also evident in habitat specific studies that indicate that, under current conditions, habitat availability for silvery minnow does not increase linearly with flow increases (Bovee 2008). Decreases in peak flows and lower base flows result in a reduction in available wetted habitat at both stages in the MRG. The diversion dams also alter sediment transport as well as the ability of the river to move within the flood plain, which affects habitat quality for silvery minnow.

Irrigation season typically runs March 1–October 31; Pueblo deliveries may continue through November 15. Impacts from diversions are not present during the winter since irrigation is shut down. There are impacts due to the presence of the diversion year round. San Acacia and Angostura Dams are thought to be complete barriers to upstream fish passage. Barriers may have long-term genetic effects on the population by preventing upstream movement of fish. There is likely a population level effect as well, especially in the uppermost reaches when population levels of silvery minnow are low and much of the reproductive effort is lost to downstream reaches. There is some thought that Isleta Dam may be passable by silvery minnow under certain gate configurations. Silvery minnow of all life stages may become entrained into the irrigation system, especially as eggs and larvae. The magnitude of entrainment in the past several years has been minor due to MRGCD modifying its operations during peak egg production periods; this is proposed to continue as a conservation measure. Outflows from drains may provide some refuge for silvery minnow during low flow periods or areas of low velocity habitat during high flows.

The summary of MRGCD effects is presented in table 44.

Table 44. Effect of operation of MRGCD diversions (3.3.1) on life history elements and PCEs of silvery minnow

<table>
<tr><th></th><th>Spawning</th><th>Eggs</th><th>Larval</th><th>Juvenile</th><th>Adult</th></tr>
<tr><td>Spring (April–June)</td><td colspan="3">The duration and magnitude of spring runoff in the MRG is decreased by MRGCD operations. The decrease to the duration of inundation of overbank habitats, which is related to spawning and recruitment of silvery minnow, is anticipated to be minor. Eggs and larvae may be entrained into the irrigation system; but with modified management during peak egg production, this is expected to be minor.
Direct and Indirect – *Operation of diversions is likely to adversely affect silvery minnow spawning and recruitment.*</td><td></td><td>There is little information on how spring flows are related to adult survival of silvery minnow. Decrease in the spring hydrograph from MRGCD operations is anticipated to be minor. Adult entrainment into the irrigation system is likely rare. ***Direct and Indirect – The operation of diversions are not likely to adversely affect adult silvery minnow.***</td></tr>
<tr><td>Summer (June–Sept)</td><td></td><td></td><td colspan="3" rowspan="2">MRGCD diversions increase the number of low flow days and drying especially in the Isleta and San Acacia Reaches. Drying can cause mortality in silvery minnow, put them at risk for predation, and may reduce their fitness when concentrated for long periods in isolated pools. Releases from drains and outfalls may provide areas of refuge for silvery minnow during low flow periods. **Direct and Indirect – *Diversions are likely to adversely affect silvery minnow in summer and fall periods.***</td></tr>
<tr><td>Fall (Sept - Nov)</td><td></td><td></td></tr>
<tr><td>Winter (Dec–March)</td><td></td><td></td><td></td><td></td><td>MRGCD does not divert water in the winter.
Direct – *Diversions have no direct effect to winter survival of adult silvery minnow.*
Indirect – Body condition of fish may be reduced going into winter months due to increased low flow periods.</td></tr>
</table>

Table 44. Effect of operation of MRGCD diversions (3.3.1) on life history elements and PCEs of silvery minnow (continued)

	Spawning	Eggs	Larval	Juvenile	Adult
Critical Habitat PCES					
Hydrologic Regime					
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats.	***Direct and Indirect – Diversions are likely to adversely affect the hydrology and maintenance of silvery minnow critical habitat within the MRG***. The current geomorphic trends of vegetation encroachment and channel simplification are driven by high flows and base flow conditions. There is little effect from MRGCD diversions on the duration and magnitude of channel altering flows (> 5,000 cfs). Increased low flow periods due to diversion operations reduces available wetted habitat. The formation of a two-stage channel within the MRG set by the high and low flow condition causes habitat availability for silvery minnow to not increase linearly with flow increases and is set to base flow levels. Drain outfalls may provide backwater and refuge habitats.				
Presence of a diversity of habitats for all life history stages					
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	Silvery minnow are known to spawn with very small flow increases. However, the Proposed Action may cause minor decreases in high flows, especially in years with limited spring runoff; **Direct and Indirect – MRGCD *operations are not likely to adversely affect silvery minnow critical habitat for spawning of silvery minnow.***				
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow	MRGCD diversions increase the number of low flow days and drying especially in the Isleta and San Acacia Reaches. Releases from drains and outfalls may provide areas of refuge for silvery minnow during low flow periods. **Direct and Indirect – *MRGCD operations are likely to adversely affect silvery minnow critical habitat during summer and fall periods.***				

Table 44. Effect of operation of MRGCD diversions (3.3.1) on life history elements and PCEs of silvery minnow (continued)

	Spawning	Eggs	Larval	Juvenile	Adult
Constant winter flow					MRGCD diversions are not operated during the winter. **Direct and Indirect –** ***MRGCD operations are not likely to adversely affect winter critical habitat for adult silvery minnow.***
Unimpounded stretches of river with a diversity of habitats and low velocity refuge areas					
River reach length	San Acacia and Angostura Dams are thought to be complete barriers to upstream fish passage. There is some thought that Isleta Dam may be passable by silvery minnow under certain gate configurations. ***Diversion Dams directly adversely affect river reach length within critical habitat***. The sinuosity changes depending on geomorphology and discharge levels. Sinuosity of the thalweg may increase during low flows, which increases the length of the river but also may promote vegetation growth on point bars within the river channel. The lack of flood stage flows also changes the potential that the river will move outside its current channel. The Proposed Action ***is not likely to indirectly adversely river reach length.***				
Habitat "quality" in each reach and refugial habitats.	Ongoing geomorphic trends will continue under the current operations. The formation of a two-stage channel within the MRG set by the high and low flow condition causes habitat availability for silvery minnow to not increase linearly with flow increases and is set to base flow levels. Drain outfalls may provide backwater and refuge habitats. Drying within the San Acacia and Isleta Reaches decreases habitat quality and quantity. Habitat quality in each reach is dependent on the structure and diversity of available habitat. Channel trends throughout the MRG are towards a more simplified channel due to vegetation encroachment. Base flow levels from the Proposed Actions drive the vegetation encroachment within the channel. The quantity of suitable habitat within each reach also changes at different flows; this relationship is not linear in most sections of the river and is dependent on channel shape. The Proposed Action ***may have indirect effects that adversely affect silvery minnow critical habitat***. ***Diversions are likely to adversely affect habitat quality within the reaches of critical habitat***.				
Substrate of sand or silt					
Substrates of predominantly sand or silt	Diversion Dams alter sediment transport within the MRG. The ongoing trends will continue within the reaches above and below Diversion Dams. ***Diversions are likely to adversely affect sediment transport within critical habitat***.				
Water quality					
Temp >1˚ - < 30 ˚C DO > 5 mg/L pH (6.6-9.0)	Water temperature, DO, and pH within the MRG may be affected during low flow conditions especially in intermittent areas. **Direct and Indirect – The operation of Diversions is likely to adversely affect water quality due to increased low flow periods.**				
Other contaminants	Drain and irrigation return water has the potential to have poor water quality, but recent studies (Buhl 2011) found no elevated levels of contaminants in the tested wasteway water. River water entering the irrigation canal system can carry high nutrient concentrations, but concentrations of nitrate, ammonium, and phosphate re-entering the river from these tributary return flows are consistently low (Zeglin and Dahm 2006). The operation of MRGCD diversions reduces the amount of water that is available to dilute contaminants that are introduced to the river from outside sources. This lack of dilution may have ***indirect effects but is not likely to adversely affect silvery minnow.***				

6.4.4.6 Effect of MRGCD Water Management Actions on flycatcher.

Within the MRG, there is a decrease in the amount of water in the river brought on by diversions. This decreases in the possibility of overbank flooding, and increases the potential for drying the river. This action also has the potential for affecting ground water levels that would have impacts to native vegetation health. Figures 83–86 demonstrate the relative difference between the predicted flow exceedence curves with MRGCD diversions and in the No Action scenario at Central and San Marcial.

Using the previously described analysis, it is predicted that, on average, MRGCD diversions would decrease overbank flooding by 1–3 days during the early irrigation season (March–June) when compared to No Action and would decrease in the overall water availability. This difference is minor, particularly when considering many areas often require more than the 4,700 cfs for flooding, and areas where flycatchers occupy are typically along the rivers' edge and, thus, within the 50-meter distance to water where 94% of flycatcher nests are located (table 45).

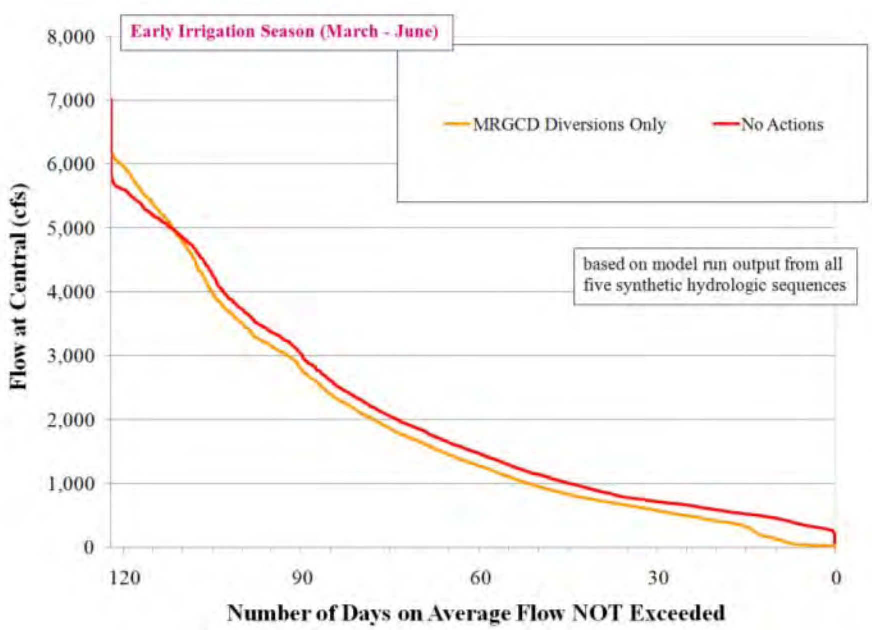

Figure 83. Relative comparison of modeled flows at Central gage considered Proposed Action of MRGCD diversions compared to No Action during the flycatcher territory establishment period.

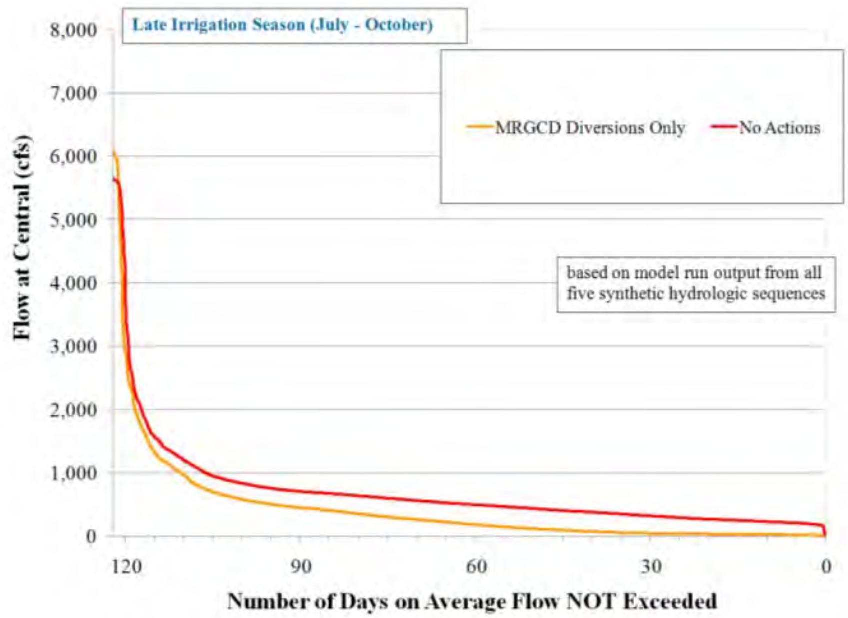

Figure 84. Relative comparison of modeled flows at Central gage considered Proposed Action of MRGCD diversions compared to No Action during the flycatcher breeding period.

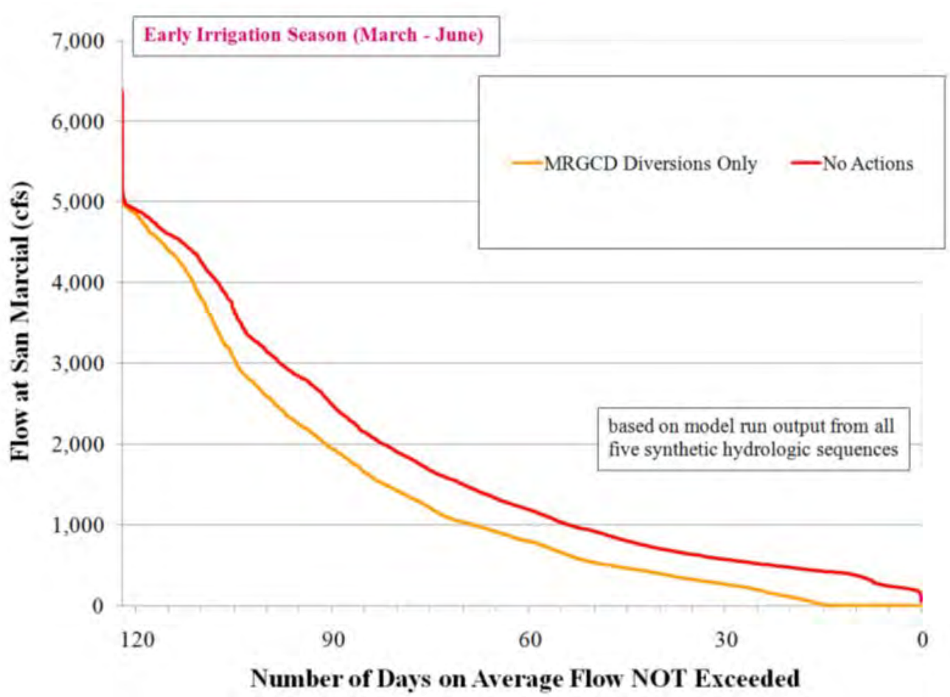

Figure 85. Relative comparison of modeled flows at San Marcial gage considered Proposed Action of MRGCD diversions compared to No Action during the flycatcher territory establishment period.

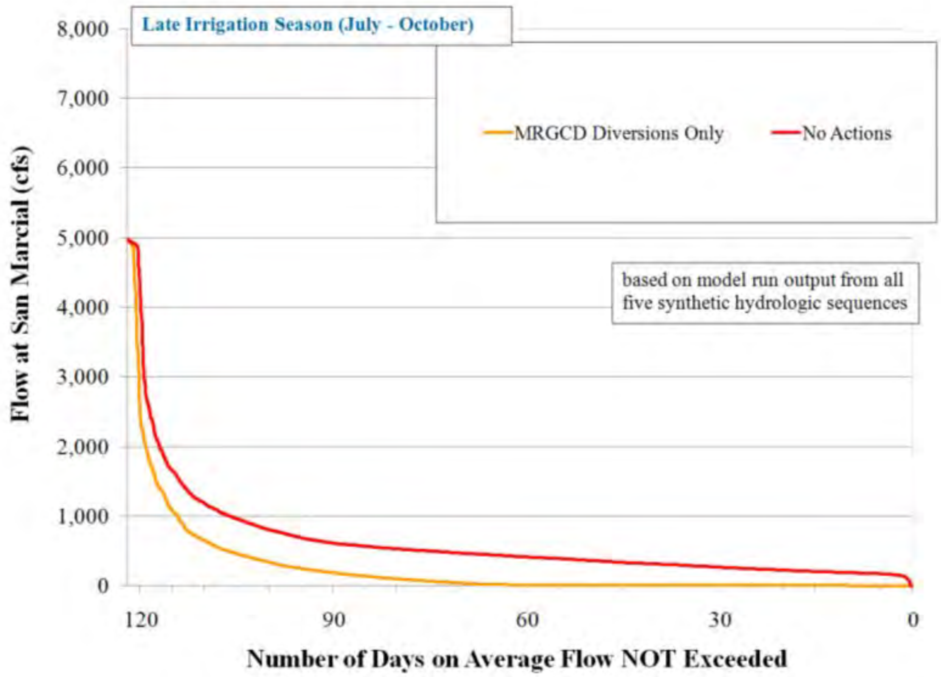

Figure 86. Relative comparison of modeled flows at San Marcial gage considered Proposed Action of MRGCD diversions compared to No Action during the flycatcher breeding period.

Table 45. Effect of MRGCD diversions on the number of potential days of overbank flooding events during early irrigation season (March–June) and flycatcher territory establishment. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with MRGCD diversions only	Number of days flows reach 4,700 cfs with MRGCD diversions only	Percent of the time flows reach 4,700 cfs with No Action	Number of days flows reach 4,700 cfs with No Action
Central	10.2%	13	11.30%	14
San Acacia	7.2%	9	10.00%	12
San Marcial	2.9%	4	4.40%	5

The same comparison but using results from the late irrigation season from July–October with No Action indicates flows would be approximately 4,700 cfs at the Central, San Acacia, and San Marcial gages 2% of the time. With MRGCD water management actions, the potential overbank flooding decreases slightly. There is not a significant difference between overbank flooding with the No Action versus the MRGCD action scenarios (table 46). For reaches below the San Acacia gage at the 1,400 cfs required for inundation within the BDANWR area, flows under the Proposed Action would meet overbank flows 45% of the time in the No

Action sequence and 39% of the time in the MRGCD diversions alone sequence. This 7-day difference would be more substantial when compared to the other reaches (table 47). The time period during late irrigation from July–October at the San Acacia gage indicates a 6-day difference in flows above 1,400 cfs and potential overbank flooding. Though this time period is less important in regard to territory establishment, it would be important for vegetative health and nest success during July and August (table 48). Table 49 presents a summary of the MRGCD Water Management Actions on flycatchers.

Table 46. Effect of MRGCD diversions on the number of potential days of overbank flooding events during late irrigation season (July–October) and flycatcher nesting period. This includes all reaches from Albuquerque to RM 62 with the exception of the reaches near the BDANWR.

Gage Location	Percent of the time flows reach 4,700 cfs with MRGCD diversions only	Number of days flows reach 4,700 cfs with MRGCD diversions only	Percent of the time flows reach 4,700 cfs with No Action	Number of days flows reach 4,700 cfs with No Action
Central	1.8%	2	2.2%	3
San Acacia	1.7%	2	2.4%	3
San Marcial	1.7%	2	2.3%	3

Table 47. Effect of MRGCD diversions on the number of potential days of overbank flooding events during early irrigation season and flycatcher territory establishment for reaches from Arroyo del las Cañas to RM 78

Gage Location	Percent of the time flows reach 1,400 cfs with MRGCD diversions only	Number of days flows reach 1,400 cfs with MRGCD diversions only	Percent of the time flows reach 1,400 cfs with No Action	Number of days flows reach 1,400 cfs with No Action
San Acacia	39.0%	48	45.00%	55

Table 48. Effect of MRGCD diversions on the number of potential days of overbank flooding events during late irrigation season and flycatcher nesting period for reaches from Arroyo del las Cañas to RM 78

Gage Location	Percent of the time flows reach 1,400 cfs with MRGCD diversions only	Number of days flows reach 1,400 cfs with MRGCD diversions only	Percent of the time flows reach 1,400 cfs with No Action	Number of days flows reach 1,400 cfs with No Action
San Acacia	5.8%	7	10.5%	13

Table 49. Effect of MRGCD Proposed Action on life history elements and PCEs of flycatchers

	Migration (April-June and July–September)	**Arrival to Territories/ Territory Establishment/ Nest Building** (May–July)	**Egg Laying/ Incubation/Nestling/ Fledgling** (June–August)
Breeding Season (April–September)	The Proposed Action would **not likely adversely affect** flycatcher stopover locations during migration because flycatchers will use habitat that is less suitable during this time and farther away from water sources.	The Proposed Action may ***indirectly affect flycatcher habitat on a negligible level***. Because the Proposed Action, when compared to No Action, would decrease the potential of overbank flooding and decrease the overall water available for vegetation, this could cause a decline in territory recruitment and canopy cover/plant health/seed establishment and ***could potentially adversely affect flycatcher habitat,*** particularly in periods of drought. However, it should be noted that the decrease in water between the two scenarios is a relatively small amount.	Territory recruitment at this stage is no longer an issue as flycatchers are more invested in their territories and less likely to abandon nests should conditions dry or decline in value. However, if vegetation does not have adequate water resources, canopy cover likely will decrease and predation and/or parasitism likely would be more prevalent. Because the Proposed Action would result in less water in the system, there would be an increased possibility of vegetation not having adequate water to maintain health and, thus, ***could adversely affect flycatcher habitat and potential nest success,*** again particularly in times of drought.
Critical Habitat PCES			
Riparian Vegetation	Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal, and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. With a decrease in the water amount reaching flycatcher suitable habitat patches, the Proposed Action could ***potentially adversely affect flycatcher riparian vegetation.***		
Insect Prey Populations	A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the No Action and the Proposed Action ***may affect, not likely to adversely affect the insect prey populations***. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

6.5 Evaluation of Conservation Measure – Collaborative Program

The conservation measure presented to offset effects of the described Proposed Actions of Reclamation and MRGCD as well as other participants is the Collaborative Program. The focus of the Collaborative Program is to promote the conservation and contribute to the recovery of the listed endangered species in the MRG, assist in attainment of ESA compliance for the signatory entities with the concurrence of the Service, and encourage water development and management. The activities of the Collaborative Program serve as a tool to conserve listed species, assist with species recovery, and help protect critical habitat.

The specific goals of the Collaborative Program are to:

- Alleviate jeopardy to the listed species in the Program area.
- Conserve and contribute to the recovery of the listed species.
- Protect existing and future water uses.
- Report to the community at large about the work of the Program.

For the purposes of the Section 7 consultation, it is assumed that:

1. Collaborative Program activities will continue to be implemented to assist in the recovery of the species, including water acquisition and management, habitat restoration, endangered species monitoring, and silvery minnow propagation.
2. The funding will be available to implement these actions.
3. Collaborative Program signatories will take appropriate steps to implement those actions.
4. Actions will be implemented in accordance with the schedule agreed to by the signatories.

Annual work plans will be continue to be developed that will define specific projects and commitments of participants.

As in the past, the Collaborative Program will continue to undertake actions and tasks to alleviate jeopardy and strive toward recovery of the listed species in the Program area by addressing many of the threats described in the recovery plans for silvery minnow and willow flycatcher (Service 2010, Service 2002). Table 50 summarizes actions that the Collaborative Program will likely continue and the associated threats that would be addressed by these actions.

Table 50. Description of likely actions for the Collaborative Program and threats addressed by these actions

Description of Action	Threats Addressed
Habitat Restoration and Management	Minnow • Prevention of overbank flooding • Altered preferred habitat • Reduced flows, which may limit the amount of preferred habitat and limit dispersal of the species • Confined flood flows • Establishment of stabilizing vegetation • Elimination of meanders, oxbows, and other components of historic aquatic habitat • Reduction of inundated floodplain areas where young can develop • Geomorphologic changes to the river channel • Fragmented habitat • Prevention of species' dispersal Flycatcher • Habitat loss and modification • Changes in abundance of other species • Vulnerability of small populations
Water Management	Minnow • Risk of 2 consecutive below-average flow years, which can affect short-lived species • Altered flow regimes • Prevention of overbank flooding • Altered preferred habitat • Stored spring runoff and summer inflow, which would normally cause flooding • Prolonged summer low flow • Reduced flows, which may limit the amount of preferred habitat and limit dispersal of the species • Reduction of inundated floodplain areas where young can develop • Confined flood flows • Annual dewatering of a large percentage of the species' habitat • Increase in contaminant concentrations during low flows, which may exacerbate other stresses Flycatcher • Habitat loss and modification. • Changes in abundance of other species. • Vulnerability of small populations

Population Augmentation/Propagation	Minnow • Reduced population numbers and potential loss of genetic diversity • Risk of 2 consecutive below-average flow years, which can affect short-lived species
Water Quality Management	Minnow • Increase in contaminant concentrations during low flows, which may exacerbate other stresses
Species Research, Monitoring and Adaptive Management	Minnow and Flycatcher • Prioritizing management actions
Program Management	Minnow and Flycatcher • Prioritizing management actions

The following sections present an evaluation of specific conservation measures that have been proposed by Reclamation and MRGCD to offset the impacts of MRG water operations. Conservation measures analyzed for Part I of this BA include Reclamation's Supplemental Water Program and the conservation measures of the MRGCD.

6.5.1 Reclamation's Supplemental Water Program

Reclamation's Supplemental Water Program, as proposed, and its effectiveness in offsetting the impacts of Reclamation's Proposed Action and those of Reclamation's non-Federal partners have been evaluated through URGWOM modeling. Reclamation's Supplemental Water Program is intended to benefit the listed species and includes the following actions:

- Supplemental water acquisition.
- Storage of acquired water in Rio Chama reservoirs and release to benefit listed species and assist in compliance with flow requirements.
- SJC Project storage waivers for contractors who have agreements to lease water to Reclamation (if there is a benefit to the United States).
- Pumping and conveyance of water from the LFCC to the Rio Grande.

Reclamation expects the water available for lease from all sources to decline from the average of 28,990 AFY that has been available under the 2003 BiOp to an average of 13,050 AFY over the 10-year analysis period for this BA. The primary source of water in the Supplemental Water Program is Reclamation's lease of annual water allocations from willing SJC Project contractors. However, SJC Project water available for lease has decreased because SJC Project contractors, including the ABCWUA (which has historically provided the largest amount of SJC Project lease water to the Program), are using more of their water for its intended purpose. The water that was available over the past decade also included significant amounts of credit water relinquished under the Compact and leased to Reclamation by the State of New Mexico under the terms of the Conservation Water Agreement and Emergency Drought Water Agreement.

Reclamation's model runs include 38,696 AF of EDWA water available for storage and lease to the Supplemental Water Program at the beginning of the 10-year analysis period. This number includes 19,196 AF of Emergency Drought Water for ESA in storage as an initial condition plus an unused allocation for storage of an additional 19,500 AF. However, the analysis does not assume that any additional credit relinquishment water becomes available. Reclamation continues to seek more water for its Supplemental Water Program.

6.5.1.1 Approach to Analysis of Reclamation's Supplemental Water Program

To evaluate the effectiveness of the Supplemental Water Program as a conservation measure, model simulations of the Proposed Water Management Actions and the Supplemental Water Program have been compared to simulation of the Proposed Water Management Actions without the Supplemental Water Program. Also, the simulations that include the Supplemental Water Program were performed using two sets of companion runs—one using the available supply of Supplemental Water and one using a hypothetical unlimited supply of Supplemental Water. In the model runs, the Supplemental Water is used to meet the flow requirements of the 2003 BiOp. In both sets of runs, there is no prioritization to the releases of Supplemental Water; if a release is needed to meet the flow requirements, the water is released until the Supplemental Water supply runs out.

6.5.1.2 Analysis of the Supplemental Water Program

The Supplemental Water Program provides water to support the habitat requirements of listed species in the MRG during periods of low flows, when the flow augmentation provided by the release of irrigation water from El Vado Dam and the operation of the San Juan-Chama Project is insufficient to maintain flow or meet flow targets. The Supplemental Water Program delays and decreases the duration of drying, which decreases mortality of silvery minnow and may have some impact on maintaining vegetation for flycatchers. The impact of this Supplemental Water varies from year to year depending on the type of water year and the amount of Supplemental Water available. The modeling runs for the use of Supplemental Water used the 2003 BiOp requirements as an example of how the water can be used to augment flows in the system and benefit the species.

The following graph breaks down the modeled uses of water acquired, stored, and released from upstream reservoirs under the Supplemental Water Program (figure 87) to meet 2003 BiOp requirements. Please note that no water is used in the model to control rates of drying after river rewetting, since this was not a BiOp requirement (and is typically performed through gradual ramp-up of MRGCD diversions). Reclamation is not proposing to continue these operations under the current Proposed Action but this information may guide the prioritization of Supplemental Water use into the future.

Traditionally, the largest use of Supplemental Water has been to maintain flows of 100 cfs or greater at the Central Avenue Gage. Water to meet this target is typically released after the recession from the spring snowmelt runoff, typically after June 15. The second largest use was to maintain continuous flows during the early irrigation season, between March 1 and June 15. The impact of both of these categories of releases can be seen at Central Avenue.

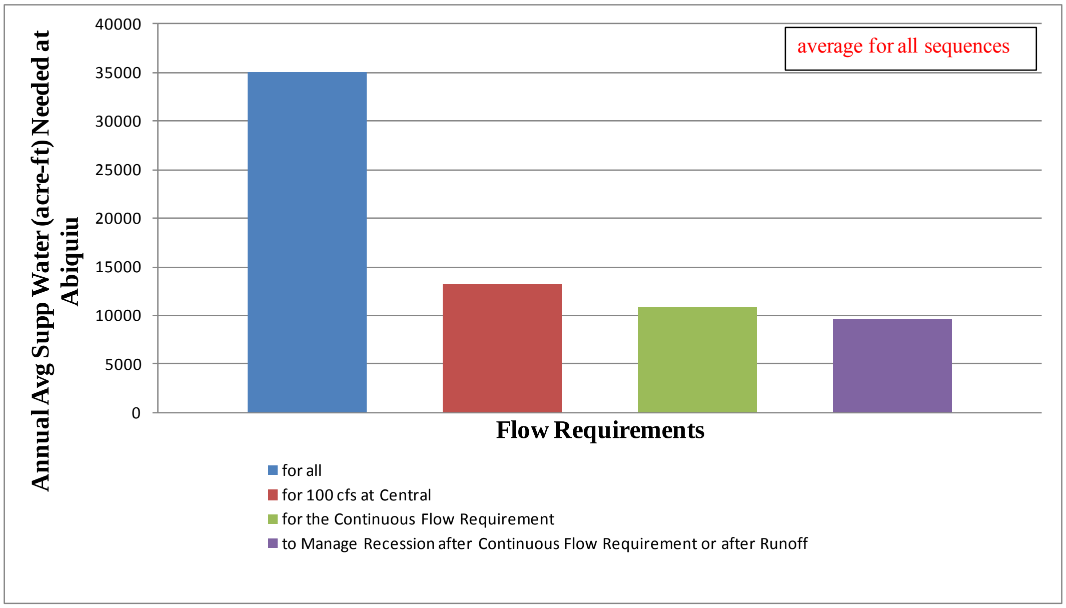

Figure 87. Uses of Supplemental Water in URGWOM simulations.

Figure 88 is a "box and whisker" plot that summarizes the impact of the Supplemental Water Program on flows at the Central Avenue Gage during the entire irrigation season, March 1–October 31. These impacts have been broken down according to ranges of low flows that would occur without the Supplemental Water Program, 0–100 cfs, 101–200 cfs, and 201–300 cfs, respectively. The impact of the Program, as indicated by the grey box, which shows the 25–75% range of probability, is primarily positive in these ranges. The "whiskers" in this plot show some apparent negative impacts in the lowest-probability portions of the distributions. These effects result from time lags and operational rules within URGWOM and do not indicate any real likelihood of negative impacts from the Supplemental Water Program. The "boxes" indicating the middle 50% show the greatest impact of the Supplemental Water Program, up to 50 cfs, in the range of flows 101–200 cfs during the irrigation season. The whiskers also show a low probability of flows below 200 cfs being supplemented by an additional flow of greater than 250 cfs.

Downstream of Central Avenue in Albuquerque, the Supplemental Water Program has the greatest impact during the early irrigation season, March 1–June 15. This period represents the time in which the 2003 BiOp has required continuous flows in the MRG during dry years. As defined in the 2003 BiOp, during dry years, benefits of Supplemental Water are not realized after June 15 in lower reaches that do not have flow targets, since Supplemental Water will, by agreement with the MRGCD, be diverted for irrigation at the dam below the downstream-most flow targets.

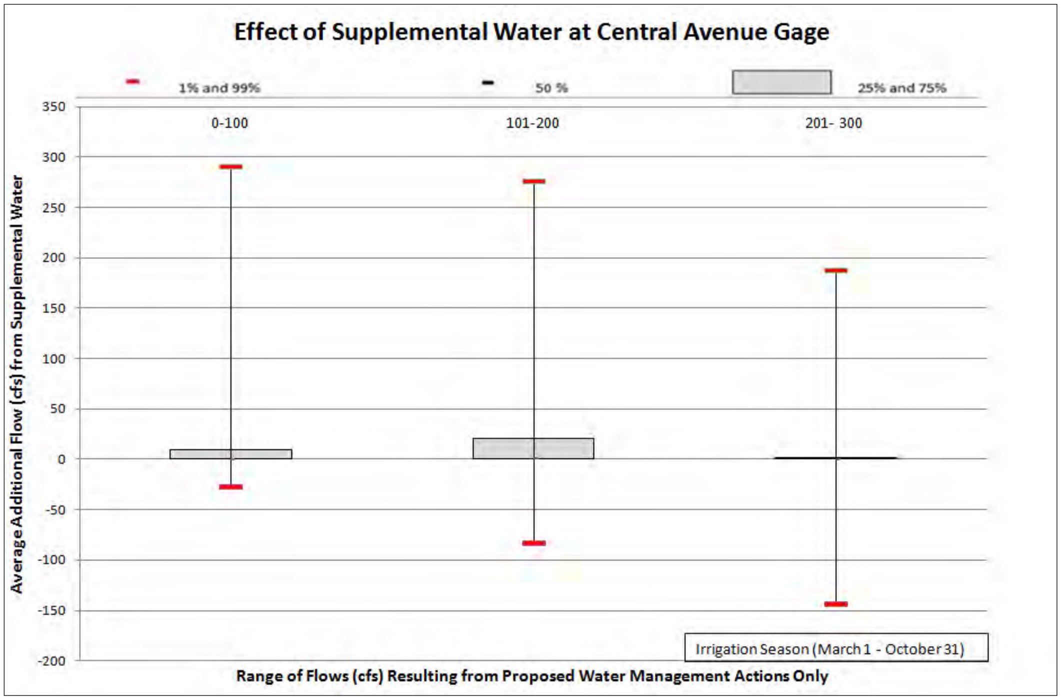

Figure 88. Impact of Supplemental Water on flows of 300 cfs or less at the Central Avenue Gage as compared to the Proposed Action.

Figure 89, below, presents the additional flow provided by the Supplemental Program at key locations downstream of Central Avenue (Isleta, San Acacia, and San Marcial) during this time period. These curves show that, at these locations, the greatest impacts of Supplemental Water, including release of water from upstream reservoirs and pumping from the LFCC to the river, is at the lowest flows, generally when flows would be below about 120 cfs. The Supplemental Water Program provides up to 80 cfs of additional flow at each of these locations under these conditions.

Figure 90 presents the impact of Supplemental Water on low flows during the early irrigation season at these same locations, Isleta, San Acacia, and San Marcial, in the form of a “box and whisker” plot, as was used to display the impact of Supplemental Water at Central Avenue. These probability distributions were created by filtering for days with flows below thresholds for each reach in which downstream drying might be expected. The grey boxes, which indicate the middle 50% of probabilities, show a consistent benefit of the Supplemental Water Program of up to 130 cfs at Isleta, 15 cfs at San Acacia, and 115 cfs at San Marcial. The benefits at Isleta and San Acacia are primarily provided by releases from upstream reservoirs. The benefits at San Marcial are primarily provided by pumping from the LFCC to the river.

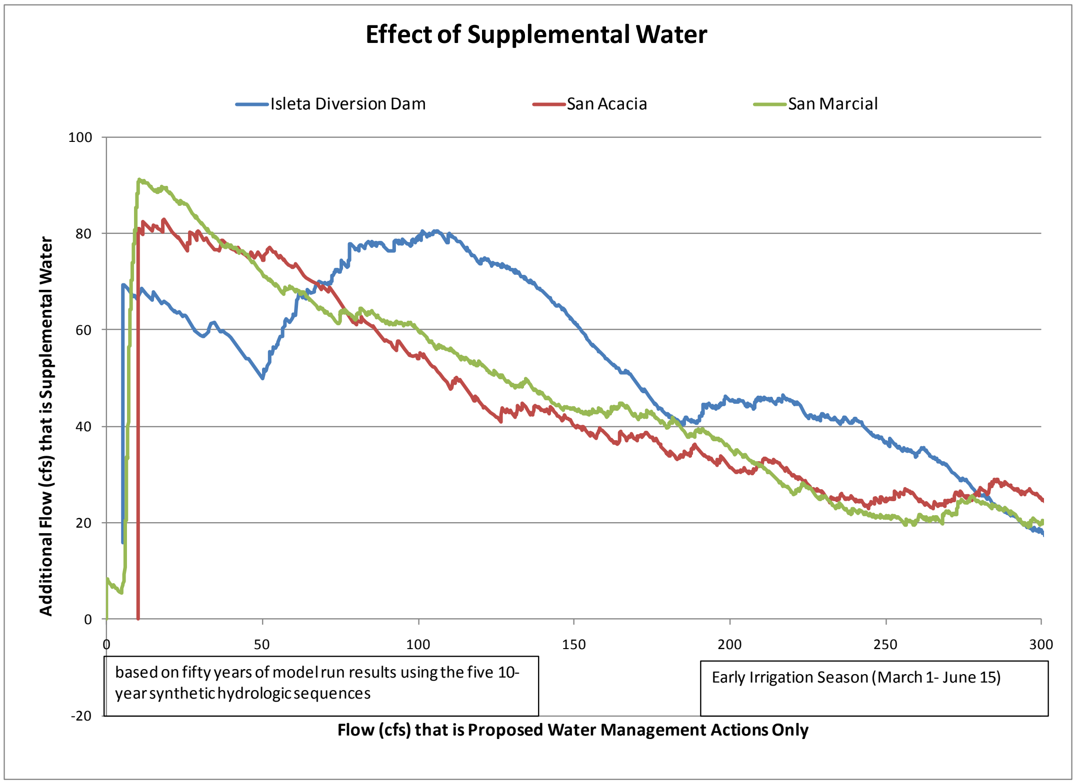

Figure 89. Graph showing the impact of Supplemental Water on flows of 300 cfs or less at Isleta, San Acacia, and San Marcial as compared to the Proposed Action.

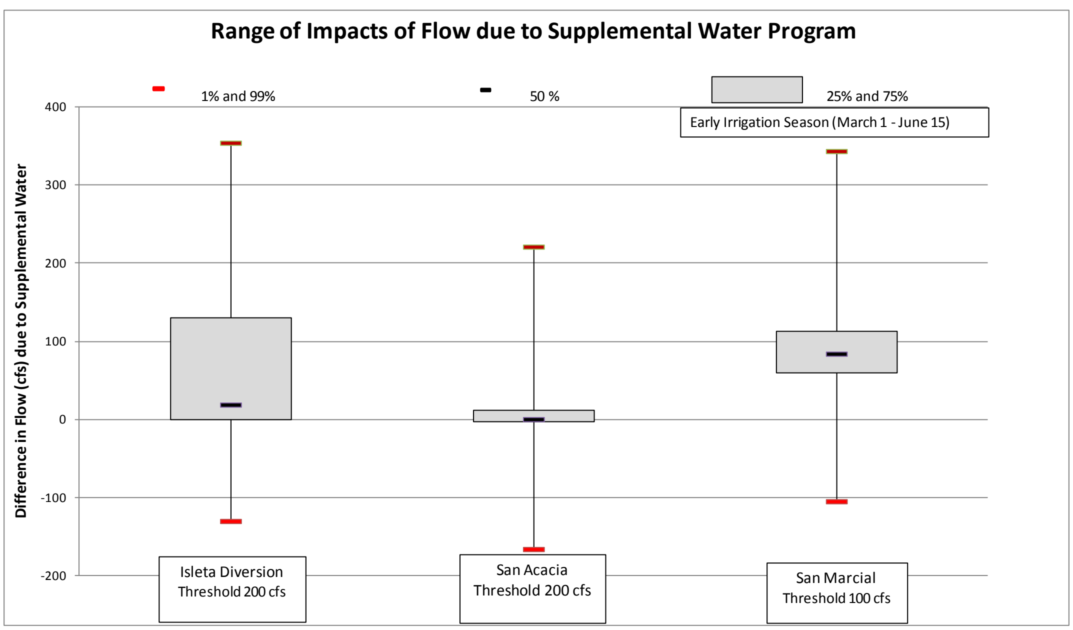

Figure 90. "Box and whisker plot" showing the impact of Supplemental Water on low flows at Isleta, San Acacia, and San Marcial during the early irrigation season compared to the Proposed Action.

The need for Supplemental Water can be very high at times when MRGCD is in shortage operations. Under these shortage operations, diversions at Angostura are increased to meet the remaining water needs of the Pueblos, as far south as Isleta. Increased diversions at Angostura yield higher flows to the Albuquerque Drain that outfall to the river just above the Isleta diversion and are re-diverted there as they are available. Diversions at both Isleta and San Acacia continue as water remains available; but under these shortage operations, water is not specifically conveyed to these diversion structures.

During MRGCD shortage operations, ABCWUA would be using ground water to meet drinking water needs. When the MRGCD is in shortage operations, it typically increases Angostura Diversions, which results in greater potential for river drying in the Albuquerque Reach. Under these conditions, water released from storage under Reclamation's Supplemental Water Program is the primary source for flows in the river and habitat for the silvery minnow. The SJC Project water released under Reclamation's Supplemental Water Program, as available, further helps to reduce river drying when MRGCD is in shortage operations. Water from the Supplemental Water Program also contributes to a reduction in drying of the Isleta and San Acacia Reaches.

In the San Acacia Reach, the frequency and duration of river drying also would be increased by the lack of Reclamation's program of pumping water from the LFCC to the river. Without these pumping operations, increased river drying can be expected below each pump site. River drying would occur more often by 8% of the time (33 more days per year on average).

Recruitment and overbank flows in the MRG occur based on hydrologic conditions, but it should be noted that Supplemental Water is likely not of sufficient volume to provide recruitment or overbank flows and has not been modeled for these purposes. Cochiti deviations have the potential to significantly help to increase the frequency of recruitment or overbank flows. Without deviations, it is possible that overbank flows would not occur at all within the next 10 years under conditions represented by the driest hydrologic sequence. Under the wettest hydrologic sequence, up to 4 years without overbank flows could be expected.

6.5.2 Effects of the MRGCD's Proposed Conservation Measures

This section presents hydrologic and biological analyses of the flow-related conservation measures proposed by Reclamation's non-Federal partner, the MRGCD, to the extent that these measures lend themselves to such analysis. The conservation measures evaluated in this section include measures that were undertaken by the MRGCD under the 2003 BiOp as well as proposed new measures.

6.5.2.1 Measures to Enhance Coordination

Though it is difficult to quantify, these measures provide an invaluable tool for water managers and biologists who ultimately reduce the overall take of the species by ensuring that water operations are coordinated efficiently with the larger group. Additionally access to the river for species monitoring and management activities, such as fish salvage, also reduce the take numbers and aid in information gathering.

6.5.2.2 Water Management Related Measures

1. *Maintenance of Perennially Wetted Habitat Through Releases from Drain Outfalls and Wasteways*

As a general practice, the MRGCD will manage its diversions and return flows to the Rio Grande in a way that supports new habitat areas and other designated sites. The MRGCD will identify key target areas where water can be returned, especially during critically dry periods, to maintain wetted habitat for silvery minnow when drying is occurring elsewhere in the river.

Under this conservation measure, the MRGCD will deliver water to drain outfalls and wasteways to better meet the needs of RGSM. These releases will provide discrete wetted sections that will serve as refugia for RGSM, with possible Southwestern willow flycatcher benefit. This conservation measure will include the following elements:

- During critical, low water periods, the MRGCD will manage the release rates for consistency to create refugial habitat.
- As needed, and in coordination with Reclamation and the Service, the MRGCD will manage these returns flows to assist the Service with its RGSM rescue efforts.
- Details (timing, locations, quantity of water) of these releases will be developed through adaptive management.
- This action could increase wetted habitat for silvery minnow during critical low flow periods, which would decrease mortality of silvery minnow. This action may also help maintain vegetation for flycatcher.

2. *Maintenance of Wetted Habitat Downstream from Diversion Structures*

Under certain conditions, by mutual agreement, and contingent on water being physically present, MRGCD will take actions to maintain a small discharge, not to exceed 8 cfs (normal gate leakage) downstream from both the Isleta Diversion Dam and the San Acacia Diversion Dam. It is estimated that, in the Isleta Reach, this amount of water could maintain approximately 200 yards of wetted habitat.

In the San Acacia Reach, channel degradation below the dam has made the river better able to maintain water. Ground water inflow also occurs at this location. Therefore, the dam leakage likely will provide a greater length of wetted habitat, potentially up to a quarter of a mile. Ground water inflow may continue the wetted habitat further downstream.

3. Management of Diversions During Peak Egg Production To Minimize Incidental Entrainment of Silvery Minnow Eggs.

As needed, and in coordination with Reclamation and the Service, the MRGCD will minimize or temporarily suspend diversions during periods of peak egg production to minimize incidental entrainment of eggs and larvae into irrigation canals. This measure has been successful in the past at minimizing egg entrainment. Few eggs are collected during monitoring within the canal system.

4. Acceptance of Conveyance Losses for Supplemental Water

Under the 2003 BiOp, the MRGCD accepted conveyance losses of Supplemental Water. The MRGCD proposes to continue this practice under a new consultation. This conservation measure includes the following elements:

- During normal MRGCD operations, MRGCD will convey Reclamation's Supplemental Water as far as the Isleta Diversion Dam without incurring any consumptive losses. MRGCD will bear all losses to Reclamation Supplemental Water through Cochiti and Angostura Reaches.

- MRGCD will divert Reclamation's Supplemental Water as necessary at the Diversion Dams, leaving an equivalent amount of native Rio Grande water undiverted, if necessary, to meet flow targets. This water accounting exercise provides that the Supplemental Water Program's SJC Project water is fully consumed within the MRG, which is consistent with the intent of the SJC Project to provide for beneficial use of Colorado River water in New Mexico.

- During normal MRGCD operations, the MRGCD will allow a flow of native Rio Grande water equivalent to 50% of Reclamation's Supplemental Water arriving at Isleta Diversion Dam to pass through the San Acacia Diversion after an appropriate time delay. The MRGCD will bear a variable portion of losses to Reclamation's Supplemental Water, dependent on rates of flow and time of year.

In exchange for bearing the losses to Reclamation's Supplemental Water, Reclamation has, over the past 15 years, allowed the MRGCD to divert for irrigation all water remaining in the river downstream from the downstream-most flow target. This feature is also part of the proposed conservation measure under this new consultation. The following analysis compares the amount of water that the MRGCD provides to the Supplemental Water Program to the amount that the MRGCD receives from the Program. This analysis is based on the 2003 BiOp flow targets, which are used in the modeling analyses as example flow targets.

If the amount of water in the Supplemental Water Program is sufficient to meet the flow targets throughout the year (as it has been over the past decade), modeling analyses indicate that this exchange leads to a contribution from MRGCD of about 5% of the total Supplemental Water Released. This situation is broken down below in table 51, as determined from URGWOM simulations of Proposed Water Management Actions with an Unlimited Supply of Supplemental Water.

Table 51. Simulation of Proposed Water Management Actions with Unlimited Supply of Supplemental Water

		Isleta (for 100 cfs at Central dry-year summer flow target)			San Acacia (for continuous flow for average- and wet-year flow requirements)		
Sequence (10-year)	*Additional* Supplemental Water Released under Proposed Action over 10 years.	Supplemental Water Losses Covered by MRGCD	Additional Diversions with Supplemental Water	Net Impact on MRGCD	Supplemental Water Losses Covered by MRGCD	Additional Diversions with Supplemental Water	Net Impact on MRGCD
10 perc	239,712	35,871	15,367	20,504	-1,276	810	-2,086
30 perc	274,430	46,158	13,542	32,616	2,898	1,273	1,626
50 perc	187,087	21,245	17,056	4,189	2,879	1,152	1,727
70 perc	324,494	39,688	30,619	9,069	12,271	2,089	10,182
90 perc	385,282	47,250	43,649	3,601	16,227	2,924	13,304
min	187,087	21,245	13,542	3,601	-1,276	810	-2,086
avg	282,201	38,042	24,047	13,996	6,600	1,650	4,950
max	385,282	47,250	43,649	32,616	16,227	2,924	13,304
total	1,411,005	190,212	120,233	69,979	32,999	8,248	24,752
Total as Percent of Additional Supplemental Water Released		13%	9%	5%	2%	1%	2%

In most years of most sequences of URGWOM simulations of the Proposed Water Management Actions, Reclamation does not have sufficient Supplemental Water to make it through the year. Therefore, the MRGCD provides water to the Program through its acceptance of conveyance losses, but it does not receive the benefit of the use of Supplemental Water for irrigation during periods for which drying is allowed in the Isleta and San Acacia Reaches, since at those times, the Program is usually out of water. Therefore, in the simulations of the Proposed Water Management Actions with the projected supply of Supplemental Water, the exchange results in a contribution from the MRGCD of about 22% of the total amount of Supplemental Water released, as is shown in table 52.

Table 52. Simulation of Proposed Water Management Actions with projected supply of Supplemental Water

		Isleta (for 100 cfs at Central dry-year summer flow target)			San Acacia (for continuous flow for average and wet year flow requirements)		
Sequence (10 years)	Supplemental Water Released under Proposed Action over 10 years	Supplemental Water Losses Covered by MRGCD	Supplemental Water Diverted by MRGCD	Net Impact on MRGCD	Supplemental Water Losses Covered by MRGCD	Supplemental Water Diverted by MRGCD	Net Impact on MRGCD
10 perc	84,582	19,271	191	19,080	2,898	29	2,869
30 perc	84,198	27,497	2	27,495	6,213	-88	6,301
50 perc	70,919	14,140	1,158	12,981	428	313	116
70 perc	84,413	15,730	686	15,045	104	185	-81
90 perc	79,460	13,169	2,569	10,601	147	589	-442
min	70,919	13,169	2	10,601	104	-88	-442
avg	80,714	17,962	921	17,040	1,958	205	1,752
max	84,582	27,497	2,569	27,495	6,213	589	6,301
total	403,572	89,808	4,606	85,202	9,789	1,027	8,762
Total as Percent of Additional Supplemental Water Released		22%	1%	21%	2%	0%	2%

5. *Management of Diversions at Angostura Diversion Dam during MRGCD shortage and conservation operations*

During MRGCD shortage/conservation operations and when the ABCWUA has agreed to suspend diversions of native Rio Grande water, the MRGCD will reduce diversions at Angostura Diversion Dam to the minimum practical rate of flow required to meet irrigation demand within the Albuquerque division, as occurred during the fall of 2011. Diversion rates needed to serve the Albuquerque Division are typically less than 200 cfs. Any additional water available in the river will remain in the river as far as Isleta Diversion Dam.

6. Borrow/Payback during Travel Time for Supplemental Water

Under certain conditions, by mutual agreement and to prevent delay, when Reclamation has begun releasing Supplemental Water, but that water has not yet reached its intended destination, the MRGCD will assist Reclamation to achieve intended rates of flow at target locations. A simple analysis of this exchange of water indicates that, if 100 cfs is released from Abiquiu under the Supplemental Water Program and it takes 2 days for that water to reach Central Avenue, MRGCD would loan approximately 400 AF of water to the Supplemental Water Program to meet a target flow at Central Avenue. This provides more flexibility in water management and reduces take of silvery minnow.

6.6 Interrelated and Interdependent Actions

In addition to activities authorized, funded, or carried out by Federal agencies, Section 7 consultation regulations also require agencies to analyze the effects of interrelated and interdependent actions along with the direct and indirect effects of the proposed action. Interdependent actions are those having no independent utility apart from the Proposed Action (defined in 50 CFR §402.02). Interrelated actions are those actions that are part of a larger action and depend on the larger [proposed] action for their justification (defined in 50 CFR §402.02). The Proposed Action model runs also include the interrelated and interdependent actions of the Corps and the New Mexico State Engineer as described below (see table 53).

6.6.1 The Corps Actions Related to the SJC Project

Reclamation has determined that the following components of the Corps' actions are interrelated and interdependent with Reclamation's actions:

1. Storage of SJC Project water in Abiquiu Reservoir.
2. Use of SJC Project water to offset evaporation and other depletions occurring at the Cochiti Reservoir recreational pool.

6.6.1.1Storage for SJC Project Contractors at Abiquiu Reservoir

The Corps stores up to approximately 180,000 AF of SJC Project water in Abiquiu Reservoir pursuant to agreements with SJC Project contractors. The contractors take ownership of their SJC Project water upon release from Heron Dam by Reclamation and can elect to deliver this water to Abiquiu Reservoir for storage.

As discussed in the following Effects Analysis, the transport of SJC Project water within the Rio Grande Basin is beneficial to listed species and designated critical habitat because it increases both the discharge rate and volume above that of natural flow. Water stored by non-Federal entities in Abiquiu Reservoir also has been used, at their discretion, to offset ground water depletions or has been made available for purchase or lease by others, including Reclamation for its Supplemental Water Program. Reclamation expects these uses to continue in the future.

No listed species or designated critical habitat occurs between Heron Dam and Abiquiu Dam; therefore, the discretionary storage of SJC Project water in Abiquiu Reservoir will have no effect on the silvery minnow, flycatcher, or designated critical habitat of these species. The related release of such water—at the discretion of other entities—is benign or beneficial to the minnow, flycatcher, and their designated critical habitat. There is no effect on Pecos sunflower.

6.6.1.2 Use of SJC Project Water for Cochiti Recreation Pool Replacement Water

The Corps uses SJC Project water at the end of spring runoff and during the winter months to replace water that has evaporated from the Cochiti Recreation Pool. The elevation of the recreation pool increases approximately 1 to 1.5 feet with partial delivery of replacement water, and up to 3 feet after all replacement water is delivered in a given year. The Corps follows recommendations from a multi-agency biological advisory group to maximize the benefits of the replacement water to the wetlands in the delta area of Cochiti Lake (Allen et al. 1993). The use of water for the recreation pool does not change the hydrograph downstream from Cochiti Dam.

The Rio Grande silvery minnow does not occur between Heron Dam and Cochiti Lake, nor does designated critical habitat for this species.

Designated critical habitat for flycatcher does not occur between Heron Dam and Cochiti Lake. Flycatchers are known to use the river corridor upstream of Cochiti Lake during spring migration (Reclamation 2010) and are presumed to be similarly present during fall migration. The annual replenishment of evaporation losses at Cochiti Lake maintains existing riparian and wetland habitat immediately upstream of the permanent pool. Therefore, the use of recreation pool replacement water would have no effect on flycatcher. This action may have an indirect, beneficial effect by maintaining riparian habitat used by migrating flycatchers. There is no effect on Pecos sunflower.

6.6.2 The New Mexico State Engineer's Actions Related to the SJC Project

For each ground water pumper with SJC pumper water that needs or chooses to release SJC Project water for offset, the NMOSE provides Reclamation with letters describing, the volume of SJC Project water that must be released by Reclamation or MRGCD and a deadline to do so. The depletions are described by the NMOSE as cumulative effects on Elephant Butte Reservoir (and, therefore, to New Mexico's deliveries under the Compact) and cumulative effects on the Rio Grande in the MRG due to depletions above and/or below the Otowi gage.

Depletions that occur during the irrigation season when MRGCD is releasing stored water to meet demand are considered effects on the MRG and are replenished by exchange of the SJC Project water in storage to MRGCD, which holds that water for release when needed to meet demand. As such, it provides an offset of the ground water pumping effects on the river system. Depletions that occur outside of the irrigation season are considered effects on Elephant Butte Reservoir. The required amount of SJC Project water is generally released to the Rio Grande in the winter for delivery to Elephant Butte Reservoir.

6.7 Summary Effects Analysis of Proposed Water Management Actions

6.7.1 Summary of the Effects of Reclamation's Actions

The analyses show that Reclamation's ability to affect the timing and distribution of flows in the MRG is extremely limited. Reclamation's actions affect only imported SJC Project water and the portion of the native flows of the Rio Chama, a tributary to the Rio Grande, that are stored in El Vado Reservoir. Reclamation has no ability to affect the flows of the Rio Grande main stem that comprise a strong majority of the flow in the MRG.

Although Reclamation's discretionary actions have limited impact on flows in the MRG, model simulations demonstrate that these limited influences are, on the whole, positive, as measured by the ability to maintain summertime flows in the MRG. Additionally, since Reclamation's storage of water in the springtime only diminishes flows of the Rio Chama in the reach between El Vado Dam and Abiquiu Reservoir, Reclamation's actions have very little influence on the size and timing of the spring snowmelt runoff. The primary spring runoff , which has been correlated with the spring spawn of the minnow, comes from the main stem of the Rio Grande and is larger, longer in duration, and later in time than the runoff from the Rio Chama. Flows on the Rio Chama are limited to 1,800 cfs by the Corp's flood control operations at Abiquiu Dam; and, therefore, the Rio Chama on its own, with or without operation of Reclamation's Projects, cannot cause a flow in the MRG of greater than 1,800 cfs.

The water that the MRGCD diverts consists of the natural flows of the main stem of the Rio Grande and its tributaries, as well as native Rio Grande water released from El Vado Reservoir and imported SJC water from Reclamation's SJC Project. About 90% of the flows in the MRG are composed of natural flow that is native to the basin and has not been regulated by reservoirs. These natural flows provide 79.2% of the MRGCD's diversion demand, which is used to meet the needs of the

Six MRG Pueblos, MRGCD irrigators, and BDANWR. Only 5.9% of the MRGCD diversion demand is met with water released from storage at El Vado Reservoir. Reclamation's operation of Heron Dam under the SJC Project accounts for approximately 6.7% of the MRGCD diversion demand.

6.7.2 Summary of the Effects of MRGCD's Water Management Actions

The MRGCD's permit from the New Mexico Office of the State Engineer to divert flows of the Rio Grande allows the MRGCD to divert up to 100% of the available natural flow in the MRG. The MRGCD has been diverting flows from the Rio Grande, to serve irrigated acreages at and above the current level since the early 1930s. The MRGCD system replaced a pre-existing, acequia-based diversion and irrigation system that had been in place for hundreds of years, with a maximum irrigated acreage of 180,000 acres in the late 1800s.

These diversions have the effect of reducing Rio Grande flows during the irrigation season. During times of high flows, the impact may be minor. During times of lower flow, the effect may be significant and may result in river drying. However, it should be noted that, in most years, the natural flow of the Rio Grande is insufficient to sustain riparian evapotranspiration and open water evaporation of the MRG, so that drying likely would occur in the absence of MRGCD diversions. During those times, MRGCD submits requests to Reclamation to release stored water from El Vado Reservoir (when available) to augment the natural flow of the Rio Grande to the level required for MRGCD diversion works to function. During full irrigation system operations, this results in continuous flow as far downstream as Isleta Diversion Dam. The MRGCD can supply irrigation water to all of its members with no flow downstream from the Isleta Diversion Dam, since the needs of the Socorro Division (otherwise served by the San Acacia Diversion Dam) can be met by return flows from the Belen Division, transported between divisions using the Unit 7 Drain, a State drain, as a conveyance.

The effect of MRGCD diversions is to reduce flow in the Rio Grande downstream from those diversions during the irrigation season. However, the effect of operations of El Vado Reservoir, which support these diversions, is to increase flows upstream of those diversions during the same time period. Significant river drying could still occur in the MRG without the combined effects of El Vado operations and irrigation diversions. Flows from MRGCD drains and wasteways can increase flows in critical reaches, especially in the Albuquerque and Isleta Reaches.

6.7.3 Summary of Effects on Silvery Minnow

The Proposed Action includes operation of Heron Dam, El Vado Dam, and MRGCD Diversion Dams as well as interrelated and interdependent actions of the Corps. The Proposed Action has adverse effects to spawning and recruitment due to decreased peak flows and juvenile and adult survival due to low flows and drying. There is little difference between the Proposed Action and No Action scenarios in the duration of flows high enough to have channel altering capacity, so there is little direct effect to current silvery minnow habitat features within the MRG.

Reclamation's Proposed Action is specific to storage and later release of water from SJC Project water from Heron Reservoir and native Rio Chama water from El Vado Reservoir. The water then passes through two other reservoirs, operated by the Corps, prior to reaching occupied silvery minnow habitat. Stored SJC Project water is released for contractors as additional water to the Rio Grande and is beneficial to the silvery minnow.

MRGCD operations of existing diversions have a more direct effect on silvery minnow by decreasing the amount of water in the river during irrigation season. The decrease of water in the river leaves less wetted habitat for silvery minnow at both high and low flows, and ultimately decreases the population size that inhabits the river. Additionally, diversion structures cause fragmentation of silvery minnow population and habitat.

A summary of the action by action analysis is listed below.

Reclamation's Operation of Heron Dam:

- Provides a potential benefit to silvery minnow and designated critical habitat by adding imported water to the system and decreasing the likelihood of summer drying especially in the Angostura Reach upstream of Isleta Diversion Dam.

Actions by Reclamation and MRGCD Related to the Operation of El Vado Dam:

- Limited decrease in duration and magnitude of spring peak flow in silvery minnow designated critical habitat may adversely affect silvery minnow spawning and recruitment.

- Provides a potential benefit to silvery minnow and silvery minnow designated critical habitat by releasing stored water later in the irrigation season and decreasing summer drying.

MRGCD's Water Management Actions:

- Diversions decrease the amount of water within the river during the irrigation season, which may adversely affect the silvery minnow and their designated critical habitat by reducing the amount of wetted habitat.

- Diversions also create barriers to upstream movement of fish and affect the geomorphology of the river, which is likely to adversely affect silvery minnow and their designated critical habitat.

- Flows from MRGCD drains and wasteways can increase flows in critical reaches, especially in the Albuquerque and Isleta Reaches.

6.7.4 Summary of Effects on Flycatcher

Overall, Reclamation's Proposed Actions of storage and release of water from Heron and the combined operation of El Vado Reservoirs by Reclamation and MRGCD is mainly beneficial or likely to not adversely affect flycatchers or flycatcher critical habitat. The MRGCD proposed actions, however, are generally more negative in nature as the process of diverting water within the river during irrigation season removes water from the river system where flycatchers establish territories. A summary of the action-by-action analysis is listed below:

Reclamation's Operation of Heron Dam:

- Provides a potential benefit to flycatchers and flycatcher designated critical habitat by decreasing summer drying.

Actions by Reclamation and MRGCD Related to the Operation of El Vado Dam:

- Provides a potential benefit to flycatchers and flycatcher designated critical habitat by decreasing summer drying.

MRGCD's Water Management Actions:

- Diversions decrease the amount of water available for riparian vegetation used by flycatchers, which may adversely affect the species and their designated critical habitat.

- These diversions also decrease the amount of potential inundation of overbank habitat, which has effects for territory establishment of flycatchers.

6.7.5 Summary of Effects on Pecos Sunflower

- The Proposed Action is beneficial to Pecos sunflower within the La Joya WMA due to delivery of water.

- Reclamation's Proposed Action that is specific to storage and later release of San Juan Chama water from Heron is not likely to adversely affect Pecos sunflower.

- The combined Reclamation and MRGCD operation of El Vado Reservoirs that is specific to storage and release of water is not likely to adversely affect Pecos sunflower and may have some beneficial effects due to delivery of water to the La Joya Waterfowl Management Area.

- MRGCD activities have a direct beneficial effect on the Pecos sunflower through beneficial delivery of water to the La Joya Waterfowl Management Area.

- The newly established, Rhodes population may be affected by actions that decrease overbank flows such as storage and diversion of spring flows, but effects of the Proposed Action are insignificant and therefore not likely to adversely affect Pecos sunflower.

6.7.6 Summary of Effects of Conservation Measures.

Conservation measures have been developed to attempt to minimize the adverse effects of the proposed actions, especially by adding additional water to the river during low flow periods as well as the deviation program developed by the Corps to enhance high flow events. The Collaborative Program is also included as a conservation measure and will identify and implement actions that assist in the recovery of the species. For the purposes of the Section 7 consultations, it is assumed that:

1. Collaborative Program activities will continue to be implemented to assist in the recovery of the species, including water acquisition and management, habitat restoration, endangered species monitoring, and silvery minnow propagation.
2. The funding will be available to implement these actions.
3. Collaborative Program signatories will take appropriate steps to implement those actions.
4. Actions will be implemented in accordance with the schedule agreed to by the signatories.

7. Cumulative Effects Analysis

Cumulative effects are effects of future non-Federal (State, local governments, or private) activities on endangered and threatened species or critical habitat that are reasonably certain to occur within the action area of the actions subject to consultation. This cumulative effects analysis considers those non-Federal activities that may occur in the foreseeable future. The effects of non-Federal actions included in this BA as proposed actions and analyzed in the direct and indirect effects sections are not included in the cumulative effects analysis.

The following section shows a potentially dire water supply outlook for the MRG: the climate is projected to become warmer and dryer; population growth is projected to increase; and the current demand for water in the MRG outstrips the variable supply. Therefore, water management in the MRG will only become more challenging.

7.1 Future Changes in Climate and Hydrology

In future years, more pronounced changes are anticipated in the climate in the MRG Basin, including greater increases in average temperature, earlier snowmelt runoff, and even greater hydrologic variability. Projected changes in the climate and hydrology of this region were summarized in the Secure Water Report (Reclamation 2011), which Reclamation recently published and delivered to Congress, as required by the 2009 Secure Water Act. The projections summarized in that report were developed from the World Climate Research Programme Coupled Model Intercomparison Project3 (WCRP CMIP3) climate projections, which were bias-corrected and spatially downscaled to this region (http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections). The results suggest that average temperatures throughout the Rio Grande Basin may increase steadily during the 21st century. The basin-average mean-annual temperature is projected to increase by 5–6 °F during the 21st century (figure 91). The range of annual variability widens through time.

There is significant disagreement among the climate projections regarding the likely change in annual precipitation over the region. However, the combined mean from numerous projections suggests that mean-annual precipitation, averaged over the MRG Basin may gradually decrease during the 21st century. The projections also suggest that annual precipitation in the MRG Basin will remain quite variable over the next century (figure 91). The character of precipitation within the MRG Basin is expected to change in such a way that there are more frequent rainfall events and less frequent snowfall events.

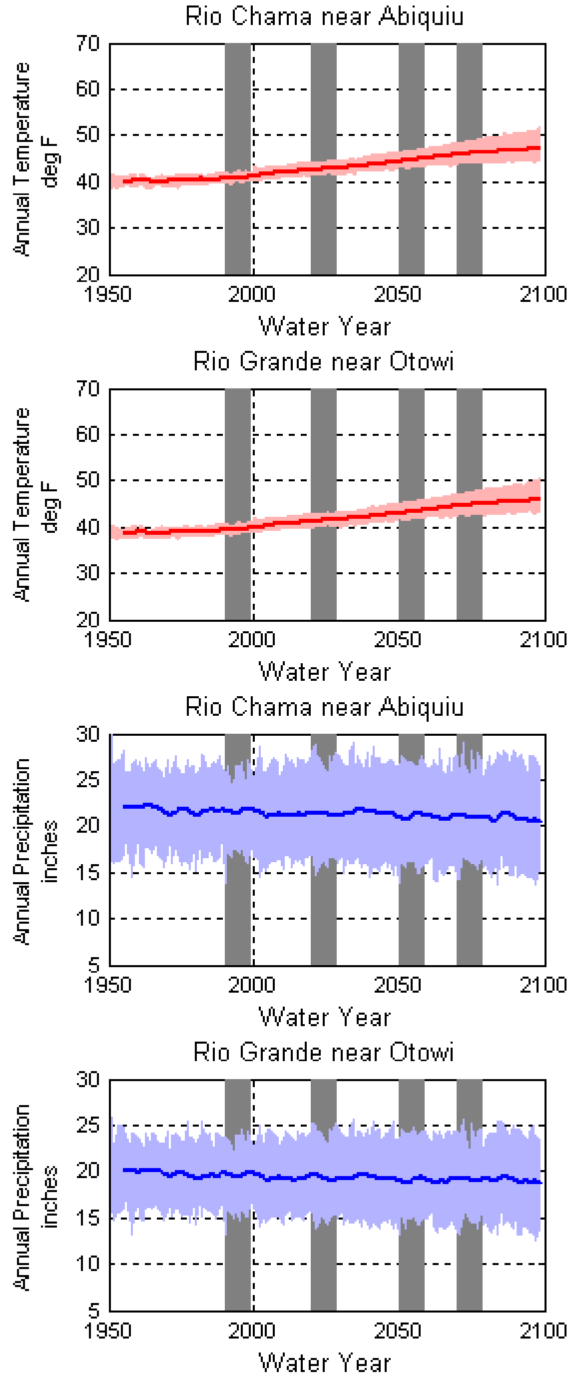

Figure 91. Simulated annual climate averaged over Rio Grande sub-basins.

Warming is expected to diminish the accumulation of snow during the cool season (i.e., late autumn through early spring) and the availability of snowmelt to sustain runoff to the MRG during the warm season (i.e., spring through early summer). Although increases or decreases in cool season precipitation could offset or amplify changes in snowpack, it is apparent that the projected warming in the Rio Grande Basin tends to dominate projected effects. Snowpack decreases are expected to be more substantial over the lower-lying portions of the basin where baseline cool season temperatures are generally closer to freezing thresholds and more sensitive to projected warming. Changes in climate and snowpack within the MRG Basin will change the availability of natural water supplies. These changes may be to annual runoff or to runoff seasonality. For example, warming without precipitation change would lead to increased evapotranspiration from the watershed and decreased annual runoff. Increases or decreases in precipitation (either rainfall or snowfall) would offset or amplify the effect. Results suggest that annual runoff changes generally are consistent throughout the basin, although local variations associated with elevation and baseline climate are evident. For example, annual runoff reductions in the Rio Chama at Abiquiu, draining the northwestern reaches of the basin, are projected to be somewhat less than reductions found at river locations draining the northern and eastern portions of the basin. However, at all locations, decade-mean annual runoff is projected to steadily decline through the 21st century, responding to both slight decreases in precipitation and warming over the region (figure 92).

The seasonality of runoff also is projected to change in the MRG in such a manner that, over time, winter flows increase and spring flows decrease. Warming would be expected to lead to more rainfall and runoff, rather than snowpack accumulation, during the winter. Conceptually, this change would lead to increases in the December–March runoff and decreases in the April–July runoff. As can be seen on figure 92, this concept is supported by results for the December through March seasonal runoff in the Rio Chama at Abiquiu, as projected mean winter runoff increases for the 2020s, 2050s, and 2070s.

However, for the three locations shown on the Rio Grande (Rio Grande at Lobatos, Rio Grande near Otowi, and Rio Grande below Elephant Butte), mean seasonal runoff changes during December through March generally follow mean annual runoff changes, without this shift from April-through-July to December-through-March runoff. However, at all four of the locations shown on figure 92, mean April-through-July runoff is expected to decline; and these declines are expected to become greater in magnitude over the course of the 21st century.

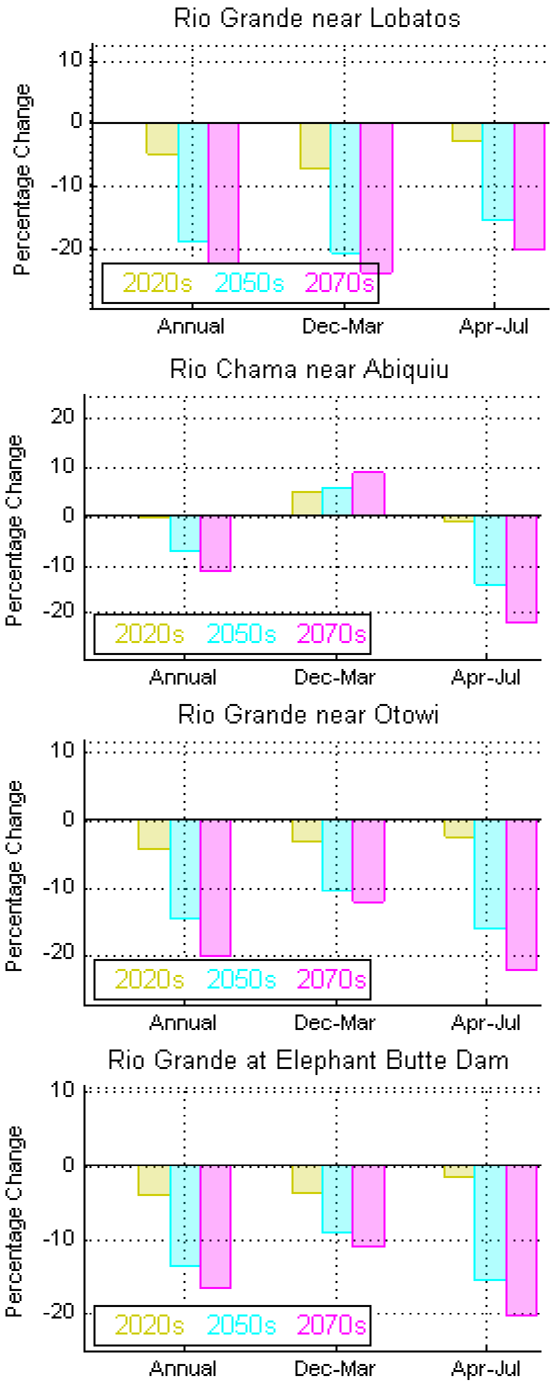

Figure 92. Simulated changes in decade-mean runoff for several sub-basins in the Rio Grande Basin.

Changes in the magnitude of flood peaks also are expected in the MRG (table 53), although there is less certainty in the analysis of these types of acute events than there is for changes in annual or seasonal runoff. Annual maximum week runoff (the maximum weekly average flowrate) and minimum week runoff (the minimum weekly average flowrate), as metrics of acute runoff events (figure 93), indicate that annual maximum week runoff may gradually decline during the 21st century. Results are generally consistent across the sub-basins shown. These results suggest that future flood events in the Rio Grande may be smaller in magnitude than those experienced in the 1990s, although the streamflow variability is expected to continue to be large. These changes have implications for flood control and ecosystem management. However, it is important to note that there is a high degree of variability among model simulations suggesting there is a high degree of uncertainty in this flood metric.

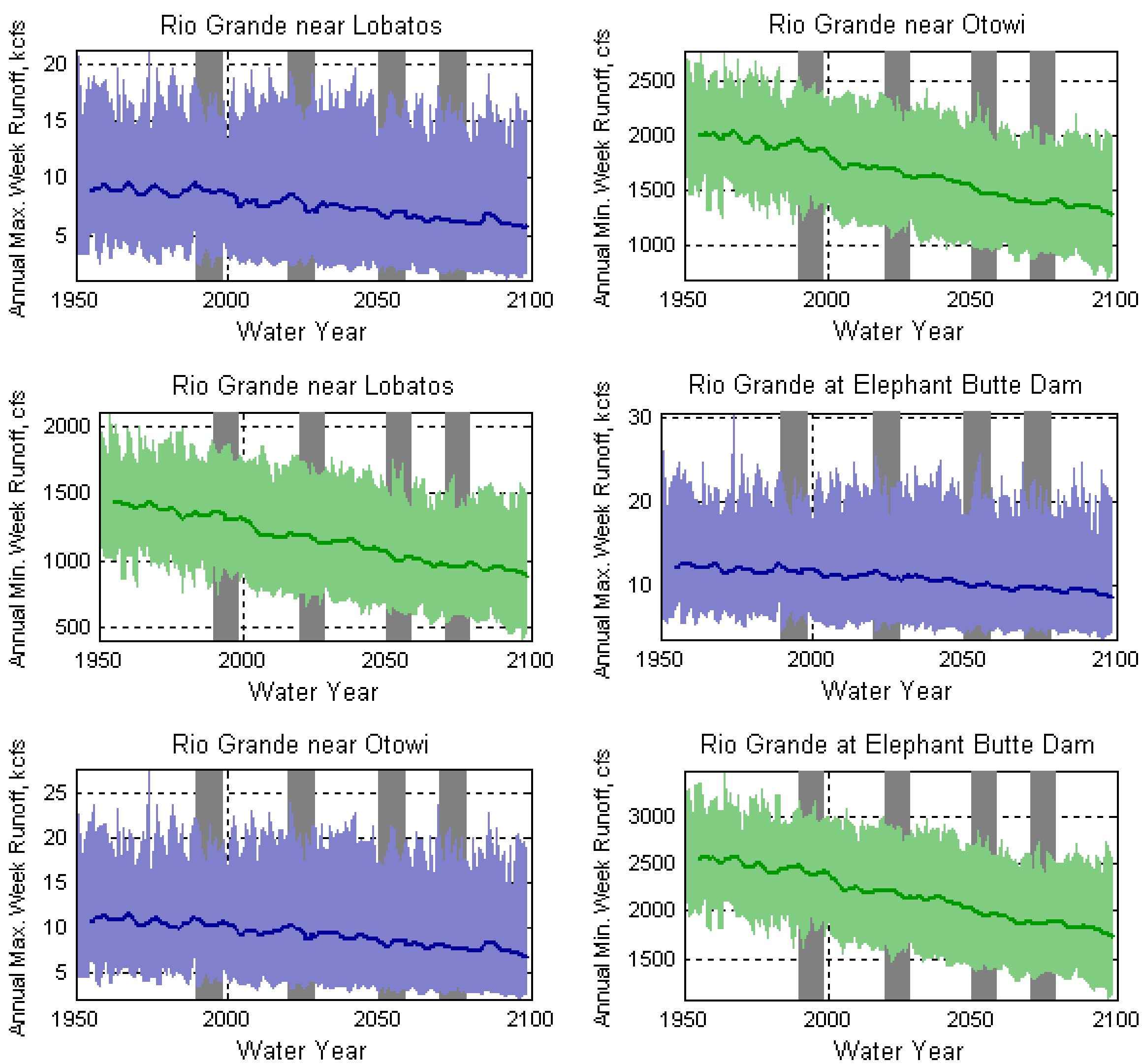

Figure 93. Simulated annual maximum and minimum week runoff for several sub-basins in the MRG Basin.

Table 53. Summary of simulated changes in decadal hydroclimate for several sub-basins in the MRG Basin

Hydroclimate Metric (change from 1990s)	***2020s***	***2050s***	***2070s***
Rio Chama near Abiquiu			
Mean Annual Temperature (°F)	1.9	3.8	5.3
Mean Annual Precipitation (%)	-1.1	-2.3	-2.5
Mean April 1 Snow Water Equivalent (%)	-47.6	-61.4	-68.2
Mean Annual Runoff (%)	-0.2	-7.3	-11.0
Mean December-March Runoff (%)	4.8	5.5	8.6
Mean April–July Runoff (%)	-1.3	-13.9	-21.7
Mean Annual Maximum Week Runoff (%)	-4.3	-9.5	-14.9
Mean Annual Minimum Week Runoff (%)	-12.1	-19.2	-23.9
Rio Grande near Otowi			
Mean Annual Temperature (°F)	1.9	3.7	5.2
Mean Annual Precipitation (%)	-1.5	-2.5	-2.4
Mean April 1 Snow Water Equivalent (%)	-48.5	-63.8	-72.9
Mean Annual Runoff (%)	-4.4	-14.4	-19.9
Mean December–March Runoff (%)	-3.1	-10.4	-12.0
Mean April–July Runoff (%)	-2.5	-15.9	-21.8
Mean Annual Maximum Week Runoff (%)	-9.3	-20.3	-25.3
Mean Annual Minimum Week Runoff (%)	-11.7	-21.6	-26.3
Rio Grande below Elephant Butte Dam			
Mean Annual Temperature (°F)	1.9	3.7	5.1
Mean Annual Precipitation (%)	-0.9	-2.3	-1.9
Mean April 1 Snow Water Equivalent (%)	-72.4	-80.7	-85.3
Mean Annual Runoff (%)	-4.1	-13.5	-16.4
Mean December–March Runoff (%)	-3.6	-8.9	-10.9
Mean April–July Runoff (%)	-1.6	-15.4	-20.0
Mean Annual Maximum Week Runoff (%)	-6.1	-15.7	-18.8
Mean Annual Minimum Week Runoff (%)	-9.6	-18.2	-22.4

Annual minimum-week streamflows also are projected to decline during the 21^{st} century (figure 85). These results suggest that future low flow periods in the Rio Grande may be drier still. However, there is a high degree of variability among model simulations, suggesting that there is a high degree of uncertainty in the magnitude of this trend. Nevertheless, nearly all projections show an overall decrease in low flow values.

7.2 Regional Water Planning: Projected Impact of Population Growth and Water Demand on Water Supplies

Historically, land use in the MRG region depended solely on surface water; however, the shift from being a dominantly rural population to being a dominantly urban population has resulted in increased ground water consumption and reduced aquifer recharge. The continued growth of human population and water-based industry in the MRG affects the availability of all water supplies, both ground and surface water - native and imported.

In New Mexico, the surface waters of the Rio Grande have been considered fully appropriated since the Compact was consummated, and the NMOSE does not allow new Rio Grande surface water appropriations (NMOSE 2000). As discussed in section 5, the NMOSE conjunctively manages surface and ground water resources within the Rio Grande Basin because ground water diversions from aquifers hydrologically connected to the Rio Grande affect the fully appropriated surface flow (NMOSE 2000). Therefore, an increase of water use in any one sector requires a reduction or transfer of use from another sector if the water supply balance is to be maintained.

Under New Mexico law, a "disconnect" exists between land use planning and water rights administration. State statutes delegate land use decisions to cities and counties, while water rights administration is delegated to the NMOSE. The New Mexico Subdivision Act requires that the NMOSE advise whether, in its opinion, an adequate supply exists for new larger subdivisions that are outside of municipal jurisdictions (NM Stat. § 47-6-1 et seq.). A finding that the supply is not adequate, however, does not prevent county government approval of the subdivision (Land and Water 2011).

In 1987, the New Mexico Legislature[27] recognized the State's need for water planning and created the State's regional water planning program to balance current and future water needs for a region. Just upstream of the MRG and within the action area of this BA is the Jemez y Sangre Planning Region (Embudo to upstream of Cochiti Reservoir), which includes Española, Los Alamos, Santa Fe, and surrounding areas. The MRG is contained in two of the State's 16 water planning regions: the Middle Rio Grande Planning Region (downstream from Cochiti Dam to Soccorro) and the Socorro and Sierra Planning Region (Socorro to below Caballo Dam). Unfortunately, water plans are not commonly implemented

[27] In 2003, the New Mexico Legislature mandated that the State develop a State Water Plan to provide a blueprint for the State to move forward into the 21st century with 21st century techniques and technologies applied to conserve and to increase the supply of water. NM Stat. § 72-14-3.1 (2011).

because they are not supported by appropriate regulations, development decisions, or in conformity with the plans; and they become outdated (Land and Water, 2011).

7.2.1 The Jemez y Sangre Planning Region

The 2003 Jemez y Sangre Regional Water Plan (JyS Plan) includes the Rio Arriba, Los Alamos, and Santa Fe Counties and all or part of eight Pueblos. The JyS Plan states that demand for water may exceed available supply during years of average precipitation and that demand exceeds supply during drought years.

The region's surface water supply for agricultural use comes primarily from the Rio Grande and the Rio Chama. The city of Santa Fe receives approximately 40% of its supply from dams in the Santa Fe River watershed above the city (JyS Plan). As discussed in Section 5, Environmental Baseline, of this BA, the city of Santa Fe and Santé Fe County have initiated, under the Buckman Project, direct use of their 5,605 AFY allocation of SJC Project and native Rio Grande water to supplement their other water supplies and have been diverting water from the Rio Grande since January 2011. Ground water is the primary supply for municipal and industrial uses and provides a small amount for agricultural use (JyS Plan).

The city of Santa Fe and areas of Santa Fe County close to the city are among the fastest growing areas in the State. The population of the region nearly doubled from 1970 to 2000; however, population growth is projected to slow during the first half of this century. The population is projected to increase from about 160,000 in 2000 to about 360,000 by 2060, and nonagricultural demand for water in 2060 is projected to be 31,500 AFY greater than current demand. Agricultural use is on a decline in the region; therefore, the increased demand for nonagricultural use potentially could be met. However, the amount of wet water currently in agricultural use is uncertain because water diverted for agricultural use is not measured or monitored, and the water rights in the region have not been adjudicated (JyS Plan).

The JyS Plan found that the projected supply and demand gap cannot be entirely eliminated through conservation or growth management. Moreover, the available SJC Project water would only meet 40% of the projected gap in the best case scenario. Additionally, reductions in agricultural uses and the elimination of all outdoor watering may be detrimental to public welfare. Some of the JyS Plan recommendations for remedying the supply shortfall are as follow:

- Create advisory boards.
- Adjudicate water right.
- Restore watershed.

- Manage storm water to enhance recharge.
- Conduct pilot cloud seeding project.
- Evaluate establishing critical management areas to protect ground water resources.
- Develop conjunctive use strategies.
- Appropriate flood flows.
- Require wastewater reuse.
- Encourage rainwater collection.
- Line ditches.
- Remove sediment in Santa Cruz Reservoir and investigate Nambe Reservoir.
- Repair leaks in water systems.
- Consider aquifer storage and recovery of excess water.
- Pursue increased storage capacity in Abiquiu Reservoir.
- Pursue water conservation.
- Pursue growth management to reduce demand.
- Limited use of domestic wells (JyS Plan).

7.2.2 The Middle Rio Grande Planning Region

The 2004 MRG Regional Water Plan (MRG Plan) comprises Sandoval, Bernalillo, and Valencia Counties, the Six MRG Pueblos—and an area covering more than 5,000 miles. More than half of New Mexico's population makes its home in the MRG planning region, and it is the largest urban water user in the State. The MRG region averages just 9 inches of rain per year and relies on surface and ground water to supply the industry, agriculture, environment, and people of the region. Surface water supplies include the Rio Grande, Rio Jemez, the Rio Puerco, and the SJC Project. Surface flows are augmented by pumped ground water in the form of 'return flows' of treated sewage, and there is an ongoing exchange between surface water and the shallow aquifer. As discussed in Section 5, Environmental Baseline, of this BA, until 2008, the city of Albuquerque's and Bernalillo County's potable water supplies were provided exclusively from ground water. Population in the region had grown by 21% since 1993 and continues to expand by about 15% each decade, which will result in even greater deficits in the future, unless some conservation actions are taken (MRG Plan).

On average, water use in the region exceeds its renewable supply by approximately 55,000 AFY, which was being supplied by nonrenewable ground water. If no remedial actions are taken, the consumptive use by the region could result in a 150,000 AFY deficit by 2050 (figure 94) (MRG Plan).

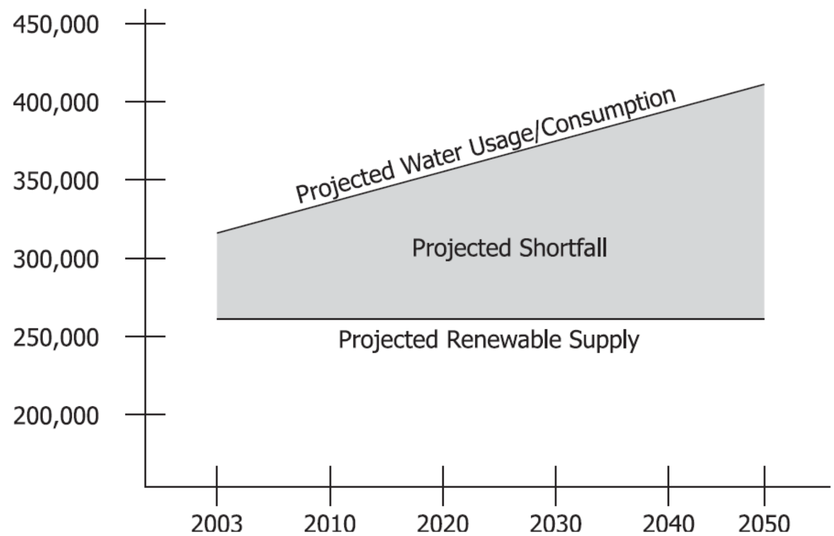

Figure 94. Projected MRG water supply shortfall (MRG Plan).

The following are some of the MRG Plan recommendations for remedying the supply shortfall:

- Establish a domestic well policy.
- Outdoor conservation programs.
- Rainwater harvesting.
- Conversion to low flow appliances.
- Urban water pricing.
- Greywater reuse.
- Treated effluent re-use.
- Growth of parks and golf courses.
- Watershed management plans.
- Water banking.
- Land use management and planning.
- Measure all water uses.
- Upgrade agricultural conveyance systems.

- Level irrigated fields.
- Implement upstream surface water storage.
- Implement upstream aquifer water storage.
- Implement aquifer storage and recovery for drought.
- Develop new water supplies through desalination.
- Investigate the potential for importing water (MRG Plan).

7.2.3 The Soccoro-Sierra Planning Region

The 2004 Soccoro-Sierra Regional Water Plan (SS Plan) includes Socorro and Sierra Counties, the latter of which is outside the action area for this BA, and covers an area of approximately 11,000 square miles. In 2004, the population in the region doubled over the last 30 years to 31,400 and was expected to increase 70%, reaching 60,000 persons in 2040. Surface water supply for the region includes the Rio Puerco, Rio Salado, and ungaged tributaries east and west of the Rio Grande; and the region has significant supplies of ground water. The SS Plan determined that demands from both human and natural processes deplete scarce water supplies, and demand outstrips supply by approximately 77,900 AFY. Results of modeling indicated that, in a low flow year, the supply falls short of meeting demand by 194,000 AF (SS Plan).

The following are some of the SS Plan recommendations for remedying the supply shortfall:

- Improve the efficiency of surface water irrigation conveyance systems.
- Improve onfarm efficiency.
- Control brush and weeds along water distribution systems and drains.
- Control nonreservoir surface water evaporation by reducing surface water in engineered and natural locations.
- Require proof of sustainable water supply for approval of new developments.
- Encourage retention of water within the planning region.
- Remove exotic vegetation (i.e., salt cedar, Russian olive) on a wide scale.
- Manage watersheds to increase yield and improve water quality.
- Develop economic potential for non-native species removal, harvest, and product output by local industries.

- Make water rights a noncondemnable resource.
- Improve reservoir management for better coordination of flows with demand.
- Identify and protect areas vulnerable to contamination.
- Adopt and implement local water conservation plans and programs, including drought contingency plans.
- Facilitate interregional water management decisions, public participation, and funding (SS Plan).

7.2.4 The MRG Water Assessment, the Water Budget, and Water Conservation

In 1997, Reclamation authored a report that assessed how human manipulation of the hydrologic system, in association with changing land use, has affected water resources in the MRG (Reclamation 1997). The Water Assessment was Reclamation's contribution to a multiagency effort, led by the city of Albuquerque, to better understand and to protect the aquifer in the MRG. The report found that meeting demands on the hydrologic system created by urbanization, agriculture, and other emerging needs will require adept and expedient regional cooperation for planning and implementing new approaches to land and water resource management. It presented that no magic bullet exists to solve the problem, that business as usual could result in gridlock, and that regional partnerships between competitors, along with innovative solutions were needed to meet the region's future water resource needs (Reclamation 1997).

In 1999, the Action Committee of the Middle Rio Grande Water Assembly published the Middle Rio Grande Water Budget (where water comes from, goes, and how much), Averages 1972–1997 (Water Budget 1999). The purpose of the Water Budget was to inform a broad audience of people interested in the MRG's water resources, with the hope that a well informed public would improve public input and water stewardship. Most significantly, the Water Budget found that a wet water deficit of 70,000 AFY (Water Budget 1999). See table 54.

Table 54. Middle Rio Grande water budget annual surface-water and ground water averages (rounded) for 1972–1997 (Water Budget 1999)

Annual Surface-Water Inflow		Amount (Native Water) (1000 ac-ft)	Annual Variability (1000 ac-ft)
Rio Grande native water at Otowi Gage ("Otowi Index")		1,100	297-2,170
San Juan-Chama Project imported water reaching Otowi Gage		55	2-150
Tributary inflow (the rios Santa Fe, Galisteo, Jemez, Tijeras, Puerco, Salado)		95	
Ungaged tributaries		unknown	
Storm-drain inflow from Albuquerque		5	
Municipal Wastewater inflow (pumped from groundwater)		70	
Discharge from shallow aquifer to surface system	*Otowi to San Acacia*	220	
		1545	
Annual Surface-Water Outflow			
Recharge to shallow aquifer	*Otowi to San Acacia*	295	
Open-water evaporation (incl.from farm fields)	*Otowi to San Acacia*	60	±30
Irrigated agriculture and valley-floor turf	*Otowi to San Acacia*	100	±30
Riparian ET, irrig. agric. & open-water evap.	*Combined below San Acacia*	100	80-180
Elephant Butte evaporation		140	41-228
Surface-water outflow from Elephant Butte Dam to downstream users		**850	300-1,435
		1545	
Groundwater Recharge(+) & Discharge(-)			
SHALLOW AQUIFER (underlying Rio Grande flood plain)			
Recharge {from surface wtr & percolation from irrig)	*Otowi to San Acacia*	+295	
Septic-tank return flow (from pumping)	*Otowi to San Acacia*	+ 10	
Inflow from deep aquifer	*Otowi to San Acacia*	+ 50	
Riparian evapotranspiration (all non-crop ET)	*Otowi to San Acacia*	- 135	
Discharge to surface-system drainage ditches	*Otowi to San Acacia*	- 220	
		0	
DEEP AQUIFER			
Deep groundwater inflow (from north & west)		+ 40	
Mountain-front & tributary recharge	*Otowi to San Acacia*	+110	
Groundwater pumped (all wells)	*Otowi to San Acacia*	- 170	
Consumed (that is, evaporated)	90		
Municipal wastewater to river	70		
Septic-tank return flow to shallow aquifer	10		
Outflow to shallow aquifer		- 50	
Groundwater mined from aquifer	*Otowi to San Acacia*	- 70	

7.2.5 Local Government Water Conservation Efforts

Local governments, specifically the County and city of Santa Fe and Santé Fe County, the city of Albuquerque, and the County of Bernalillo (ABCWUA), have undertaken substantial efforts to reduce use of and conserve water.

Santa Fe's longstanding water conservation and drought management programs have been successful in declining total annual water diversions (29%) to serve a growing number of customers (14%) since 1995. The annual water diversions shrunk to 9,226 acre-feet in 2010, compared with 12,737 acre-feet in 1995, while the number of customers served increased to approximately 79,244 people in 2010, from an estimated 67,839 in 1995. Santa Fe's water customers reduced their water use by 38 percent from 1995 to 2010. Per person usage dropped from 168 gallons per capita per day (gpcd) in 1995, to 104 gpcd by the end of 2010. Santa Fe has reduced its per capita water demand levels by implementing a comprehensive set of ordinances that require its citizens and businesses to comply with water conservation requirements. Santa Fe's low per capita per day water production statistics are among the lowest in New Mexico and the Southwestern United States (Santa Fe Conservation Plan, 2010). Santa Fe has implemented many of the recommended water conservation measures contained in the Jemez y Sangre Regional Water Plan, and Santa Fe's water conservation successes and the construction of the Buckman Direct Diversion project have significantly contributed to the closing of the 40-year supply shortfall 'gap' in the Santa Fe subregion. (Santa Fe Conservation Plan 2010).

ABCWUA has made substantial progress in its water conservation program, shifting from among the highest municipal water users in the Southwest to among the lowest. The conservation program has achieved a 44% overall water reduction in per account use over the last 16 years through a combination of public information, rate restructuring, in-school education, rebate incentives, landscape ordinances, and other programs. In 2010, the ABCWUA achieved a reduced average peak use that was 21% less than prior to the start of the conservation program, despite a population increase of more than 150,000 people. Per person usage dropped from 250 gpcd when the program began in 1995, to 157 by the end of 2010. When re-use water is deducted, usage actually drops to 154 gpcd, and ABCWUA is on track to reach 150 gpcd by 2014 (Authority Conservation Plan, 2012).

7.3 Water Rights Transfers and Offsets

As discussed in Section 5, Environmental Baseline, water rights are alienable private property rights that can be conveyed like other property rights, and water right owners in the MRG continue to transfer their water rights subject to the approval of the NMOSE. Demand for water in the MRG outstrips supply. Municipal and industrial uses of water are increasing; and because no new water is available, entities seeking water must acquire it from other uses and transfer it to new uses. In the MRG, as with other places in the Western United States, cities and towns have relied on ground water supplies and the transfer of water from irrigation use to municipal and industrial use.

Future changes in use of water rights in the MRG can impact flows in the Rio Grande in several ways. The movement of water from a place of use with a downstream point of diversion to a place of use with an upstream point of diversion can result in decreased flows in the intervening reach. Additionally, formally irrigated fields must be maintained to avoid revegetation with phreatophytic vegetation, such as salt cedar, which may consume as much or more water than the previous crops. Also, monitoring is required to ensure that the lands previously appurtenant to the transferred water rights do not continue to receive water deliveries.

7.4 Pueblo Water Rights

The Pueblos hold water rights that are recognized and protected under Federal law, including but not limited to aboriginal time-immemorial water rights. With respect to the Six MRG Pueblos, a certain portion of their water rights are statutorily recognized under the Acts of 1928 and 1935. However, these Acts of Congress may not establish the full extent of the water to which these Pueblos may be entitled. Section 5, Environmental Baseline, of this BA includes the junior, un-adjudicated uses of water by non-Pueblo water users and recognizes the existence of unquantified, aboriginal water rights held by the Six MRG Pueblos. At such time when the full extent of the Pueblos' water rights are quantified, through water rights settlement or otherwise, and applied to beneficial use, junior water uses may be curtailed pursuant to New Mexico water law.

7.5 Conclusion

The regional water plans for the MRG estimate a substantial additional water demand in 40–50 years in the municipal and industrial sector. If that increase is only accommodated through the transfer of water rights, about 57,000 acres of such rights would need to be transferred (Schmidt-Peterson 2007). Estimates of the total amount of land currently irrigated within the MRGCD are between 50,000 and 65,000 acres, and the claims to the water is likely much greater than the actual amount of wet water, particularly during drought. (Sandia Report 2004).

The degree to which the stakeholders in the MRG can work together to take remedial actions and return the hydrology of the basin to balance is uncertain. The efforts of the Collaborative Program participants both collectively and individually will help determine how well equipped the water managers will be to cope with future water conditions.

The long-term biological effects of future development in the MRG are uncertain. It is likely that less and less water will be available for the river and the species that depend on it. Less water in the river will have the greatest impacts on silvery minnow since they must carry out their entire life cycle within the waters of the MRG.

8. Composite Effect of Proposed Water Management and Maintenance

The type of lotic and riparian habitats that develop on the MRG are dependent on the interrelationship between the flow of water, the movement of sediment, and the variable character and composition of the channel boundaries over both time and space. These habitats are temporarily and spatially dynamic. The channel boundaries are influenced by the sediment erosion and depositional patterns present in the channel's bed forms, plan form patterns, and its cross section shape. Vegetation establishment and its life stage development process also effects the channels boundaries and morphology. The complexities of the fluvial and riparian processes are confounded by ongoing natural and anthropogenic actions. The river's morphology and habitat respond to these actions with varying physical and biological feedback relationships. Anthropogenic and natural occurrences in the environment have effects that interact with the proposed Water Management and Maintenance Actions to shape the river. Examples of these may include fires and runoff from upland areas, water management actions in Colorado, invasive species, and natural climate oscillations.

Since flow magnitude, frequency, and duration and sediment supply are important drivers of the morphological changes on the MRG, it is important to look at the effects of the proposed actions on these drivers. The water management actions, as described in the Part I – Water Management report for the Joint Biological Assessment of Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande have some effect on flow magnitude, flow duration, and a limited effect on sediment supply. The effects are primarily from the initial storage of water and the timing of the release of the stored water from El Vado Reservoir and diversion of water from the river and the flood control actions of the Corps at Cochiti Reservoir. The maintenance actions, as described in the Part II- Maintenance report for the Joint Biological Assessment of Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande may influence the sediment supply in a particular reach, especially if activities are designed to destabilize established vegetation in the active river corridor. The amount of influence is dependent on whether the river flow mobilizes the sediment in these destabilized areas. Assuming the river mobilizes sediment, particles may be transported as either wash or bed material load. Only the bed material load (typically particles greater than 0.0625 mm in size) has an influence on the character and composition of the channel boundaries, bed form habitats, and its pattern. The maintenance activities described in this BA do not directly affect the flow magnitude and duration. The flow magnitude and duration are driven by seasonal precipitation (spring snowmelt runoff and monsoonal thunderstorm events) and operational factors. Maintenance activities, as described, provide for the effective safe passage of flows through the system.

The interactions between water operation and maintenance actions are ancillary compared to the very complex relationships that form the current habitat types on the MRG. These complex relationships make the quantification of the effects of these interactions difficult. The most significant effect of maintenance, including river maintenance, LFCC maintenance, drain maintenance, and MRGCD maintenance, on water management is the ability to decrease water losses between the river reaches. Water management scenarios describing future conditions assume that the baseline flow conveyance losses and gains are constant, and these are predicated on the ability to continue to perform maintenance activities. Another significant effect of the maintenance is to maintain the resiliency of the overall system to pass peak flows with minimal impacts to water delivery and riverside infrastructure.

The effects of water management on maintenance are more complicated. The lack of channel resetting flows is driven primarily by the current dry hydrological cycles, while other continuing trends are influenced, to a limited degree, by water management actions for hydrologic connectivity measures. The constant low flow conditions promote the continuation of some of the observed major current geomorphic trends on the MRG (e.g., channel narrowing) due to vegetation encroachment. The lack of channel resetting events discourages natural disturbances that may promote greater diversity in the channel boundary habitat through establishing variable vegetation age classes and the availability of bed substrates that can shift and move with the river flows, creating variable depth and velocity habitats.

Flood control via reservoir operations on the river reduces the magnitude and duration of the peak flows at the highest flow levels to protect public safety. During high flow periods, additional river and MRGCD maintenance activities may occur to protect infrastructure from damage caused by channel erosion or flooding. The MRG system and its function can be impaired if either localized or reach scale problem areas develop that necessitate flood control regulation. These types of problem areas may result from the lack of maintenance, reach channel instabilities, or public infrastructure threatened by its close proximity to the river. These problem areas significantly limit the ability of the channel to self-regulate or reset itself.

The proposed water management also may have some potential for temporarily storing early spring runoff flows for later timed release to enhance a spring runoff hydrograph during low flow years near the mean annual peak flow but this is limited due to the small relative volume from the Rio Chama. Deviation actions from the Corps may have a greater potential to benefit the river, especially if the magnitude and duration are sufficient to rework the channel. This initially may result in an increase in the amount of river maintenance activity, especially emergency work, but may result in less river maintenance work over the long term if the channel resetting events occurred with enough frequency to avoid establishing well armored channel boundaries.

The release of stored water during nonflood periods, both for irrigation and to keep the river wet, provides more water in the river system during dry periods. These stored flow releases promote the encroachment of vegetation and limit its desiccation in the active channel. This effectively armors the channel banks and narrows the active channel width. In reaches where the sediment transport capacity is greater than the sediment supply, the channel response may include channel deepening and/or velocity increasing. This would tend to decrease the variability along the channel boundaries and also may cause a decrease in the amount of overbanking flows for flood flows. This process also may encourage bend migration by selectively armoring bars and islands through establishing woody vegetation, leaving the historical flood plain bank less hydraulically rough and, thus, more susceptible to erosion compared to the other surfaces.

In reaches where the sediment transport capacity is less than the sediment supply, the channel response may include the continued reduction of sediment transport capacity, potentially leading to sediment accumulation (aggradation) and, in some areas, sediment plugs. This also would tend to decrease the variability along the channel boundaries and also may cause an increase in the amount of overbanking flows for flood flows.

River maintenance activities, a subset of the proposed maintenance actions, historically have focused on symptoms of the observed geomorphic trends on the MRG. The objective of the proposed river maintenance action of using reach strategies is to address the causes of the observed geomorphic trends. The intention is that this effort will have a long-term effect of creating a more ecologically viable option that minimizes the amount of required river maintenance in the future because it is working better with the current understanding of the MRG.

While the effect of water management activities on river habitat conditions is continuous and is present throughout the action area, specific maintenance actions have sporadic temporal effects that may be localized or have reach-wide effects depending on the scope of the project. Long term effects for the species and their habitat are generally negligible though, it is difficult to predict the magnitude of the effect these maintenance measures have due to the complexity of the interactions of actions on the river, the river responses, and also the variability in the amount and frequency of maintenance work. Typically, maintenance activities to protect infrastructure and maintain drains and diversions have only local effect to habitats. The main short-term effect of maintenance activities is the direct disturbance of species and their habitat during construction, with negligible long-term effects on species and their habitats.

Based on the information and analysis of effects presented in this biological assessment, the following determinations were made for the silvery minnow, Southwestern willow flycatcher, Pecos sunflower, and interior least tern.

8.1 Rio Grande Silvery Minnow

The Composite Proposed Action comprised of Reclamation and non-Federal water management and maintenance actions in the Middle Rio Grande **are likely to adversely affect the silvery minnow**. The proposed actions are also **likely to adversely modify designated critical habitat for the silvery minnow.**

The following addresses adverse impacts of the Proposed Action on the listed species as described in the BA. The most significant direct effects to silvery minnow include increased drying in particular subreaches and disturbance due to construction activities. Indirect effects include modification of habitat by water operations and maintenance activities. Critical habitat is affected by the decrease in wetted habitat and increase in the number of low flow days, which has impacts on habitat quality and quantity as well as water quality. Less significant is the small decrease in the magnitude and duration of spring high flows that could affect annual recruitment of silvery minnow. Maintenance activities will be designed with a priority to avoid direct impacts to silvery minnow and critical habitat. The existence of the Collaborative Program will facilitate actions to minimize the adverse effects of these actions and improve the status of the silvery minnow. The Collaborative Program will identify specific management activities, monitoring, and research that will be used to evaluate and improve management decisions and will allow for flexible water management while also moving toward the recovery of the species.

8.2 Southwestern Willow Flycatcher

The Composite Proposed Action comprised of Reclamation and non-Federal water management and maintenance actions of the Middle Rio Grande Project **are likely to adversely affect the willow flycatcher**. The proposed actions **are also likely to adversely modify designated critical habitat for the willow flycatcher**.

Specific effects to flycatchers include the decrease in available water for established riparian vegetation and a small decrease in the amount of overbank flooding that would occur without the action. Long-term effects include establishing new vegetation within the current channel width that may benefit birds in the short term but may have long-term negative effects if this vegetation causes the flood plain to become disconnected from the river. Maintenance activities will be designed with a priority to avoid direct impacts to flycatchers and suitable habitat. The Collaborative Program will identify specific management activities, monitoring, and research that will be used to evaluate and improve management decisions and will allow flexible water management while also moving toward the recovery of the species.

8.3 Pecos Sunflower

The Composite Proposed Action comprised of Reclamation and non-Federal water management and maintenance actions of the Middle Rio Grande Project are **beneficial to the Pecos sunflower on La Joya Wildlife Management Area** due to delivery of water through the irrigation system on which they depend. The newly established Rhodes population of Pecos sunflower is not likely to be adversely affected due to the insignificant magnitude of the changes to overbank flows high enough to inundate this population. Maintenance activities will be designed with a priority to avoid direct impacts to Pecos sunflower.

8.4 Interior Least Tern

The Composite Proposed Action comprised of Reclamation and non-Federal water management and maintenance actions of the Middle Rio Grande Project of the Middle Rio Grande Project will have no effect on the interior least tern.

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RECLAMATION

Managing Water in the West

Joint Biological Assessment

Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico

Part I – Water Management Appendices

Middle Rio Grande Project, New Mexico
San Juan-Chama Project, New Mexico
Upper Colorado Region

U.S. Department of the Interior
Bureau of Reclamation

July 2012 (Amended January 2013)

Mission Statements

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

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

Joint Biological Assessment

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San Juan-Chama Project, New Mexico
Upper Colorado Region

Submitted to the U.S. Fish and Wildlife Service

Rio Grande Silvery Minnow	**Southwestern Willow Flycatcher**
Pecos Sunflower	**Interior Least Tern**

U.S. Department of the Interior
Bureau of Reclamation

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Selection of Five Synthetic Flow Sequences for Detailed Analysis with the Upper Rio Grande Water Operations Planning Model.

Prepared by

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Abstract:

This document describes the methods utilized to select five, ten-year climate sequences to drive the Upper Rio Grande Water Operations Model (URGWOM) Planning Model. 1000 synthetic climate sequences each 100 years in length, made up by historic years from 1950-2004 inclusive, were generated based on 604 years of tree ring data. From these sequences, 91,000 possible ten year sequences were evaluated according to the average Otowi Index Supply (OIS) for each, and the five sequences comprised of historic years from1975 forward only, closest to 10%, 30%, 50%, 70%, and 90% exceedance were selected for analysis with the daily timestep URGWOM Planning Model.

Introduction:

Managing water resources in New Mexico's Rio Grande basin as efficiently as possible requires an understanding of the uncertainties associated with water supply, as well as the operational flexibilities of storage and conveyance facilities in the basin. URGWOM has been developed to analyze the operational flexibilities of storage and conveyance facilities, however due to the computational restrictions of this daily timestep, basin scale model, it is not practical to run the model with the large numbers of long climate sequences that would be necessary to generate understanding of the range of system impacts associated with supply uncertainties. To get around this problem, the distribution of potential climate sequences based on over 600 years of tree ring data was evaluated, and five climate sequences, each ten years long were selected as representative of a wide range of hydrologic conditions in the basin. This process occurred in two steps, first synthetic sequences were generated, and second, representative, ten-year sequences were selected from within the synthetic climate sequences.

Generation of Synthetic Sequences:

The first step was generation of synthetic sequences of flow years from the observed record whose overall statistics were based on longer term climatic trends from available tree ring records. This work was done by AMEC Earth and Environmental in Boulder Colorado (AMEC) and is summarized briefly here. A 2½ degree gridded Palmer Drought Severity Index (PDSI) was reconstructed from tree ring data by Cook et al (2004). From this data set, AMEC chose a single grid cell in which the reconstructed

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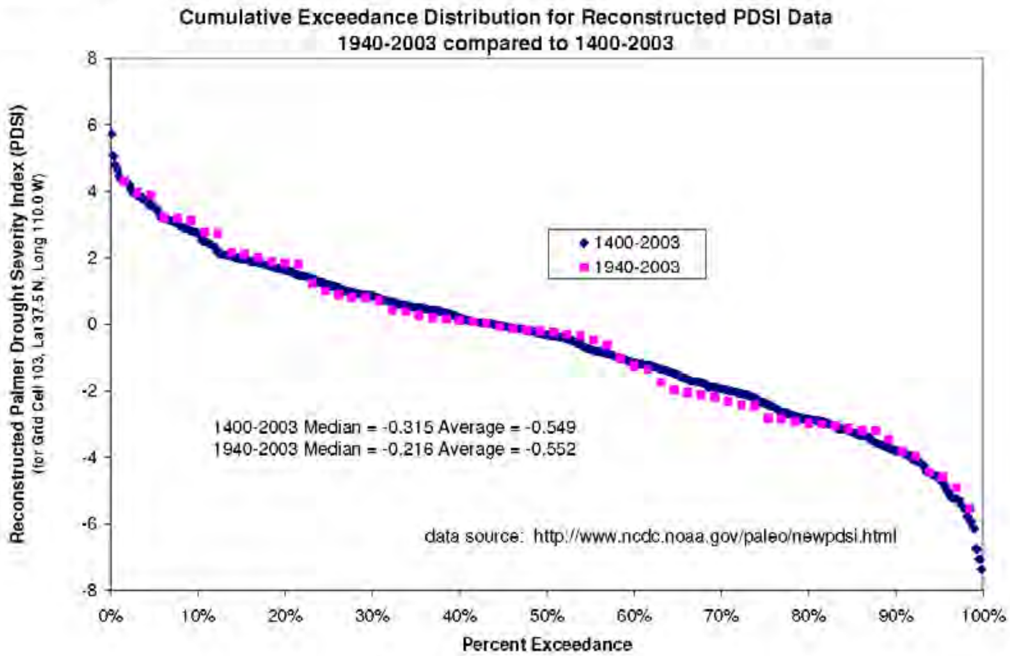
PDSI correlated most closely to the OIS for the period 1940-2003 which is the period of overlap for the two data sets. This grid cell is centered at latitude 37.5N, and longitude 110.0W, and encompasses area in Utah, Colorado, Arizona, and New Mexico. 604 years (1400-2003) of this reconstructed PDSI timeseries were then classified as either wet or dry, with the definition of wet and dry selected so that approximately half of the years fell in each class. Next, the observed state of the system (wet or dry) through time was used to generate a transient two state transition probability matrix. A two state transition probability matrix gives the likelihood of moving from a wet year to a dry year, a wet year to a wet year, a dry year to a dry year, or a dry year to a wet year from one year to the next. A transient transition probability matrix then changes through time. So, for example, a dry year was less likely to be followed by a dry year early in the 19th century than later that same century. This approach is used so that climate cycles may be captured in the synthetic sequences, rather than relying on long term averages alone. Once the transient transition probability matrix was developed, 1000, 100 year long synthetic climate sequences were generated by selecting at random an initial state (wet or dry), and moving through a randomly selected 100 year window of the transient transition probability matrix one year at a time, randomly generating either a wet or a dry climatic state based on the previous year state and the transition probability matrix that year.

The next step was to replace wet and dry climatic years with wet and dry years from the observed record, effectively going from a synthetic climatic sequence to a synthetic hydrologic sequence. This was accomplished by specifying the smallest 50% of the 1940-2007 annual Otowi Index Supply (OIS) values as occurring in "dry" years, and the rest as occurring in "wet" years, implicitly assuming that climate during the period from 1940-2007 was representative of the long term statistics derived for the 1400-2003 climate. This assumption was not listed or checked by AMEC, but was checked independently, and found to be reasonable as seen in Figure 1.

The final step was to substitute each "wet" or "dry" year in the synthetic climate sequence with a "wet" or "dry" historic year using a process called "conditional K-nearest neighbor bootstrap" selection. In transitioning from one historic year to another, transitions from similar years in the observed record were favored, thus retaining some of the year to year transition properties that have been observed historically. So if the year 1977 ("dry", 297 kAF OIS) was the last year selected, and the climate sequence called for another dry year, then "dry" years that followed a year similar to 1977 would be the most likely selections for the next year in the sequence. This selection process is referred to as a conditional K-nearest neighbor (K-nn) bootstrap selection, and is designed to maintain historically observed transition magnitudes. As a result of the K-nn bootstrap approach, in many of the sequences, historic years appear in sequential order. The combination of a transient transition probability matrix and a K-nn bootstrap approach was introduced by Prairie et al (2008) for stochastic analysis of the Colorado River at Lees Ferry, and is designed to take advantage of the strengths of both long term paleoreconstructed data, and the observed hydrologic records to generate synthetic sequences. Using this approach AMEC Earth and Environmental delivered 1000, 100 year sequences of historic years between 1950 and 2004 as synthetic sequences representative of long term climate variability in New Mexico's Rio Grande Basin. The reader is referred to the technical memo from AMEC to Dr. Nabil Shafike of the New Mexico Interstate Stream Commission dated June 24, 2008 (Gangopadhyay and Harding, 2008) for additional details on the methods used to generate the synthetic sequences.

Figure 1: Comparison of 1940-2003 Palmer Drought Severity Index (PDSI) to 1400-2003 PDSI. The close overlap of the exceedance distribution curves suggests that 1940-2003 conditions are representative of 1400-2003 conditions, and thus median Otowi Index Supply 1940-2007 can be used as the cutoff between wet and dry years.



Selection of Representative 10 Year Sequences:

Due to the computational restrictions of the daily timestep URGWOM planning model, model runs are limited to 10 year sequences and analysis of more than five potential climatic sequences is not desired. In addition, the synthetic sequences were generated with observed years from 1950-2004 so that they could be run with a monthly timestep version of the URGWOM planning model developed in the software Powersim Studio 2005 by Sandia National Laboratories (SNL), which can run any combination of historic years from 1950-2004 as input data for scenario analysis. However, the data necessary to drive the daily timestep URGWOM planning model currently extends back only to 1975. Therefore, from the 1000, 100 year synthetic sequences developed by AMEC, it was necessary to select three to five sequences of ten year duration, made up of historic years from 1975 forward only. This was accomplished as follows. There are 91 ten year sequences in each 100 year synthetic sequence (years 1..10, 2..11, …, 90-99, 91..100), thus 91,000 total sequences in the 1000, 100 year sequences. First, the average OIS for the 91,000 ten year sequences was calculated. Next, the 91,000 values for average 10 year OIS were sorted in ascending order, and ranked according to Equation 1 below.

$$\%rank = \frac{r}{n+1} \qquad (1)$$

where r is the absolute rank (1 for the smallest value, 91,000 for the largest value), and n is the number of total records (91,000). In hydrology, distributions such as this are often described with exceedance, meaning how many of the records exceed the value of the individual record in question. Percent exceedance was calculated by subtracting the percent rank from 1 as shown in Equation 2 below.

$$\%exceedance = 1 - \%rank \qquad (2)$$

Table 1 demonstrates the calculation of percent exceedance for the 12 sequences with exceedance closest to 50%. The entire table contains 91,000 data rows.

Table 1: Portion of 91,000 data row table showing ranked 10 year sequences close to 50% exceedance compared to all 91,000 sequences.

Sequence (1-1000)	10 Year Sequence Start Year (1-91)	10 yr ave Otowi Index Flow Volume [kAF/yr]	Rank r	%Rank r/(n+1)	%Exceedance 1- (r/(n+1))
532	19	883.82	45495	49.994%	50.006%
615	26	883.84	45496	49.995%	50.005%
659	53	883.84	45497	49.996%	50.004%
17	85	883.85	45498	49.997%	50.003%
380	22	883.85	45499	49.998%	50.002%
726	31	883.86	45500	49.999%	50.001%
808	37	883.86	45501	50.001%	49.999%
753	24	883.87	45502	50.002%	49.998%
800	62	883.88	45503	50.003%	49.997%
433	85	883.88	45504	50.004%	49.996%
246	27	883.89	45505	50.005%	49.995%
742	62	883.91	45506	50.006%	49.994%

Plotting the 10 year average OIS (column 3 in Table 1) against % exceedance (column 6 in Table 1) for all 91,000 ten year sequence points yields the exceedance curve shown in Figure 2. Also shown for perspective in Figure 2, are the four, ten year sequences that were used to drive the URGWOM Planning Model for the Upper Rio Grande Water Operations (URGWOPS) Environmental Impact Study (EIS).

Next, of the 91,000 10-year sequences, 1088 sequences contained years from 1975 forward only. Of these, the five sequences closest to 10%, 30%, 50%, 70%, and 90% exceedance were selected as drivers for the URGWOM Planning Model. Table A-1 in Appendix A lists alternate sequences that were the next closest sequences to the 10%, 30%, 50%, 70%, and 90% exceedance targets.

Figure 2: Exceedance distribution curve for 10-year average Otowi Index Flow for 91,000 synthetic 10-year sequences generated based on 604 years of tree ring data.

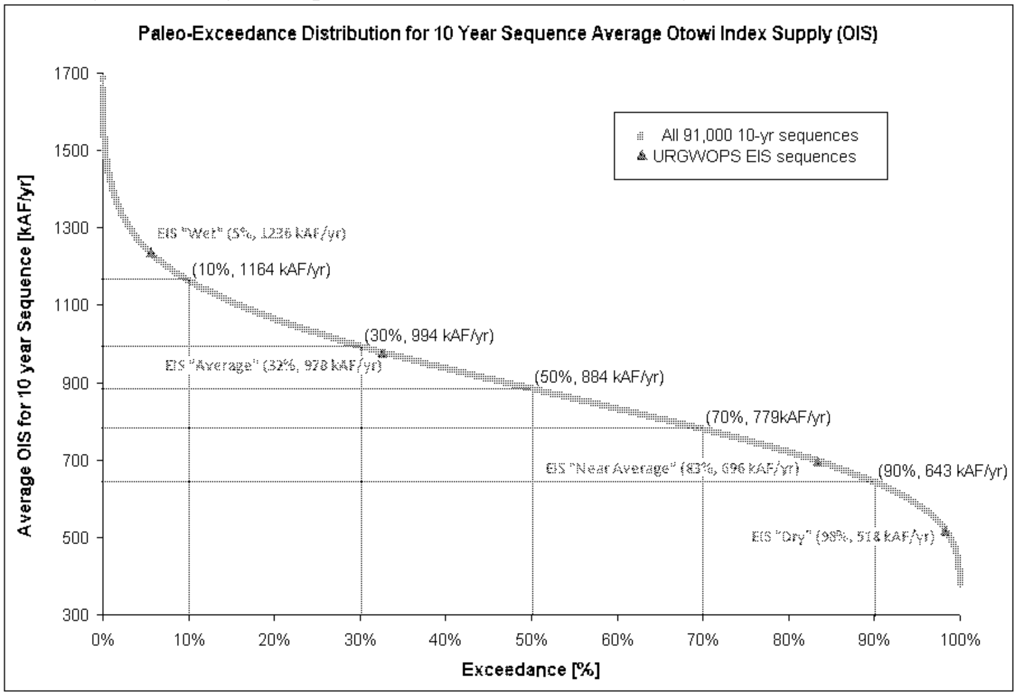


Figure 3 shows the 1088 1975 and forward sequences and the five chosen sequences in relation to the overall exceedance curve. Note that because 1975-2004 was wetter than average, sequences comprised of these years only tend to lie on the wetter (left) side of the exceedance curve distribution. Of the sequences made up only of years from 1975 forward, there were two with exactly 1164.75 kAF/yr average 10-year Otowi Index Supply. Of these, the one with the larger variation, as measured by the standard deviation of the annual Otowi Index Supply values was selected for use. This decision was based on group discussion and consensus that the high variability sequence would test the system and model more, and thus be of more use to planning efforts. Figure A-1 in Appendix A shows these two sequences in relation to one another.

The historic years making up the five selected sequences are shown in Table 2. Figures 3-7 show the individual Otowi Index Supply for the years that make up the sequences. Figure 9 compares the Otowi Index Supply for all sequence years sorted by the magnitude of annual Otowi Index Supply of each year.

Figure 3: Distribution of sequences made up of years 1975 and greater only as compared to overall exceedance curve. Note that because 1975-2004 was wetter than average, sequences comprised of these years only tend to lie on the wetter (left) side of the exceedance curve distribution. Also shown are the five sequences selected for further analysis with the daily timestep URGWOM Planning Model.

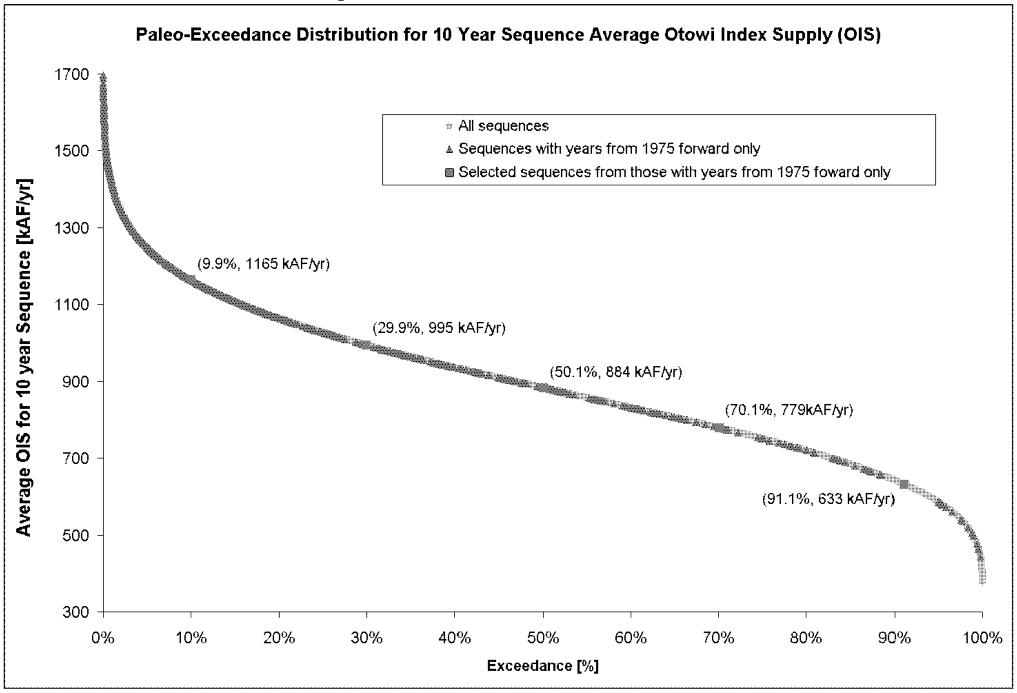


Table 2: Historic years making up each of the 5 selected sequences.

		Historic Year Used				
		Sequence Name				
		10% paleo-exceedance	30% paleo-exceedance	50% paleo-exceedance	70% paleo-exceedance	90% paleo-exceedance
Sequence Year	1	1985	1976	2004	1989	2000
	2	1996	1977	1991	1990	1990
	3	2004	1982	1992	1977	1977
	4	1977	1995	2000	2004	2003
	5	1978	1987	1977	1990	2004
	6	1979	1994	1978	1977	1991
	7	1980	1992	1990	1978	2002
	8	1992	1999	1991	1991	2003
	9	1986	1988	1976	1992	1982
	10	1994	1977	1979	1993	1976

Figure 4: Otowi Index Supply for individual years in 10% exceedance sequence selected for further analysis with the daily timestep URGWOM Planning Model.

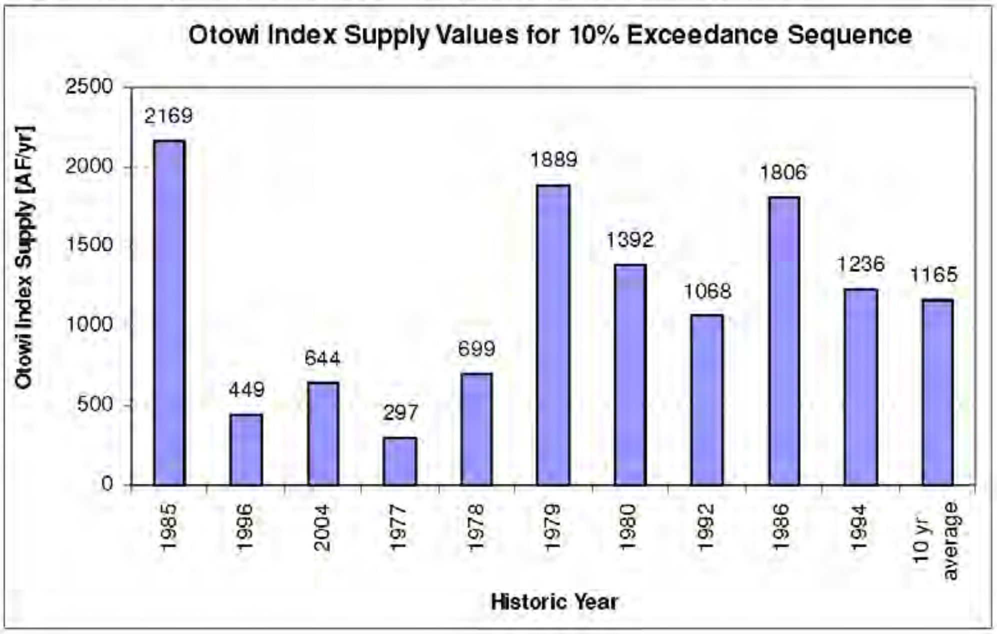


Figure 5: Otowi Index Supply for individual years in 30% exceedance sequence selected for further analysis with the daily timestep URGWOM Planning Model.

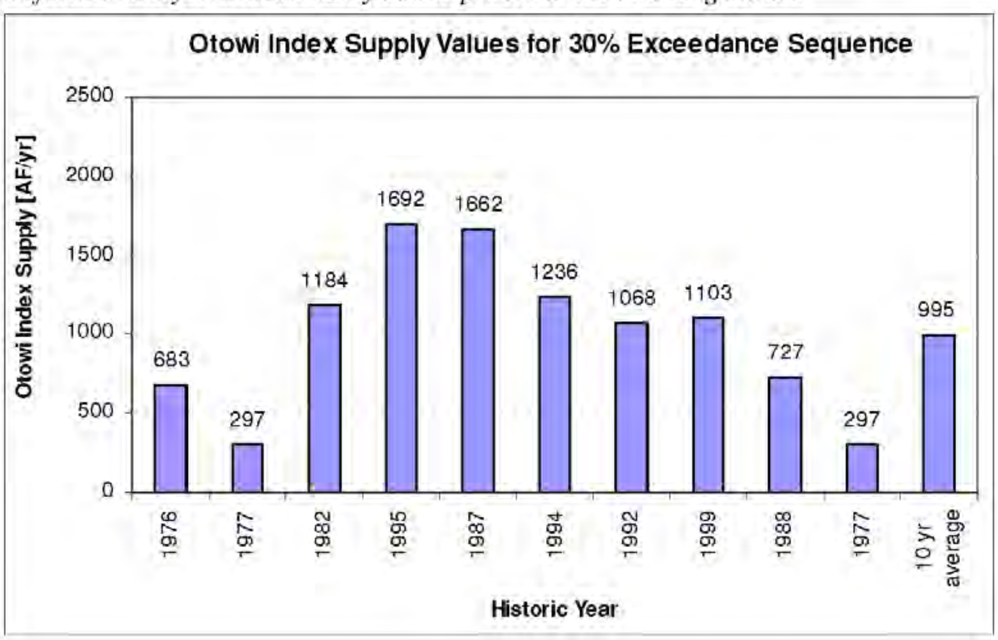


Figure 6: Otowi Index Supply for individual years in 50% exceedance sequence selected for further analysis with the daily timestep URGWOM Planning Model.

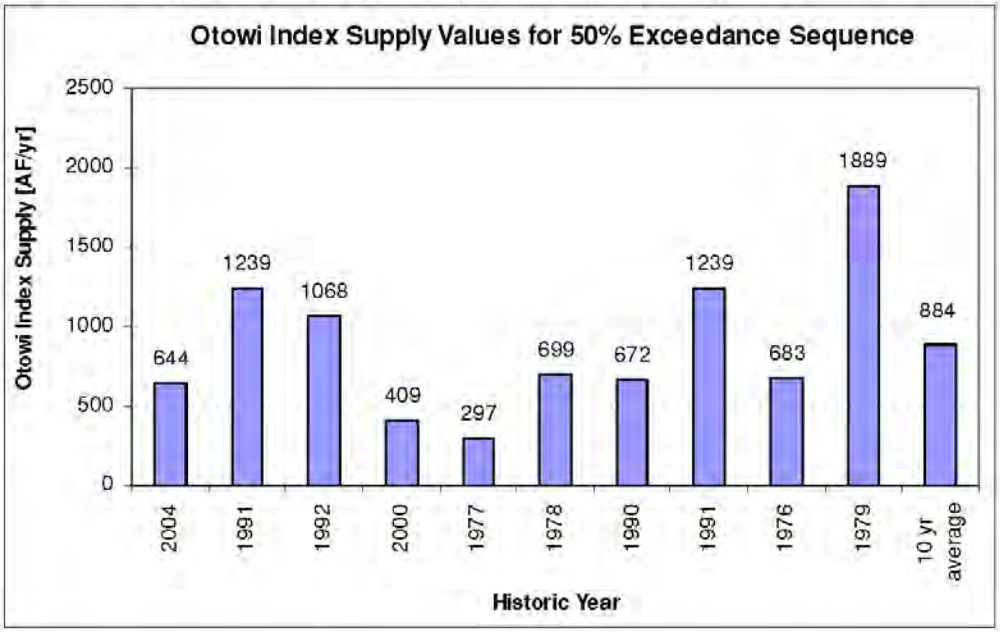


Figure 7: Otowi Index Supply for individual years in 70% exceedance sequence selected for further analysis with the daily timestep URGWOM Planning Model.

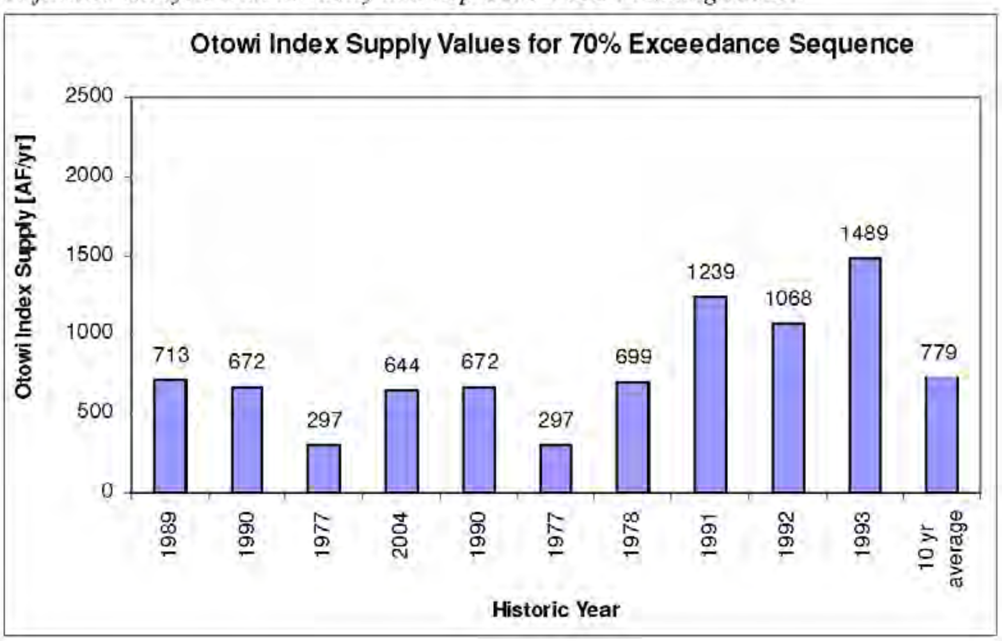


Figure 8: Otowi Index Supply for individual years in 90% exceedance sequence selected for further analysis with the daily timestep URGWOM Planning Model.

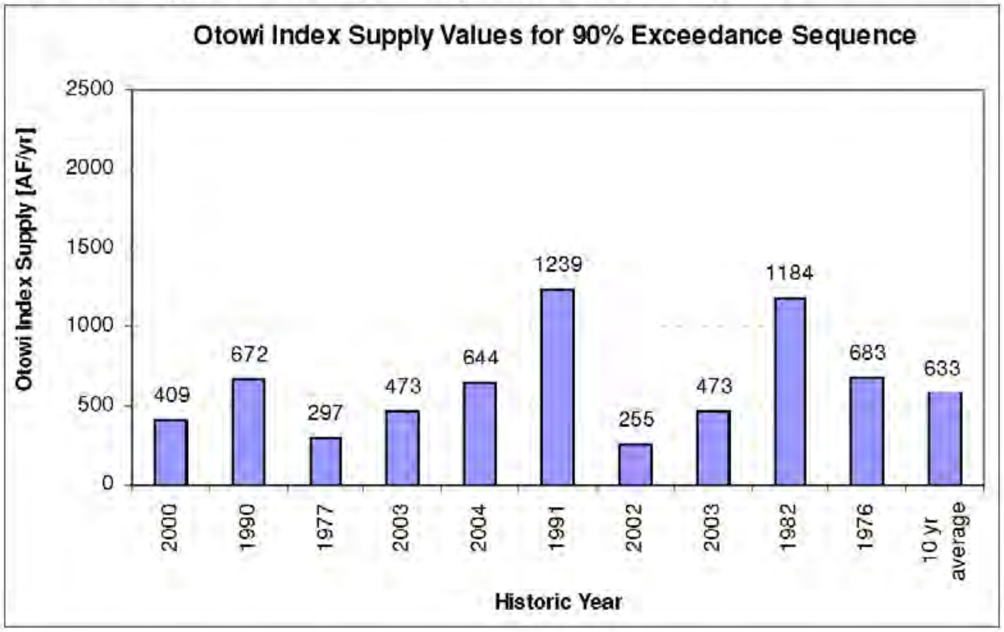
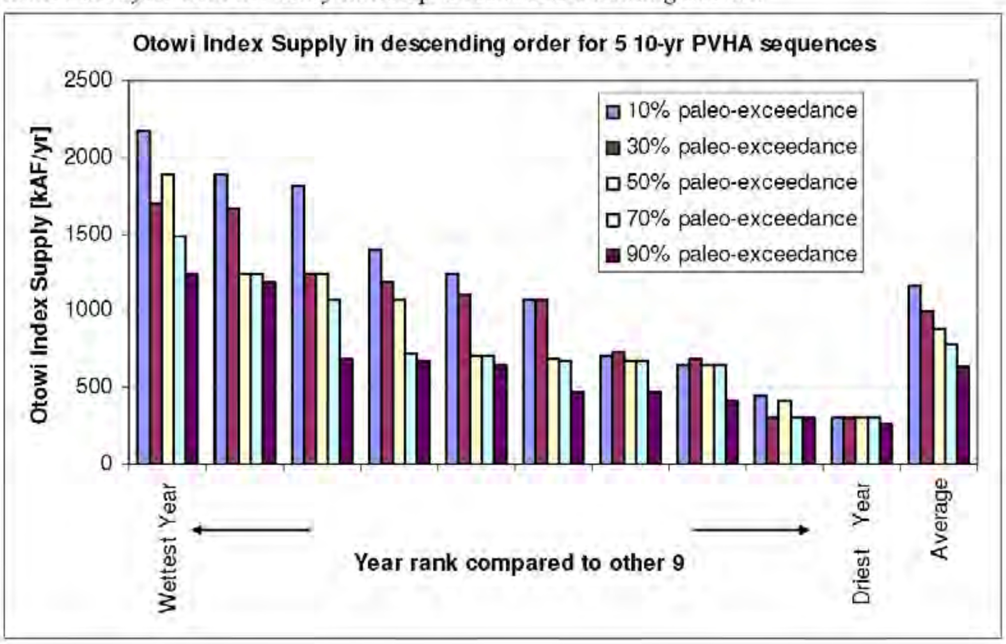


Figure 9: Otowi Index Supply for individual years in all five sequences selected for further analysis with the daily timestep URGWOM Planning Model.



Relative Monsoon Strength of Selected Sequences:

One of the most significant challenges currently facing Rio Grande water operators is in providing sufficient water to maintain established agricultural rights, growing municipal and industrial demands, and in-stream flows necessary to support endangered species habitat. Late summer can represent a bottleneck in this balance, when demands are at a peak, and supply is past the spring snowmelt generated peak. Summer monsoon based precipitation can provide an important supply during this time. Of interest to water planners is the total water that enters the surface water system below Otowi from July through September from all gaged and ungaged tributary inflows. To evaluate the relative strength of the summer monsoon, a "representative monsoon volume" was defined as the sum of gaged tributary inflows to URGWOM between Otowi and Elephant Butte Reservoirs from July through September of each year. Formally:

$$RMV^{y} = Q_{SantaFe}^{July_y - Sept_y} + Q_{Galisteo}^{July_y - Sept_y} + Q_{Jemez}^{July_y - Sept_y} + Q_{Northflood}^{July_y - Sept_y} + Q_{Southdiv}^{July_y - Sept_y} + Q_{Tijeras}^{July_y - Sept_y} + Q_{Puerco}^{July_y - Sept_y}$$

Where RMV^{y} is the annual representative monsoon volume in year y, $Q_{SantaFe}^{July_y - Sept_y}$ is the total gaged volume in the Santa Fe River above Cochiti (United States Geological Survey (USGS) gage number 8317200) for July, August, and September in year y. Similarly for Galisteo Creek below Galisteo Dam (USGS-8317950), the Jemez River near Jemez (USGS-8324000), the North Floodway Channel near Alameda (USGS-8329900), the South Diversion Channel above Tijeras Arroyo (USGS-8330775), Tijeras Arroyo near Albuquerque (USGS-8330600), and the Rio Puerco near Bernardo (USGS-8353000). The RMV was calculated for each year from 1950 through 2004. Synthetic gage data generated by the USGS was used in place of any missing data (Engdahl, et al 2008).

RMV for each year from 1950-2007 were calculated, and compared to the corresponding OIS values to get a sense of the relationship between flow at Otowi, and summer tributary inflows. Interestingly, as shown in Figure 10, with the exception of an unusual year in 1957, large summer RMV values are rarely associated with large annual OIS values, meaning that strong monsoon events almost never follow winters with heavy precipitation. The physical mechanism for this might be that monsoons are driven by land mass heating in the summer, which is reduced in summers that follow a wet winter. Average annual RMV for each ten year sequence was also calculated. Figure 11 shows RMV plotted against OIS for all 91,000 ten year sequences. The effect of the 1957outlier is lost to the 10 year average, and the pattern of no strong monsoon sequences occurring with large spring runoff sequences emerges clearly. Also plotted in Figure 11 are the five selected sequences, none of which can be classified as an outlier by visual inspection of this particular plot.

Next, RMV exceedance probabilities were calculated for all 91,000 runs according to Equations 1 and 2 above as described previously for Otowi Index Supply values. The exceedance distribution for all sequences is shown in Figure 12. Also shown in Figure 12, are the RMV values for the five selected sequences. Consistent with the preceding discussion, the 10% OIS exceedance, which is wet in terms of Otowi Volume, is dry with respect to RMV.

Figure 10: Otowi Index Supply (OIS) compared to Representative Monsoon Volume (RMV) for individual years from 1950-2007. Historic years 1950-2004 drive the 91,000 sequences considered here. Note that with the exception of 1957, strong monsoon signals as estimated by RMV almost never coincide with high annual Otowi flows.

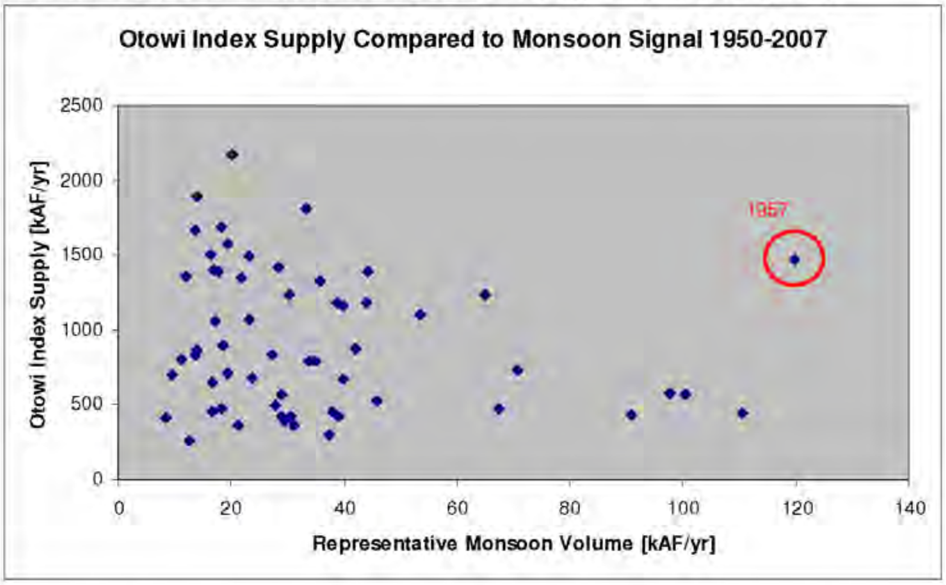


Figure 11: Ten year average Otowi Index Supply (OIS) compared to ten year average Representative Monsoon Volume (RMV) for all 91,000 ten year sequences considered here as well as the five selected sequences.

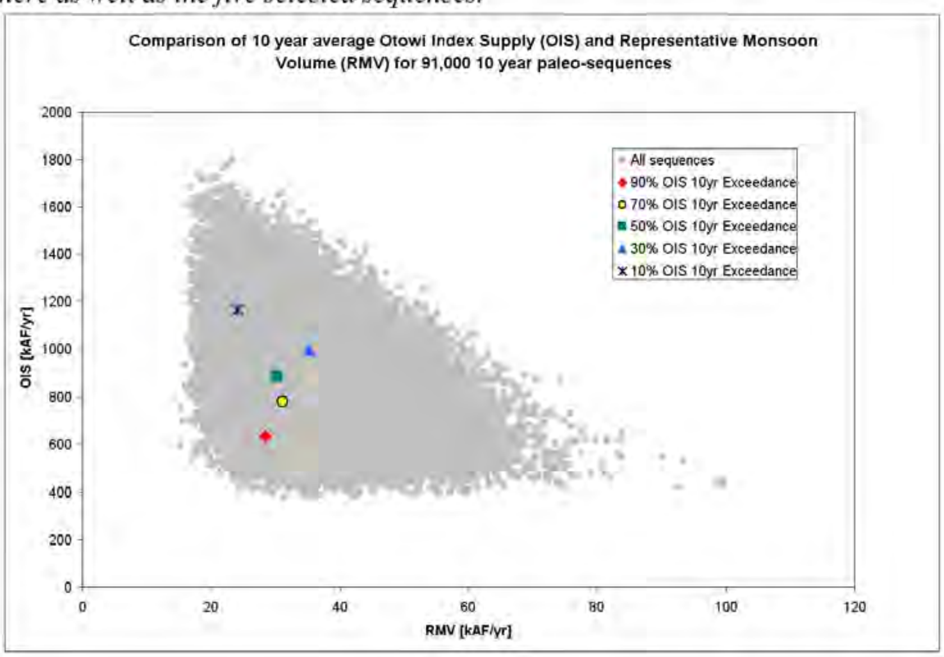
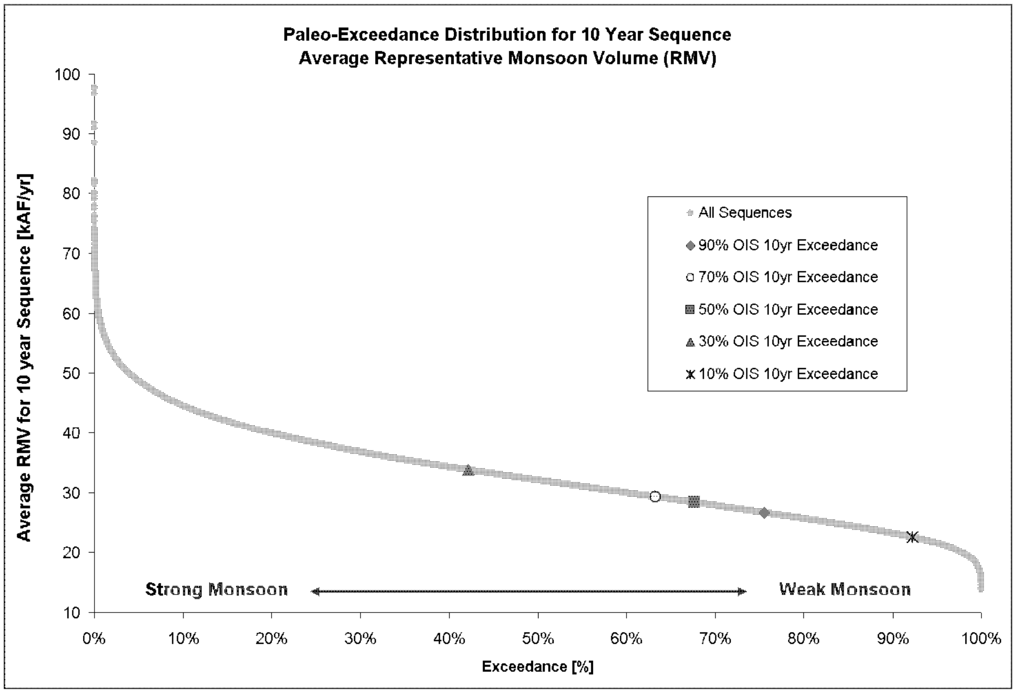


Figure 12: Exceedance distribution curve for 10-year average Representative Monsoon Volume for 91,000 synthetic 10-year sequences generated based on 604 years of tree ring data.



RMV values and their exceedance probabilities for the five selected sequences are shown in Table 3 below.

Table 3: 10 year average Representative Monsoon Volumes (RMV) and associated exceedance probabilities for the five selected sequences.

Sequence Name	10yr ave RMV [kAF/yr]	10yr RMV % Exceedence
90% OIS	26.6	76%
70% OIS	29.3	63%
50% OIS	28.3	68%
30% OIS	33.8	42%
10% OIS	22.5	92%

Figures 13-17 show the annual Representative Monsoon Volumes for all individual years in each of the five selected sequences.

Figure 13: Representative Monsoon Volume (RMV) for individual years in 10% exceedance sequence selected for further analysis with URGWOM.

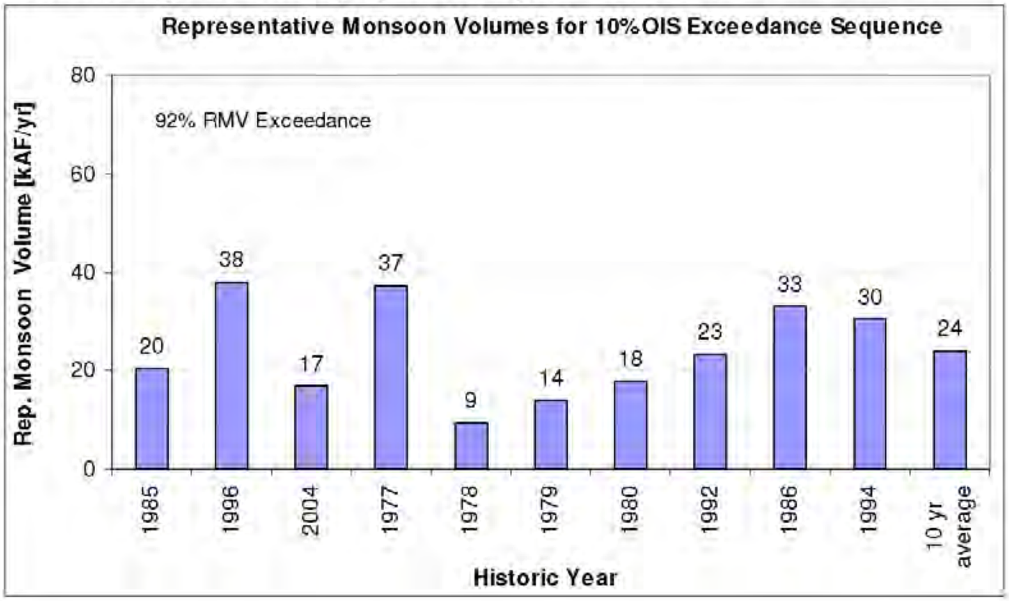


Figure 14: Representative Monsoon Volume (RMV) for individual years in 30% exceedance sequence selected for further analysis with URGWOM.

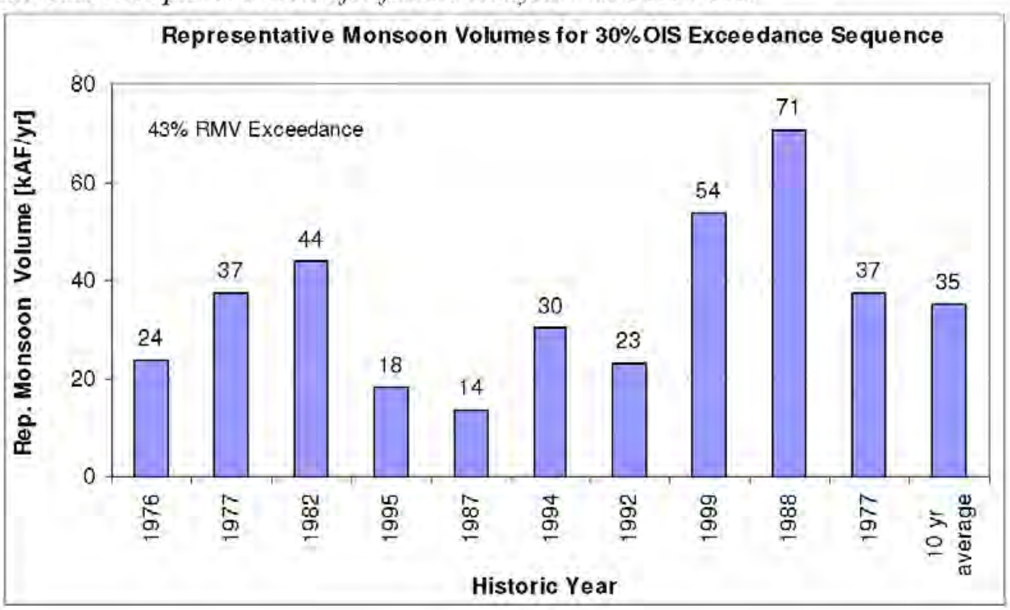


Figure 15: Representative Monsoon Volume (RMV) for individual years in 50% exceedance sequence selected for further analysis with URGWOM.

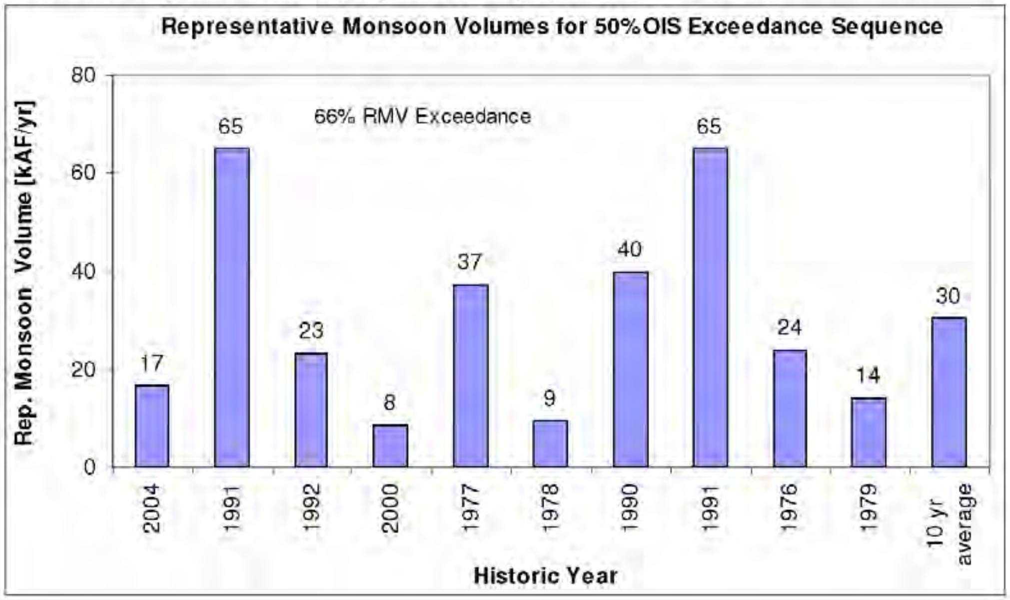


Figure 16: Representative Monsoon Volume (RMV) for individual years in 70% exceedance sequence selected for further analysis with URGWOM.

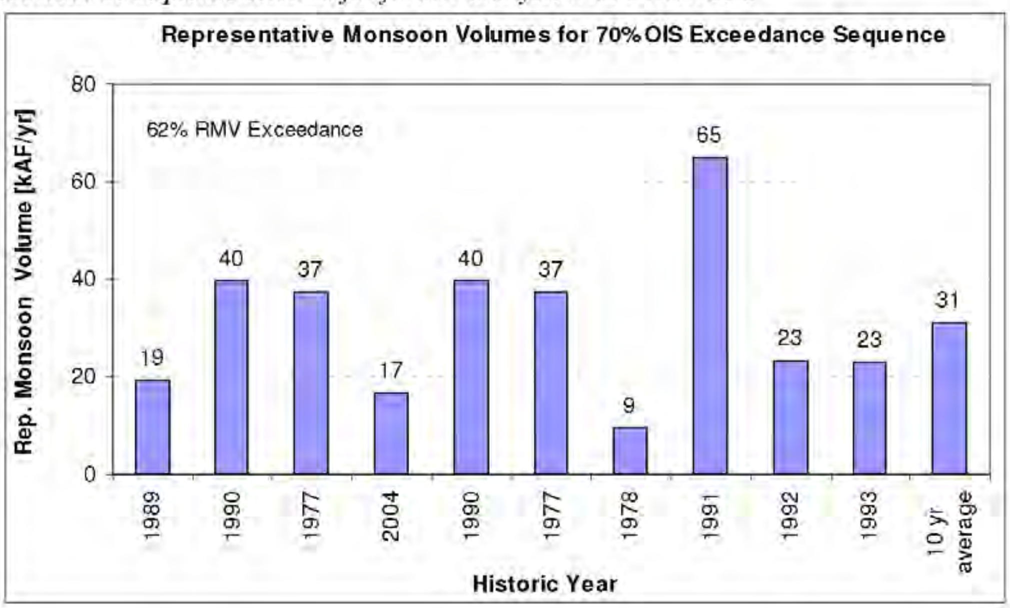
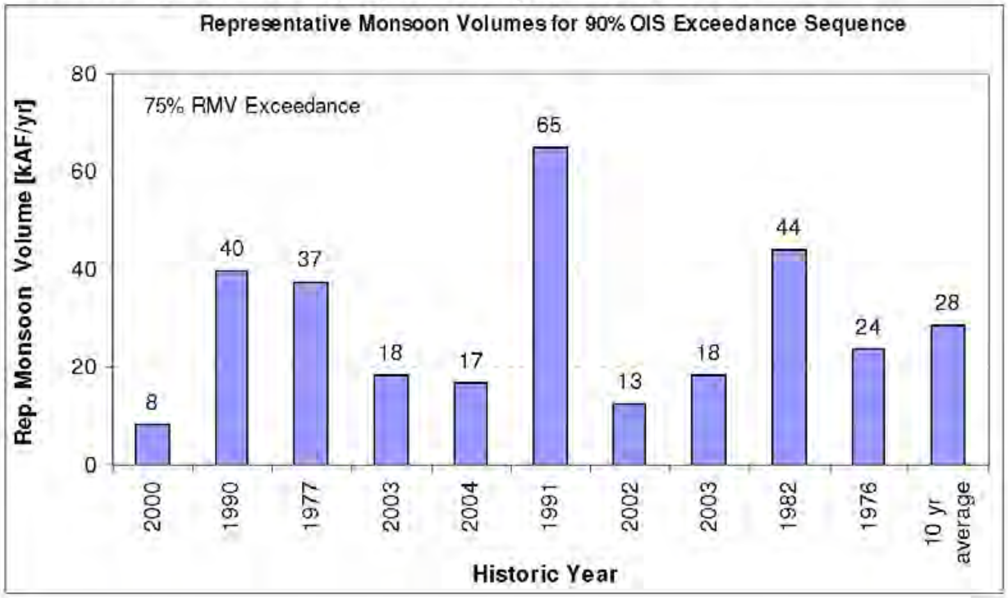


Figure 17: Representative Monsoon Volume (RMV) for individual years in 90% exceedance sequence selected for further analysis with URGWOM.



Finally, in order to compare relative Otowi flow and monsoon signal for each year of the selected sequences, OIS and RMV values were normalized by dividing by the annual average value for each from all years in the paleo based synthetic sequences. These values are 895,000 AF/year and 34,700 AF/summer for OIS and RMV respectively. The result is unitless OIS and RMV values representing a fraction of average. Figures 18-22 show year by year relative comparisons of unitless OIS and RMV values for the five selected sequences.

Figure 18: Normalized Otowi Index Supply and Representative Monsoon Volumes in each year of the 10% Exceedance Sequence. Values are normalized to annual average value of all years in the paleo based synthetic sequences.

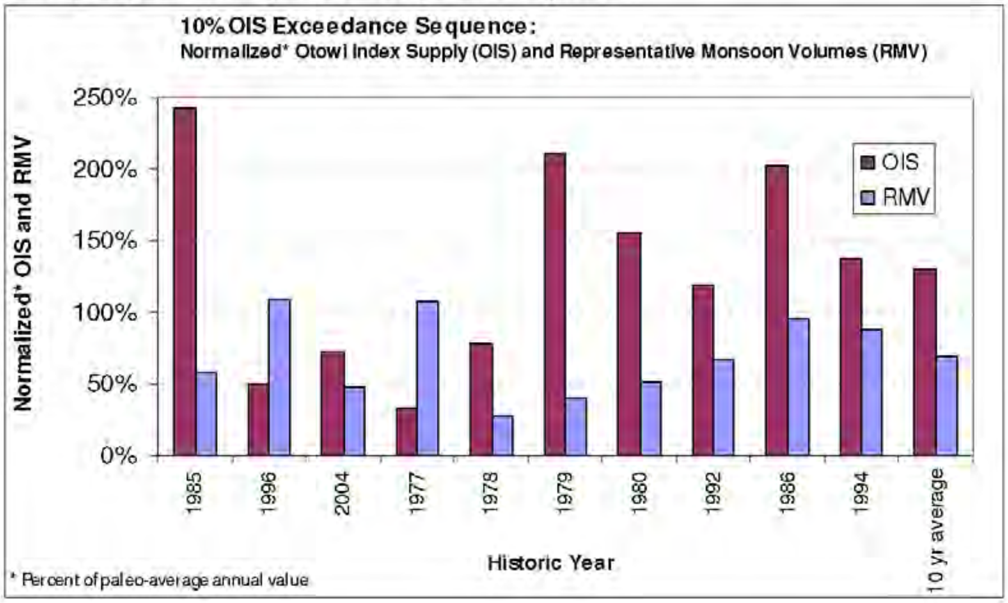


Figure 19: Normalized Otowi Index Supply and Representative Monsoon Volumes in each year of the 30% Exceedance Sequence. Values are normalized to annual average value of all years in the paleo based synthetic sequences.

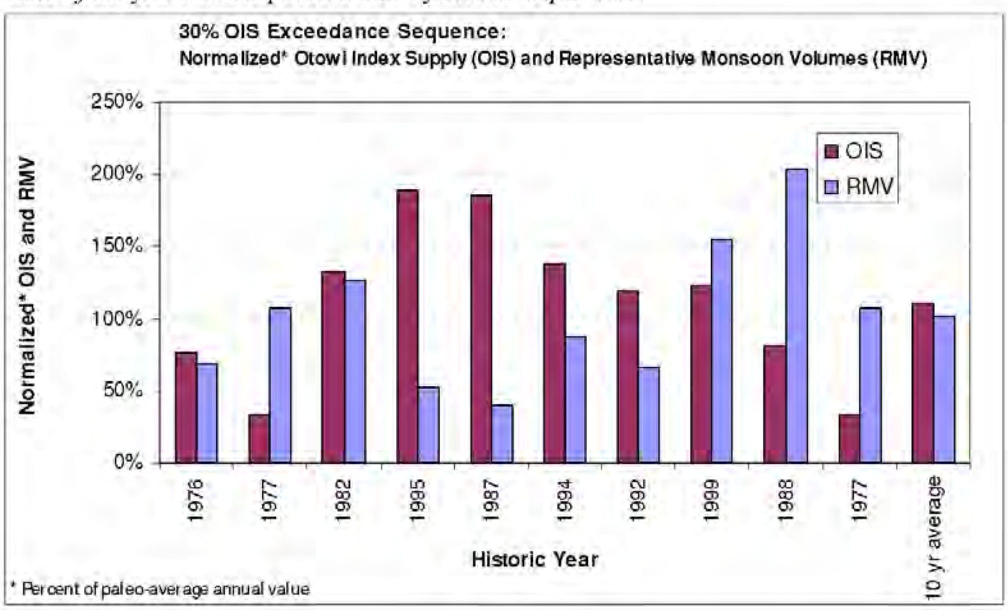


Figure 20: Normalized Otowi Index Supply and Representative Monsoon Volumes in each year of the 50% Exceedance Sequence. Values are normalized to annual average value of all years in the paleo based synthetic sequences.

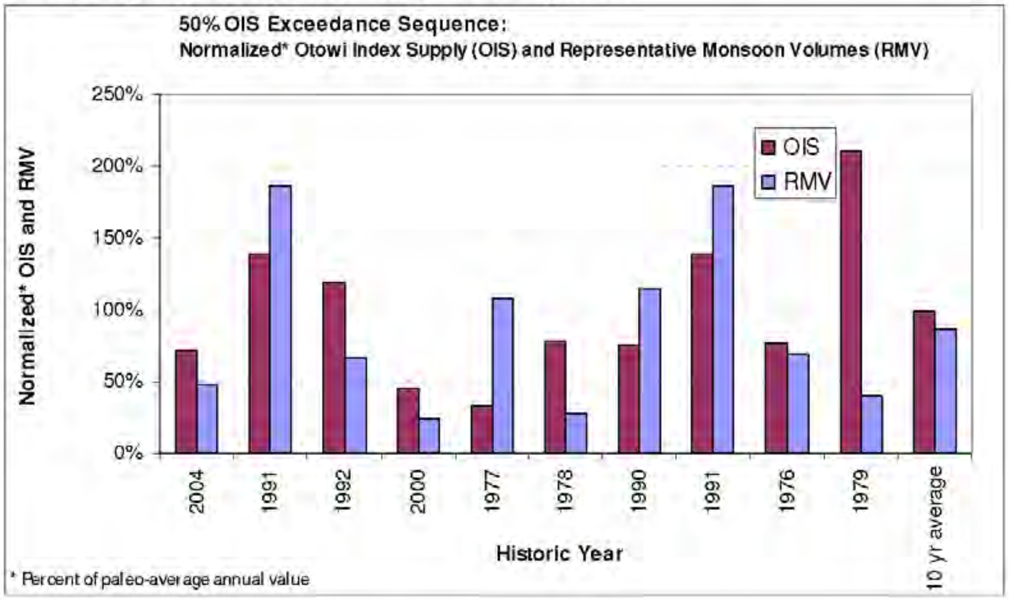


Figure 21: Normalized Otowi Index Supply and Representative Monsoon Volumes in each year of the 70% Exceedance Sequence. Values are normalized to annual average value of all years in the paleo based synthetic sequences.

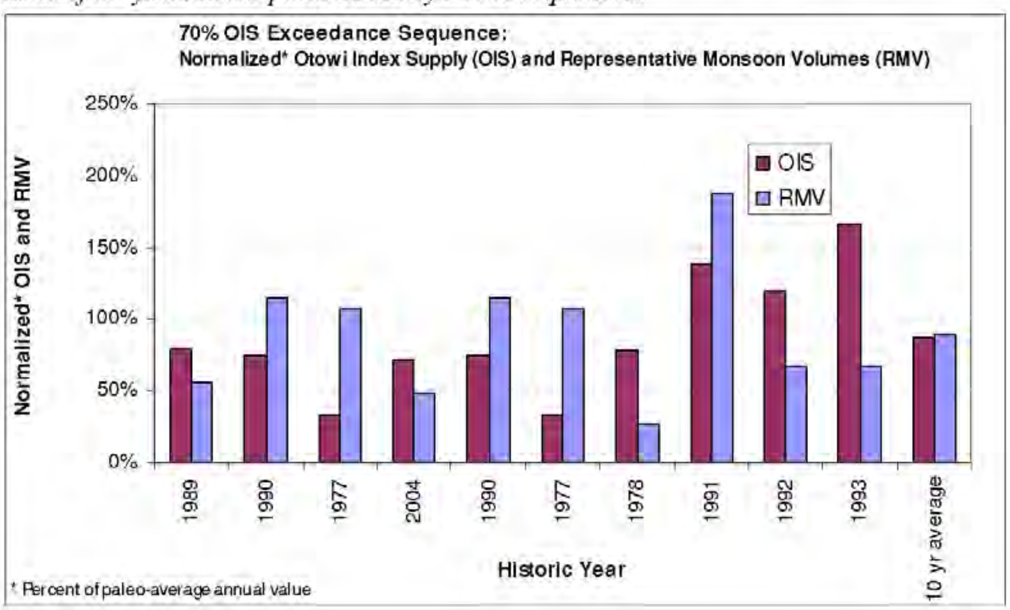
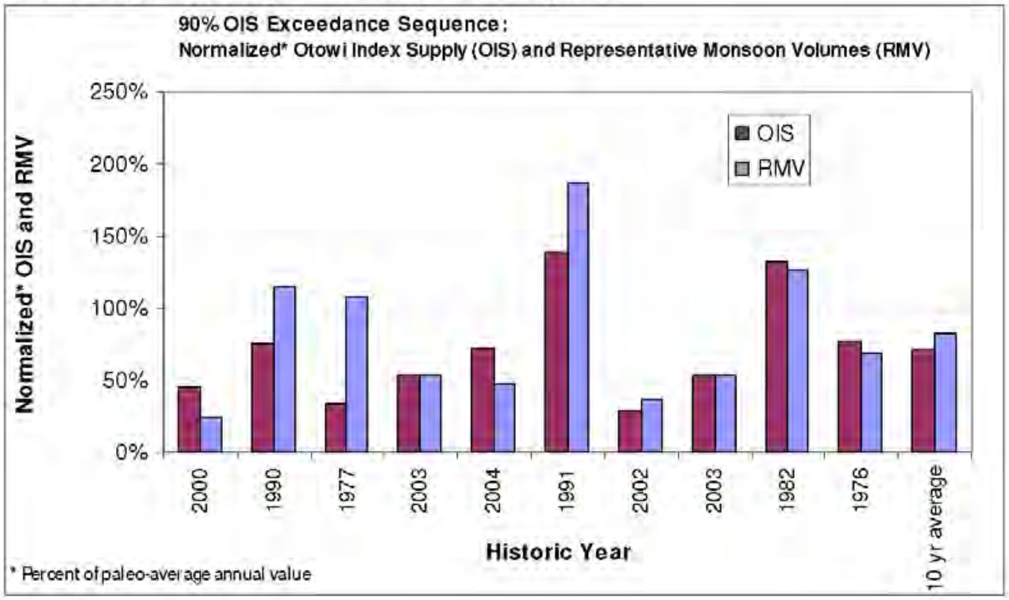


Figure 22: Normalized Otowi Index Supply and Representative Monsoon Volumes in each year of the 90% Exceedance Sequence. Values are normalized to annual average value of all years in the paleo based synthetic sequences.



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http://www.agu.org/pubs/crossref/2008/2007WR006684.shtml

Acknowledgment:

Thanks to Craig Boroughs for significant help in this analysis.

Appendix A:

Figure A-1: Otowi Index Supply for individual years in two sequences with identical 10-year average Otowi Index Supply. The sequence (in blue) beginning with 1985 was chosen for further analysis with the daily timestep URGWOM Planning Model because of a larger OIS standard deviation (647 kAF/yr) than that of the sequence (in red) beginning with historic year 1994 (385 kAF/yr).

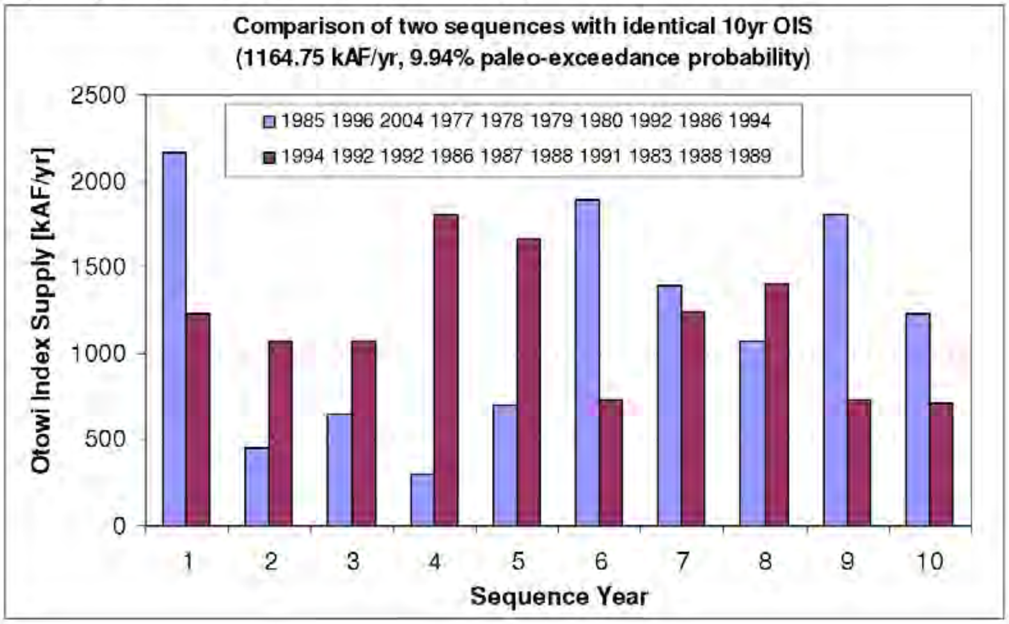

Table A-1: This table shows the sequences chosen for further analysis (named 10%, 30%, 50%, 70%, and 90%), along with two alternate sequences for each. This table is included in case additional analysis on a similar sequence is desired, or in case one of the selected sequences is discarded after additional analysis.

Sequence Name	10 yr ave OIS [kAF/yr]	% Exceed	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
10%	633	91.1%	2000	1990	1977	2003	2004	1991	2002	2003	1982	1976
10% alt1	632	91.2%	2004	1978	1989	1977	1978	1990	1977	2004	1991	1981
10% alt2	655	88.6%	2002	1989	1990	1977	2004	1990	1977	1978	1991	1992
30%	778.81	70.09%	1989	1990	1977	2004	1990	1977	1978	1991	1992	1993
30% alt1	778.76	70.10%	1981	1982	2000	2003	1997	1992	1983	1981	2001	2002
30% alt2	778.65	70.11%	1982	2000	1977	2001	1981	1997	1976	1989	1991	1976
50%	884	50.05%	2004	1991	1992	2000	1977	1978	1990	1991	1976	1979
50% alt1	886	49.64%	1998	1992	1983	1984	1984	1976	1989	1977	2003	2004
50% alt2	882	50.42%	1982	2002	2001	1993	1994	1983	2002	1982	1976	1977
70%	995	29.93%	1976	1977	1982	1995	1987	1994	1992	1999	1988	1977
70% alt1	993	30.23%	1982	1976	1991	1992	1983	1994	1998	1992	1976	2003
70% alt2	997	29.60%	1980	1981	2001	2002	1978	1979	1980	1981	1982	1993
90%	1164.75	9.938%	1985	1996	2004	1977	1978	1979	1980	1992	1986	1994
90% alt1	1164.75	9.939%	1994	1992	1992	1986	1987	1988	1991	1983	1988	1989
90% alt2	1165.2	9.90%	1980	2000	1982	1994	1993	1994	1995	1994	1996	1997

Table A-2: Historic Annual Otowi Index Supply Values. Values provided by Dr. Nabil Shafike, New Mexico Interstate Stream Commission, personal communication August 2008. To read table, add year number to decade. For example, the Annual Otowi Index Supply Value for 1944 was 1363.2 kAF/yr.

Annual Otowi Index Supply [kAF/yr]											
		Year									
		0	1	2	3	4	5	6	7	8	9
Decade	1940	590	2686.8	2079.9	693.6	1363.2	1137.9	474.2	754.4	1370.9	1344.7
	1950	492.2	358.3	1423.2	522.3	431.3	438.7	359.8	1473.2	1507.1	424.8
	1960	798.8	788.6	1056.2	416.7	394.7	1387.5	793.8	567.6	870.6	1167.2
	1970	832.2	566.1	474.3	1576.3	450.4	1185.8	682.5	296.5	699	1888.7
	1980	1392.2	416.9	1183.5	1402.5	1343.1	2169.1	1805.9	1662.4	726.5	713.4
	1990	671.5	1239	1067.8	1489.4	1235.7	1692	449.1	1329.3	892.5	1103.2
	2000	409.2	833.7	254.8	473	643.5	1353	574.3	859.9	-	-

APPENDIX 2

AMEC MEMORANDUM
SUBJECT: STOCHASTIC STREAMFLOW SIMULATIONS FOR THE OTOWI GAGE

MEMORANDUM

TO: Dr. Nabil Shafike, P.E., New Mexico Instream Commission

FROM: Subhrendu Gangopadhyay and Ben Harding
AMEC Earth & Environmental

SUBJECT: Stochastic Streamflow Simulations for the Otowi gage

DATE: June 24, 2008

In this memorandum we present the results of stochastic simulation of Otowi ensemble flows developed using two approaches. The first set of simulations is based on the non-homogeneous Markov Chain (NHMC) algorithm of *Prairie et al* [2008]. The second set is based on the homogeneous Markov Chain (HMC) algorithm [*Haan*, 1977] using transition probability matrix developed by *Ward* [2008] for the Otowi gage.

Non-homogeneous Markov Chain Simulations

The non-homogeneous Markov Chain algorithm with an application to the Lees Ferry gage (Colorado River, AZ) ensemble streamflow simulation is described in the paper by *Prairie et al.* [2008]. Conceptually, this approach provides a method to combine transient state information (wet/dry) from paleo reconstructions of hydrologic markers (e.g., streamflow, Palmer Drought Severity Index – PDSI) with observed streamflow records to generate streamflow ensembles. Please refer to *Prairie et al* [2008] paper for the detailed description of this algorithm.

The starting point to apply this algorithm for the Otowi simulations was to study the correlation between the gridded paleo PDSI [*Cook et al*, 2004] for grid points in the vicinity of the Otowi gage and the natural streamflow of the Otowi gage. Naturalized streamflow for the Otowi gage is presently available for the period 1940-2007. The gridded PDSI data is available from the NCDC (National Climate Data Center) website, http://www.ncdc.noaa.gov/paleo/newpdsi.html. Results of the correlation analysis are shown in Figure 1. The grid point (longitude, 110.0W; latitude, 37.5N; number, 103) was found to have the highest correlation with the Otowi naturalized flow. Paleo reconstructed PDSI [*Cook et al*, 2004] for this grid point (number, 103) was used to define the flow states of the Otowi gage – 604 years of PDSI values for the period 1400-2003. Two states (dry – 0, wet – 1) were assigned to each of the 604 years of the PDSI time series. The mean and median PDSI for the 604 year period was found to be, -0.5490 and -0.3150 respectively. Consequently, positive PDSI values (PDSI > 0.0) were assigned to state wet, and PDSI values less than and equal to zero were assigned to state dry. This resulted in a binary [0, 1] time series of length 604.

This binary time series was used to develop the transient transition probability matrix corresponding to four transitions, dd (dry-dry); dw (dry-wet); wd (wet-dry); and wet-wet (ww). The transient transition probability plot is given in Figure 2. The transient transitions were developed using a non-parametric kernel smoothing algorithm following *Prairie et al.* [2008]. It should be noted in Figure 2 that certain epochs have a higher (lower) probability of transitioning from dry (wet) to wet (dry) states. The NHMC algorithm then randomly selects an epoch of given length (100 in this case), randomly selects the initial state (dry or wet), and marches through the transitions [*Haan,* 1977] to get the simulated 100 year state time series. In addition, the historical Otowi naturalized flow time series is also classified into two states. Median flow over the 1940-2007 period, 833 kaf, was used to assign dry and wet states to each of the 68 years. If annual flow for a given year was greater than 833 kaf that year was identified to be wet, else the year was in dry state. Using the above simulated states from the paleo PDSI, the flow state from the observed period and flow magnitudes of the observed period, a conditional K-nearest neighbor (K-nn) bootstrap was performed [*Prairie et al.,* 2008] to generate an ensemble member of years and hence flow. The step of randomly selecting an epoch and conditional K-nn was repeated to generate a 1000 member ensemble of traces, each of length 100. The simulated years and flows are available in files *NM_paleo.txt* and *NM_paleo_flow.txt* respectively (the files are in matrix format, 100 rows x 1000 columns) in directory *NHMC.*

To test the simulated flows a suite of basic distributional statistics were computed from the flow ensemble including the ensemble member (i) mean, (ii) standard deviation, (iii) coefficient of skew, (iv) maximum, (v) minimum, and (vi) lag-1 autocorrelation. Drought statistics include, (i) average deficit, (ii) maximum deficit, (iii) average drought run intensity, and (iv) maximum drought run length. The drought statistics were derived using the respective median values as the threshold (drought – below median flows).

The results are displayed as boxplots in Figures 3 and 4, where the box represents the interquartile range (IQR) and whiskers approximate the 5th and 95th percentile of the simulations and outliers are shown as open circles beyond the whiskers. The statistics of the observed record are represented as a filled red triangle. Performance on a given statistic is considered good when the observed statistic of interest falls within the box (i.e., IQR) of the boxplots, while increased variability is indicated by a wider boxplot.

Generally, in all cases the observed record (red triangle) falls within the IQR of the boxplots except the drought statistic, maximum run length. The maximum drought run length in the observed flow record is 4 years (1953-1956), the maximum drought length from the PDSI record is 14 years (1870-1883). The NHMC is able to generate flows that span extended drought periods not experienced in the observed period. This we believe is valuable to the ISC in using these simulated flows in the URGWOM model.

In the next section we present the results from the homogeneous Markov Chain simulations using transition probability matrix from *Ward* [2008].

Homogeneous Markov Chain Simulations

Markov chain simulation using a single (hence the notion of homogeneity) transition probability matrix is given in *Haan* [1977]. The transition probability matrix (four state - very dry, dry, wet, very wet) used in simulating the Otowi flows is based on the matrix derived using 2000-year paleo record (Table 4, *Ward*, 2008). The transition probability matrix is given in Table 1. The flows for the observed, 1940-2007 period were assigned the four states based on thresholds defined in Table 6 of *Ward* [2008] (2000-year record upper bounding flows – very dry (444.5 kaf); dry (843.1 kaf); wet (1463.2 kaf); very wet (maximum)).

The simulated years and flows (1000 simulations each of length 100) are available in files *Ward_SimYear.out* and *Ward_SimFlow.out* respectively (the files are in matrix format, 100 rows x 1000 columns) in directory *Ward.* Similar to the NHMC simulations, basic distributional statistics and drought statistics were calculated from the simulated flows and the results are presented as boxplots in Figures 5 and 6. Generally, the observed statistic (red triangle) is within the IQR of the boxplots, except for the statistic maximum drought run length. Using the homogeneous Markov Chain model we were able to generate flow traces with longer drought lengths (median length of 7 to 8 years) than the observed maximum of 4 years (1953-1956). This again, we believe is of value to ISC in using these simulated flows in the URGWOM model.

Transition Probability Comparison

As part of the above analyses we also compared the transition probability matrix (four state – very dry, dry, wet, very wet) of *Ward* [2008] derived using 2000 year of paleo record with the one we developed (four state) using the 604 years (1400-2003) PDSI values for grid 103 (longitude, 110.0W; latitude, 37.5N; *Cook et al.,* 2004). This may not be the case for the Otowi gage, but from our experience on working with tree-ring chronologies on the Colorado River for the Lees Ferry gage (e.g., *Gangopadhyay et al.,* 2008), limited tree-ring chronologies are available prior to c. 1400, and we believe any hydrologic reconstruction prior to this time will likely have large uncertainties. This was the motivation for using the PDSI time series starting in 1400.

The definition of the four states for the above PDSI data as used in this comparison is given in Table 2. We believe these state definitions to be objective as it is based on the standard PDSI state classification system [e.g., http://weather.nmsu.edu/drought/053102/drought6.pdf]. Using the PDSI classification from Table 2, each of the 604 years (1400-2003) were assigned a state – very dry, dry, wet and very wet. The four state transition probability matrix is given in Table 3. Overall the transitions in Table 3 compare well with the transitions in Table 1 [*Ward,* 2008] except that we found no transition in the 604 year record and based on our state definition (Table 2) from very dry to very wet state. It is intuitive that for the semi-arid Rio Grande valley to move from a very dry state (very low soil moisture) to a very wet state (very high soil moisture) within a year is mostly unlikely. From a steady state transition probability estimation analysis (alternatively, Table 2 column labeled – *Count Pct)* we found that the system will be in very dry, dry, wet and very wet states 17%, 39%, 36%, and 8% of the time respectively. *Ward* [2008, Table 5] estimated these states to be 17% (very dry), 35% (dry), 33% (wet), and 15% (very wet). Again these state percentages compare well, except for the very wet state, where we get nearly half (8%) as compared to 15% by *Ward* [2008]. No flow simulations were carried out using our transition probability matrix (Table 3) at this time.

Future Work

The following additional work is proposed to be carried out on this project.

(1) Use the transition probability matrix (Table 3) to generate flow ensembles using the homogeneous Markov Chain (HMC) algorithm.

(2) Derive two state homogeneous transition probability matrix (e.g., average of the NHMC transient transition probability matrix) and generate flow ensembles using the *Prairie et al.*[2008] conditional bootstrap algorithm.

(3) Repeat (2) above using alternative PDSI thresholds corresponding to mean and median flows from the observed period. The current transition probability matrix is derived using PDSI value of zero as the dry/wet transition threshold.

(4) Perform NHMC simulations using the additional two state transition probability matrix derived in (3) above.

(5) Perform HMC simulations using a three state (based on observed Otowi flow terciles) transition probability matrix with unconditional and possibly conditional resampling of flows. Current conditional resampling codes are based on a two state system, will need additional development for extending it to more states.

(6) Evaluate cross-validation statistics for selected Markov Chain simulations.

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Table 1. Transition probability matrix used in homogeneous Markov Chain simulations.

	Very Dry	*Dry*	*Wet*	*Very Wet*	**Steady State**
Very Dry	0.22	0.42	0.29	0.07	17%
Dry	0.20	0.41	0.29	0.10	35%
Wet	0.16	0.31	0.35	0.19	33%
Very Wet	0.07	0.25	0.40	0.29	15%

Source: Ward [2008].

Table 2. Definition of four states for the Cook et al. [2004] PDSI data.

State	*Description*	*Definition*	*Count*	*Count Pct*
1	Very Dry	PDSI ≤ -3.00	105	17%
2	Dry	-2.99 ≤ PDSI ≤ 0.00	233	39%
3	Wet	0.01 ≤ PDSI ≤ 2.99	220	36%
4	Very Wet	PDSI ≥ 3.00	46	8%

Table 3. Four state transition probability matrix using state definition from Table 2 and Cook et al. [2004] PDSI time series for grid 103 for the period 1400-2003.

	Very Dry	*Dry*	*Wet*	*Very Wet*
Very Dry	0.27	0.52	0.21	0.00
Dry	0.20	0.42	0.33	0.05
Wet	0.13	0.30	0.46	0.10
Very Wet	0.02	0.33	0.39	0.26

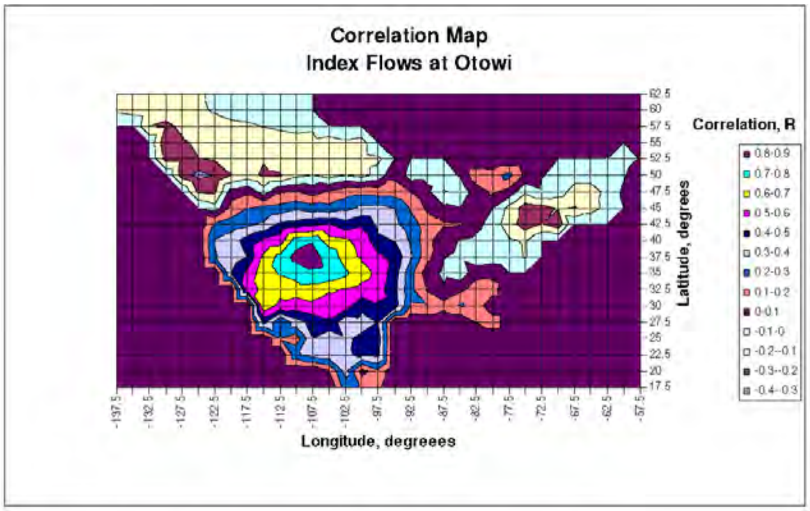

Figure 1. Correlation of gridded PDSI to Otowi index flows.

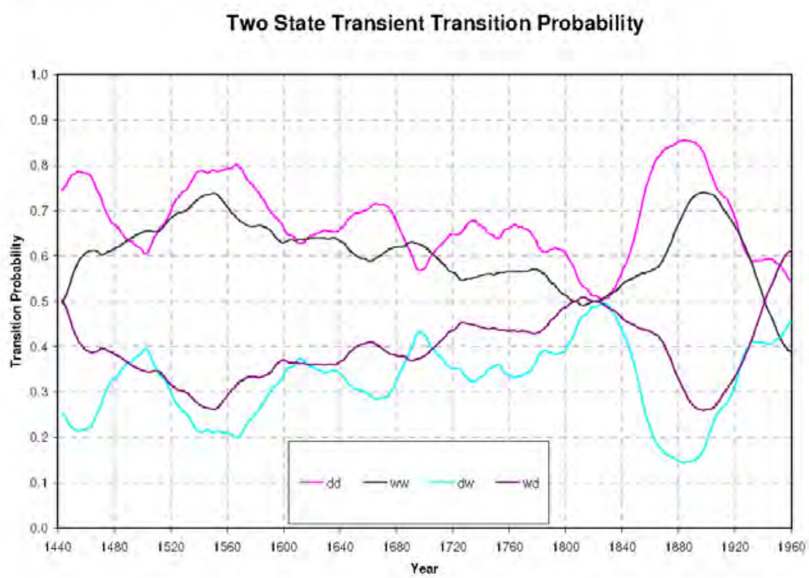

Figure 2. Two state – four transitions (dd, dw, wd, ww) transient transition probability based on the binary dry/wet time series of length 604 (1400-2003).

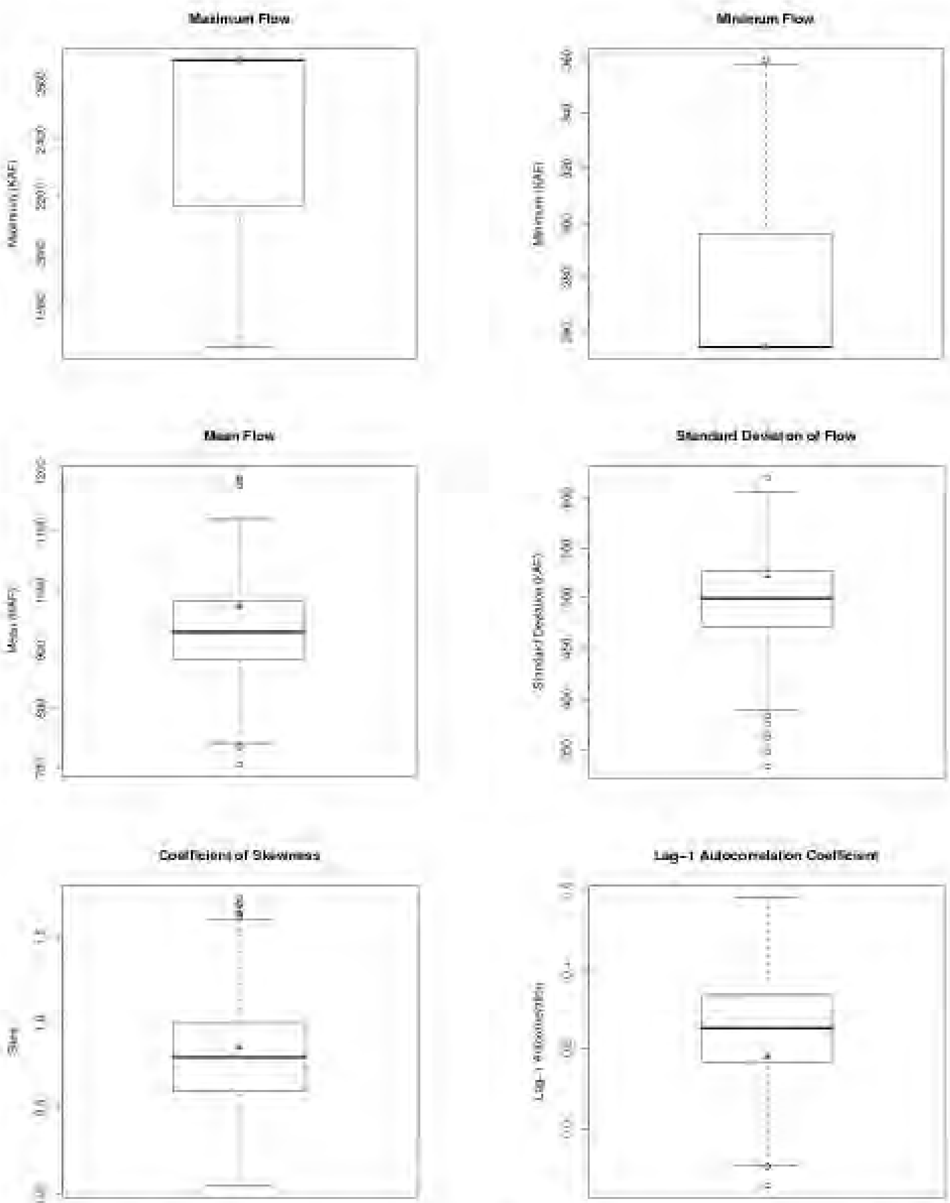

Figure 3. Distributions of statistics of annual flows for the traces generated by the NHMC.

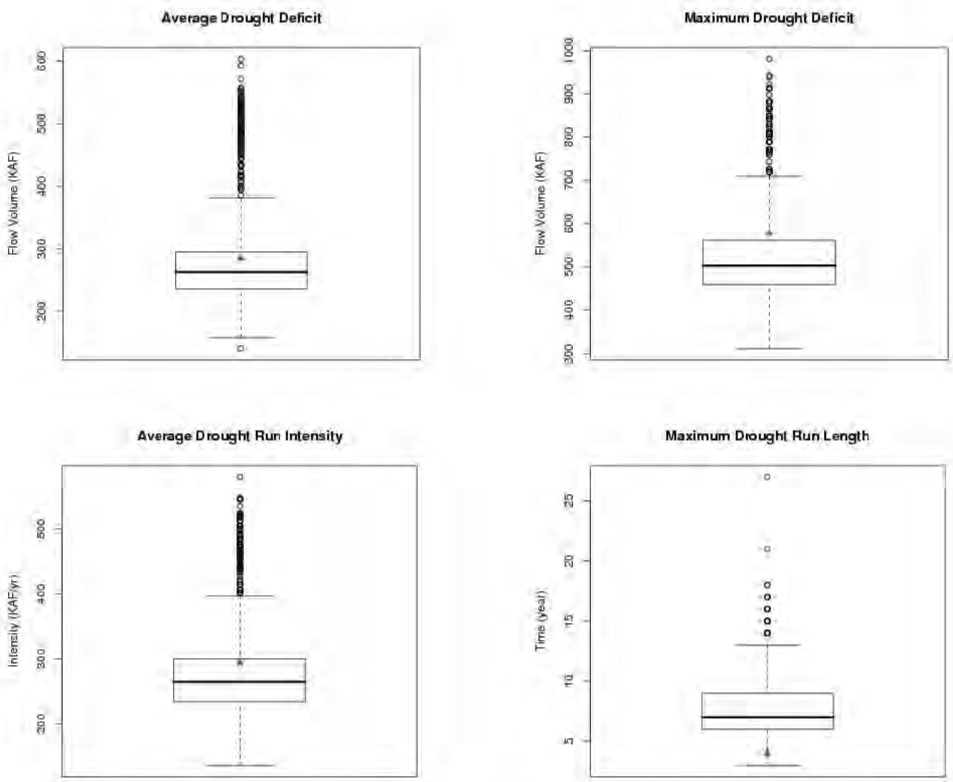

Figure 4. Distributions of statistics of drought for the traces generated by the NHMC

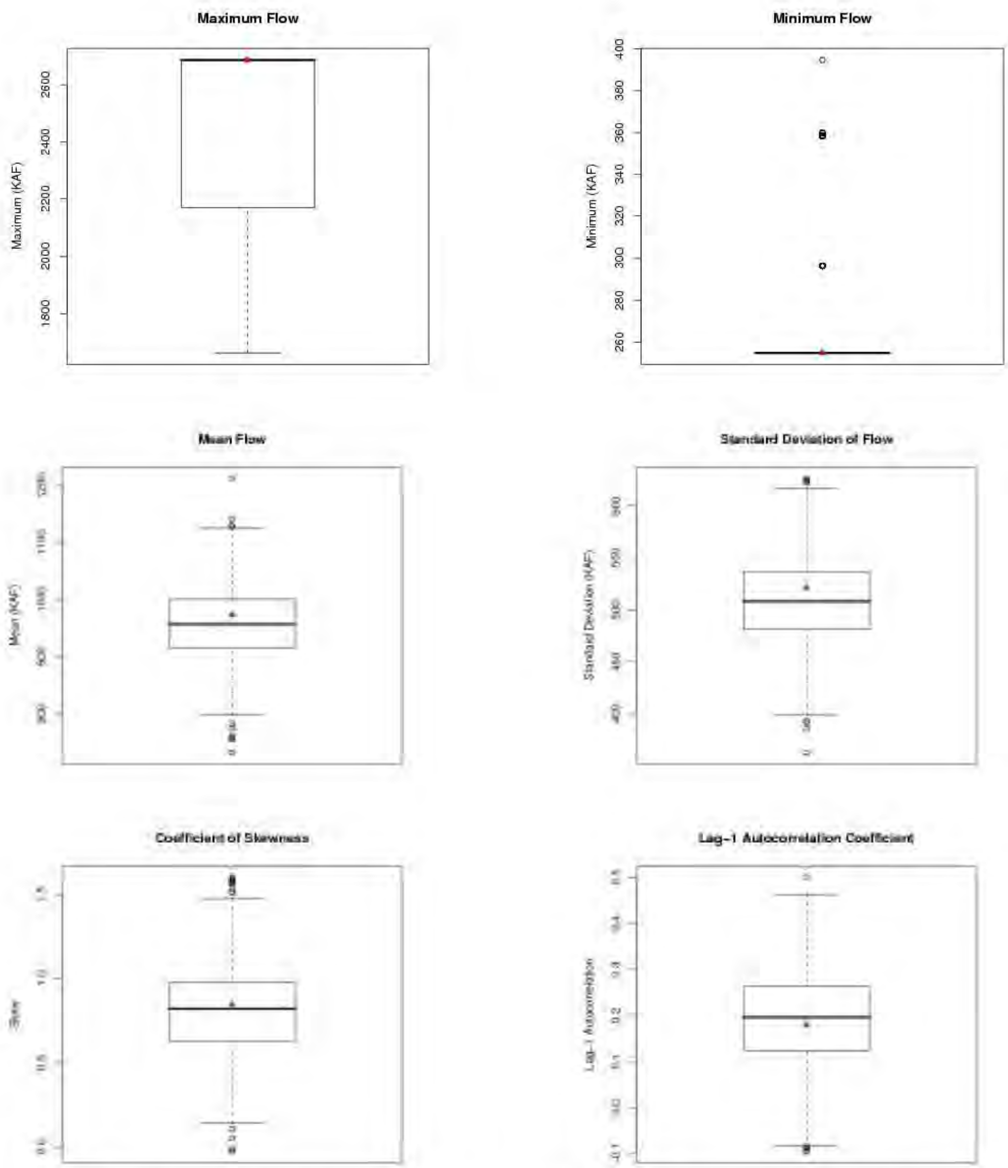

Figure 5. Distributions of statistics of annual flows for the traces generated by the HMC.

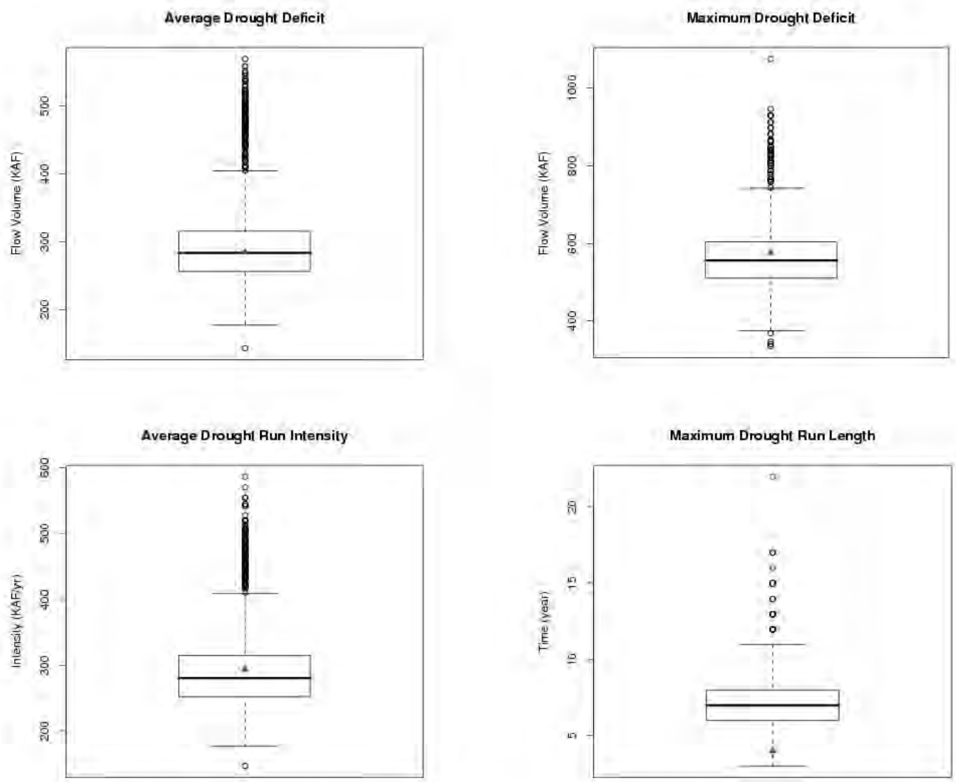

Figure 6. Distributions of statistics of drought for the traces generated by the HMC

APPENDIX 3

HABITAT RESTORATION TECHNIQUES COMMONLY USED IN THE MIDDLE RIO GRANDE

Appendix 3 – Habitat Restoration Techniques Commonly Used in the Middle Rio Grande

Method	Geomorphic Response	Habitat Characteristics	Biological Response
Riparian vegetation establishment	Can cause sediment deposition in overbank areas due to increased flow resistance. Sediment deposition in the overbank can increase main channel sediment transport capacity by raising the bank height.	Directly adds to the amount of riparian vegetation.	Increased growth of riparian vegetation in overbank areas can enhance habitat conditions for both the flycatcher and the silvery minnow. Encroachment of mature vegetation may eventually lead to a narrower and more confined channe,l which is negative for silvery minnow habitat.
Longitudinal bank and bar/island lowering	Lowered bank line can promote a wider channel width and decreases in main channel velocity, depth, shear stress, and sediment transport capacity reduces potential for channel degradation, thereby maintaining a higher water table and more connectivity with backwaters and side channels. Increases overbank flooding, creating variable depth and velocity habitat. During subsequent years, sediment may deposit in the lowered bank line area occupied by vegetation, which may reduce overbank conveyance capacity.	Promotes overbank flooding favorable for establishment of riparian vegetation as well as creating variable depth and velocity habitat. Reduces potential for channel degradation, thereby maintaining a higher water table and more connectivity with backwaters and side channels.	Increased overbank flooding creates variable depth and velocity habitat types including silvery minnow nursery habitat during spring runoff. Increased overbank flooding maintains moist soil conditions during flycatcher territory establishment. Growth of native riparian vegetation can enhance habitat conditions for the flycatcher.
Bankline embayments (willow swales and backwater areas)	Historical channel slow water velocity and shallow depth bank line habitat is restored/rehabilitated. Bank line embayments are zones of sediment deposition and have a finite lifespan without periodic re-excavation.	Slow water velocity and shallow depth bank line habitat.	Increase in egg retention and availability of nursery larval habitat during high flow. Increases probability of native vegetation growth and potential for flycatcher habitat.
large woody debris (LWD)/ perennial pools	Creates pools, generates scour and substrate sorting, and increases depth and velocity complexity. Can promote side channel formation and maintenance. LWD in the Middle Rio Grande can lead to sediment deposition, including formation of islands, in reaches with large sand loads. Prone to sedimentation after inundation. Short life span for LWD using cottonwood trees on Middle Rio Grande.	Adds complexity to the system. Sediment deposition can create areas where new riparian vegetation becomes established. Can create variable depth and velocity habitat. Can provide structure and habitat for fish.	May provide for habitat diversity in areas with monotypic flow patterns and refugia habitat during low flows. These habitats may also provide refuge for predatory fishes. Increased areas of moist or flooded soil conditions could assist in flycatcher territory establishment and native vegetation recruitment.

Exotic vegetation removal	Exotic vegetation removal may result in channel widening and increased flood plain connectivity. Channel widening could reduce channel flow depth and velocity. Degree of change is dependent on degree of connection between the main channel and the surface upon which the exotic vegetation is being removed. In removal areas that are currently disconnected from the river, there is a negligible effect on the fluvial geomorphology of the river channel. The degree of influence exotic vegetation removal has on the geomorphology is also influenced by the timing of peak flows in relation to the period when exotic vegetation removal occurred. May also have an influence on the geomorphology of disconnected, historical flood plain areas as the removal of trees may allow for a higher groundwater table.	Could result in channel widening, increased flood plain connectivity, allow for a higher groundwater table and increase chances of native vegetation outcompeting exotics.	Dependant on site-specific details, the removal of exotic vegetation could temporarily remove flycatcher habitat as species such as saltcedar do provide the structural composition required for nesting. Over the long term, if replaced with native vegetation and a wider channel and increased flood plain connectivity, could re-establish better nesting habitat over time. The temporary removal of vegetation may allow for a more active channel with connectivity to the flood plain creating silvery minnow habitat.
Island and bank destabilization	Promotes a wider channel with greater flood plain connectivity and balances sediment. Reduces further degradation of the channel and lowering of the local water table. Sediments from destabilized areas may deposit new bars suitable for vegetation growth. Can locally increase sediment supply for a temporary period of time if erosion occurs. New sediment balance may be temporary unless incoming loads also increase. Can provide increased flood carrying capacity. Cleared and lowered bankline or island areas can become zones of sediment deposition and may need to be re-cleared and re-excavated for benefits to continue. Degree of change is dependent on degree of connection between the main channel and flood plain and the timing of peak flows in relation to the period when destabilization occurred	Reduces further degradation of the channel and lowering of the water table. Sediments from destabilized areas may deposit new bars suitable for vegetation. Clearing and destabilization would result in the temporary loss of this habitat. Islands/bars that are more connected to the main channel can provide RGSM with a greater variety of depth and velocity habitat types.	Provides low velocity habitat during high flows for adult fish. Increased overbank flooding creates variable depth and velocity habitat types including silvery minnow nursery habitat during spring runoff and aids in increasing egg and larval entrainment. Loss of habitat may be temporarily negative depending on site-specific details and proximity to flycatcher territories; however, sediment accumulation forming new bars or islands could promote new seed source establishment and potentially young native successional stands to develop into flycatcher habitat. By reducing further degradation of the channel and lowering of the water table, the flood plain has a better chance of connectivity, which is better overall for the flycatcher.

Side channel (high flow and oxbow reconnection)	Important to natural systems for passage of peak flows. Maintains higher water surface elevation and ground water table. Can reconnect the flood plain to the channel. Sediment tends to fill in high flow side channels over time. Can decrease peak flow water surface elevation and may decrease sediment transport capacity until sediment blocks the side channel. Method provides for reduced main channel sediment transport capacity. Sediment tends to deposit at the inlets and outlets. Periodic inlets and outlets sediment removal may be needed to maintain project benefits.	Side channels result in raising the ground water table and surface flows to developing riparian areas. Maintains higher water surface elevation and ground water table, adding to the health of the riparian zone. Can reconnect the flood plain to the channel, creating nursery habitat for the Rio Grande shiny minnow (RGSM) with variable depth and velocity habitats.	Provides low velocity habitat during high flows for adult fish and developing larvae. Increase in retention of eggs and larvae during high flows. Raising the ground water table to provide water to developing riparian areas increases vegetation health. Periods of increased surface flows, particularly during mid-May to mid-June, increases probability of flycatcher territory establishment in areas with suitable habitat.
GRF/sill	Grade controls can reduce the gradient upstream by controlling the bed elevation and dissipating energy in discrete steps. At least during low flows, the upstream water surface is raised, depending on structure height above bed. Upstream velocity is reduced. For low head structures (1 to 2 feet), the amount of upstream sediment storage is low and usually does not cause downstream bed level lowering as a result of upstream sediment storage. In sediment supply-limited reaches, channel degradation downstream of the structure will continue as a result of excessive sediment transport capacity. For gradient restoration facilities (GRF), the bed is fixed; for a rock sill, the rock launches into the downstream scour hole.	Reduces channel degradation upstream of this feature and can promote overbank flooding and raise the water table. This provides more opportunity for riparian zone establishment and development. Backwater areas could develop upstream, which would raise the water table. If downstream degradation continued, then the water table would be lowered, reducing water availability to the riparian forest.	Increased overbank flooding upstream creates variable depth and velocity habitat types including potential spring runoff silvery minnow nursery habitat. Steeper apron slopes may restrict fish movement, while lower slopes can meet flow velocity requirements for fish passage. A reduction in channel degradation and increase in overbank flooding and water table levels would likely increase vegetative health and could attract flycatchers, particularly if overbank flooding conditions occurred during territory establishment. However, the opposite effect likely would occur downstream.

Bendway weirs	The location of the thalweg is shifted away from the outer bank line. Local scour at the tip occurs because of the three-dimensional flow patterns. Secondary currents are interrupted, and flows are redirected away from the bank. The outer bank can become a zone of lower velocity. The combined effect of the tip scour and lower velocity along the bank line creates a flow condition of variable depth and velocity. Scalloping also can occur along the bank line, or sediment deposition between structures depending upon local conditions and bendway weir geometry. Can reduce local sediment supplied from bank erosion, because the current river alignment is maintained.	Sediment deposition between structures may allow establishment of riparian vegetation and backwater areas. Channel deepening and tip scour could locally lower the riverbed and lower the ground water table.	Depending on site-specific details, bendway weirs would allow for overbank flooding conditions for flycatchers. However, depending on the location and the degree of lowering the ground water table, construction efforts could impact flycatcher suitable habitat. Silvery minnows could be stranded in pools that would form between weirs as flow receeded. However, it could provide habitat diversity and deep habitat during low flow conditions.
Rootwads	Creates local scour pools and variable depth and velocity habitat Increases flow resistance along the bank line, which dissipates energy, traps and retains sediments, and creates turbulence that can move the main current away from the bank line. Cottonwood tree rootwads have a design span of about 5 years; therefore, this method has been used with many other methods to create habitat.	Adds complexity to the system. Variable depth and velocity conditions can be created. Some potential for creating areas of sediment deposition (depending on specific placement), which is generally beneficial to the establishment and development of riparian vegetation.	Can provide structure and habitat for silvery minnow. Isolated pools are often maintained in scour pools caused by debris, including rootwads. This can serve as refugia habitat for silvery minnow during low flow periods. Similar to LWD. Could trap sediment and encourage new native vegetative growth.
Jetty removal	Jetty removal may result in channel widening and increased flood plain connectivity. However, vegetation often promotes more bank stability than jetties, thus removal may not result in channel widening and increased flood plain connectivity. Channel widening could reduce channel flow depth and velocity.	The habitat may not change if the existing vegetation has more effect on bank stability than the jetties themselves. Otherwise, channel widening could reduce channel flow depth and velocity and create more bank line habitat.	If banks are destabilized, there can be an increased availability of shallower and lower velocity habitat for the silvery minnow. By destabilizing the bank, could encourage lateral migration of the river providing more opportunity for successional age classes of potentially native vegetation for flycatcher habitat.

Removal of lateral constraints	Can encourage current geomorphic processes to continue, such as lateral migration, and the creation of new flood plain and riparian areas. This may increase opportunities for the river to connect with historical channels and oxbows. For incised channels, may provide an opportunity to establish new inset flood plain and riparian zone. Lateral river movement creates broader flood plain. Lateral bank movement should result in deposition of sediment downstream. The river may establish bars and low surfaces as lateral migration continues to occur. Longer meander bends may establish greater pool depth and eroding banks providing additional complexity.	Lateral river movement creates broader flood plain and more favorable riparian zone habitat. Lateral bank movement should result in deposition of sediment downstream. The river will establish bars and low surfaces, where vegetation can become established. Longer meander bends may establish greater pool depth and eroding banks with vegetation falling into the channel, providing fish cover and habitat complexity.	Inset flood plain and riparian zones increase overbank flooding and create variable depth and velocity habitat types including potential spring runoff for silvery minnow nursery habitat. The lateral migration of the river provides more opportunity for successional age classes of potentially native vegetation for flycatcher habitat.
Longitudinal stone toe with bioengineering	Studies about longer reach response are contradictory. Maintains the local current river alignment, and the point bar remains static. The flow velocity and depth are greater than typically found in natural channels along the outside bank of a river bend. Can be susceptible to flanking if upstream channel migration occurs. Eliminates sediment supplied from bank erosion. Bank line vegetation is established.	Prevents lateral migration and the establishment of new depositional zones where vegetation could become established. Eliminates sediment supplied from bank erosion. The steep bank angle on the outside of the bend limits fish cover, except for the riprap interstitial spaces. The point bar remains connected to the main channel and remains static. The flow velocity and depth are greater than typically found in natural channels along the outside bank of a river bend. Bioengineering provides very minimal benefits to riparian community.	

APPENDIX 4

CRAIG BOROUGH'S MEMORANDUM SUBJECT: ESTIMATION OF DECEMBER 31, 2011, CONDITIONS TO USE AS INITIAL CONDITIONS FOR UPDATED URGWOM SIMULATIONS FOR RECLAMATION'S WATER OPERATIONS BIOLOGICAL ASSESSMENT DATED DECEMBER 15, 2011

Memorandum

To: Warren Sharp Reclamation –Albuquerque

CC: URGWOM Technical Team

From: Craig Boroughs

Date: December 15, 2011

Re: Estimation of December 31, 2011 Conditions to Use as Initial Conditions for Updated URGWOM Simulations for Reclamation's Water Operations Biological Assessment

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Introduction

Initial condition information is needed for modeling of river system operations for development of the Bureau of Reclamation's (Reclamation) Middle Rio Grande Water Operations Biological Assessment (BA) using an updated planning module of the Upper Rio Grande Water Operations Model (URGWOM). Initial conditions were developed to reflect expected conditions on December 31, 2011 to represent the latest and best information on starting conditions for the 10-year planning model runs. Estimated initial conditions are based on recent information regarding the current status of storage in the reservoirs in the basin and the account status as reflected in the Accounting Model maintained by Reclamation. The December 31, 2011 conditions were developed based on several basic assumptions for the movement of water and accounting adjustments expected before the end of the year as documented below. It is emphasized that the resulting estimated storage levels for December 31, 2011 will not match the actual storage levels on that date but represent reasonable and clean starting conditions that are adequate for planning model runs.

Approach for Estimating December 31, 2011 Conditions

Initial conditions needed to complete URGWOM runs include initial values for numerous series such as reservoir storage levels and the storage for all the individual storage accounts at each reservoir including the Compact credit at Elephant Butte Reservoir. Initial values are also needed for incidental content, carryover storage, and reservoir sedimentation at Abiquiu Reservoir, Cochiti Lake, and Jemez Reservoir. Values are needed for initial reach flows, total reservoir releases, and releases of native Rio Grande flow; although, it should be emphasized that initial river flows needed to start calculations in the model actually have little impact on the model results as long as the values are reasonable.

Storage conditions on December 31, 2011 were estimated starting with actual values for total reservoir storage and account storage on November 21, 2011. Refer to Table 1 for the actual November 21, 2011 values which include storage for the different accounts for San Juan-Chama Project water at Heron Reservoir along with the common pool for San Juan-Chama Project water

(Note that data errors for the gaged flows in the Low Flow Conveyance Channel at San Marcial and the pool elevation at Elephant Butte Reservoir on October 25th were corrected in the provided Accounting Model prior to evaluating conditions at Elephant Butte Reservoir). Storage of San Juan-Chama Project water in allocated space at El Vado and Abiquiu Reservoirs for Albuquerque, MRGCD, and the Combined account is also needed where the Combined account includes storage for all contractors other than Albuquerque, MRGCD, or the Cochiti Recreation Pool. Storage of Reclamation's leased San Juan-Chama Project water is included. Storage must also be input for the NMISC and Jemez Sediment Pool accounts which are not used. Storage of native Rio Grande water at each reservoir is included along with storage of Emergency Drought water from relinquished Compact credits as represented with the MRGCD Drought and Supplemental ESA accounts at El Vado Reservoir. Storage of Prior and Paramount (P&P) water at El Vado is represented by the Indian Storage account. Conservation storage at Abiquiu, Cochiti, or Jemez Reservoirs is set to zero. An initial estimate for the Compact credit at Elephant Butte Reservoir is also included. Storage of Albuquerque and Santa Fe San Juan-Chama Project water at Elephant Butte Reservoir along with Colorado credit water is input as an initial condition to assure initial account storage adds up correctly at Elephant Butte Reservoir.

Table 1. Actual November 21, 2011 Total and Account Storage Levels and Incidental, Carryover, and Sediment Contents

Account	Heron	El Vado	Abiquiu	Cochiti	Jemez	Elephant Butte
TOTAL	237,132	97,834	180,042	51,748	0	226,557
San Juan-Chama Project Water:						
Federal Pool	150,682	---	---	---	---	---
Albuquerque	48,200	0	166,735	---	---	30,787
MRGCD	13,966	65,360	1100	---	---	---
Combined	20,601	0	2386	---	---	19,103
Cochiti Rec Pool	2783	---	---	45,319	---	---
Reclamation	0	111	6198	---	---	---
NMISC	---	---	0	---	---	---
Jemez Sediment Pool	---	---	---	---	0	---
Native Rio Grande Water:						
Rio Grande	900	0	-125	540	-1114	52,356
Indian Storage	---	13,168	---	---	---	---
MRGCD Drought	---	0	---	---	---	---
Supplemental ESA	---	19,196	---	---	---	---
Rio Grande Conservation	---	---	0	0	0	---
NM Credit	---	---	---	---	---	123,151*
CO Credit	---	---	---	---	---	1160*
Incidental Content	---	---	-125	540	-1114	---
Carryover Content	---	---	0	0	0	---
Sed Deposition	---	---	3748	5889	1114	---
Total storage at Caballo Reservoir is 11,093 acre-ft.						
* Compact credits prior to the end of the year for New Mexico and Colorado are actually 164,700 and 1600 acre-ft, respectively, but the reported values in the Accounting Model for November 21, 2011 reflect daily evaporation losses for the year based on the accounting method in the model.						

Adjustments were made to the November 21, 2011 storage levels to reflect expected movement of water and accounting adjustments to be completed by December 31, 2011. Adjustments were made for all the assumed remaining actions listed in Table 2 and discussed further in the separate sections below. All other potential reservoir inflows and outflows were neglected for the remainder of the year as these inflows and outflows are expected to be smaller and partially offsetting. Evaporation, precipitation, and sedimentation effects at the reservoirs for the remainder of the year were also neglected.

Table 2. Assumptions for Actions before December 31, 2011 Reflected by Adjustments to the November 21, 2011 Conditions to Estimate December 31, 2011 Conditions

#	Assumed Actions
1	Movement of MRGCD Water from Heron Reservoir to El Vado Reservoir
2	Movement of Cochiti Rec Pool Water at Heron Reservoir to Cochiti Lake
3	End-of-year Rio Grande Adjustment at Heron Reservoir for Evaporation and Recreation
4	P&P Storage Evacuated from El Vado Reservoir
5	Movement of Reclamation's Leased Water at El Vado Reservoir to Abiquiu Reservoir
6	Reclamation Lease of Albuquerque Water at Abiquiu Reservoir
7	Delivery of Albuquerque Water to Surface Water Diversion
8	Delivery of Combined Account Water to the Buckman Direct Diversion
9	Delivery of Albuquerque Account Letter Water
10	Rio Grande Storage at Abiquiu and Cochiti Returned to Zero
11	End-of-Year Compact Credit Adjustment at Elephant Butte Reservoir
12	Additional Storage of Rio Grande Inflows to Elephant Butte Reservoir

1. Movement of MRGCD Water from Heron Reservoir to El Vado Reservoir

It is assumed that MRGCD San Juan-Chama Project water at Heron Reservoir on November 21st would be moved to El Vado Reservoir prior to December 31st, so estimated storage of MRGCD San Juan-Chama Project water at Heron Reservoir on December 31st is set to zero (with the total reservoir storage adjusted accordingly) and storage in the MRGCD San Juan-Chama account at El Vado is set to 79,326 acre-ft to include the additional 13,966 acre-ft of water in Heron. Total storage at El Vado Reservoir is also adjusted accordingly. The San Juan-Chama loss rate between Heron Reservoir and El Vado Reservoir is zero, so no loss is applied for this transfer.

2. Movement of Cochiti Rec Pool Water at Heron Reservoir to Cochiti Lake

It is assumed the 2783 acre-ft of Cochiti Rec Pool water at Heron Reservoir on November 21st would be moved to Cochiti Lake by the end of the year, so the estimated storage of Cochiti Rec Pool water at Heron Reservoir on December 31, 2011 was set to zero (with the total storage at Heron Reservoir adjusted accordingly), and the amount of Cochiti Rec Pool water at Cochiti Lake was increased from 45,319 acre-ft to 48,037 for the additional water from Heron minus a loss based on the 2.33 percent San Juan-Chama loss rate between Heron Reservoir and Cochiti Lake.

3. End-of-year Rio Grande Adjustment at Heron Reservoir for Evaporation and Recreation

An end-of-year accounting adjustment is made to transfer Rio Grande water to the Federal pool to offset for the impacts of Rio Grande storage on evaporation losses of San Juan-Chama Project water along with recreation considerations. This adjustment entails a transfer of 350 acre-ft from the Rio Grande account to the Federal pool, so implementing this adjustment entails adjusting the November 21, 2011 Rio Grande storage to zero and increasing the Federal San Juan account storage by 350 acre-ft. Note that it is also assumed that additional Rio Grande water in storage on November 21 would be evacuated from Heron Reservoir and also bypassed at El Vado Dam due to Article VII being in effect.

4. P&P Storage Evacuated from El Vado Reservoir

It is assumed that water remaining in the Indian Storage account, representing remaining P&P storage, will be fully evacuated from El Vado Reservoir by December 31, 2011, so the storage in the Indian Storage account was set to zero. Since P&P water was stored when storage restrictions per Article VII of the Compact were in effect, the water is evacuated as opposed to being transferred to the Rio Grande account.

5. Movement of Reclamation's Leased Water at El Vado Reservoir to Abiquiu Reservoir

It is assumed that Reclamation's 111 acre-ft of leased San Juan-Chama Project water in storage at El Vado Reservoir would be moved to Abiquiu Reservoir by the end of the year as this water would be moved when convenient and as space at Abiquiu Reservoir becomes available, so the storage in the Reclamation account at El Vado Reservoir was decreased to zero (with the total El Vado Reservoir storage adjusted accordingly), and the storage in the Reclamation account at Abiquiu Reservoir was increased accordingly, considering San Juan-Chama losses between El Vado Reservoir and Abiquiu Reservoir.

6. Reclamation Lease of Albuquerque Water at Abiquiu Reservoir

It is assumed that a Reclamation lease of 10,000 acre-ft from Albuquerque will occur before the end of the year and is reflected as a transfer from the Albuquerque account to the Reclamation account at Abiquiu Reservoir (Donnelly, 2011). Albuquerque storage at Abiquiu on November 21st is decreased by 10,000 acre-ft for this transaction, and Reclamation's account storage is increased by 10,000 acre-ft. Note that the pending leases of approximately 12,000 acre-ft by Reclamation of contractor water in storage at Heron Reservoir, known as an initial condition, will actually be modeled during the first year of simulation.

7. Delivery of Albuquerque Water to Surface Water Diversion

It is assumed that water will continue to be delivered to the Albuquerque surface water diversion for the remainder of the calendar year. The daily release of Albuquerque San Juan-Chama Project water from Abiquiu on November 21, 2011 was 32 cfs, and this release rate is assumed for the remainder of the year (Kandl, 2011). The storage in the Albuquerque account at Abiquiu

Reservoir is thus reduced by the resulting release volume of 2539 acre-ft to estimate a December 31, 2011 storage level.

8. Delivery of Combined Account Water to the Buckman Direct Diversion

It is assumed that Santa Fe water will continue to be delivered to the Buckman Direct Diversion at a rate of 5.59 cfs for the remainder of the calendar year (Kandl, 2011). The storage in the Combined account at Abiquiu Reservoir is reduced by the resulting release volume of 444 acre-ft for estimating the December 31, 2011 storage level.

9. Delivery of Albuquerque Account Letter Water

It is estimated that a letter water delivery prior to the end of the year will occur at Elephant Butte Reservoir as a transfer of 1300 acre-ft of San Juan-Chama Project water from the Albuquerque account to the Rio Grande account. To reflect this pending transfer, the storage in the Albuquerque account was decreased by 1300 acre-ft. Note that a final estimated storage for the Rio Grande account at Elephant Butte Reservoir was set to an estimated value that also reflects an end-of-year Compact credit adjustment and estimated inflows for the remainder of 2011.

10. Rio Grande Storage at Abiquiu and Cochiti Returned to Zero

Storage levels of Rio Grande water at Abiquiu Reservoir and Cochiti Lake were reset from -125 and 540 acre-ft, respectively, to zero. It is assumed that operations would be conducted to correct for the incidental content apparent on November 21, 2011 to return to zero Rio Grande storage at both Abiquiu and Cochiti on December 31, 2011. Total storage at each reservoir was adjusted accordingly.

11. End-of-Year Compact Credit Adjustment at Elephant Butte Reservoir

The Compact credit as tracked with the NMCredit account at Elephant Butte Reservoir was adjusted for the end-of-year annual Compact calculations and the impacts of evaporation resulting in a new estimated total Compact credit of 65,000 acre-ft. The Colorado credit was also adjusted to 2000 acre-ft.

12. Additional Storage of Rio Grande Inflows to Elephant Butte Reservoir

It is assumed that additional storage of native Rio Grande inflows to Elephant Butte Reservoir plus the end-of-year Compact credit adjustment and the letter water transfer from the Albuquerque account will yield a storage of 164,410 acre-ft of native Rio Grande water at the end of the year resulting in a total Elephant Butte Reservoir storage of 280,000 acre-ft.

Resulting Estimated December 31, 2011 Conditions

Reservoir and Account Storage Levels

Resulting estimated conditions for December 31, 2011 are presented in Table 3. Areas with gray shading are unchanged from the referenced November 21, 2011 conditions. Values in blue bold font were increased as a result of the aforementioned adjustments, and values in the red italics font were reduced with the changes.

Note that initial allocations for storage of Emergency Drought water for MRGCD and ESA include water already in storage of 0 and 19,196 acre-ft, respectively, plus additional unused allocations from previous Relinquished Compact credits. The estimated unused allocations for December 31, 2011 are 50,500 acre-ft for MRGCD and 19,500 acre-ft for ESA. Additional Emergency Drought water will be stored during the Planning Model runs up to the unused allocation amount. The resulting total initial allocations will be set in the model to 50,500 acre-ft and 38,696 acre-ft to include both Emergency Drought water already in storage and the unused allocations.

Initial values for all Account Accruals and Gain Losses are all set to zero. The initial tallies for the cumulative Cochiti Rec Pool release from Heron Dam and account fill releases as needed to start calculations are set to zero. Heron waiver balances are set on January 1st during the simulation to the input storage values for the individual accounts at Heron Reservoir for December 31st.

Table 3. Estimated December 31, 2011 Total and Account Storage Levels and Incidental, Carryover, and Sediment Contents

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.						

Initial River Flows

Initial total reservoir outflows are required for each dam along with the outflow of native Rio Grande water at El Vado, Abiquiu, and Cochiti dams (Refer to Table 4 for the estimated initial reservoir outflows). Initial flows at gage sites and reach inflows are also required. Estimated values for December 31, 2011 are presented in Table 5. All assumed initial flows are typical values for December 31st and based on the historical average for December 31st for most locations. The initial flow values have little impact on the Planning Model results but are simply required to start a simulation.

Initial values for the accounting supplies for the release of water from the Indian Storage, MRGCD Drought, and Supplemental ESA accounts at El Vado Reservoir downstream are set to zero. Initial inflows needed for the following locations within MRGCD's system or on the Low Flow Conveyance Channel are all set to zero: Central East Side Lag, Isleta to Bernardo East Side Lag, Isleta to Bernardo West Side Lag, Drain Unit 7 Return, San Acacia to San Marcial Low Flow Time Lag, and San Acacia to San Marcial Canal Time Lag.

Table 4. Estimated Initial Reservoir Outflows

Reservoir	Rio Grande Outflow (cfs)	Total Outflow (cfs)
Heron	---	---
El Vado	100	100
Abiquiu	110	148
Cochiti	600	600
Jemez	---	27
Elephant Butte [1]	---	17
Caballo [2]	---	2

[1] Same total outflow from Elephant Butte Dam for December 30th and 31st.
[2] Same total outflow from Caballo Dam for December 24th through 31st.

Table 5. Estimated Initial Gage and Reach Inflows

Reach (or Gage)	Inflow (cfs)
Lobatos	200
Cerro to Taos[1]	297
Embudo to Confluence	512
Below Abiquiu to Chamita	210
Otowi to Cochiti	828
Cochiti to Central	821
Central to Bernardo	895
Bernardo to San Marcial	712
San Marcial to Elephant Butte	884
Leasburg to Mesilla	2
Mesilla to El Paso	2

[1] Value needed for 12/30 for the Cerro to Taos reach also set to 293 cfs

Initial Values for Shallow Aquifer Groundwater Levels

Initial groundwater storage levels for all the groundwater objects in the Middle Valley portion of the model were identified separately by the URGWOM Technical Team based on equilibrium conditions from completed calibration runs. The initial values are unchanged from the initial conditions used for other previous simulations completed with the planning module of URGWOM.

References

Donnelly, Carolyn. 2011. Personal Communication. Bureau of Reclamation. Albuquerque, New Mexico.

Kandl, Ed. 2011. Personal Communication. Bureau of Reclamation. Albuquerque, New Mexico.

APPENDIX 5

MRGCD DEMAND CURVES USED IN URGWOM PLANNING MODE

MRGCD Demand Curves Used in URGWOM Planning Model[1]

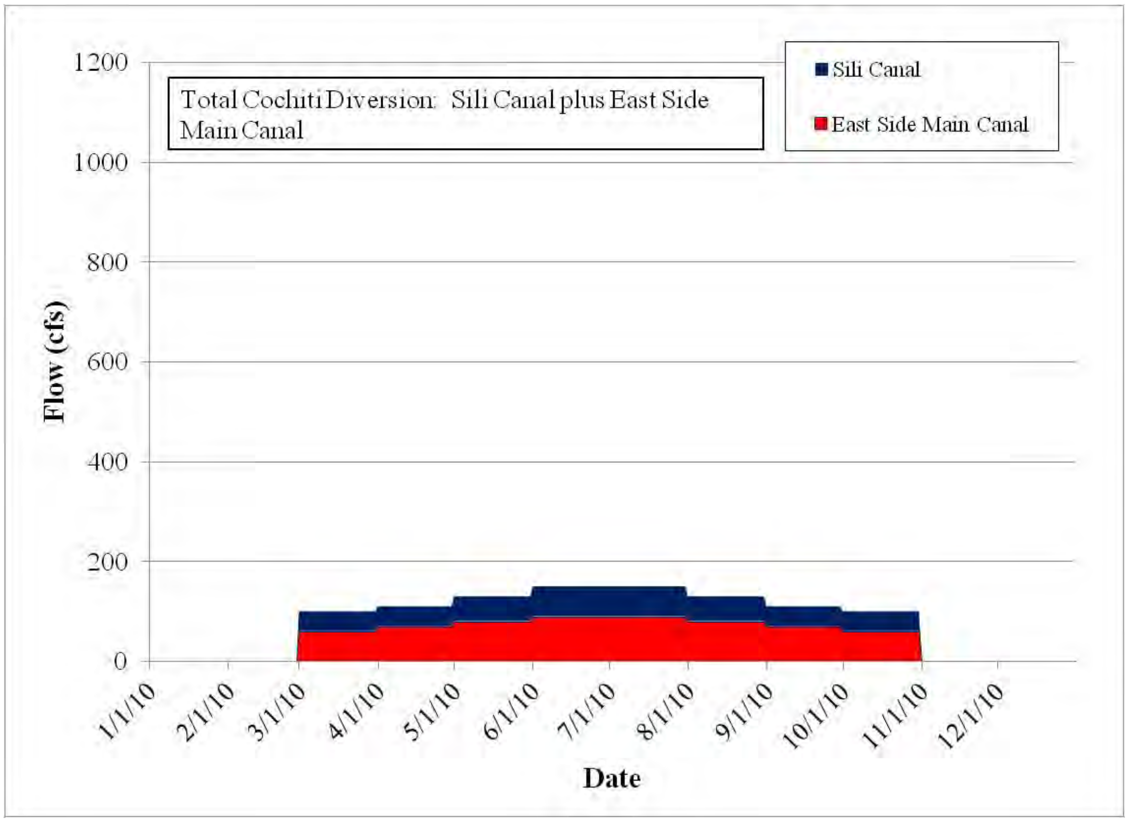

Figure 1. MRGCD Demand at Diversions to the Cochiti Division.

1 MRGCD = Middle Rio Grande Conservancy District; URGWOM = Middle Rio Grande Conservancy District (MRGCD) Demand Curves Used in Upper Rio Grande Water Operations Model (URGWOM) Planning Model.

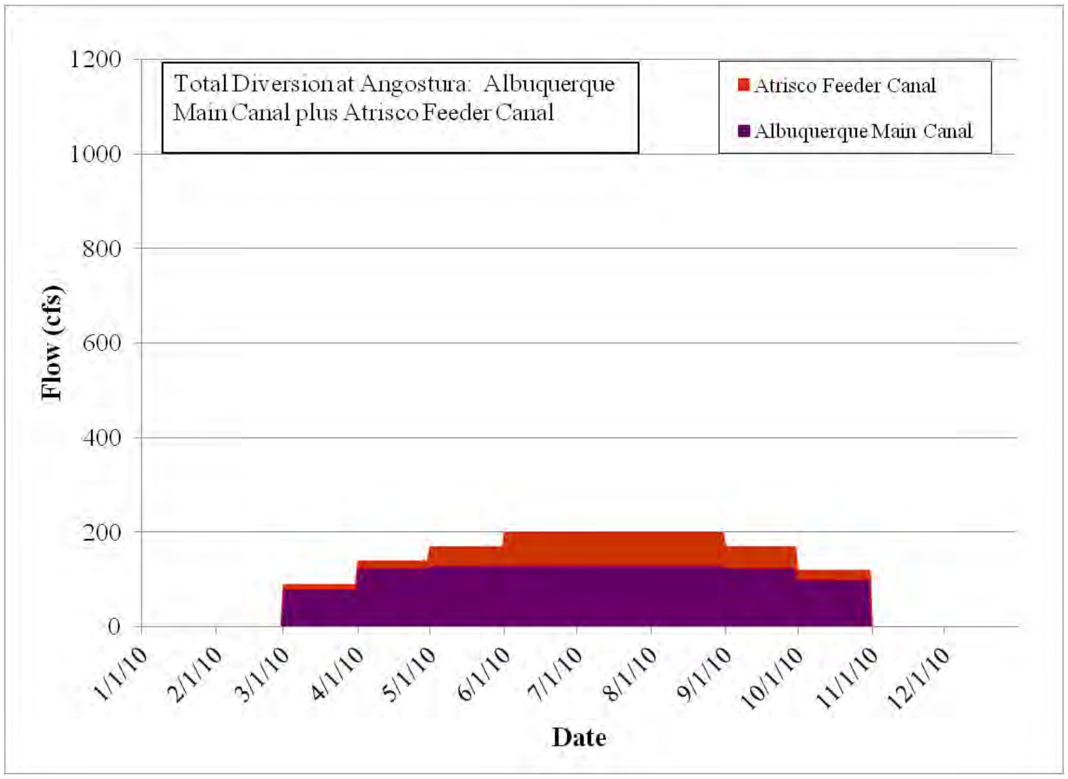

Figure 2: MRGCD Demand at Diversions to the Albuquerque Division.

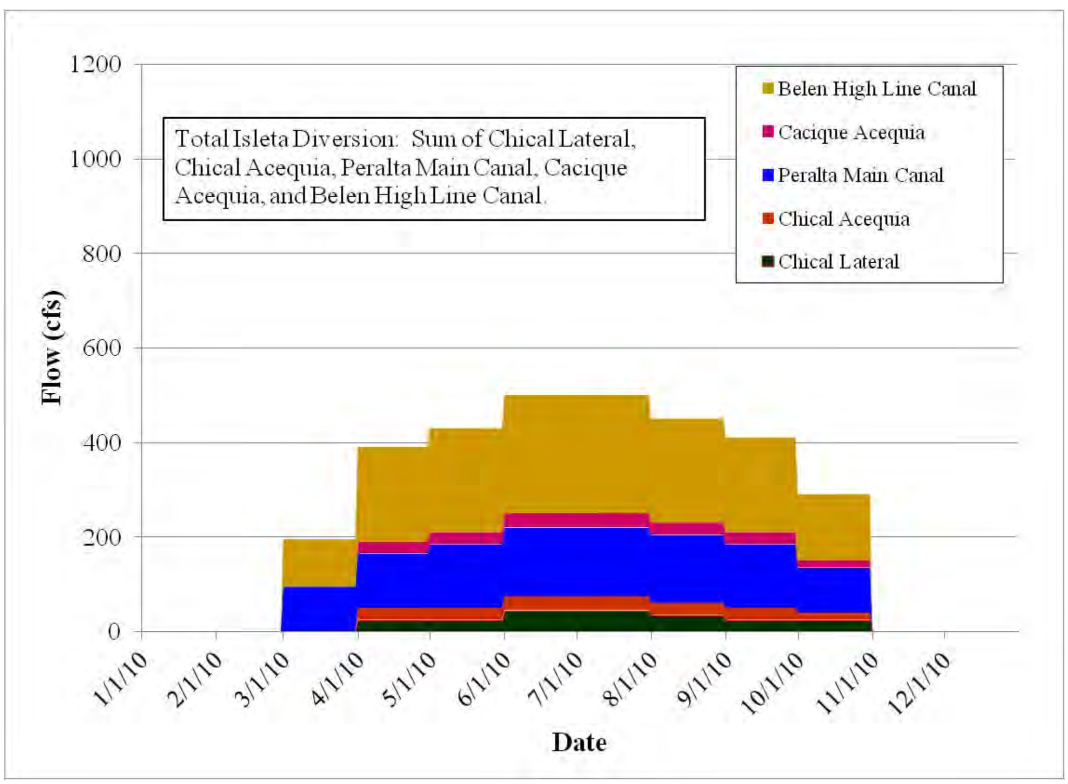

Figure 3. Total MRGCD Demand at Diversions to the Isleta Division.

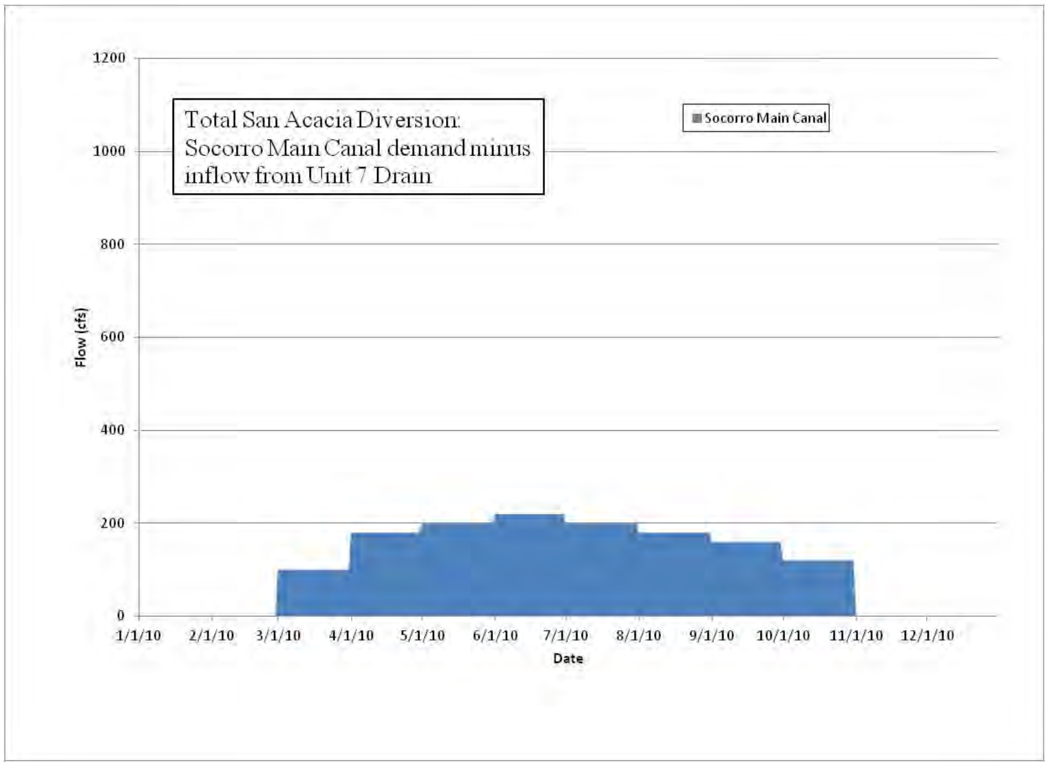

Figure 4. Total MRGCD Demand at Diversions to the San Acacia Division.

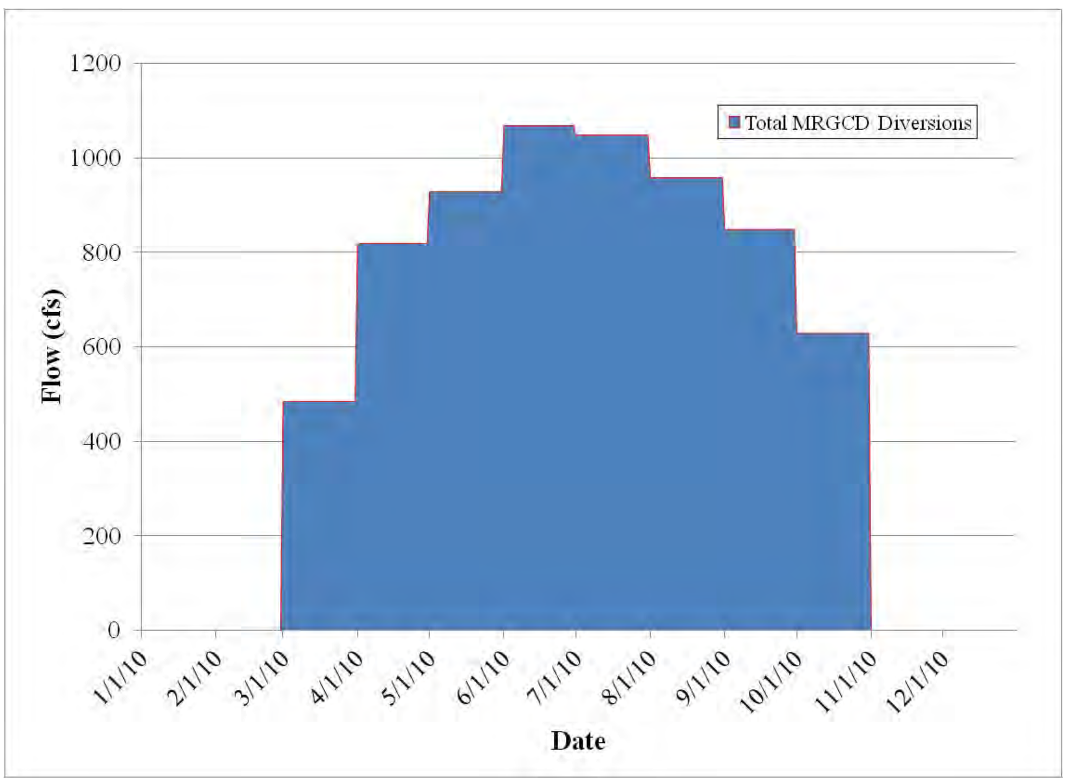

Figure 5. Total of MRGCD Demand Curves.

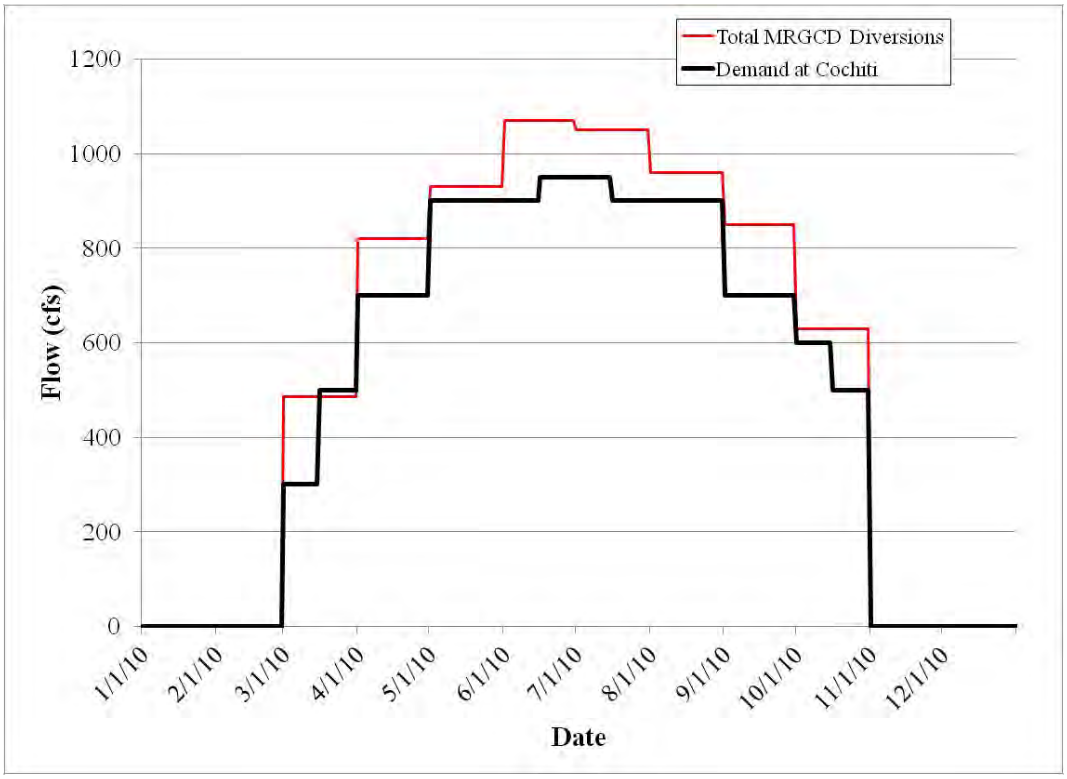

Figure 6. Comparison of Total MRGCD Demand at Cochiti to Total of Demand at All Diversions (difference is due to return flows).

APPENDIX 6

RECLAMATION AND CORPS COMPLETED CONSULTATIONS

10.0 Bureau of Reclamation's Water and River Maintenance Operations, U.S. Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande

On February 19, 2003, a biological assessment (BA) was submitted to the U.S. Fish and Wildlife Service (Service) requesting formal consultation pursuant to Section 7 of the Endangered Species Act (ESA) for the proposed actions associated with water operations, river maintenance, and flood control on the Middle Rio Grande (MRG). The BA and subsequent biological opinion (BO) (Consultation #2-22-03-F-0129), issued March 17, 2003, addressed Federal and non-Federal entities actions related to typical operations, including net depletions and withdrawals, water and river management activities, operation of the Middle Rio Grande Project, flood control, and other management actions on the Middle Rio Grande, as well as their effects on the endangered silvery minnow and its designated critical habitat, the endangered flycatcher, threatened bald eagle, and endangered interior least tern.

The Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (Corps) determined that the proposed action "may affect, is not likely to adversely affect" the bald eagle and the least tern and "may affect, is likely to adversely affect" the silvery minnow and flycatcher and "may adversely modify" designated critical habitat of the minnow. The Service concurred with the determinations for the eagle and tern. The Service also concluded that water operations and river maintenance of the Middle Rio Grande, as proposed in the February 2003 BA, are likely to jeopardize the continued existence of the silvery minnow and the flycatcher and adversely modify critical habitat of the silvery minnow.

In April 2006, Reclamation and the Corps subsequently reinitiated consultation (Consultation #2-22-03-F-0129-R1) requesting amendment to the 2003 BO evaluating effects on flycatcher designated critical habitat, amending Term and Condition 1.1 of RPM 1, and evaluating the effects of recent river drying on the minnow. The Service transmitted a letter amending the 2003 BO, determining that the proposed action did not destroy or adversely modify flycatcher designated critical habitat and also determined that all other determinations included in the 2003 BO regarding the silvery minnow and its critical habitat and the flycatcher remained unchanged.

Environmental commitments associated with the 2003 BO included Reasonable and Prudent Alternatives (RPAs) addressing water operations elements, habitat restoration elements, salvage and captive propagation elements, water quality elements, and reporting elements. Additional terms and conditions affiliated with RPMs included commitments to 1) minimize silvery minnow take within the Rio Grande while performing water operations activities, flood control activities, and river maintenance activities and 2) minimizing loss of river drying and reduction of flycatcher reproductive success.

Improvements in operations that have occurred since the March 17, 2003, Biological Opinion (2003 BiOp) include a reduction in Middle Rio Grande Conservancy District (MRGCD) river diversions, improvements in water operations (daily coordination conference calls, etc.), Rio Grande Compact (Compact) relinquishment of credit water in 2003 and 2008, implementation of habitat restoration work, levee and Low Flow Conveyance Channel (LFCC) setback work in the San Acacia Reach, implementation of the Rio Grande silvery minnow (RGSM) augmentation program, Cochiti deviation to create spawning and recruitment flow, and various efforts to slow river degradation.

10.1 Corps of Engineers Actions with Early or Completed Consultation

10.1.1 Rio Grande Nature Center Habitat Restoration Project

In September 2006, the Corps submitted a biological assessment to the Service for the proposed Rio Grande Nature Center Habitat Restoration Project for the Albuquerque Reach of the Rio Grande and requested formal Section 7 consultation (Consultation #22420-2006-F-161). This project rehabilitated flood plain areas, reconnected the old channel to the river to create habitat for the minnow, and facilitated the regeneration of native vegetation suitable for the flycatcher while meeting priorities of the MRG ESA Collaborative Program to complete restoration projects in the Albuquerque Reach. The Service concurred with the Corps determination that the proposed project "may affect, is not likely to adversely affect" the bald eagle, flycatcher and critical habitat for the minnow. The Service determined that the proposed project is not likely to jeopardize the continued existence of the minnow; and although it may minimally adversely affect individual minnows in the 15-acre project area, the proposed project is anticipated to have a long-term positive impact on the species through improvements to quality and availability of suitable habitat.

Environmental commitments associated with the proposed Rio Grande Nature Center Habitat Restoration Project included development of protocols to monitor minnows in the ephemeral channel following high flows and to determine whether channel maintenance is warranted, reporting injured or dead minnows to the Service, and providing a final restoration monitoring report outlining results and effectiveness of the side channel restoration and embayments to the Service. Additional commitments were to monitor and report on water quality before, during, and after construction activity and scheduling, to the extent possible, embayment construction during dry or frozen soil conditions.

10.1.2 Bosque Revitalization at Route 66 Project

In March 2008, the Corps submitted a biological assessment to the Service for the proposed Bosque Revitalization at Route 66 project for the Albuquerque Reach of the Rio Grande and requested formal Section 7 consultation (Consultation #22420-2008-F-0125). This project entails jetty jack removal, non-native shrub removal, native woody plantings, and creation of willow swales throughout a 121-acre area adjacent to the Central Avenue and Bridge Boulevard Bridges in Albuquerque. These riparian features would improve habitat conditions for the flycatcher and minnow. Three high flow side channels are expected to establish diverse mesohabitats that support the silvery minnow. Such habitat benefits the species through improved egg and larval retention, increased recruitment rates, and increased survival of both young-of-year (YOY) and adult minnows.

The Service concurred with the Corps' determination that the proposed project "may affect, is not likely to adversely affect" the flycatcher and designated critical habitat for the silvery minnow. The Service determined that the proposed project is not likely to jeopardize the continued existence of the minnow; and although it may minimally adversely affect individual minnows when constructing channel embayment areas, the project is anticipated to have a long-term positive impact on the species through improvements to quality and availability of suitable habitat.

The attendant Incidental Take Statement included Reasonable and Prudent measures to minimize take of silvery minnow due to habitat restoration activities; manage for the protection of water quality from activities associated with the restoration project; and to continue to work collaboratively with the Service on the Middle Rio Grande Endangered Species Act Collaborative Program.

10.2 Reclamation Actions with Early or Completed Consultation and General Commitments

10.2.1 Middle Rio Grande Riverine Habitat Restoration Project for the Albuquerque Reach of the Rio Grande in Bernalillo County, New Mexico (New Mexico Interstate Stream Commission)

In September 2005, Reclamation submitted a biological assessment to the Service on behalf of the New Mexico Interstate Stream Commission (ISC), addressing potential impacts of a proposed habitat restoration project within the Albuquerque Reach on the endangered silvery minnow, the endangered flycatcher, and the threatened bald eagle (Consultation #22420-2006-F-02). The Service concurred with Reclamation's determination of "may affect, not likely to adversely affect" for the willow flycatcher and bald eagle, provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow, that the proposed action "may affect is likely to adversely affect" minnows in the short-term with long-term "positive impact on the species," and that the proposed action is "not likely to destroy or adversely modify designated critical habitat" for the minnow.

Environmental commitments for the Albuquerque Reach Habitat Restoration Project required the ISC to monitor minnows at construction sites, use adaptive management as appropriate, develop and submit a Restoration Monitoring Plan to the Service, and report dead or injured minnows to the Service. Additional commitments were to schedule crossings during dry or frozen soil conditions, measure and report water quality parameters before, during, and after construction, as well as to report any hazardous materials spills (i.e., fuels, hydraulic fluids) to the Service.

10.2.2 Sandia Priority Site Project

In June 2006, Reclamation submitted a biological assessment to the Service of the proposed action on the endangered silvery minnow, the endangered flycatcher, and the threatened bald eagle. The proposed project included the protection of the east levee and canal system along the Albuquerque Reach between U.S. Highway 550 and into the Sandia Pueblo by creating secondary channels, realigning the main river channel, and installing bendway weirs and rootwad revetments to reduce bank erosion threatening the levee. The Service concurred (Consultation #22420-2006-F-039) with Reclamation's determination of "may affect, not likely to adversely affect" the flycatcher and eagle, also determined that the project "may affect, is not likely to adversely affect" minnow critical habitat, and that long-term effects would be beneficial. The Service concluded that the Sandia Priority Site Project was "not likely to jeopardize the continued existence of the silvery minnow," and that impacts on the population would be minimal because of the small area within occupied habitat.

Environmental commitments for the Sandia Priority Site Project required Reclamation to monitor minnows at construction sites, use adaptive management to modify construction activities, partial dewatering and habitat improvement activities, as appropriate, and to report dead or injured minnows to the Service. Additional commitments were to schedule crossings during dry or frozen soil conditions, measure and report water quality parameters before, during, and after construction, to report water quality measurements per conditions of Reclamation's Clean Water Act 401 certification to the Service and the Sandia

Pueblo, as well as to report any exceedance of pueblo water quality standards or spills (i.e., fuels, hydraulic fluids) to the Service and the Sandia Pueblo, and immediately remediate those conditions.

10.2.3 Middle Rio Grande Riverine Habitat Restoration Phase II Project for the Albuquerque Reach (ISC)

In August 2006, Reclamation submitted a biological assessment to the Service on behalf of the ISC, addressing potential impacts of Phase II of a proposed habitat restoration project within the Albuquerque Reach on the endangered silvery minnow, the endangered flycatcher, and the threatened bald eagle. This phase of the proposed project was to create or improve habitat for minnows, including promoting egg-retention, larval rearing, young-of-year and overwintering habitat for silvery minnow within four subreaches of the Albuquerque Reach in support of Element S of the RPA in the 2003 BiOp. Habitat restoration techniques included island modifications, bank scouring, and installation of woody debris to improve aquatic habitats. The Service concurred (Consultation #22420-2006-F-160) with Reclamation's determination of "may affect, not likely to adversely affect" for the bald eagle and the flycatcher and its critical habitat, and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow and is not likely to destroy or adversely modify designated critical habitat. The Service also determined that the proposed action may adversely affect individual minnows in the short term, but that the proposed action was likely to have a long-term positive impact on the species.

Environmental commitments for the Albuquerque Reach Habitat Restoration Project required the ISC to monitor minnows at construction sites, use adaptive management as appropriate, develop protocol to monitor for minnows in ephemeral channels following high flows, and determine whether channel maintenance is warranted in coordination with the Service, report effectiveness of all treatments to the Service in a timely manner, and report dead or injured minnows to the Service. Additional commitments were to schedule crossings during dry or frozen soil conditions, measure and report water quality parameters before, during, and after construction, as well as report water quality measurements per conditions of Reclamation's Clean Water Act 401 certification to the Service and the Sandia Pueblo.

10.2.4 Santo Domingo Pueblo Restoration Project Phase II

Reclamation submitted a BA to the Service in April 2007, requesting concurrence for proposed activities associated with the Santo Domingo Pueblo Restoration Project Phase II, entailing three excavation sites on the east side of the Rio Grande beginning 1.5 miles south of SP88 and Bridge No. M102, during winter and placement of large woody debris in the Rio Grande to reduce water velocity and enhance sediment deposition as a means for improving habitat for the minnow in the Cochiti Reach. Reclamation determined that the proposed action "may affect, is not likely to adversely affect" the endangered silvery minnow and the threatened bald eagle. The Service concurred with Reclamation's determinations by letter dated April 19, 2007, provided that general environmental commitments for the bald eagle were followed, and excavation would take place during winter low flows or dry periods, no equipment would enter the river, silt fences and sand bags would be used to isolate the excavation area from the river and minimize transport of sediment from the work area into the river, standard best management practices (BMPs) would be used, and that the Santo Domingo Pueblo would be responsible for monitoring and notifying the Service if silvery minnows were to use ephemeral channels or other isolated habitats forming in the channel.

10.2.5 Proposed Installation of Crump Weir and Passive Integrated Transponder Tag Readers in the Albuquerque Drinking Water Project Fishway

Reclamation submitted a biological assessment to the Service on May 1, 2007, the proposed installation of crump weir and passive integrated transponder tag readers in the Albuquerque Drinking Water Project Fishway. Reclamation determined that the proposed action "may affect, is not likely to adversely affect" the minnow or its designated critical habitat. The Service concurred with Reclamation's determinations by letter dated June 21, 2007, provided that the following conditions were followed: 1) block nets would be used to exclude minnows from the work area and installation would occur by hand.

10.2.6 Perennial Rio Grande Silvery Minnow Refugia at Drain Outfalls

Reclamation submitted a biological assessment to the Service on October 4, 2006, for the proposed Perennial Rio Grande Silvery Minnow Refugia at Drain Outfalls Project (Perennial Outfalls Project), located in the Isleta Reach of the MRG. The project partners will create habitat structures for minnows using large woody debris in three drain outfalls: Los Chavez and Peralta Wasteways and the Lower Peralta Drain #1. Reclamation determined that the proposed action "may affect, is not likely to adversely affect" the flycatcher or its designated critical habitat, or the bald eagle. The Service (Consultation #22420-2007-F-0021) concurred with Reclamation's determinations and also found that the project would have temporary adverse effects to the minnow and its designated critical habitat; the project would benefit the minnow during dry conditions by creating refugial habitat.

Environmental commitments for the Perennial Outfalls Project required Reclamation to minimize take of silvery minnow during construction; manage for water quality protection from activities associated with construction by avoiding the wetted river channel with heavy equipment during high flows; and by monitoring water quality before, during, and after construction activities. Additional commitments included monitoring of piscivores in newly created habitats and reporting monitoring results to the Service; coordinating with the Service if poor water quality, potential for stranding, high predation levels, or occurrence of disease were observed in the pools created by the project; and to determine if a decrease in habitat suitability or value occurred due to the project, and if observed, required removal of the structures.

10.2.7 Corrales Siphon River Maintenance Project

In September 2007, Reclamation submitted a biological assessment to the Service of the proposed action on the endangered silvery minnow and the endangered flycatcher and their respective designated critical habitats. The proposed project would protect the inverted siphon and associated infrastructure from damage caused by potential westward migration of the Rio Grande by moving the river eastward using a bioengineering technique designed to create and improve habitat for the minnow. Reclamation determined that the proposed project "may affect, but is not likely to adversely affect" the flycatcher or its designated habitat. The Service concurred with this determination (Consultation #22420-2007-F-0056) and also determined that the proposed project was not likely to jeopardize the continued existence of the minnow or result in adverse modification of its designated critical habitat. The project also was anticipated to be of long-term benefit to silvery minnow habitat quality.

Environmental commitments for the Corrales Siphon Project included monitoring for minnows prior to, and at least four times during, and after construction, reporting findings and results to the Service, transporting fill materials with heavy equipment across the Rio Grande as few times as possible to minimize destabilization of sediments, avoidance (to the extent possible) of crossing the wetted channel of the river at flows exceeding 900 cubic feet per second (cfs), and monitoring water quality during and after equipment operating in the river.

10.2.8 Proposed Pueblo of San Felipe Bosque Restoration Project

In September 2007, Reclamation submitted a biological assessment to the Service on behalf of the Pueblo of San Felipe, addressing potential impacts of a bosque restoration project under Section 7 of the Endangered Species Act of 1973, as amended. The proposed project would remove about 10 acres of non-native vegetation in the abandoned riparian flood plain of the bosque and subsequent replanting of Goodding's willow (*Salix gooddingii*) and Rio Grande cottonwood

(*Populus deltoides* var. *wislizeni*) poles. Reclamation determined that the proposed action "may affect, is not likely to adversely affect" the minnow or its designated critical habitat or the flycatcher and its designated critical habitat. The Service concurred with these determinations (Consultation # 22420-2008-IC-0010) provided that no vegetation would be removed within 20 feet of the Rio Grande; bankline would not be disturbed; and the construction would take place outside normal breeding and nesting seasons for the flycatcher.

10.2.9 Elephant Butte Reservoir Temporary Channel Maintenance Project

In October 2007, Reclamation submitted a BA addressing the effects of the proposed project on the endangered flycatcher and the minnow and the designated critical habitat for each. The proposed action was described by reaches and by activities, and includes maintenance of the temporary channel, which facilitates delivery of water and sediment from RM 57.8 to Elephant Butte Reservoir, for a period of 5½ years. Activities included ongoing non-channel enhancement features, maintenance operations, future temporary channel construction, and widening and realignment of the existing temporary channel. The Service determined (Consultation # 22420-2008-F-0017) that the project was not likely to jeopardize the continued existence of the minnow or flycatcher or result in adverse modification of designated critical habitat. In April 2008, the Service transmitted a letter amending the January 2008 BO, pursuant to communication among the Service and Reclamation in February and March.

In order to fulfill environmental commitments for this project, Reclamation will: 1) to the extent possible, operate airboats in the middle of the channel; 2) avoid pumping directly from the channel to minimize minnow egg and larvae entrainment, and use sumps adjacent to the channel whenever feasible; 3) in coordination with the Service, fund a program to monitor minnows in the temporary channel; 4) support CP efforts to prioritize and implement habitat restoration projects in the San Acacia Reach pursuant to the Long-Term Plan (MRGESCP 2006); 5) excavate an area as few times as possible; and when excavating within the wetted channel, minimize movement of excavator tracks and bucket contact with the bed of the channel to minimize sediment disturbance; 6) monitor water quality before, during, and after the project, which may include visual observations or direct sampling; 7) use current flycatcher monitoring data and avoid working within 0.25 mile of an active nest; 8) monitor vegetation health, incorporating vegetation mapping; 9) monitor ground water levels from the north boundary of the Bosque del Apache (BDA) refuge, along the temporary channel and the west side of the reservoir, as needed; 10) monitor the riverbed and movement of the headcut; and 11) work with the Service to plan and implement a specific restoration project to establish flycatcher habitat on the Rio Grande, outside the San Marcial Reach, by January 2009, and implemented by July 2013.

10.2.10 Rio Grande Restoration Project at Santa Ana Pueblo

In June 2007, Reclamation submitted a biological assessment to the Service on behalf of the Santa Ana Pueblo, to perform a project to protect existing levees and associated infrastructure using bioengineering and other techniques, including installation of 13 bendway weirs to protect a threatened bankline by moving the river westward and relocating sediment to the west bank of the river, and to provide habitat for listed species, the endangered silvery minnow and Southwestern willow flycatcher. No critical habitat exists for either species and, therefore, will not be affected. Reclamation determined that the project "may affect, is not likely to adversely affect" the flycatcher. The Service concurred (Consultation # 22420-1998-F-0168-R002) and also determined that the Santa Ana Restoration Project is not likely to jeopardize the continued existence of the silvery minnow or result in adverse modification of designated critical habitat. The minnow and its food base will be adversely affected by the use of heavy equipment and placement of fill in the wetted channel of the river.

Environmental commitments for the Santa Ana Restoration Project include limiting equipment crossing speeds to 5 miles per hour (mph) for the first three crossings per day and, to the extent feasible, limit all crossing speeds to 5 mph, reporting of dead or injured minnows to the Service, and immediately cease construction activity until the Service determines it is safe to resume. Additionally, Reclamation would transport fill materials across the Rio Grande as few times as possible, avoid crossing the wetted channel of the river at greater than (>) 900-cfs flows, monitor water quality before, during, and after construction activities.

10.2.11 River Mile 111 Priority Site Project

In March 2008, Reclamation submitted a biological assessment to the Service evaluating the effects of relocation of the Low Flow Conveyance Channel (LFCC) and the associated levee to allow the Rio Grande more freedom to move within its historic flood plain on the endangered flycatcher and minnow and its designated critical habitat. Reclamation determined that the project "may affect, is not likely to adversely affect" the minnow and its designated habitat. The Service concurred with this determination (Consultation #22420-2008-I-0067), provided the following conditions were met: All construction of woody debris piles would occur under dry working conditions or during low flow conditions, recent surveys of the LFCC downstream of the proposed construction area did not find any minnows, the Lemitar radial gate structure would be closed during the construction operations, cottonwood root wads would be placed on the bank near RM 111 and would cascade into the river as it migrates west, the Mitigation Plan described in the BA would be fully implemented, and the Conservation Measures described in the BA would also be fully implemented by Reclamation.

10.2.12 Drain Unit 7 Extension River Maintenance Priority Site Project

On June 13, 2008, Reclamation submitted a biological assessment, along with a letter formally requesting consultation re-initiation, to the Service for the proposed Drain Unit 7 (DU7) Extension River Maintenance Priority Site Project. The project will reinforce the bankline and protect the adjacent access road and drain by placing riprap along the bank within the active river channel. Reclamation determined that the proposed action may affect, and is likely to adversely affect, the endangered minnow during construction and may affect, and is not likely to adversely affect designated minnow critical habitat. The Service concluded that the proposed action is not likely to jeopardize the continued existence of the minnow and that there is likely to be short-term adverse effects on a very small portion of designated critical habitat at the construction site.

Environmental commitments associated with the proposed DU7 Project include implementing construction BMPs and dust abatement during construction and revegetating the site, along with performing construction outside minnow spawning periods (construction exclusion period of April 15–July 1).

10.2.13 Rio Grande Sediment Plug Removal Project at Bosque del Apache National Wildlife Refuge

In August 2008, Reclamation submitted a biological assessment to the Service addressing potential impacts of removal of a sediment plug that formed within the Rio Grande at the BDA during spring runoff 2008, on the endangered minnow and its designated critical habitat, and on the endangered flycatcher proposed habitat restoration project within the Albuquerque Reach on the endangered silvery minnow, the endangered flycatcher, and the threatened bald eagle (Consultation #22420-2006-F-160). This phase of the proposed project was to create or improve habitat for minnows, including promoting egg-retention, larval rearing, young-of-year, and overwintering habitat for silvery minnow within four subreaches of the Albuquerque Reach in support of Element S of the RPAs in the 2003 BiOp. Habitat restoration techniques included island modifications, bank scouring, and installation of woody debris to improve aquatic habitats. The Service concurred with Reclamation's determination of "may affect, not likely to adversely affect" for the bald eagle and the flycatcher and its critical habitat and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow and is not likely to destroy or adversely modify designated critical habitat. The Service also determined that the proposed action may adversely affect individual minnows in the short term, but that the proposed action was likely to have a long-term positive impact on the species.

Reclamation's environmental commitments for the Sediment Plug Removal Project include: 1) construction of at least four embayments (approximately 30–50 feet in width and 50–70 feet in length, each) on the west side of the pilot channel to promote channel widening to be completed during Phase I(b); 2) collection of data for 4 years following excavation of the pilot channel to monitor channel degradation/aggradation and overbanking patterns—including cross-section data of the river channel from the north boundary of BDA to the San Marcial Railroad Bridge, at least two inspections of the river channel by boat when overbanking begins during runoff, and at least once during the 4 years, cross-section data of the river channel and flood plains will extend between endpoints for these rangelines; 3) Data collected as above will be analyzed and compared to 2002 and 2005 cross-section data to assess changes to the riverbed thalweg and channel geometry including width/depth ratio, and data and analysis will be provided to the Service (NMESFO and the BDA); and 4) indepth analysis of alternatives to pilot channel construction within the aforementioned reach of river will be initiated within 6 months of completion of Phase I(b) of the project and will include at least three strategies to address sediment transport through the reach, maintenance of connected unvegetated river bars, opportunities for river realignment following sand plug formation, river connectivity during low flows, river/flood plain surface connectivity, surface water supplies to adjacent wetlands, and effects on threatened, endangered, or candidate species. This analysis must be conducted in coordination with the Service, and the final report must be completed within 3 years and will be used in all future sediment plug removal or maintenance activities within the BDA.

10.2.14 Middle Rio Grande Isleta Reach Riverine Habitat Restoration Project

In October 2008, Reclamation submitted a biological assessment to the Service on behalf of the ISC, addressing potential impacts of a proposed riverine habitat restoration project within the Isleta Reach on the endangered silvery minnow and the endangered flycatcher. The proposed project was to create or improve habitat for minnows, including promoting egg-retention, larval rearing, and young-of-year habitat for silvery minnow within the Isleta Reach in support of Element S of the RPA in the March 2003 BO. Habitat restoration techniques included creation of bankline embayments, ephemeral channels, island modifications, bank scouring, placement of woody debris, removal of lateral constraints, as well as flood plain vegetation management. The Service concurred (Consultation #22420-2009-F-0002) with Reclamation's determination of "may affect, not likely to adversely affect" for the flycatcher and its critical habitat and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow and is not likely to destroy or adversely modify designated critical habitat.

Environmental commitments for the Isleta Reach Riverine Habitat Restoration Project required Reclamation to monitor minnows at construction sites, report site-specific monitoring protocol availability and effectiveness of all treatments to the Service in a timely manner, and report dead or injured minnows to the Service. Additional commitments were to encourage adaptive management of flows and conservation of water to benefit listed species, and to measure and report water quality parameters before, during, and after construction, as well as report water quality measurements per conditions of Reclamation's Clean Water Act 401 certification to the Service.

10.2.15 Middle Rio Grande Isleta Reach Riverine Habitat Phase IIa Restoration Project

In November 2008, Reclamation submitted a biological assessment to the Service on behalf of the ISC, addressing potential impacts of a proposed riverine habitat restoration project within the Angostura Reach on the endangered silvery minnow and the endangered flycatcher. The proposed project was to create or improve habitat for minnows, including promoting egg-retention, larval rearing and young-of-year habitat for silvery minnow, as well as to facilitate evaluation of habitat restoration techniques. The project supported Element S of the RPA in the 2003 BiOp. Habitat restoration techniques included island, bar, and bankline modifications. The Service concurred (Consultation #22420-2009-F-0016) with Reclamation's determination of "may affect, not likely to adversely affect" for the flycatcher and its critical habitat and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow and is not likely to destroy or adversely modify designated critical habitat.

Environmental commitments for the Isleta Reach Riverine Habitat Restoration Phase IIa Project required Reclamation to monitor minnows at construction sites, ensure post-construction monitoring protocol for silvery minnow entrapment is implemented, report effectiveness of all treatments to the Service in a timely manner, and report dead or injured minnows to the Service. Additional commitments were to encourage adaptive management of flows and conservation of water to benefit listed species and to measure and report water quality parameters before, during, and after construction, as well as report water quality measurements per conditions of Reclamation's Clean Water Act 401 certification to the Service.

10.2.16 Pueblo of Sandia Bosque Rehabilitation Project

In December 2008, Reclamation submitted a biological assessment to the Service on behalf of the Pueblo of Sandia, addressing potential impacts of a proposed habitat restoration project within the Pueblo of Sandia on the endangered silvery minnow and the endangered flycatcher. The proposed project was to design and implement techniques to restore and enhance riverine and riparian habitat for the benefit of the silvery minnow, including promoting egg-retention, larval rearing, and young-of-year habitat for silvery minnow, as well as creating suitable habitat for future use by flycatchers. Habitat restoration techniques included the renovation of a side channel, placement of woody debris within the renovated channel, and planting approximately 5 acres of native woody vegetation. The Service concurred (Consultation #22420-2009-F-0022) with Reclamation's determination of "may affect, not likely to adversely affect" for the flycatcher and its critical habitat and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow and is not likely to destroy or adversely modify designated critical habitat. The Service also determined that the proposed action may be anticipated to have long-term beneficial effects on silvery minnows by restoring and enhancing riverine and riparian habitat.

Environmental commitments for the Pueblo of Sandia Bosque Rehabilitation Project required Reclamation and the Pueblo of Sandia to ensure that restoration treatment occurs between September 1 and April 15, to monitor minnows at construction sites, to use adaptive management as appropriate, to monitor for minnows in ephemeral channels following high flows, to report effectiveness of all treatments and dead or injured minnows to the Service in a timely manner. Additional commitments were to measure and report water quality parameters before, during, and after construction as well as report water quality measurements.

10.2.17 Pueblo de San Felipe Priority Sites Phase I Project

In September 2009, Reclamation submitted a biological assessment to the Service addressing potential impacts of proposed river channel maintenance activities, at four priority sites within the Pueblo of San Felipe on the endangered silvery minnow and its designated critical habitat. The proposed project was to eliminate bank erosion and migration through bankline improvements. Techniques included removal of vegetation and jetty jacks, vegetation planting, bar removal, lining banks with riprap, and installation of bioengineered bankline stabilization. The Service concurred (Consultation #22420-2009-F-0089) with Reclamation's determination of "may affect, not likely to adversely affect" for the minnow and its critical habitat and is not likely to adversely modify designated critical habitat.

Environmental commitments for the Pueblo de San Felipe Priority Sites Phase I Project required Reclamation to ensure that in water work not be conducted during spring runoff, monitor minnows at construction sites, report site-specific monitoring results, and report dead or injured minnows to the Service. Additional commitments were to encourage adaptive management of flows and conservation of water to benefit listed species and to pursue population surveys for silvery minnow in the Cochiti Reach.

10.2.18 Two Rivers and Three Falls Flycatcher Habitat Expansion Project

In October 2009, Reclamation submitted a memorandum requesting concurrence for proposed activities to enhance, create, and expand flycatcher habitat at Ohkay Owingeh in Sandoval County, New Mexico. The proposed project was to improve the quality of riparian habitat by excavating a filled-in secondary channel and reconnect it to the river. The Service concurred (Consultation #22420-2010-I-0005) with Reclamation's determination of "may affect, not likely to adversely affect" for the flycatcher and its critical habitat and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow and is not likely to destroy or adversely modify designated critical habitat.

10.2.19 Middle Rio Grande Isleta Reach Phase II Riverine Habitat Restoration Project

In April 2010, Reclamation submitted a biological assessment to the Service on behalf of the ISC, addressing potential impacts of a proposed riverine habitat restoration project within the Isleta Reach on the endangered silvery minnow and the endangered flycatcher and respective designated critical habitats. The purpose of the proposed project was to create or improve habitat and provide benefits for the silvery minnow, the flycatcher, and the Middle Rio Grande ecosystem as a whole. Long-term goals included diversifying mesohabitat types to promote egg-retention, larval rearing and young-of-year habitat, create habitat adjacent to perennial water sources for silvery minnow, increase the extent of overbank inundation, and encourage fluvial process and river dynamics in four subreaches within the Isleta Reach. Habitat restoration techniques included creation of bankline benches, backwater embayments, ephemeral channels, and island/bar modifications. The Service concurred (Consultation #22420-2010-F-0060) with Reclamation's determination of "may affect, not likely to adversely affect" for the flycatcher or its critical habitat, and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow, and is not likely to destroy or adversely modify designated critical habitat.

Environmental commitments for the Isleta Reach Phase II Riverine Habitat Restoration Project required Reclamation to monitor minnows at construction sites, implement *Protocol for Monitoring Silvery Minnow Entrapment*, and report effectiveness of all treatments, as well as dead or injured minnows to the Service in a timely manner. Additional commitments were to encourage adaptive management of flows and conservation of water to benefit listed species, and to measure and report water quality parameters before, during, and after construction as well as report water quality measurements.

10.2.20 Pueblo of Sandia Riverine Habitat Restoration Project

In May 2010, Reclamation submitted a biological assessment to the Service on behalf of the Pueblo of Sandia, addressing potential impacts of a proposed riverine habitat restoration project within the Sandia subreach of the Angostura (or Albuquerque) Reach on the endangered silvery minnow and the endangered flycatcher. The purpose of the proposed project was to create or improve habitat and provide benefits for the silvery minnow, the flycatcher, and the Middle Rio Grande ecosystem as a whole. Long-term goals included diversifying mesohabitat types to promote egg-retention, larval rearing and young-of-year habitat, create habitat adjacent to perennial water sources for silvery minnow, increase the extent of overbank inundation, and encourage fluvial process and river dynamics in support of Element S of the RPA in the 2003 BiOp. Habitat restoration techniques included creation of bankline benches, backwater embayments, ephemeral channels, and island/bar modifications. The Service concurred (Consultation #22420-2010-F-0083) with Reclamation's determination of "may affect, not likely to adversely affect" for the flycatcher and provided an opinion that the proposed action is not likely to jeopardize the continued existence of the minnow.

Environmental commitments for the Pueblo of Sandia Riverine Habitat Restoration Project required Reclamation to monitor minnows at construction sites, implement *Protocol for Monitoring Silvery Minnow Entrapment,* and report effectiveness of all treatments, as well as dead or injured minnows to the Service in a timely manner. Additional commitments were to encourage adaptive management of flows and conservation of water to benefit listed species and to measure and report water quality parameters before, during, and after construction, as well as report water quality measurements.

10.3 General Environmental Commitments from Early or Completed Consultations

The following are general environmental commitments from the aforementioned consultations pertaining to listed species and their habitats.

10.3.1 Southwestern Willow Flycatcher

Construction disturbance will be avoided near occupied and known flycatcher territories from April 15–August 15. A predetermined, standard-setting buffer distance around willow flycatcher territories has not been established; instead, such buffer zones will be defined on a case-by-case basis (Reclamation, 2001).

Future project sites with occupied or suitable habitat shall be surveyed for at least one breeding season prior to the start of any project activities. If flycatchers are detected within the boundaries of proposed projects, consultations will be initiated with the Service. It is Reclamation's intent to use the principles of adaptive management and monitor project sites sufficiently to accumulate the necessary data and information for future decisionmaking (Reclamation, 2001).

Reclamation will minimize the number of new transects that are cleared in conjunction with river surveying activities. As referenced in the 2001 BA, the collection and use of hydrographic data from transects provide better management of the Middle Rio Grande flood plain and river channel. Transect clearing or maintenance will not occur in occupied habitat. Out-of-use transects will be allowed to revegetate. Brushing will occur only when necessary for project purposes. If transect brushing is necessary, brushing or surveys during the breeding period (April 15–August 15) shall be avoided to minimize disturbance. Suitable or potential flycatcher habitat also can be avoided in certain cases by limiting brushing to the river's edge and not clearing beyond that point. All sites proposed for transect clearing will be reviewed by Reclamation biologists. If it is determined that the site is not suitable or potential willow flycatcher habitat, transect clearing will proceed under the above conditions (Reclamation, 2001).

10.3.2 Rio Grande Silvery Minnow

Reclamation will continue to conduct fish population monitoring at established locations in the Middle Rio Grande between Angostura Diversion Dam and the headwaters of Elephant Butte Reservoir. Pre- and post-construction monitoring for fish species will continue at constructed and proposed river maintenance sites through the Middle Rio Grande (Reclamation, 2001).

If it is necessary to redirect flows away from a construction site, steps will be taken to allow flows to recede from the area gradually so silvery minnow can avoid entrapment. Any disconnected aquatic habitat, e.g., isolated pools, associated with a river maintenance site will be sampled for silvery minnow which, if found, will be relocated into adjacent areas of flowing water (Reclamation, 2001).

Construction activities requiring the movement of equipment within the river channel will avoid potential silvery minnow habitat to the extent possible. When feasible, xeric conditions will be sought to minimize direct impacts of construction activities to silvery minnow. While many of the proposed habitat enhancement activities involve extensive construction activity in or near the river channel, disturbance to the aquatic environment will be minimized (Reclamation, 2001).

10.3.3 Additional General Commitments

- Reclamation will carry out its actions to encourage seasonal overbank flooding and associated low velocity aquatic habitats in or near suitable willow flycatcher habitat within the bounds of the expected natural hydrograph.

- Reclamation will review the Southwestern Willow Flycatcher Recovery Plan and update the environmental commitments related to the willow flycatcher as appropriate.

- Reclamation will work with the MRGCD to: 1) facilitate fish passage at the three main diversion dams to allow upstream movement of the silvery minnow, 2) investigate the effects of fish, eggs, and larvae passage over the structures, and 3) alleviate the entrainment of silvery minnow into the irrigation system. Reclamation is currently conducting a planning study that focuses on some of these issues at San Acacia Diversion Dam.

- Reclamation will pursue habitat restoration along the Middle Rio Grande, in coordination with other parties, which includes the restoration of the river channel to create and enhance aquatic habitat for the silvery minnow and native riparian habitat for the willow flycatcher and bald eagle. The principles of adaptive resource management will be incorporated into habitat restoration. Reclamation, as a component of the river maintenance program, will perform two river restoration projects annually.

- Increase the number and distribution of overbank flooding sites and sites with shallow, low velocity water conditions to enhance silvery minnow habitat, assist in regeneration of native vegetation, and provide for flooding in suitable habitat for the willow flycatcher during the breeding season. Monitoring will be conducted to quantify the extent of overbank flooding.

- Eliminate mowing of native riparian vegetation unless it contributes to habitat restoration or is required for safe conveyance of flood flows.

- In areas where impacts to mature cottonwoods cannot be avoided, Reclamation will replace the trees at a 10:1 ratio.

- Reclamation will continue to work with the MRGCD to improve gaging and real-time monitoring of water operations.

  Reclamation will initiate efforts to define a suite of characteristics important for flycatcher habitat occupancy and nesting success. Conduct a preliminary examination and assessment of habitat parameters of occupied habitat within the delta of Elephant Butte Reservoir (near the LFCC) to determine features that characterize optimal habitat selected by flycatchers.

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

Prepared by

Craig Boroughs, Ph.D., P.E.

February 2012

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Acknowledgments

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.

Significant appreciation must also be expressed to the URGWOM Technical Team (Tech Team) contributors for the work on model development, completed simulations, and post-processing and analyses including the close involvement from Tech Team members, Warren Sharp with Reclamation, Marc Sidlow with the Corps, and Nabil Shafike with ISC. Their efforts were vital for assuring the PHVA work group's analyses were a priority and for assuring a quality modeling study was completed. Other Tech Team members contributing to the study include Don Gallegos and Amy Louise with the Corps, Steve Bowser and Michelle Estrada-Lopez with Reclamation, Jesse Roach with Sandia National Laboratories, Mike Roark with the U.S. Geological Survey (USGS), and contractors Tomas Stockton and Bill Miller.

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 (*Hyboganthus 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).

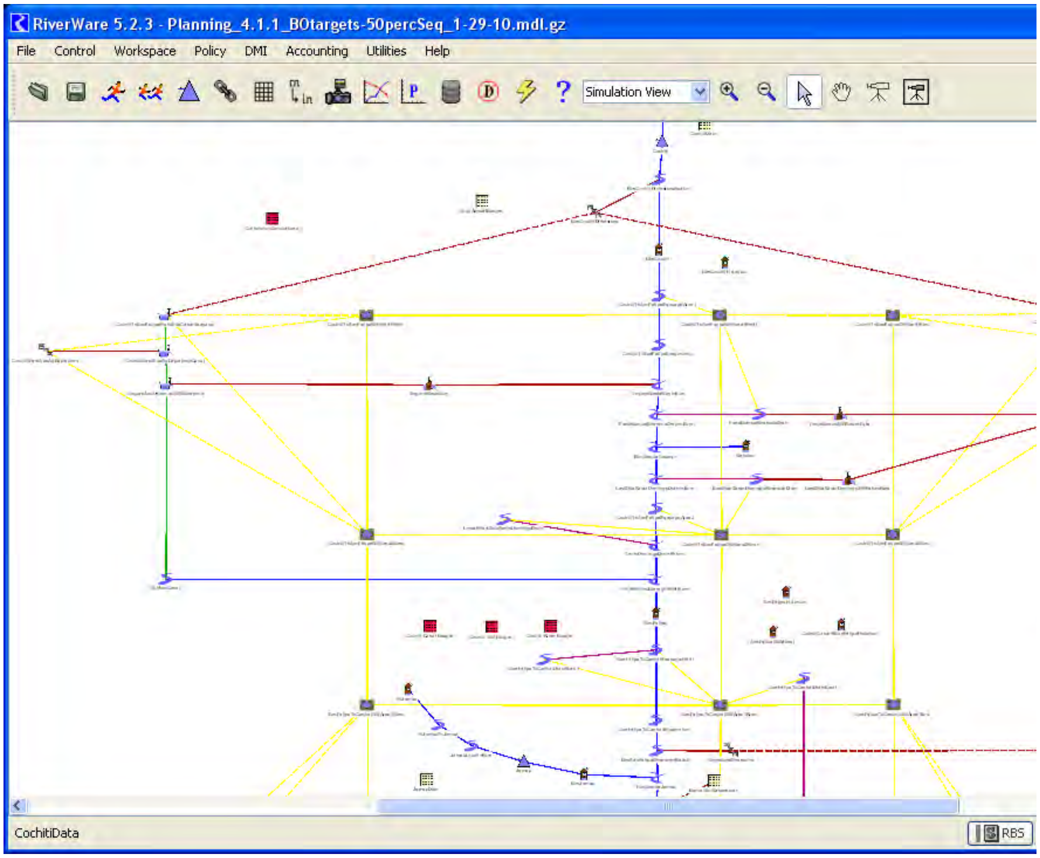

Figure 2.1. Screen Capture of the Representation of the Top Portion of the Middle Rio Grande System in URGWOM

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).

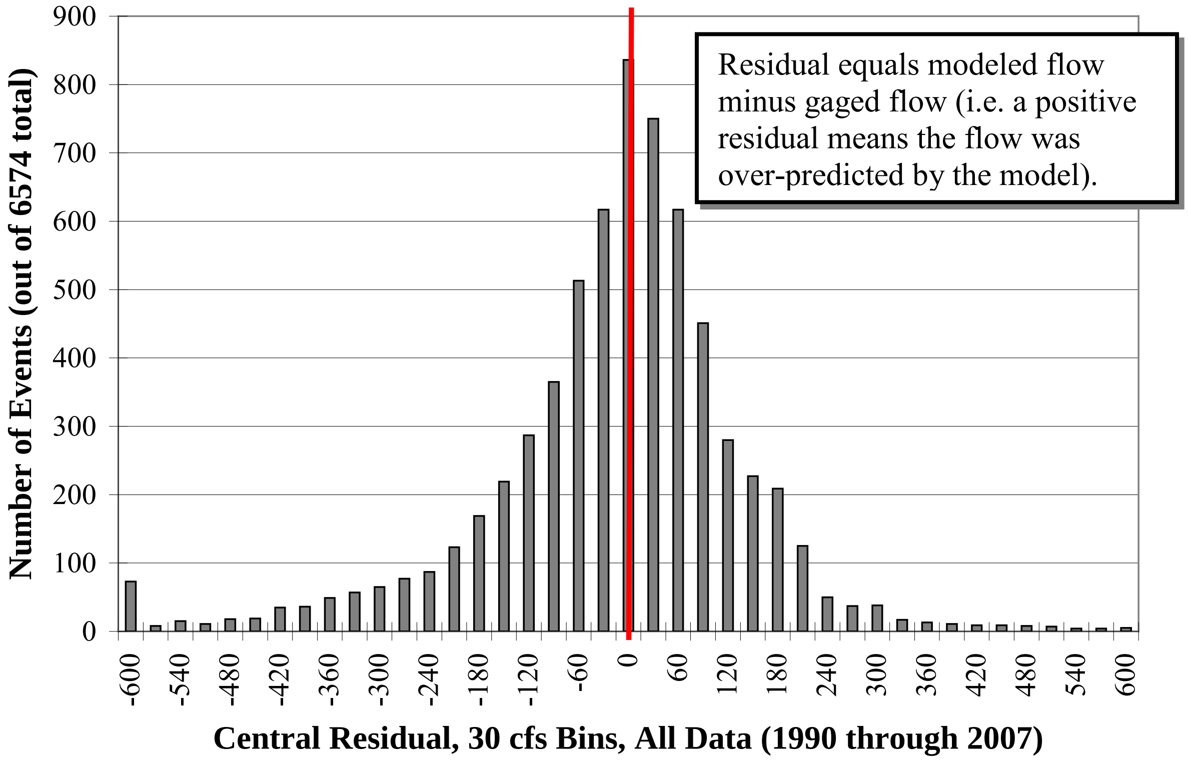

Figure 2.2. Sample Plot of Distribution of Residuals – Central

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.

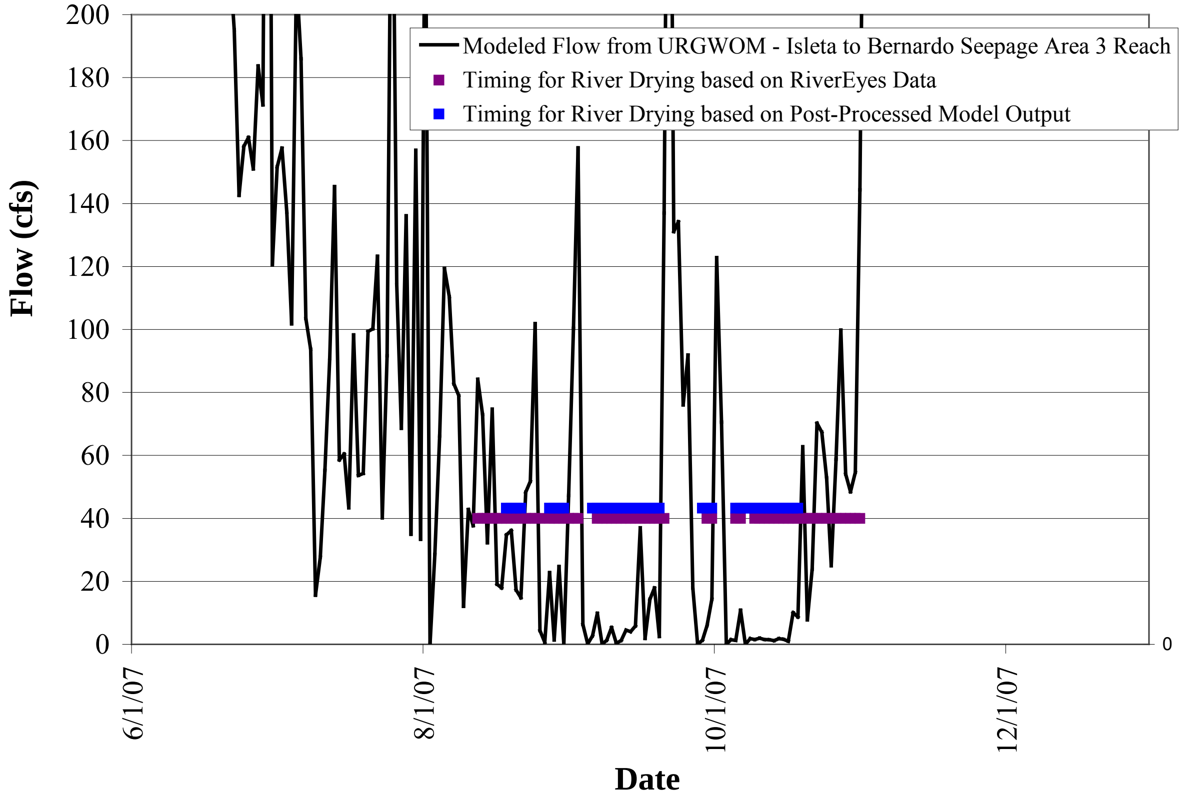

Figure 2.3. Sample Plot of Simulation Results for River Drying versus RiverEyes Data

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.

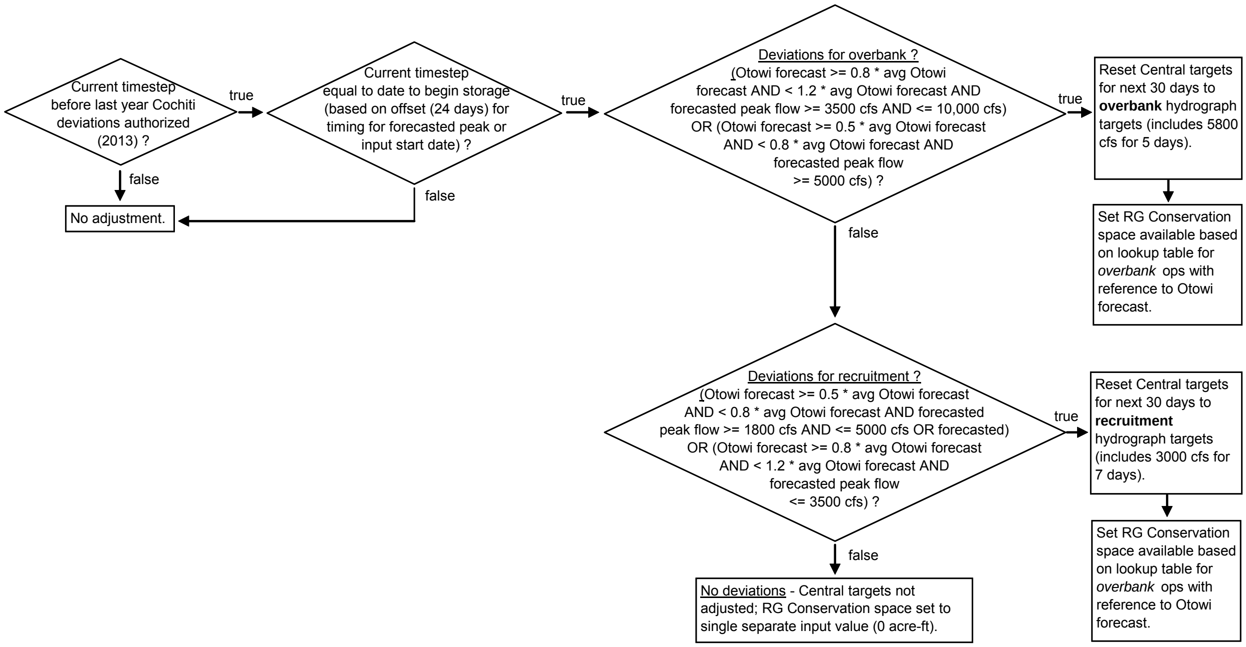

Figure 2.4. Flowchart for Implementing Cochiti Deviations

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

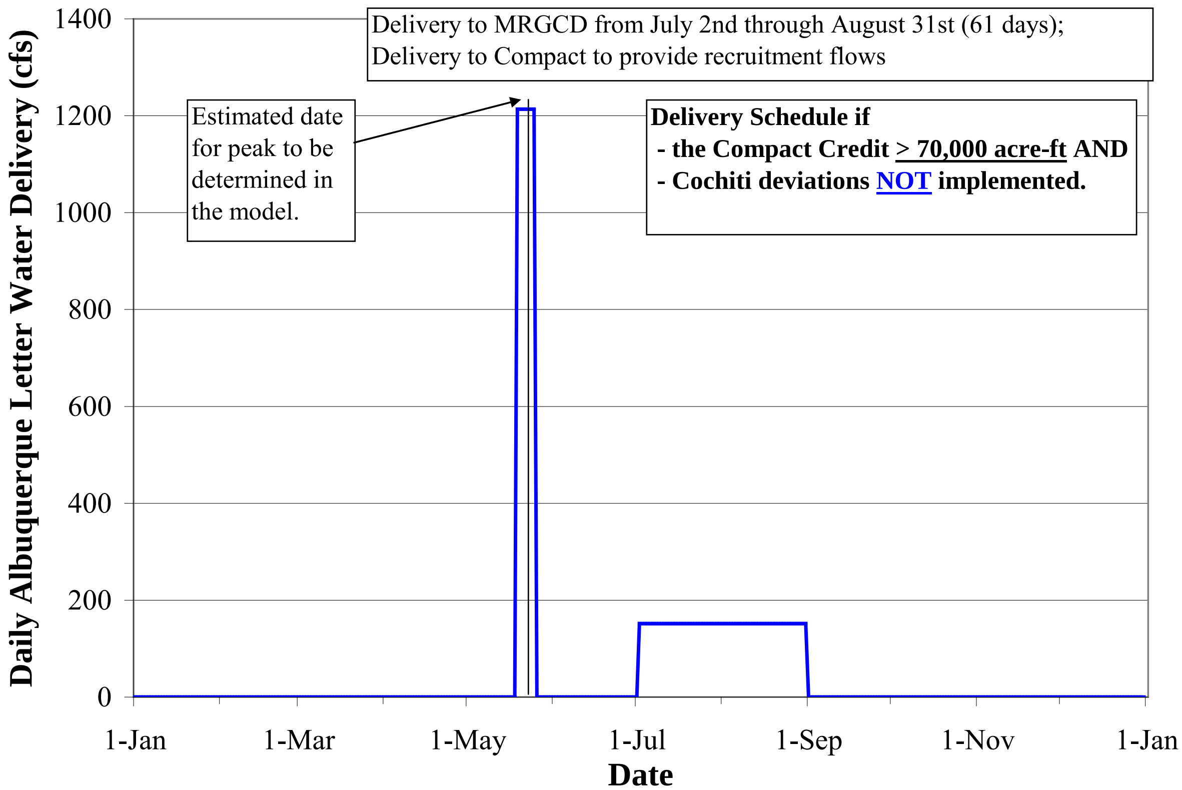

Figure 2.6. Sample *Alternate* Schedule for ABCWUA Letter Water Deliveries to Provide Spiked Release

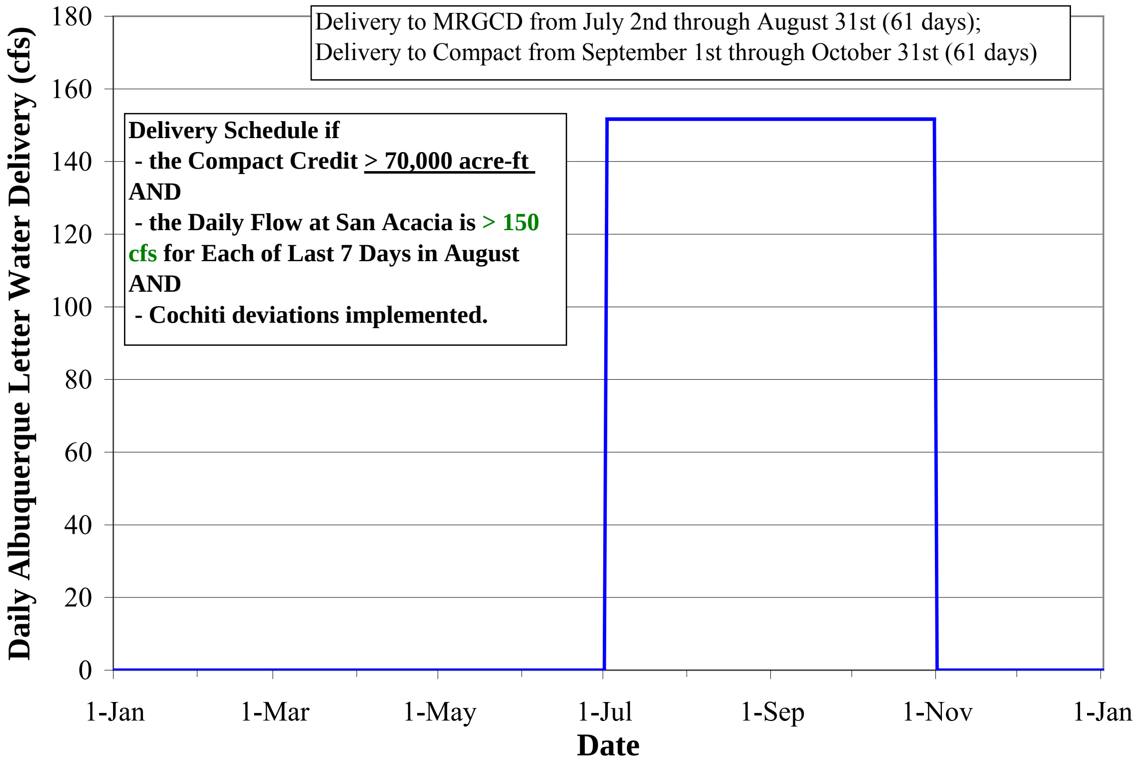

Figure 2.7. Sample *Alternate* Schedule for ABCWUA Letter Water Deliveries

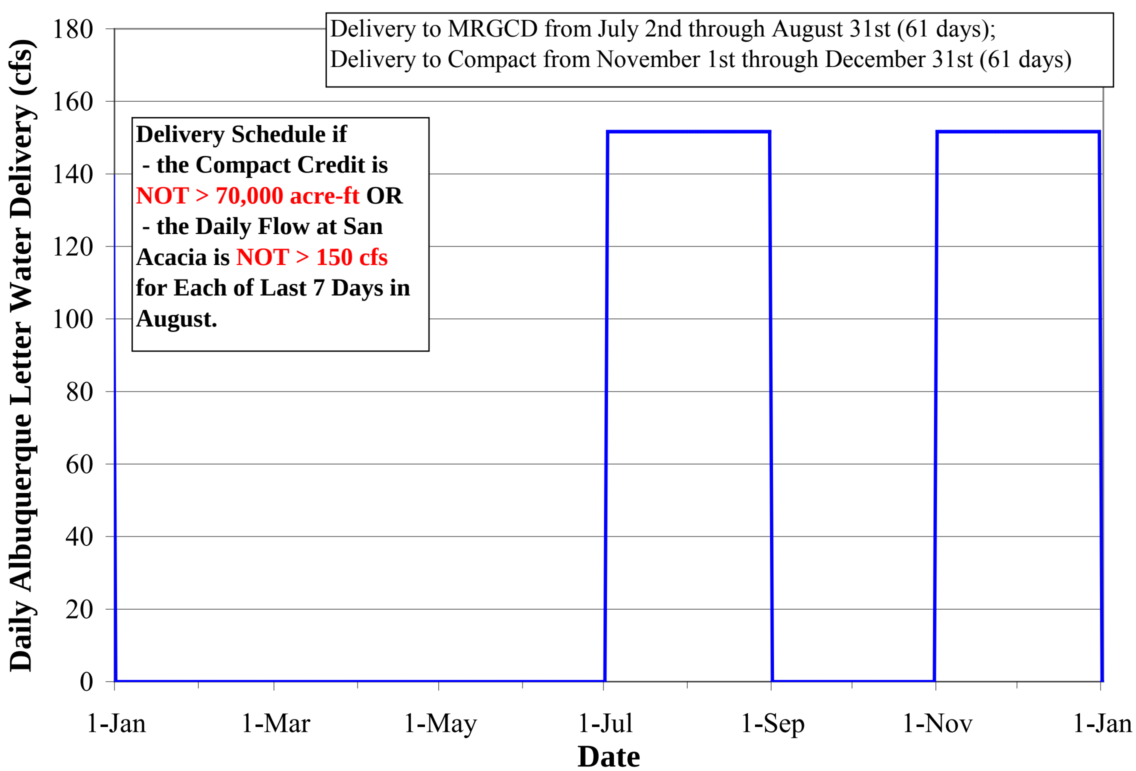

Figure 2.8. Sample Typical Schedule for ABCWUA Letter Water Deliveries

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.

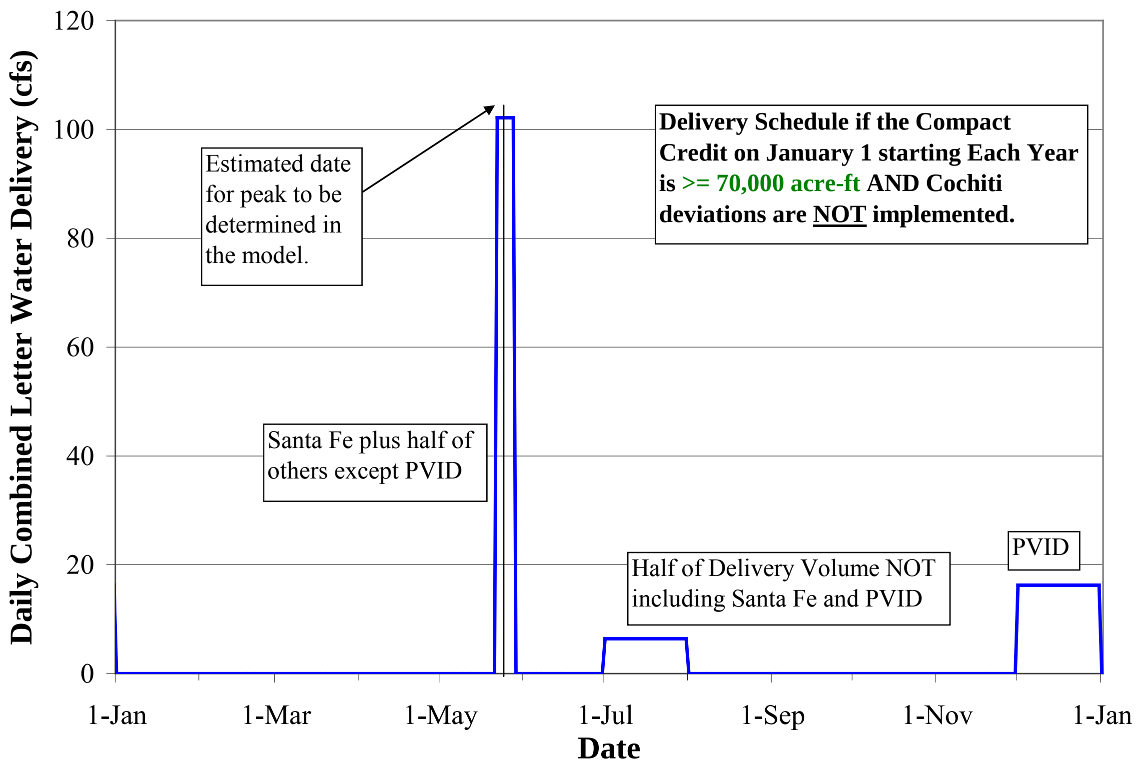

Figure 2.9. Sample *Alternate* Schedule for Combined Account Letter Water Deliveries to Provide Spiked Release

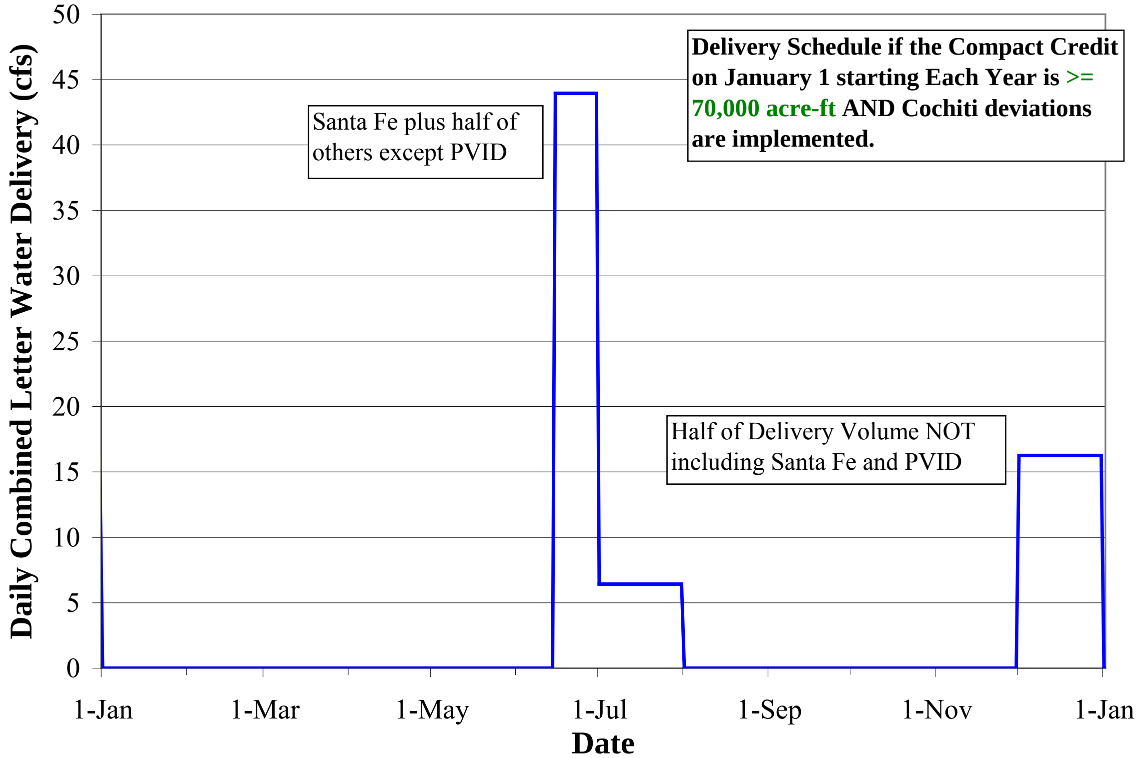

Figure 2.10. Sample *Alternate* Schedule for Combined Account Letter Water Deliveries

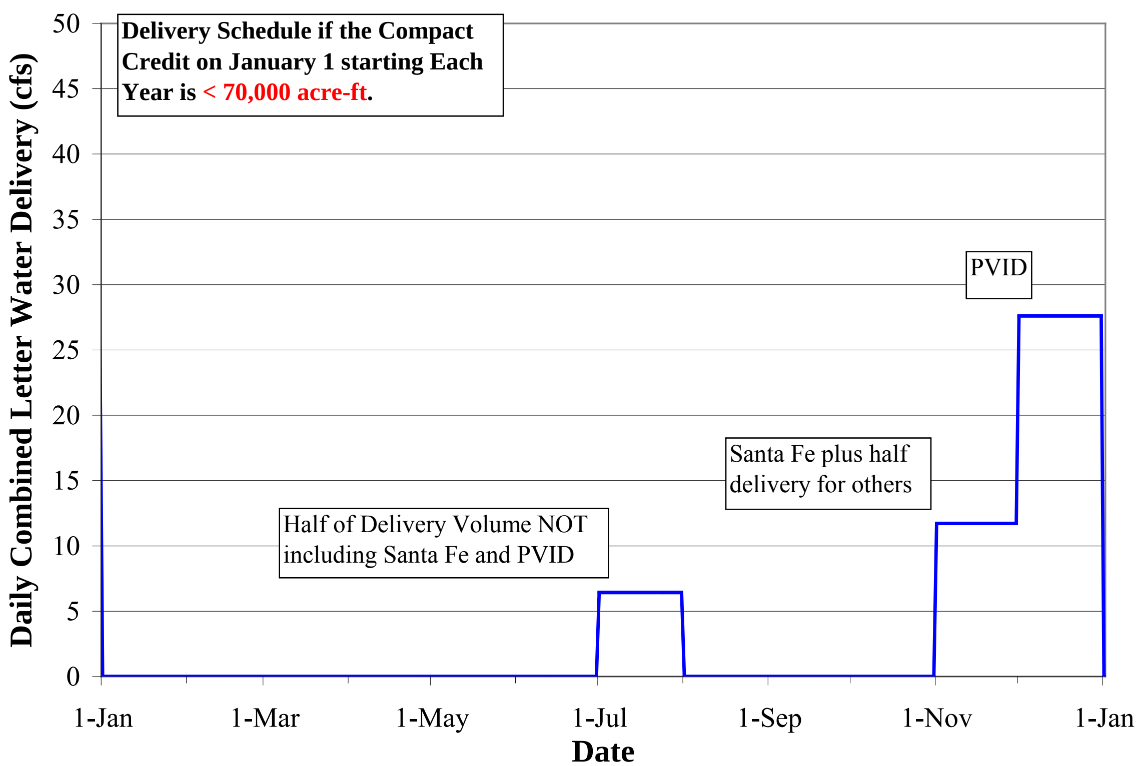

Figure 2.11. Sample Typical Schedule for Combined Account Letter Water Deliveries

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.

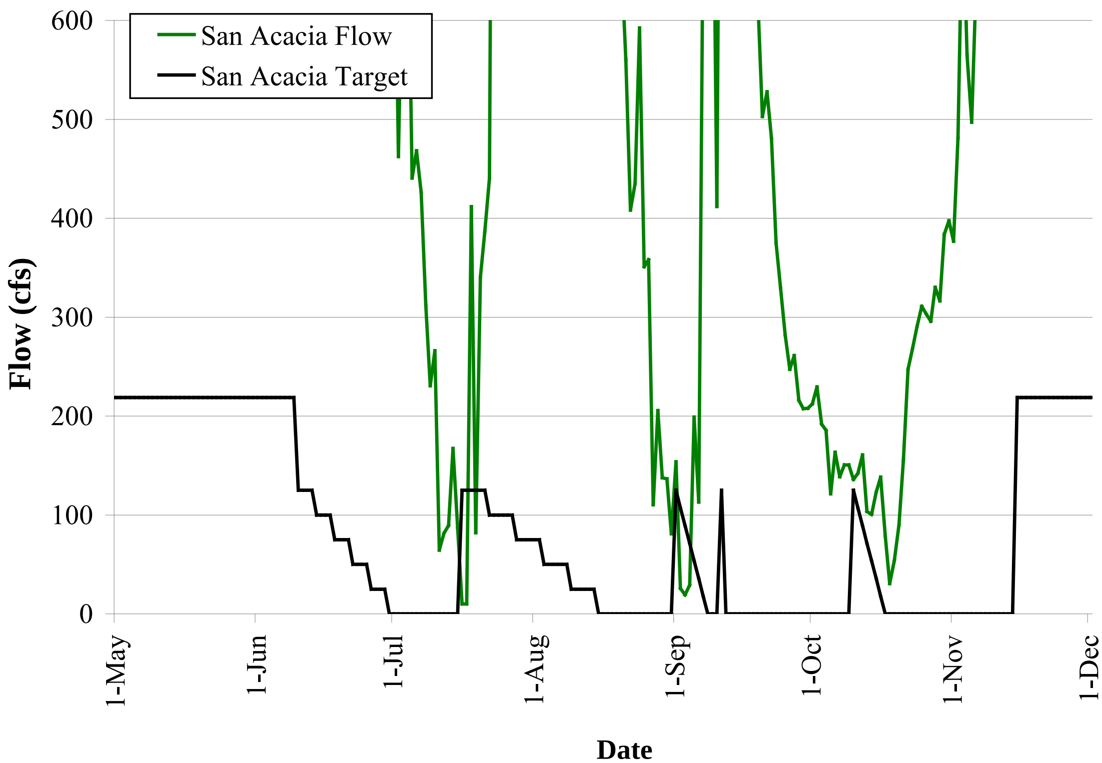

Figure 2.12. Sample Plot of Step Downs in Target Flows at San Acacia

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.

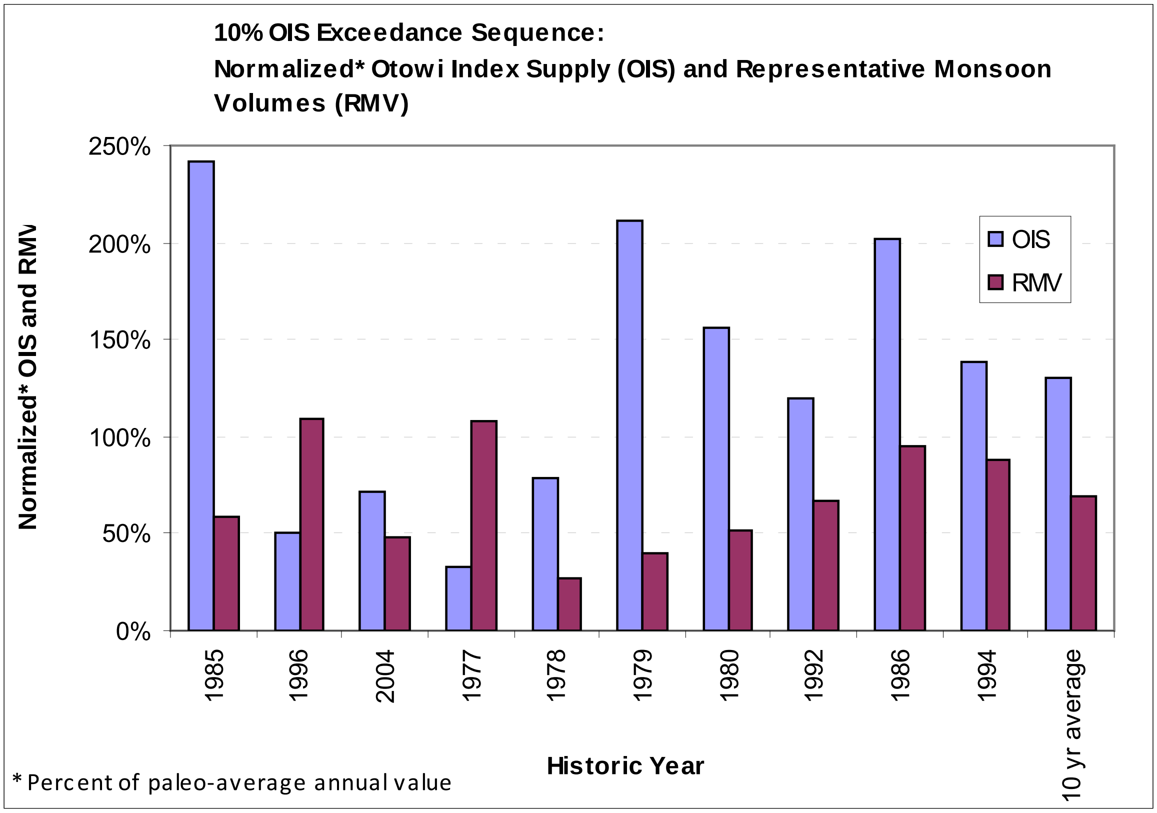

Figure 3.1. Synthetic Hydrologic Sequence with 10 percent Exceedence

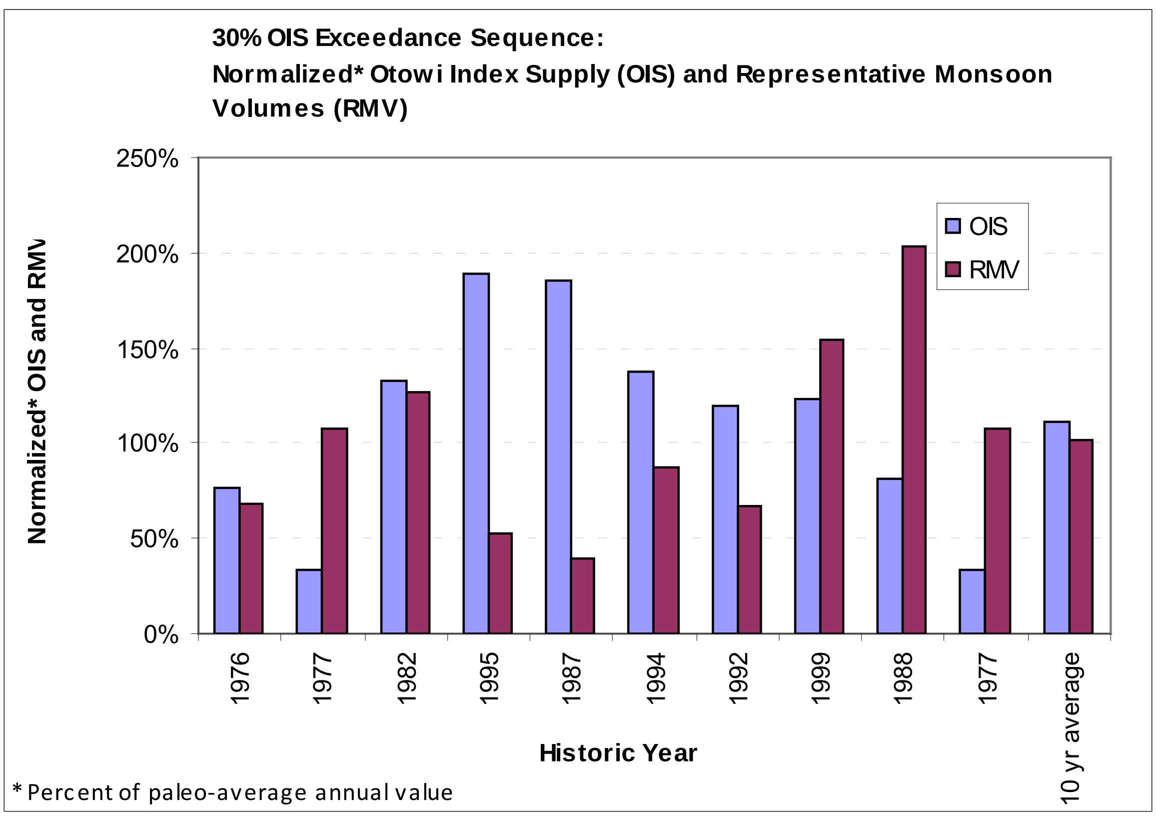

Figure 3.2. Synthetic Hydrologic Sequence with 30 percent Exceedence

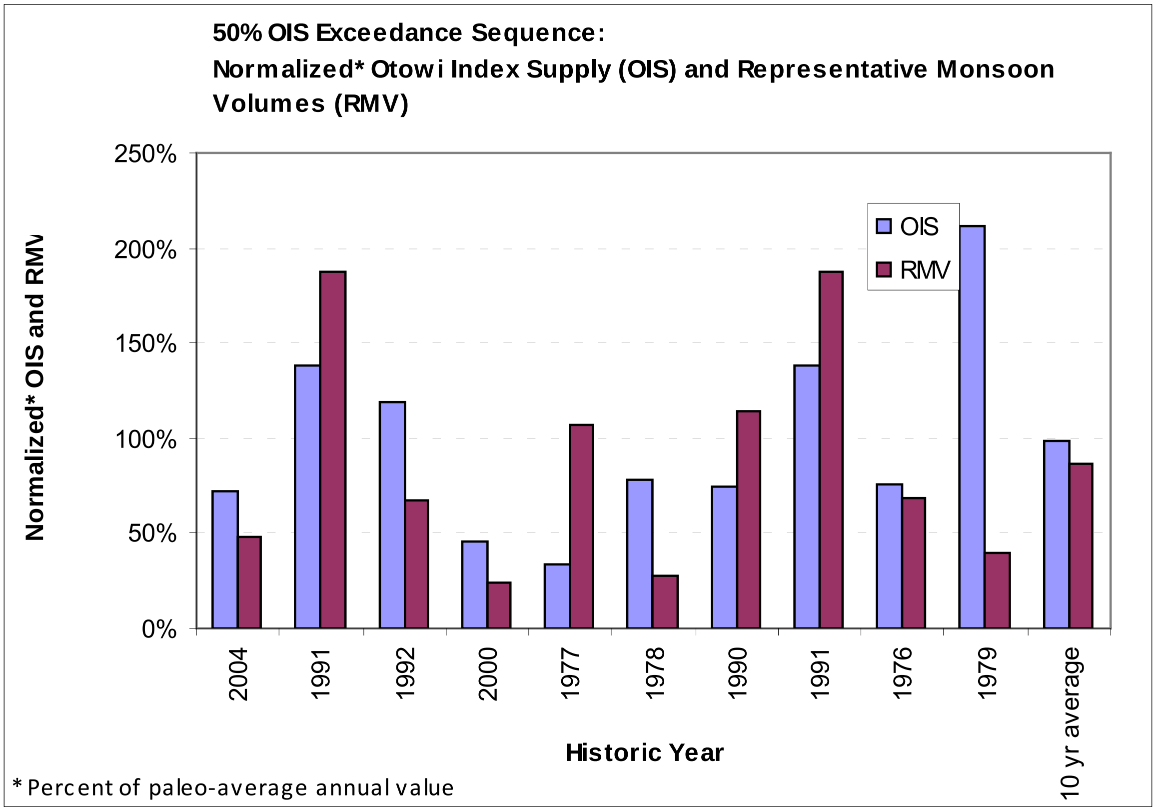

Figure 3.3. Synthetic Hydrologic Sequence with 50 percent Exceedence

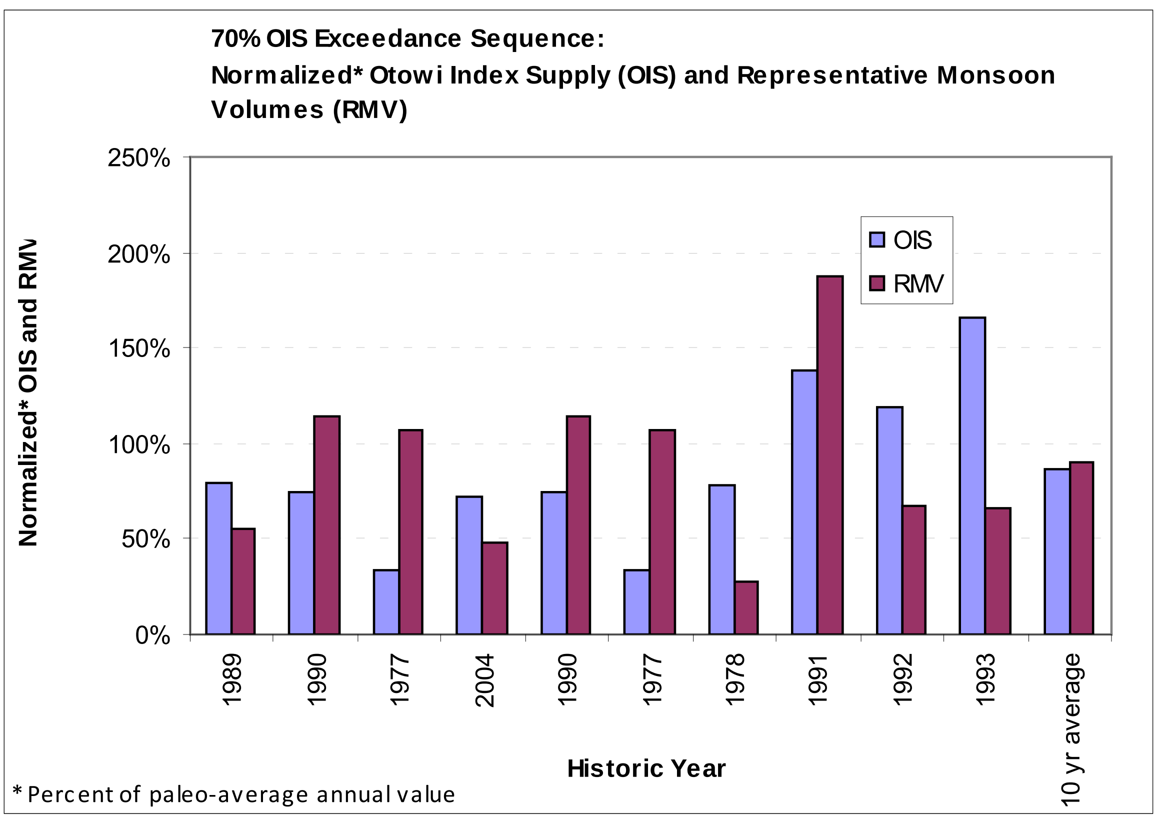

Figure 3.4. Synthetic Hydrologic Sequence with 70 percent Exceedence

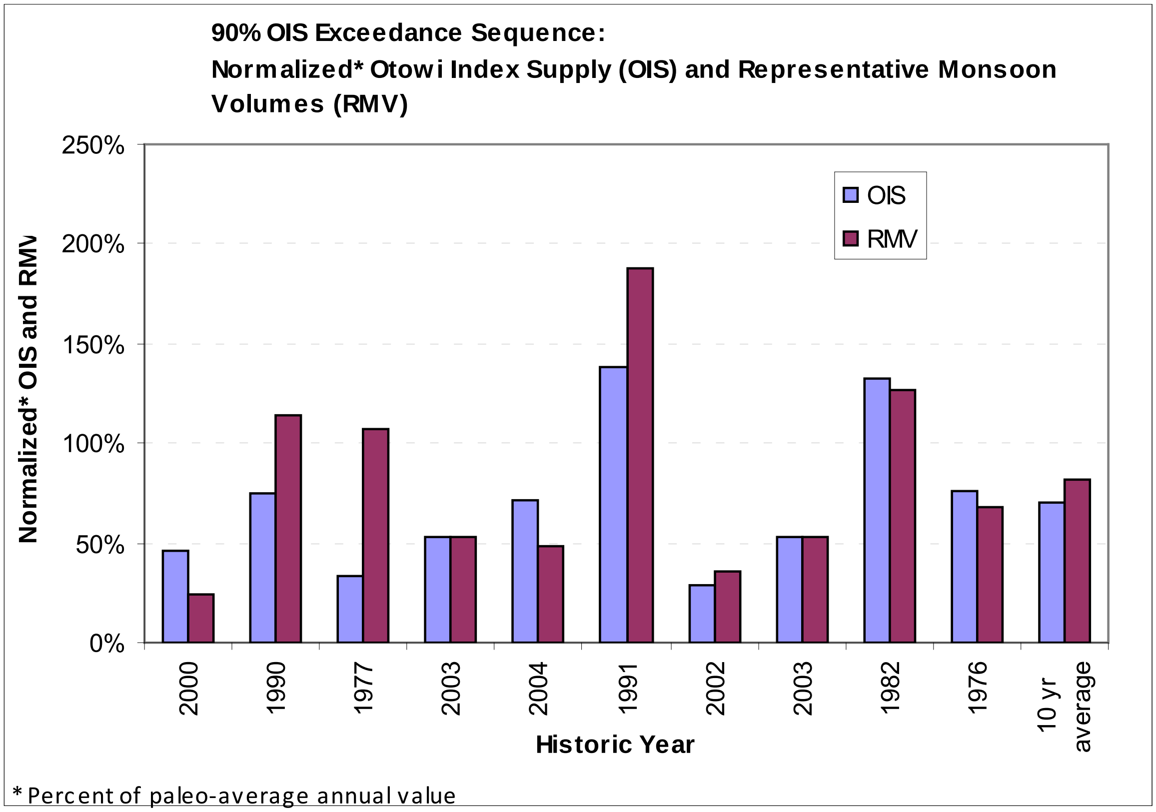

Figure 3.5. Synthetic Hydrologic Sequence with 90 percent Exceedence

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.

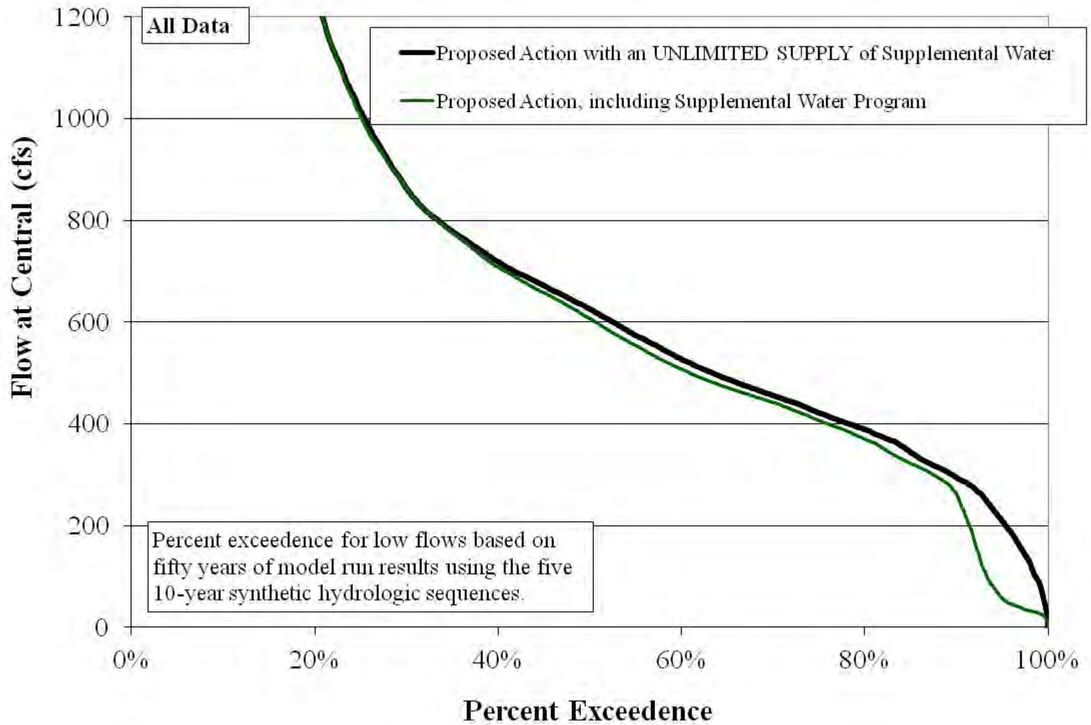

Figure 4.1. Exceedence Curves for Modeled Flows at Central – All Data

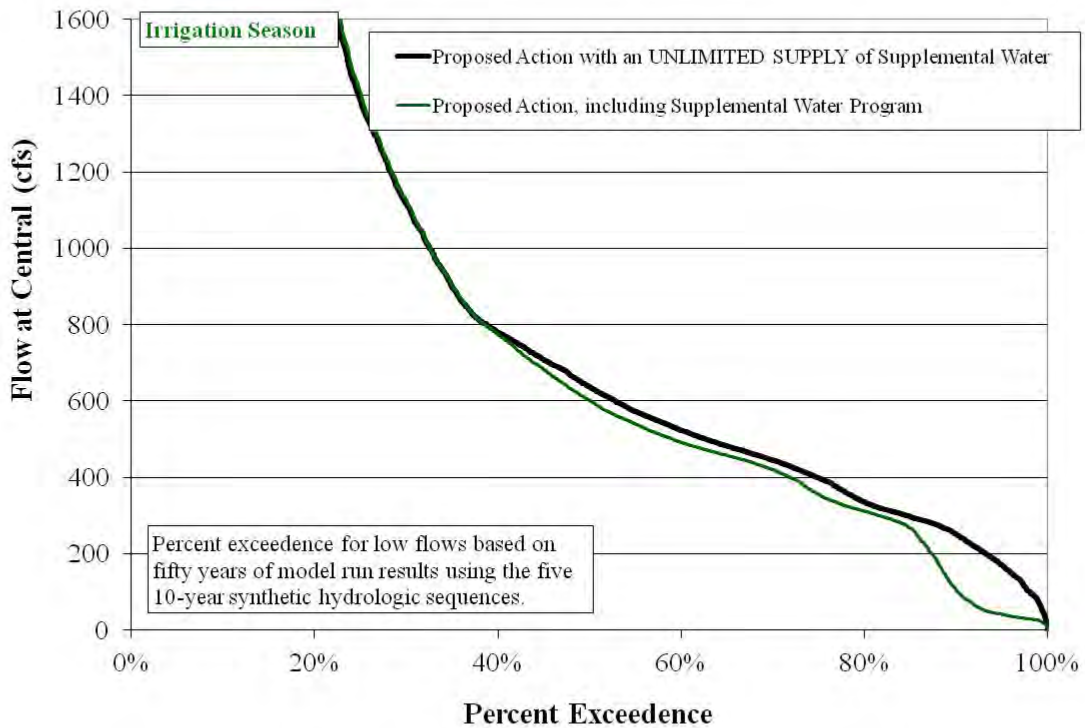

Figure 4.2. Exceedence Curves for Modeled Flows at Central – Irrigation Season

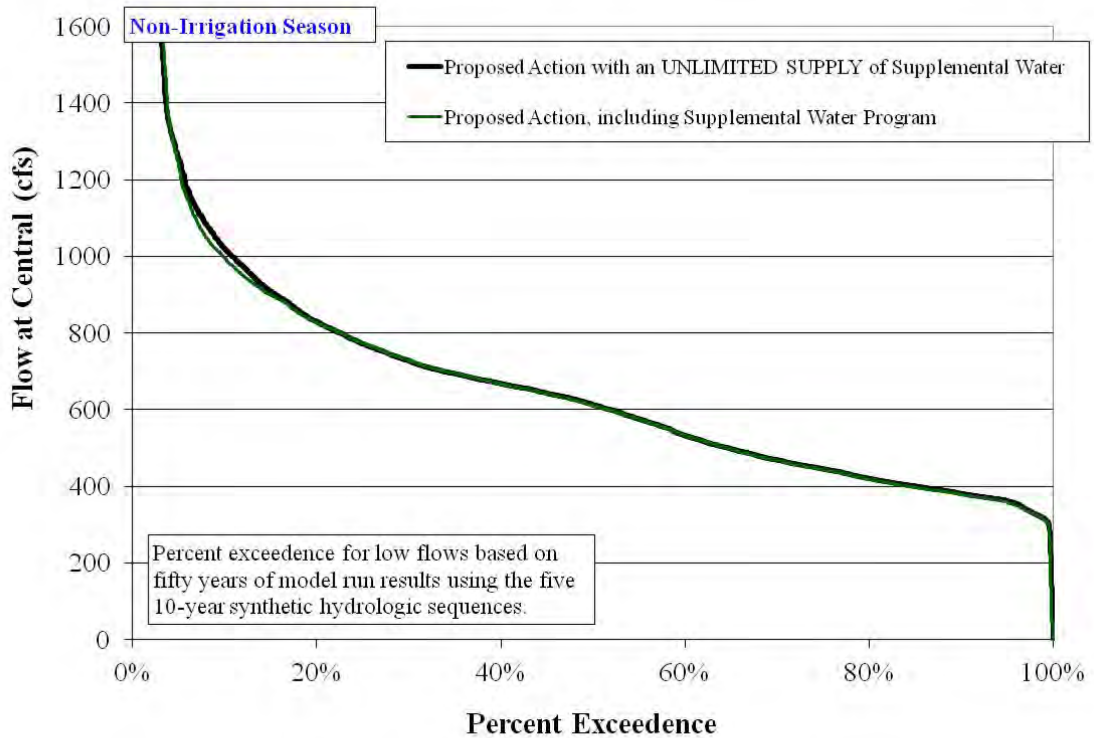

Figure 4.3. Exceedence Curves for Modeled Flows at Central – Non-Irrigation Season

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.

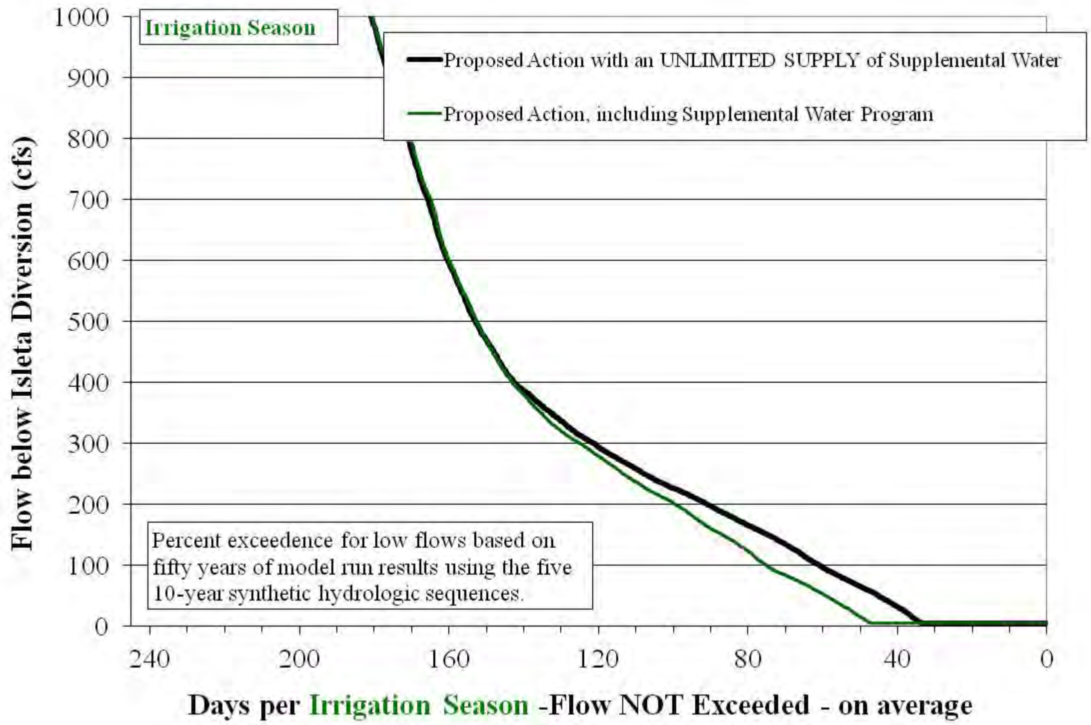

Figure 4.4. Exceedence Curves for Modeled Flows at Isleta – Irrigation Season

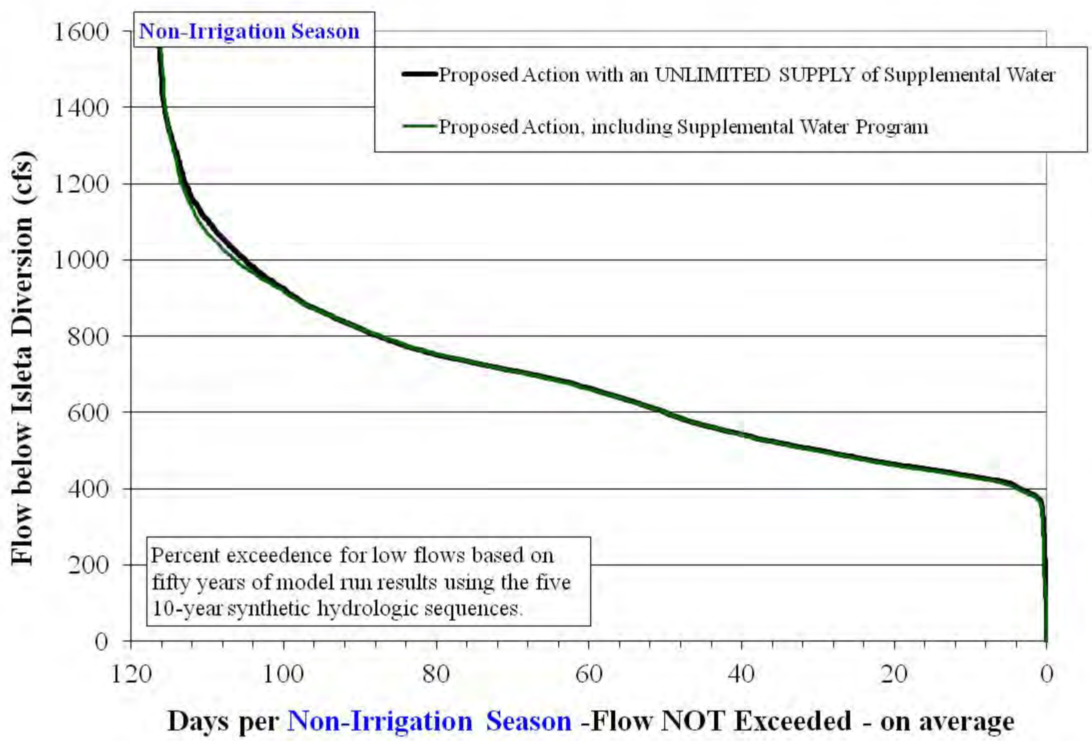

Figure 4.5. Exceedence Curves for Modeled Flows at Isleta – Non-Irrigation Season

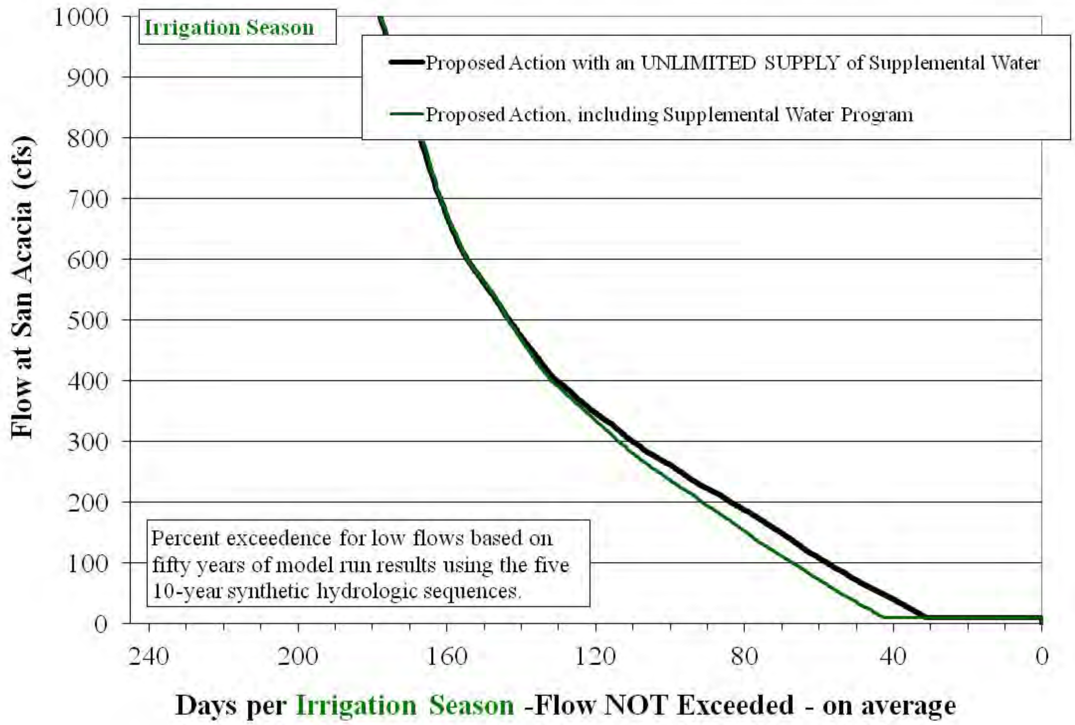

Figure 4.6. Exceedence Curves for Modeled Flows at San Acacia – Irrigation Season

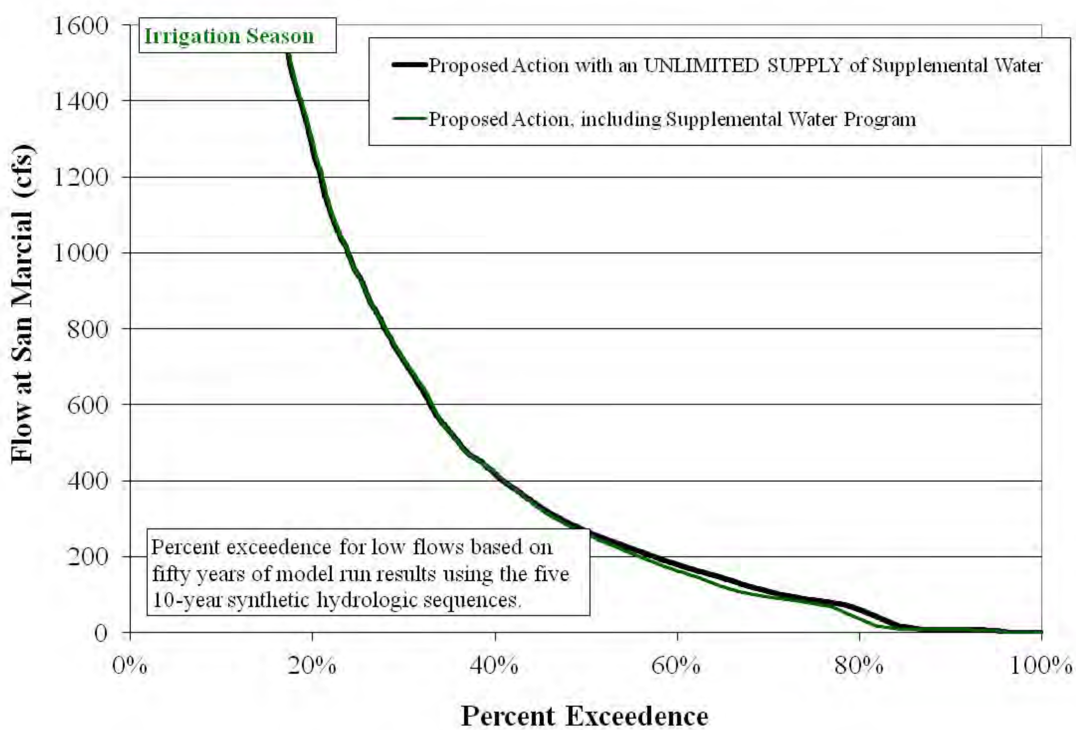

Figure 4.7 Exceedence Curves for Modeled Flows at San Marcial – Irrigation Season

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.

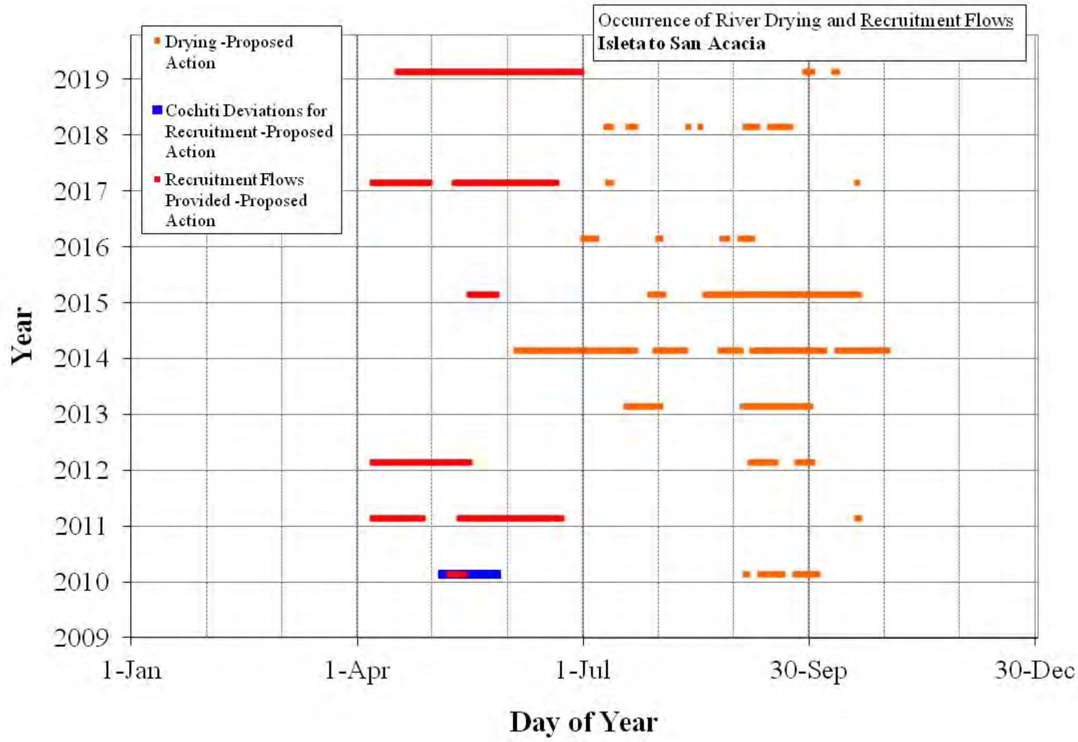

Figure 4.8. Depiction of Timing of River Drying and Recruitment Flows (and Cochiti Deviations for Recruitment) for Proposed Action – 50 percent Exceedence Sequence

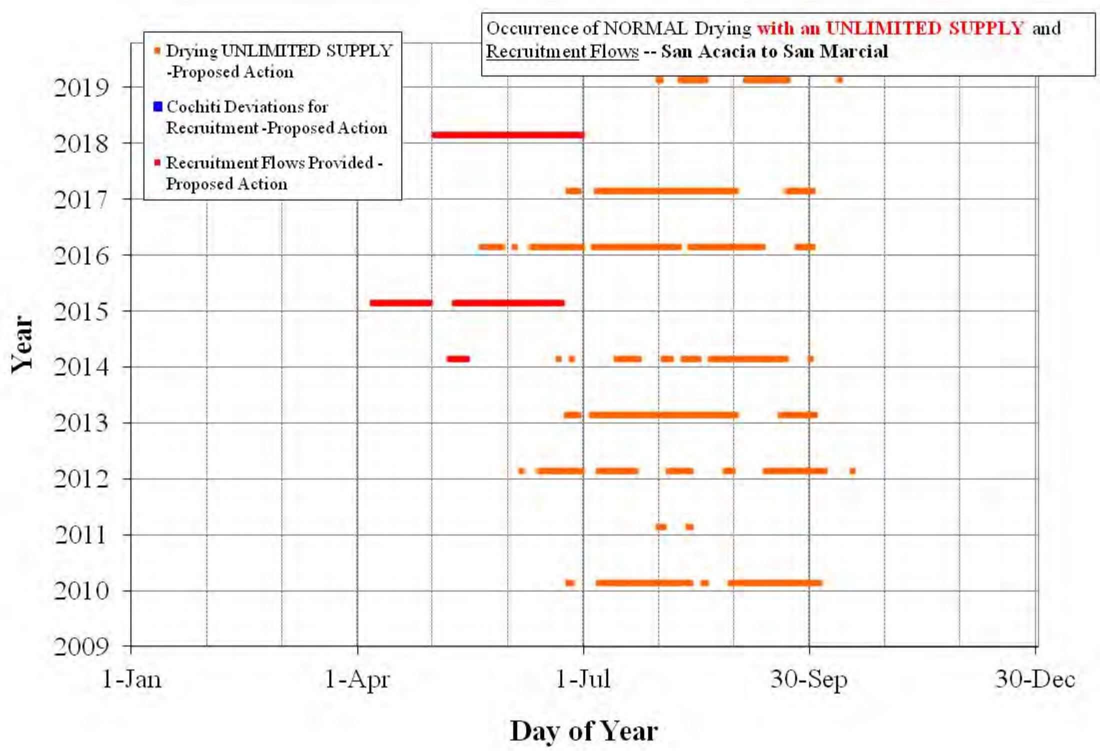

Figure 4.9. Depiction of Timing of River Drying and Recruitment Flows (and Cochiti Deviations for Recruitment) for Proposed Action *with an Unlimited Supply* – 90 percent Exceedence Sequence

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.

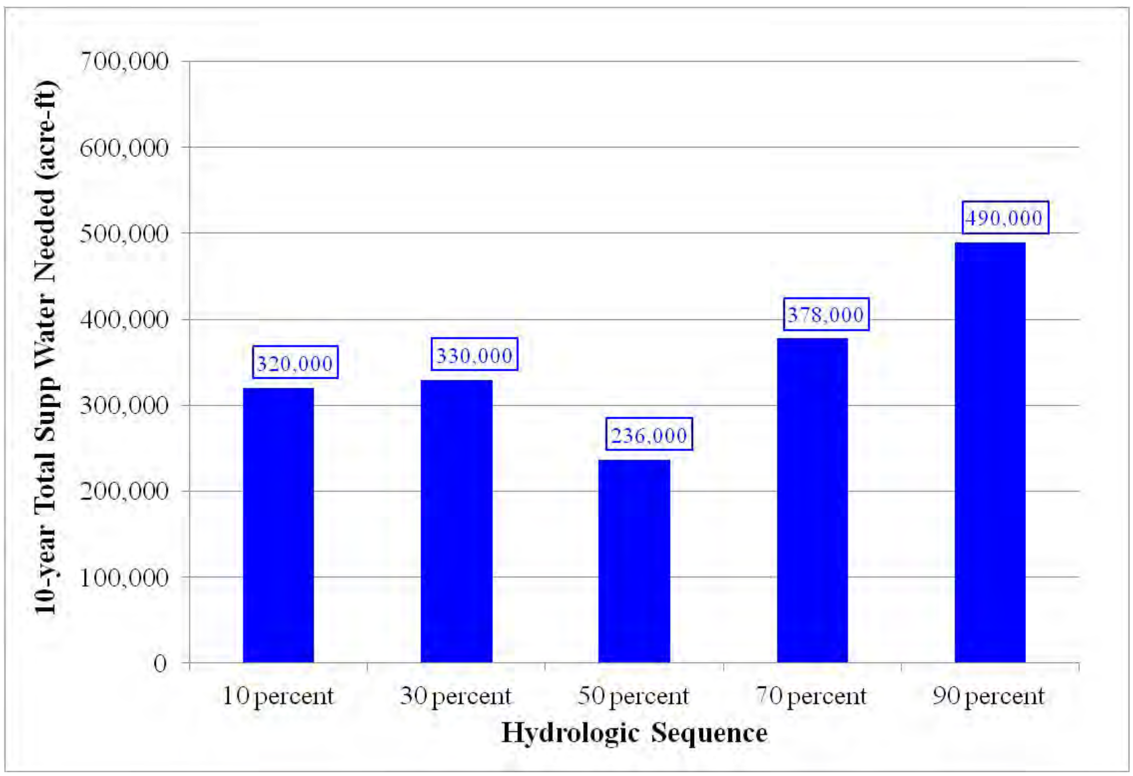

Figure 4.10. 10-year Total Supplemental Water Needed to Meet 2003 BO Flow Requirements

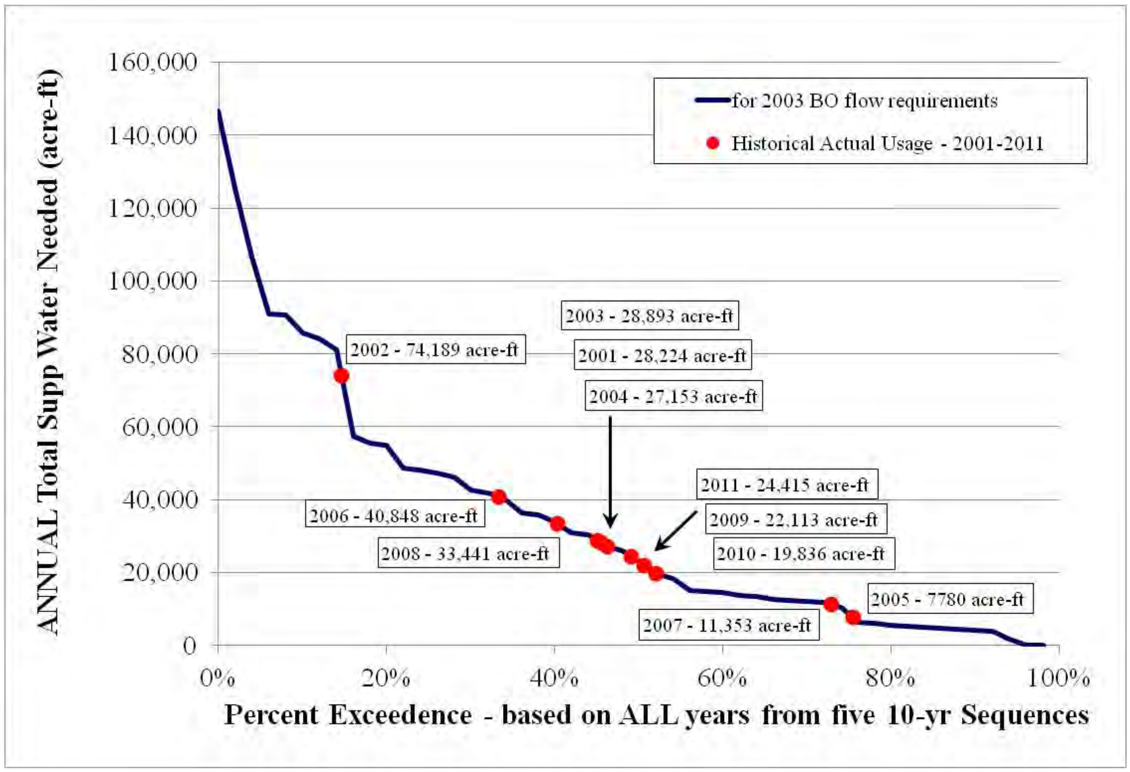

Figure 4.11. Exceedence Chart for Annual Total Supplemental Water Needed to Meet 2003 BO Flow Requirements

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.

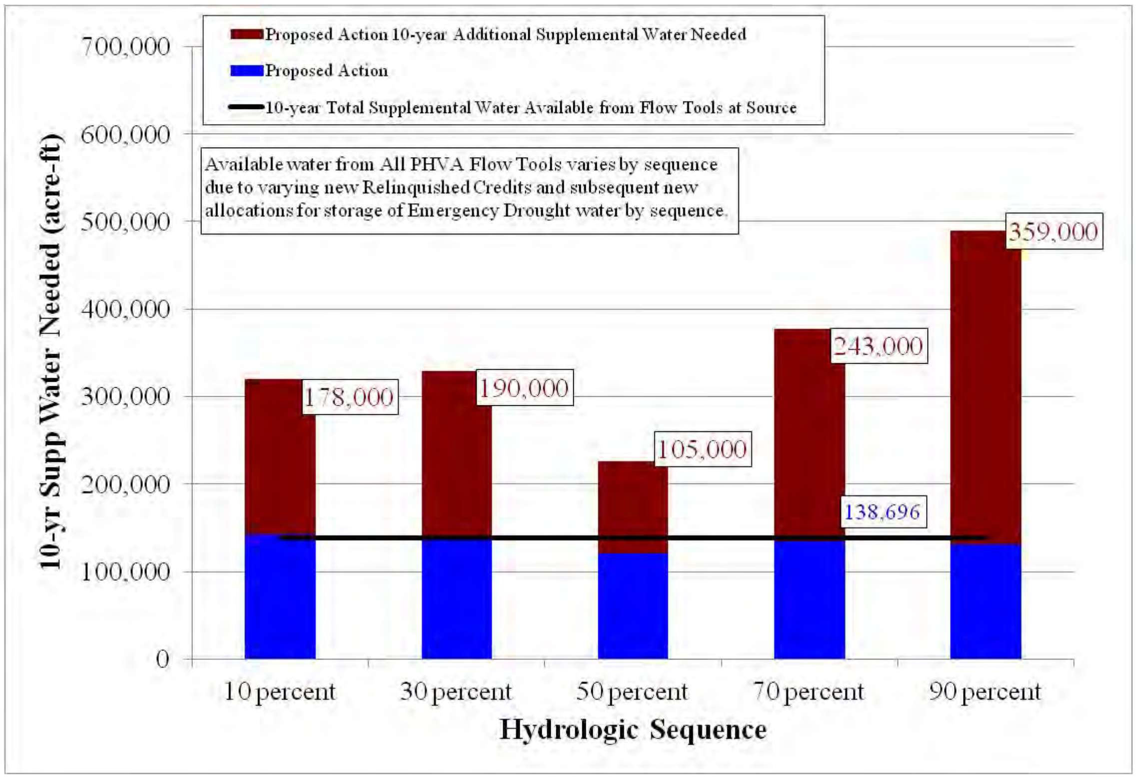

Figure 4.12. 10-year Additional Supplemental Water Needed under the Proposed Action

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.

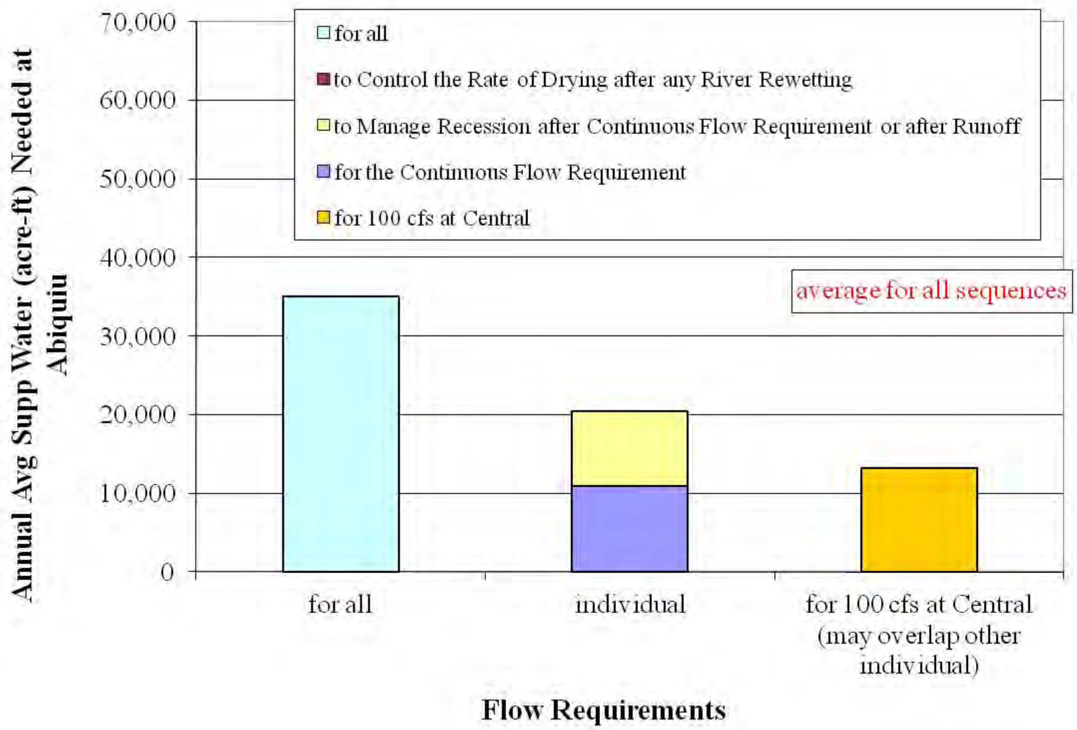

Figure 4.13. 10-year Additional Supplemental Water Needed with All PHVA Flow Tools

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.

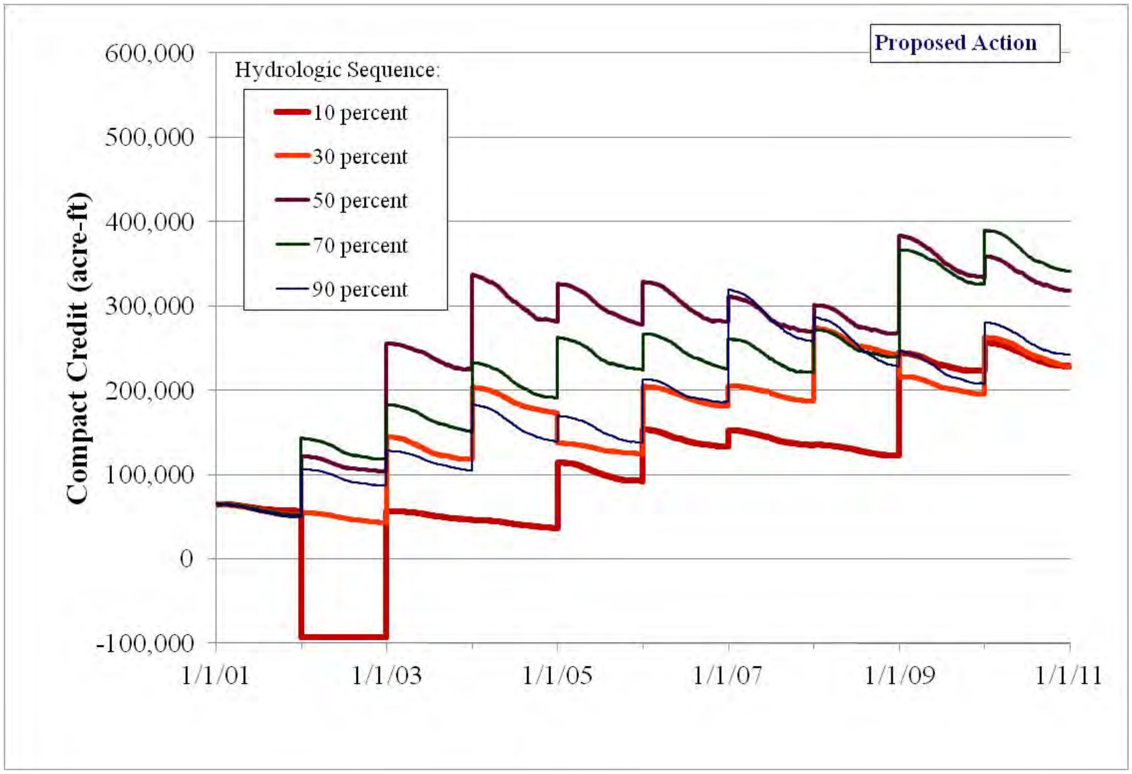

Figure 4.14. Cumulative Compact Credit under the Proposed Action for Each Hydrologic Sequence

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.

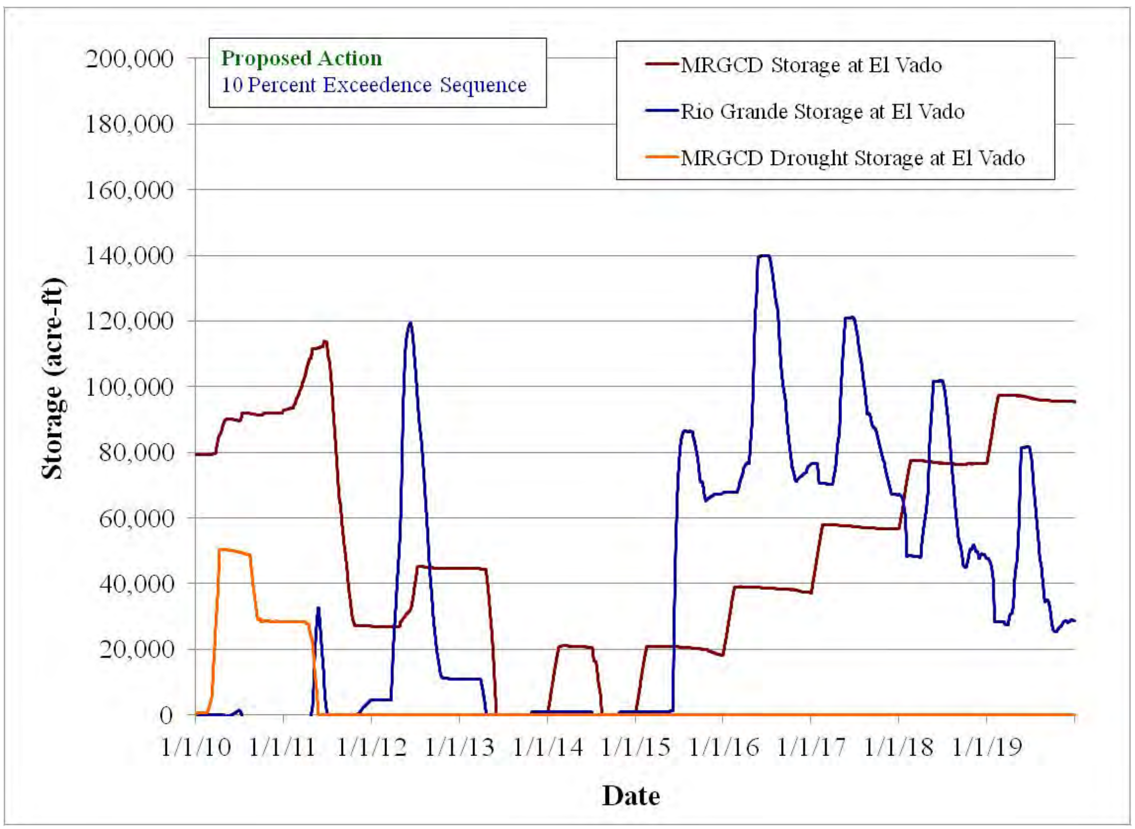

Figure 4.15. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 10 percent Exceedence Sequence

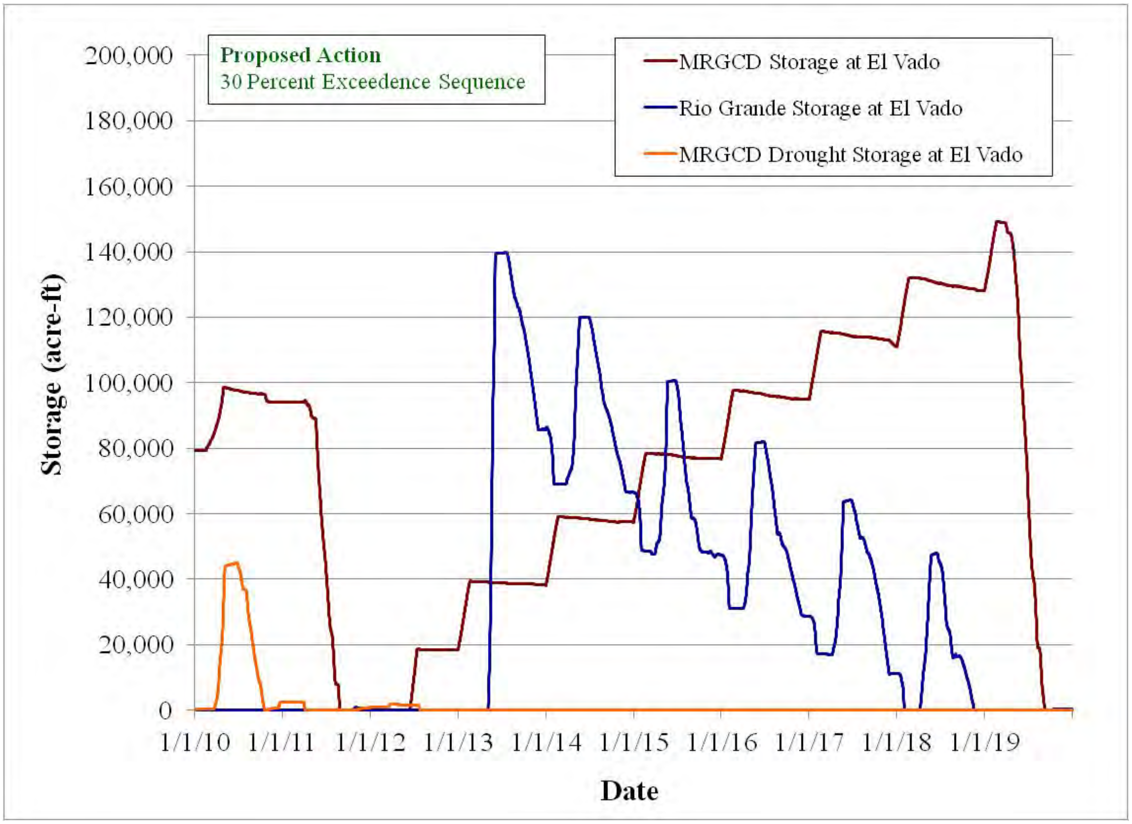

Figure 4.16. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 30 percent Exceedence Sequence

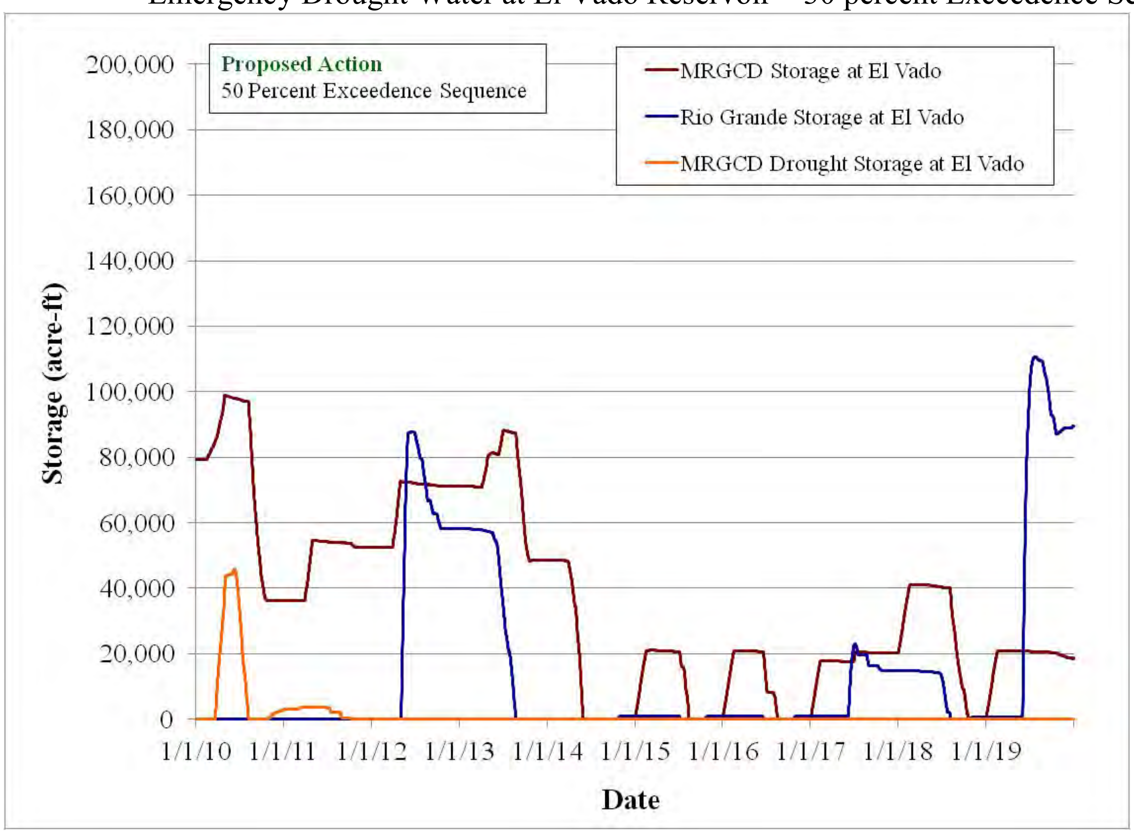

Figure 4.17. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 50 percent Exceedence Sequence

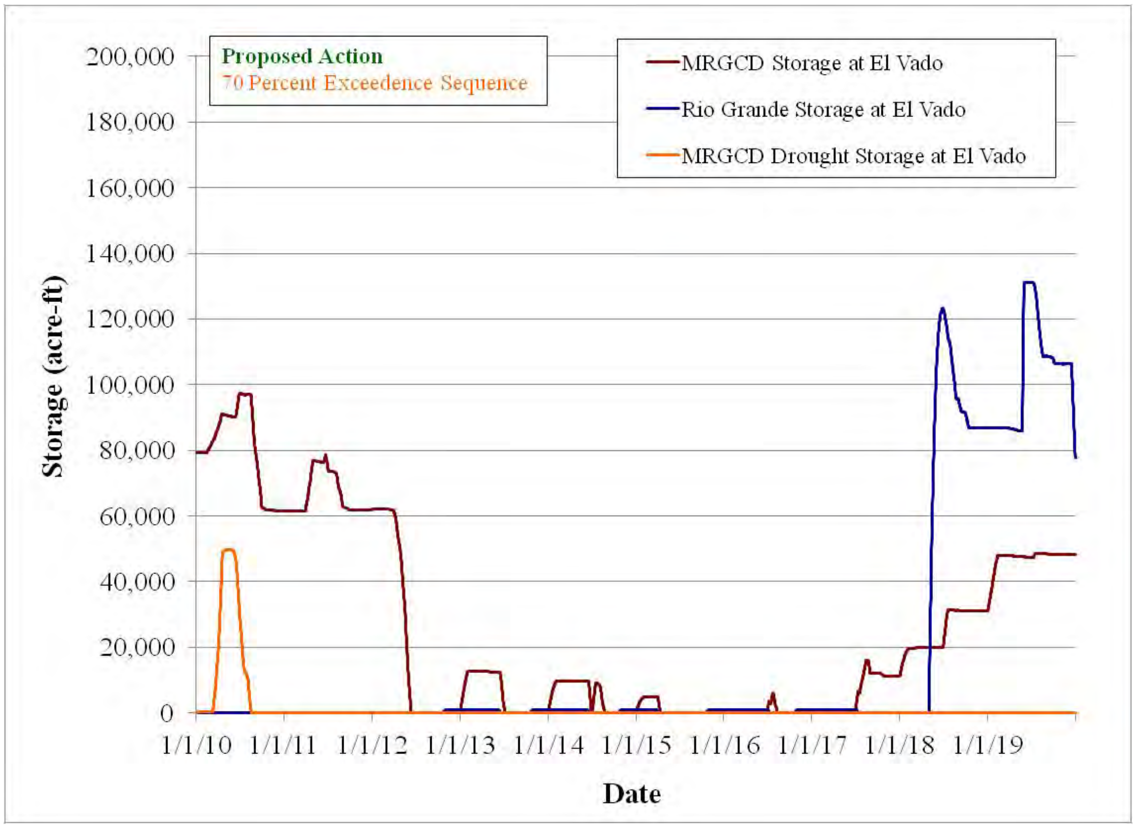

Figure 4.18. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 70 percent Exceedence Sequence

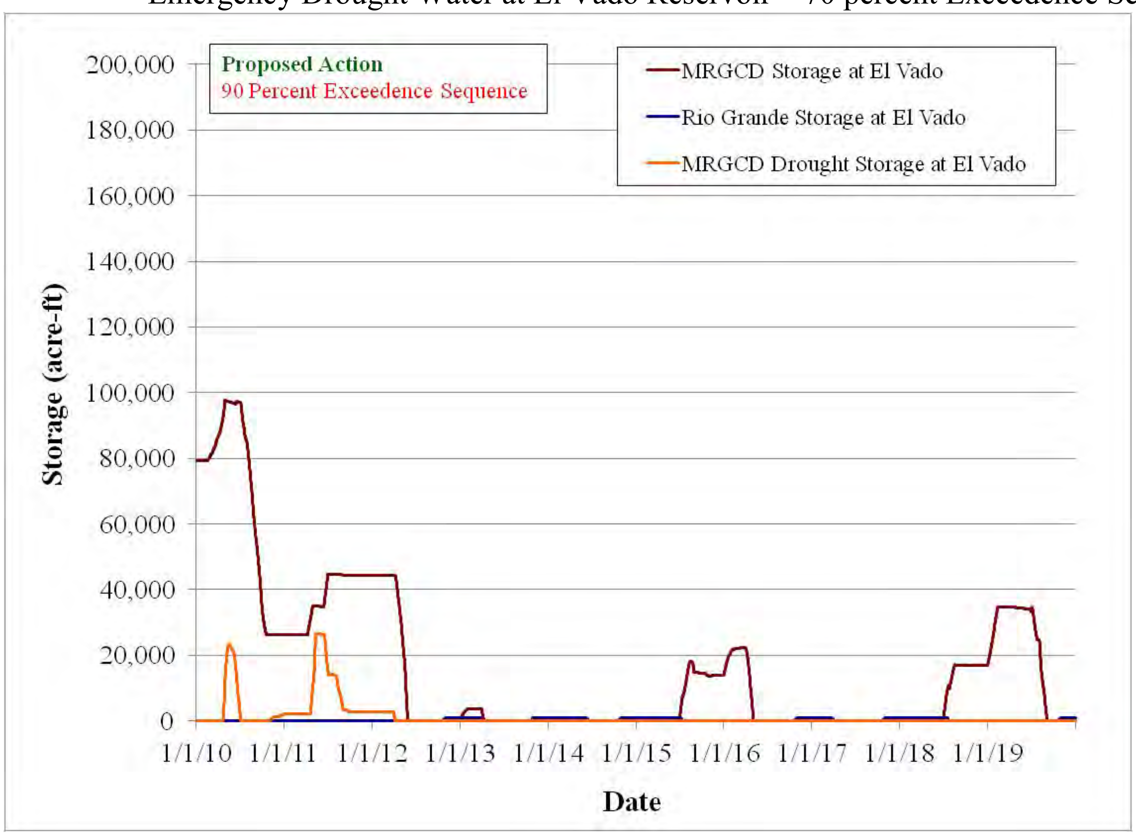

Figure 4.19. MRGCD's Supply of San Juan-Chama Water, Native Rio Grande Water, and Emergency Drought Water at El Vado Reservoir – 90 percent Exceedence Sequence

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.

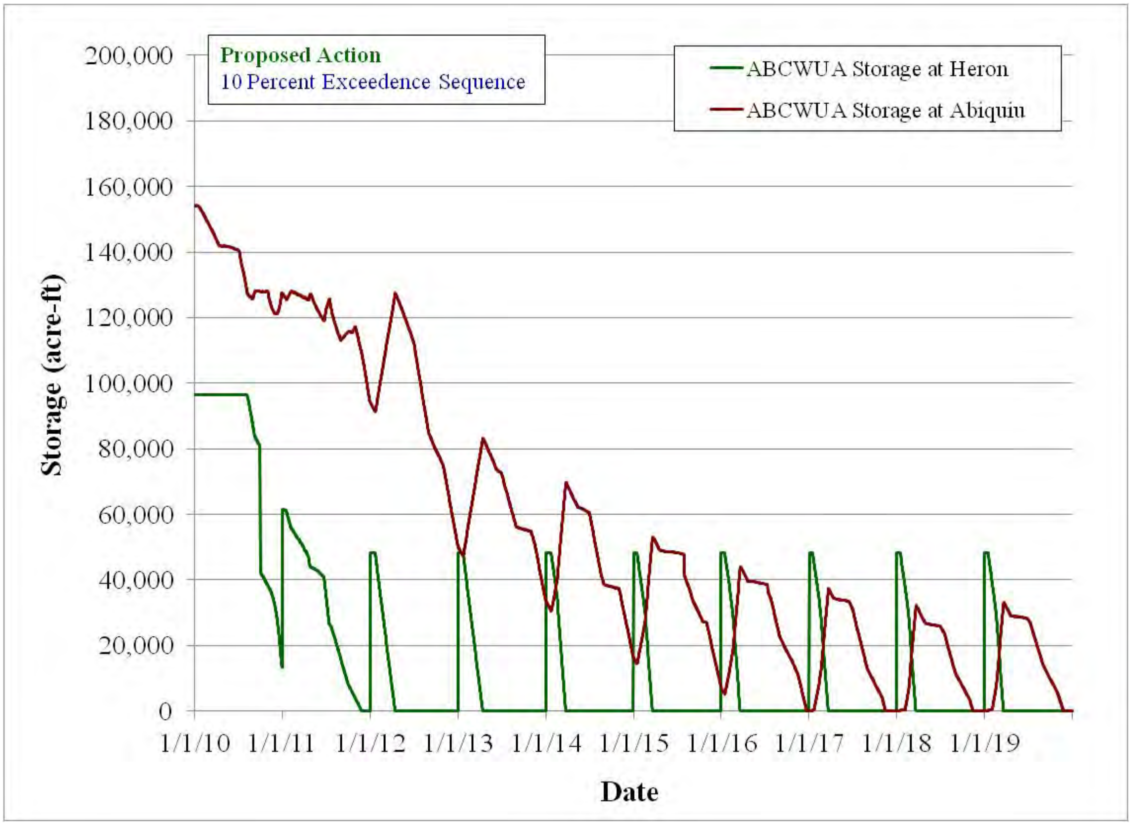

Figure 4.20. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 10 percent Exceedence Sequence

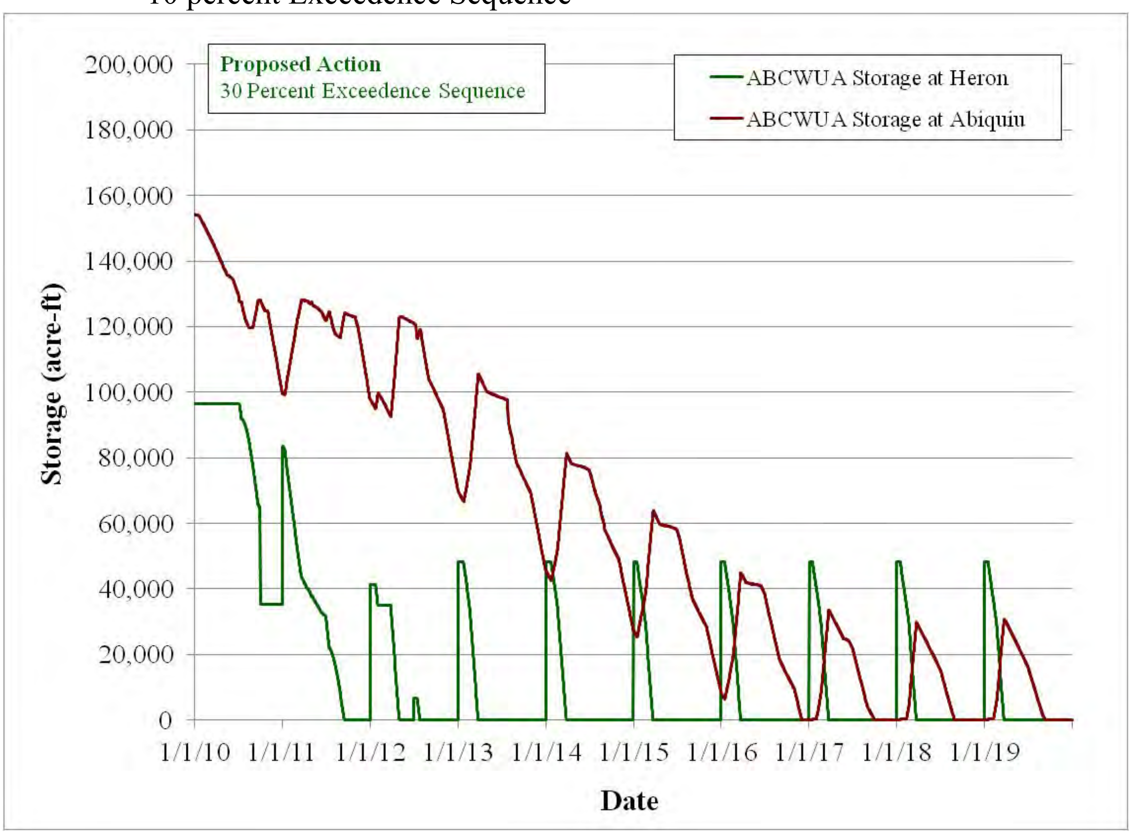

Figure 4.21. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 30 percent Exceedence Sequence

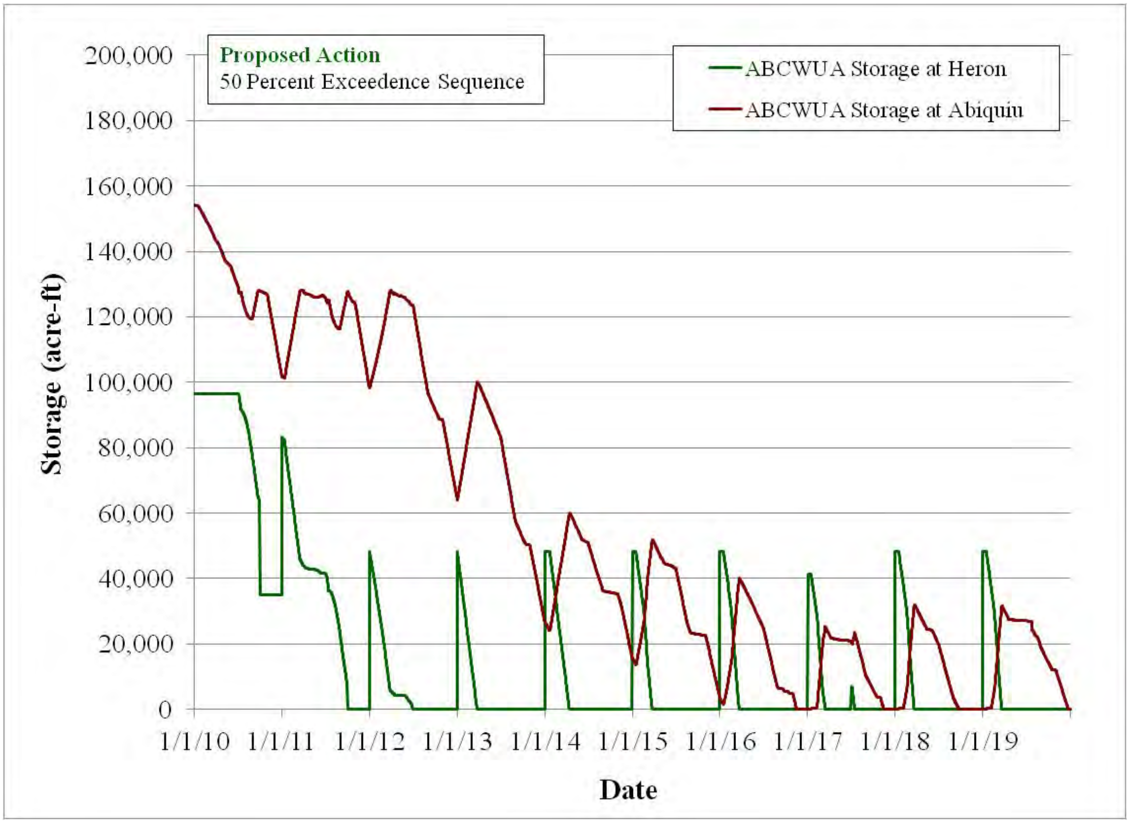

Figure 4.22. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 50 percent Exceedence Sequence

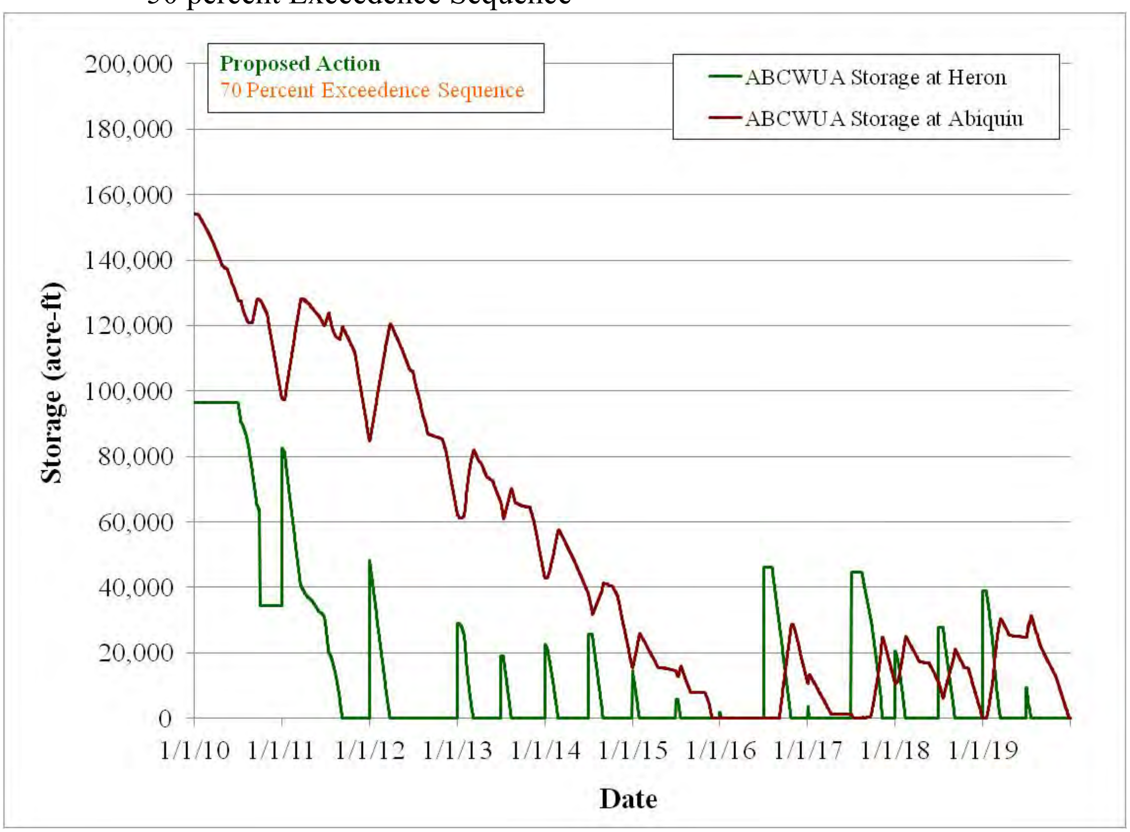

Figure 4.23. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 70 percent Exceedence Sequence

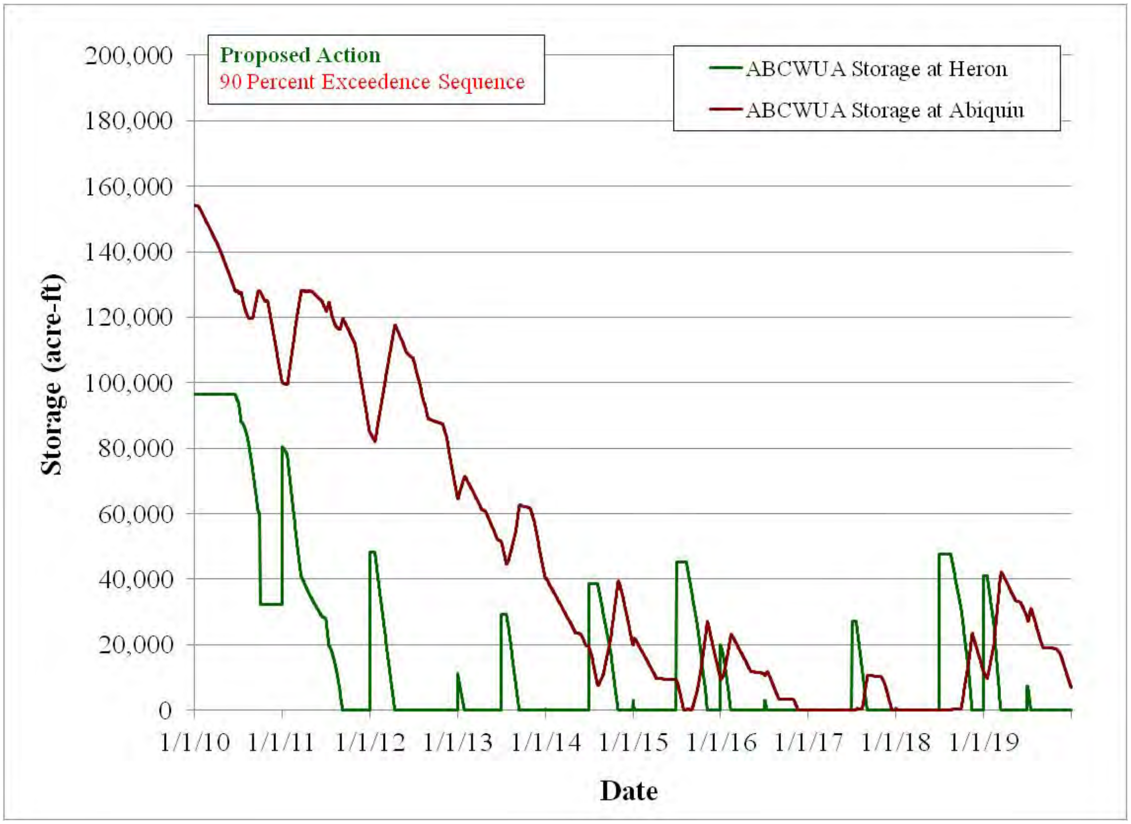

Figure 4.24. ABCWUA's Supply of San Juan-Chama Water at Heron and El Vado Reservoirs – 90 percent Exceedence Sequence

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.

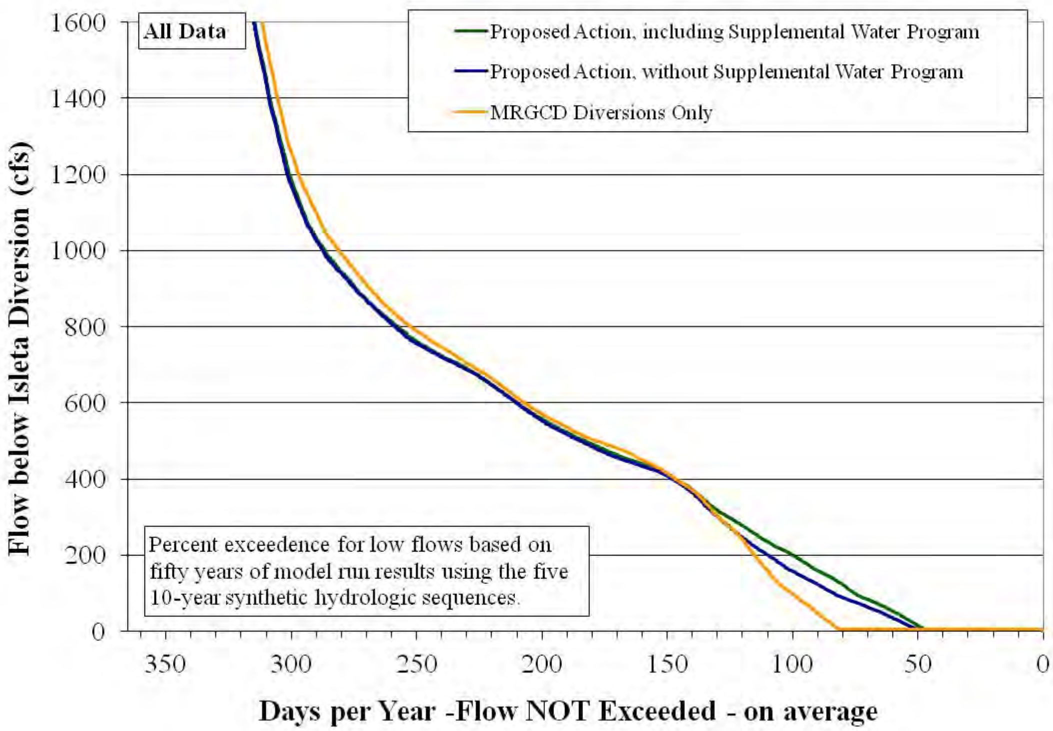

Figure 4.25. Flow Exceedence Curves Depicting the Impact of Reclamation's Actions (Heron Dam Operations for San Juan-Chama Project and El Vado Dam Operations) and the Supplemental Water Program on Flows at below the Isleta Diversion Dam

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.

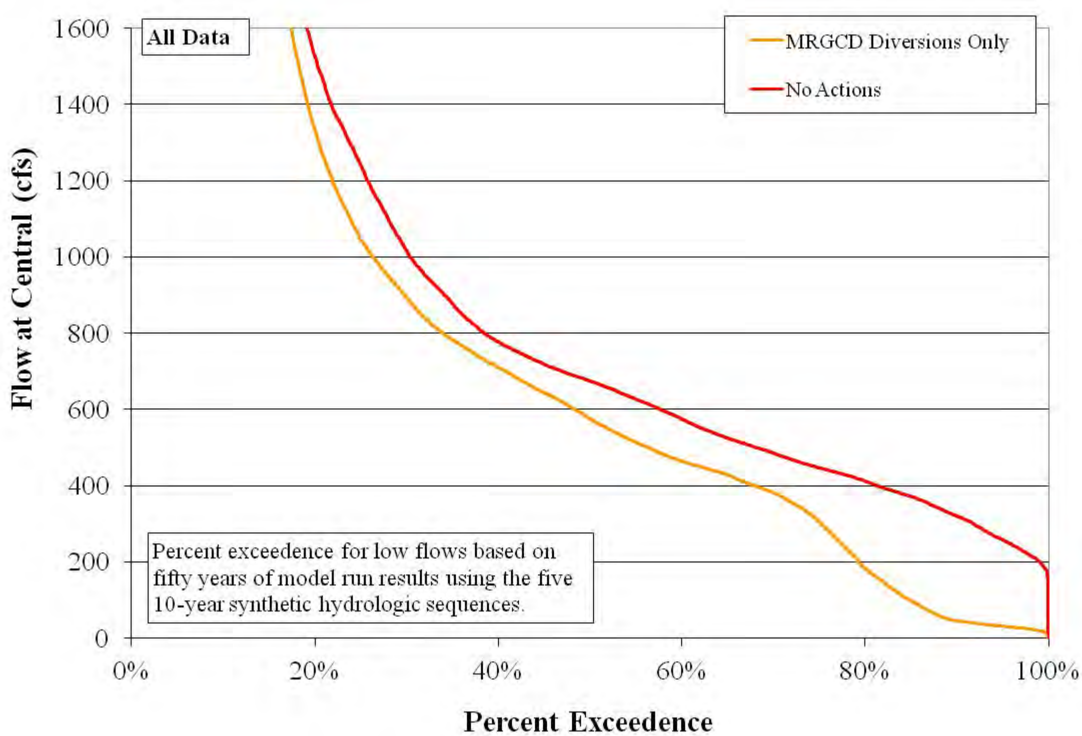

Figure 4.26. Flow Exceedence Curves Depicting Impacts of MRGCD Diversions on Flows at Central

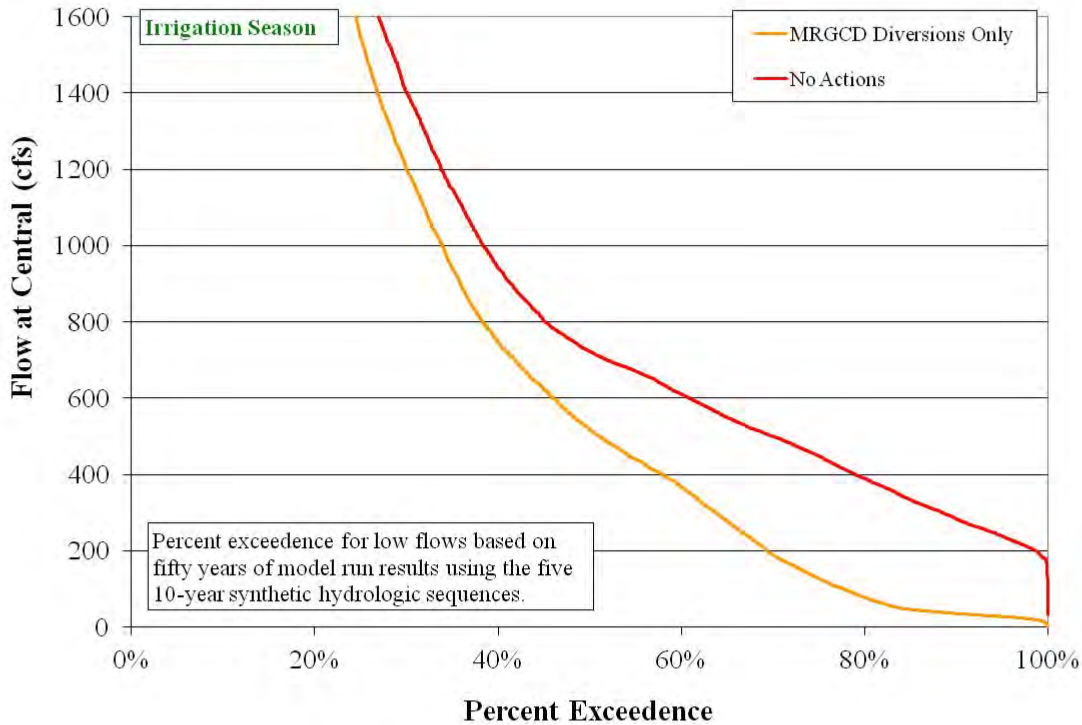

Figure 4.27. Flow Exceedence Curves Depicting Impacts of MRGCD Diversions on Flows at Central – Irrigation Season

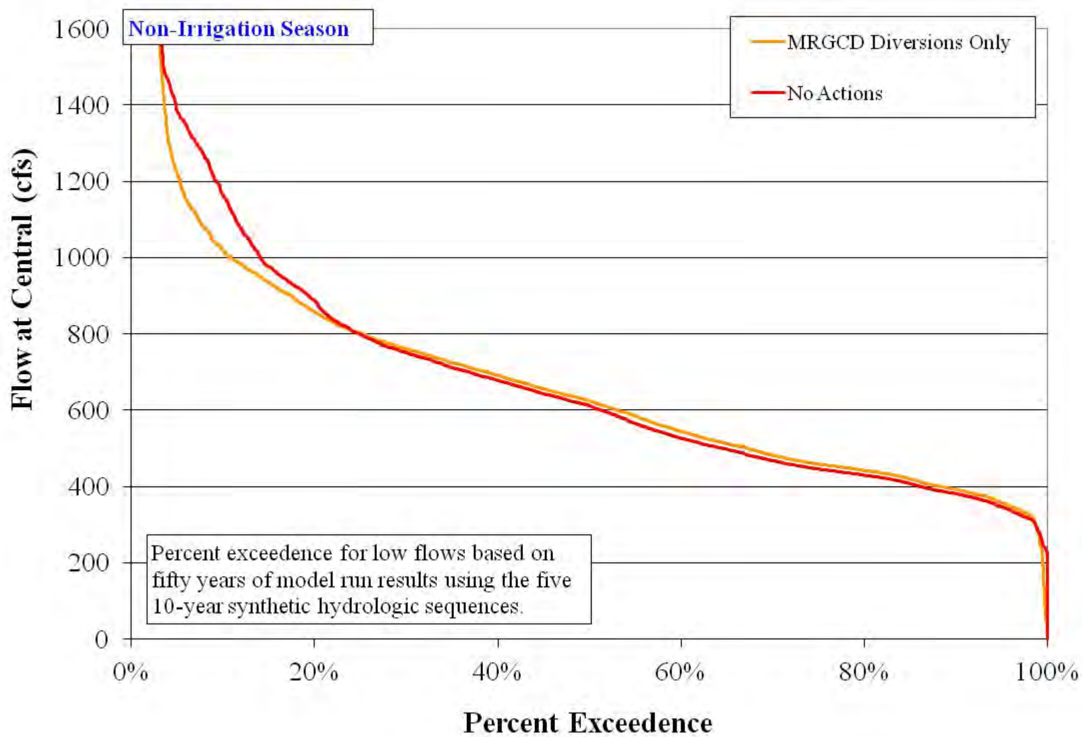

Figure 4.28. Flow Exceedence Curves Depicting Impacts of MRGCD Diversions on Flows at Central – Non-Irrigation Season

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

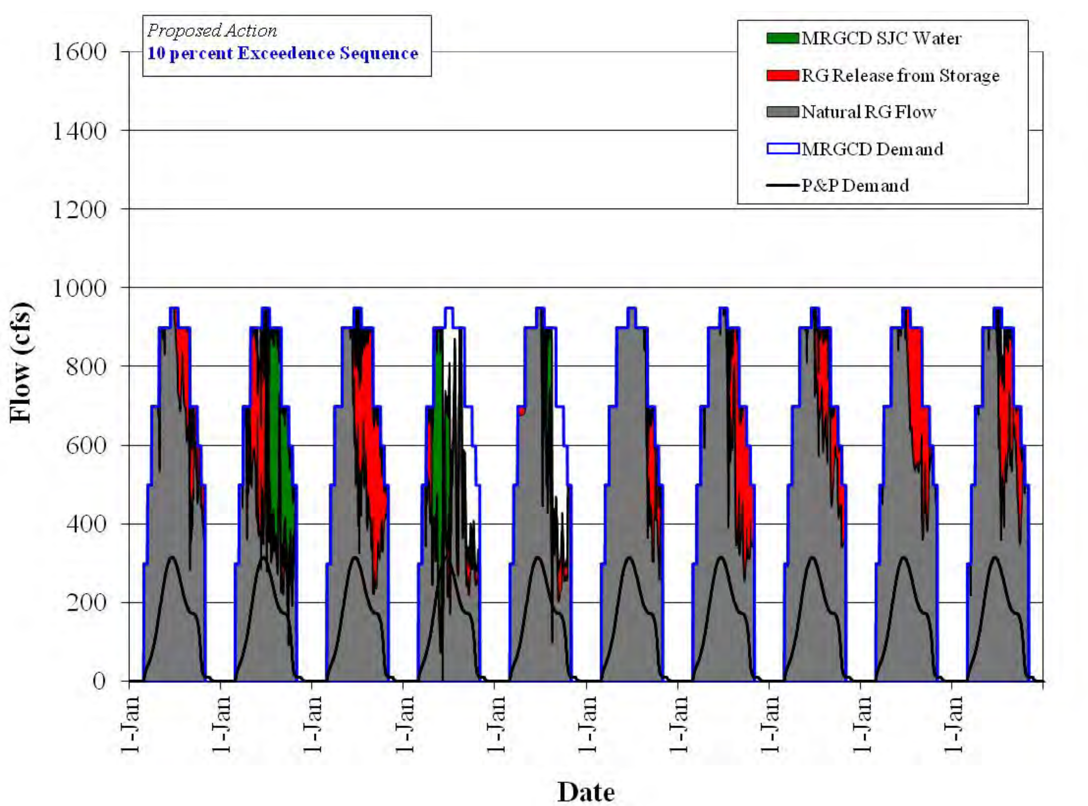

Figure 4.29. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 10 percent Exceedence Hydrologic Sequence

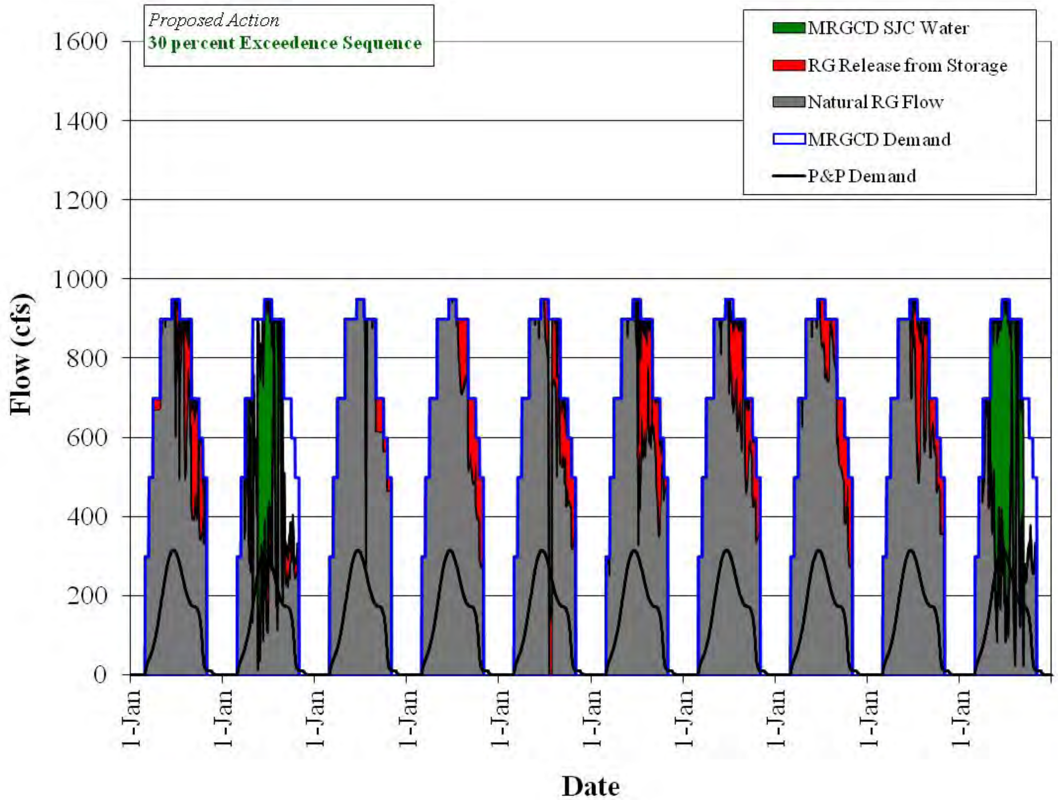

Figure 4.30. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 30 percent Exceedence Hydrologic Sequence

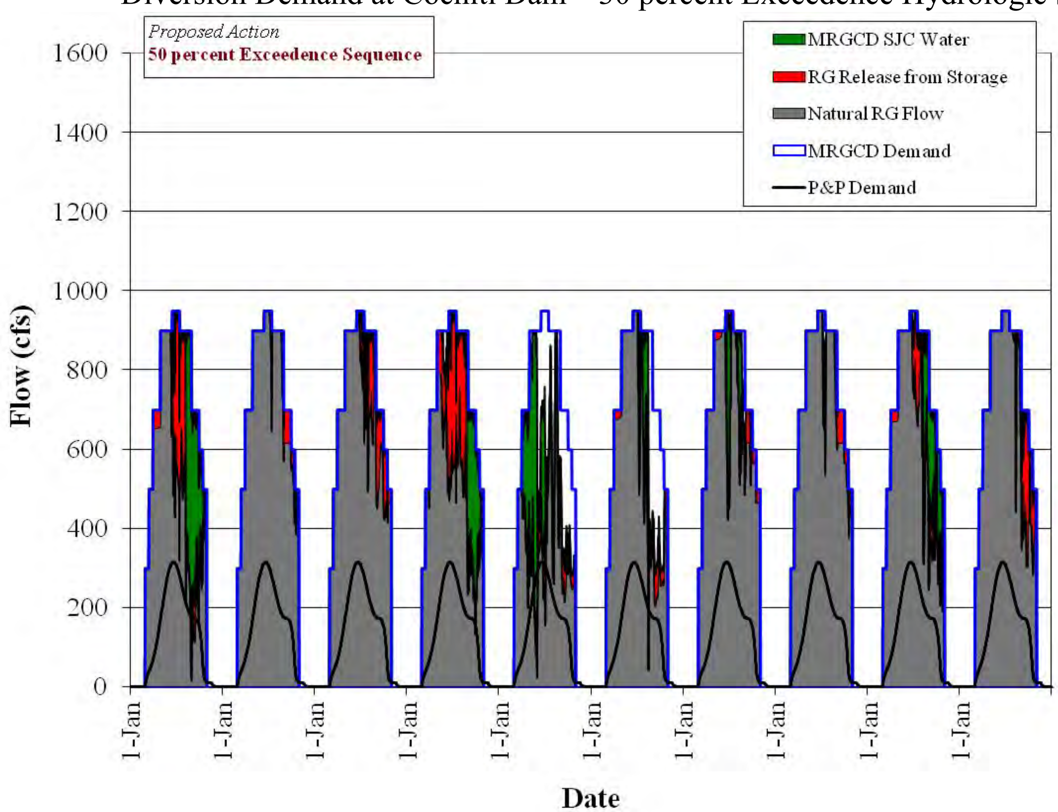

Figure 4.31. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 50 percent Exceedence Hydrologic Sequence

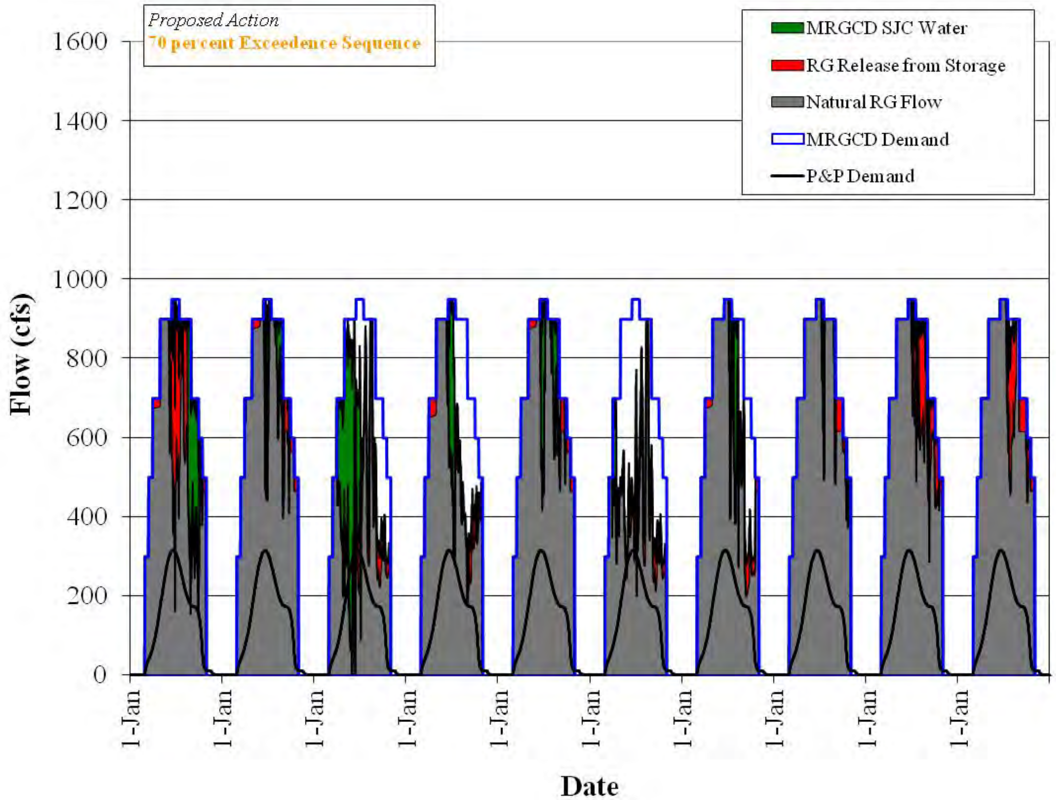

Figure 4.32. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 70 percent Exceedence Hydrologic Sequence

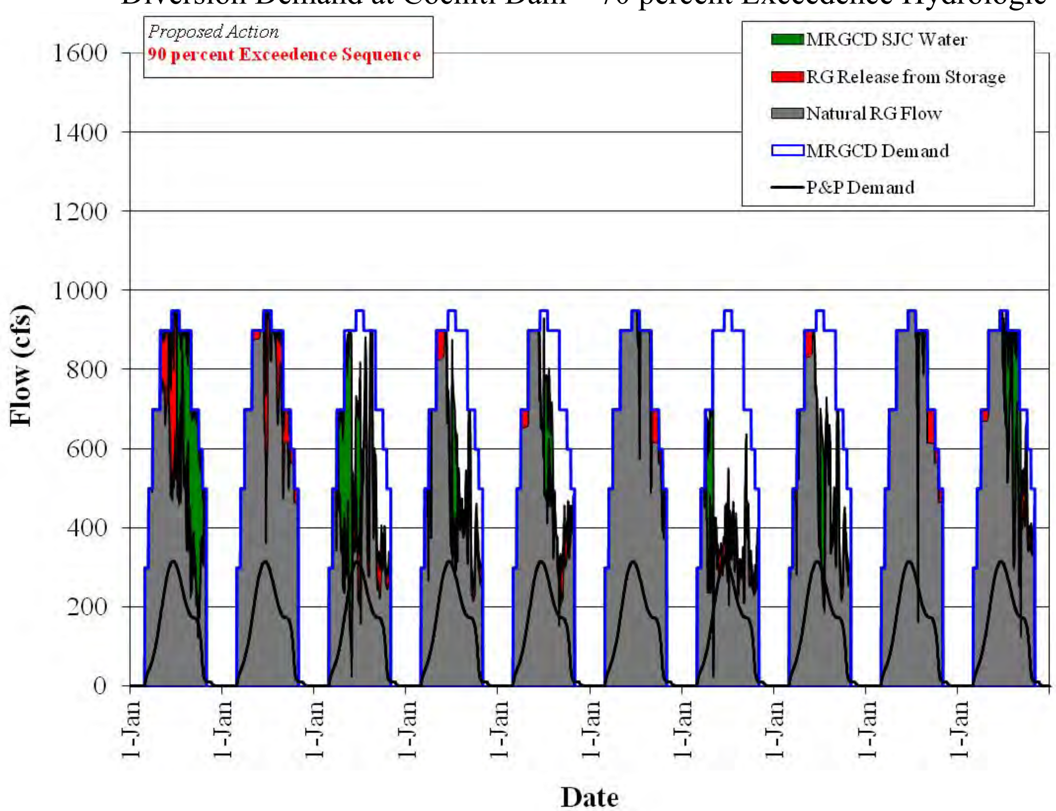

Figure 4.33. Breakdown in Contributions to Meeting the Full Middle Rio Grande Project Diversion Demand at Cochiti Dam – 90 percent Exceedence Hydrologic Sequence

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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APPENDIX 8

MRGCD PROPOSED CONSERVATION MEASURES – APPROVED BY THE MRGCD BOARD OF DIRECTORS ON JULY 24, 2012

Middle Rio Grande Conservancy District

Memorandum

To: MIKE HAMMAN, AREA MANAGER – US BUREAU OF RECLAMATION

From: SUBHAS K. SHAH, CE/CEO

Date: JULY 24, 2012

Re: **PROPOSED BA CONSERVATIONS MEASURES**

Attached are the proposed Conservation Measures to the Biological Assessment that were approved by the Middle Rio Grande Conservancy District Board of Directors at their regular meeting on July 23, 2012.

Please contact me if you have additional questions.

SKS/eb

Attachment

Proposed MRGCD Conservation Measures

Preamble

1. Pursuant to its statutory general grant of powers (NMSA 1978, § 73-14-48), MRGCD has authority to enter into an endangered species Recovery Implementation Program (RIP) and to undertake certain species survival and recovery actions to be incorporated within the MRGRIP Action Plan. However, MRGCD has no authority to violate its statutory obligations and MRGCD is specifically prohibited from relinquishing control of the waters or lands of the District or from administering or managing District waters in such a way as to impair the private water rights of individual irrigators or its own statutory water rights (NMSA 1978, § 73-14-47).[1]

2. MRGCD has the authority to develop an Operating Plan to carry out some of the programs within the RIP that will benefit listed species (NMSA 1978, §§ 73-14-48 *et seq.*), but MRGCD has no authority to relinquish its authority to implement the terms of such an Operating Plan to any third party, particularly when such implementation may involve control of the use of the District waters or lands (NMSA 1978, § 73-14-47).

3. MRGCD has the authority to lease or otherwise provide reservoir storage space for a "supplemental water pool" and to assist in developing programs for use of that storage to provide protection for the RGSM consistent with the RIP, and as a contribution to cost-share, but it cannot do so in a way that reduces storage for persons entitled to receive water from the MRGCD (NMSA 1978, § 73-14-47).

Consistent with the above limitations, the MRGCD proposes the following actions for conservation of the species:

A. The MRGCD recognizes the need for ESA compliance and the need to continue to cooperate with Reclamation in future compliance efforts, which include the conjunctive management of water for species needs, municipal withdrawals, RGC obligations, and irrigation needs. The MRGCD will develop annually an Operating Plan. This Plan will coordinate the delivery of irrigation water to water rights holders and water users within the MRGCD. The Plan will also assist in meeting the needs of the listed species for population survival and recovery, including spawning, recruitment and survival habitat needs as determined by using the best available scientific information. The development and implementation of this MRGCD

[1] *See Gutierrez v. MRGCD*, 34 N.M. 346, 282 P. 1 (1929) (citing the full protection of private water rights afforded by Section 316 of the Conservancy Act).

Operating Plan will be incorporated into the Middle Rio Grande Recovery Implementation Program (MRGRIP) Action Plan as part of the conservation actions and/or tasks which are expected to permit the MRGRIP to attain and maintain compliance with the ESA.

B. The MRGCD will cooperate with state and federal agencies in creation and operation of a "supplemental water pool" consisting of up to 30,000 AF to be stored in available space in Abiquiu reservoir. Water stored for ESA purposes may, subject to ISC approval, be stored under the authority of the Strategic Water Reserve. Water stored separately by MRGCD for irrigation purposes will be managed by the MRGCD under its authority contained in the Conservancy Act. The conjunctive management of MRGCD water will provide some environmental and biological benefits to RGSM. The creation of the SWR was authorized by the NM Legislature in 2005, for the purposes of providing a water reserve to help New Mexicans manage through drought periods. In addition to meeting the needs of water users and NM's delivery obligations under the RGC, a goal of the pool will be to assist in providing flows needed for ESA purposes, and in so doing, to protect the rights of existing water users. Storage space at Abiquiu Reservoir for the pool was set aside by the ABCWUA as a result of a settlement between ABCWUA and Environmental groups when the ABCWUA was seeking to permit and construct its SJC Diversion works.

Water supply for the pool may come from a variety of sources including uncontracted SJC water and purchases of SJC water by the Federal Government from willing sellers. The use of surplus SJC water would be a primary choice for development of water supply, along with RG water stored as a result of NM having relinquished credit water in Elephant Butte reservoir to Texas under the Rio Grande Compact. Use of this water would be subject to the limitations of New Mexico water law. MRGCD is largest and most likely recipient of credit water stored as a result of relinquishment and in the absence of ESA requirements would logically be the recipient of most of this water. Relinquishment credit water (more correctly stated as the right to store water against relinquished NM RGC credits) is made available by the New Mexico Rio Grande Compact Commissioner. MRGCD will urge that a percentage of water resulting from credit relinquishments to the pool be allocated for ESA purposes. MRGCD will cooperate with appropriate entities to maximize NM credit status under the RGC, and increase the opportunities for future credit relinquishment to benefit both the ESA needs and MRGCD water supply. Concurrently, MRGCD will expand its opportunity for storage to manage through drought by completion of agreements with ABCWUA to store up to 50,000 AF of water at Abiquiu Reservoir. Space at Abiquiu reservoir for this purpose was pledged by ABCWUA as a result of MRGCD withdrawing its objections to permitting and construction of the ABCWUA SJC diversion works. While MRGCD has authority over water it holds in storage, MRGCD will cooperate and coordinate with NMISC, ABCWUA, BOR and other appropriate entities to conjunctively manage releases from storage and releases from the pool to maximize flexibility in Rio Chama water operations for the benefit of environmental/recreational concerns, and to minimize evaporative or conveyance losses.

C. Depending on the available water supply and consistent with its primary statutory mission of conveying and delivering water for its use in agriculture, when MRGCD has water surplus to the needs of its irrigators within its canal system, the MRGCD will manage its diversions and outfalls to return excess flows to the Rio Grande for habitat areas and other designated sites, as determined by, and consistent with tasks identified within the MRGRIP Action Plan. The MRGCD will participate with other MRGRIP entities, in particular with the U.S. Fish and Wildlife Service, the MRGRIP Science Coordinator and scientific workgroups, and the MRGRIP management and Executive Committee, to identify and study key habitat areas to which water can be returned, especially during critically dry periods, to serve species population needs for survival and recovery, as determined by the best available scientific information, by maintaining wetted habitat for silvery minnow when drying is occurring elsewhere in the river. This commitment will not compel the District to deliver water to habitat or other sites when it is needed to serve irrigators' requirements.

When the MRGCD determines that water surplus to irrigation needs is not available within the MRGCD system, and flow to designated habitat or other areas for species needs is desired, MRGCD will convey water to these areas from available species water resources. MRGCD's contribution will be to bear the conveyance loss from point of release at a reservoir to point of delivery at habitat area, if MRGCD is delivering water along these same pathways for irrigation purposes. An exception may occur if delivery of water to a designated habitat area requires the use of a canal or other water pathway which is not normally or currently in use, in which case species water would be required to incur actual conveyance losses.

D. The MRGCD will cooperate and assist with the creation and enhancement of specific habitat areas, the so-called "String of Pearls" to provide a series of refuge areas where RGSM populations may be maintained during normal periods of low and intermittent flow in the MRG. These areas tend to be located near MRGCD outfalls which typically discharge excess water, or which can be readily used to convey species water with minimal losses. These areas are located in the Albuquerque, Isleta, and San Acacia reaches of the Rio Grande. The MRGCD will maintain its outfalls and, consistent with existing agreements, the federal agencies will provide maintenance and enhancement of river areas through channel shaping, bank modification, vegetation management, food management, and biological management (non-native or predator removal) to provide conditions suitable to preserving maximum numbers of RGSM in good health for extended periods of time. The "String of Pearls" will provide RGSM refugial habitat between Cochiti reservoir and Bosque del Apache. The locations of the pearls are illustrated in the following map:

E. To allow more precise control and management of water supply to San Acacia dam, MRGCD will pursue construction of a siphon near Bernardo, NM to deliver excess irrigation returns from the San Juan Riverside Drain system directly to the Unit 7/Socorro Main Canal system. This is envisioned to allow for more reliable water supply to the MRGCD Socorro division while simultaneously reducing the total annual volume of water required for diversion at San Acacia dam. This would be anticipated in turn to benefit peak flows through San Acacia dam, and sediment movement and river morphology upstream and downstream of San Acacia dam with associated benefits for RGSM. During times of low or no flow, the Bernardo siphon could be envisioned to assist with management of the "String of Pearls" by creating a refugial area downstream of the siphon itself, and creating a more dependable water supply at San Acacia dam for the maintenance of a refugial area downstream of the dam. It is anticipated that costs of this project operations will be borne in part by the MRGCD, and in part by the federal government. Once the anticipated water supply benefits of the Bernardo Siphon Project have been realized, distribution of water supplies resulting from the Project could be directed by the District to meet the needs of water users in the MRGCD Socorro division in conjunction with those of the listed species.

F. To provide a water supply for the last pearl on the string, MRGCD will construct a return flow collection system at its southern boundary. Excess water from the San Antonio Acequia, the Socorro Main South Canal, the Socorro Riverside Drain, and the Elemendorf Drain will be routed to a central collection/distribution point. At the distribution point, water will be directed into the Low Flow Conveyance Channel and will be lifted back to the Rio Grande through a permanent electrically powered pumping station to be constructed by the MRGCD and operated and maintained by the BOR. It is anticipated that costs of these operations will be supported as cost-share by the MRGCD, and also by the federal agencies and the MRGRIP. Distribution of water at this point will be to meet the needs of the listed species, the water rights of the Bosque del Apache National Wildlife Refuge, and RGC delivery obligations.

G. Recession Management

During inevitable low and intermittent flow periods on the RG, RGSM mortality may be greatly reduced by controlled rates of recession, allowing individuals to move to suitable habitat locations (the String of Pearls). Controlling this rate of recession can be challenging, and has in the past resulted in usage of large amounts of species water. This may be at the conclusion of the spring snowmelt period, or after periods of heavy precipitation. To the extent permitted by the Rio Grande Compact, a controlled rate of recession may be produced by USACE reducing releases from Cochiti reservoir in a series of small steps. As a part of the conservation measures to the MRGRIP, the MRGCD will establish a policy where during times of floodwater storage and managed recession for RGSM, MRGCD available natural flow will be determined by the theoretical release from Cochiti reservoir in the absence of any such managed recession. In this way, USACE may have greater flexibility in controlling the rate of recession for RGSM without affecting NM's RGC deliveries to Elephant Butte. This mechanism would require an update to the Water Control Manual for Cochiti reservoir.

H. The MRGCD will actively participate in the creation of habitat to benefit the lifecycle of the RGSM. Habitat creation will be the responsibility of an interagency team consisting of MRGCD, the NMISC, BOR, USFWS, and USACE. The MRGCD will provide assistance in obtaining funding (cost share, etc.) and/or land for habitat restoration. Habitat restoration may be focused on enhancing the interconnection between active river channel and floodplain, as well as other types of restoration. Habitat restoration will be engineered to provide progressively greater levels of inundation at increasing flows, resulting in a range of habitat types. An initial goal over a XX year period will be 75 acres of RGSM habitat across the range of discharges.

I. To the degree permitted by New Mexico water law, the MRGCD will cooperate with efforts to establish a program whereby groundwater users within the MRGCD may offer water for lease to BOR or other groups for the express purpose of providing flows from wells for endangered species. Water provided to this program will be from willing lessees with pre-1907 or pre-basin groundwater pumping rights for agricultural use. Transfers of use of irrigation wells to instream uses will need to go through the OSE application and permitting process. Administration of this program must necessarily involve close coordination with the NMOSE and MRGCD to establish appropriate volumes of water and rates of flow, and to insure and verify that land from which pre-1907 water rights have been transferred for species use do not continue to be irrigated (absent an MRGCD water bank withdrawal).

J. While the development of new modeling and analysis continues to assist in addressing species management uncertainties, the MRGCD will continue to fund the current PVA and statistical data analysis efforts through a research agreement as a contribution to the scientific understanding of the RGSM.

APPENDIX 9

MRGCD ALTERNATIVE HYDROLOGY ANALYSIS

Comparison of No Action (Baseline) Water Management Conditions in the Middle Rio Grande with the Proposed Action Condition Using ET Toolbox as Inputs for MRG Consumptive Uses.

1.0 Introduction:

The URGWOM model does a remarkably good job of simulating realistic water management scenarios through the Rio Grande/Rio Chama system to Cochiti Reservoir based on past gauge data, expected runoff volumes, and reservoir operating rules. However, the outputs from the URGWOM model become appreciably less certain once water passes below Cochiti Dam. This is due to a highly complex interaction of consumptive uses and groundwater exchange into and out of the river. In recent years, significant effort has gone into calibrating the URGWOM model to better reflect MRG conditions, and it is improved. Still, calibration has only been possible against observed conditions, and considerable unknowns remain. The model has been adjusted in the MRG to produce outputs that mesh with observed conditions, but some of the underlying mechanisms that produce those conditions are not understood well enough to actually be modeled. The use of URGWOM to model MRG flows entering the MRG is appropriate, but URGWOM inadequate when estimating the effects of those flows at points of interest within the MRG for Reclamation's BA.

Language in the ESA and BA guidance documents requires the analysis of the effects of a proposed action, compared to the baseline condition, which indicate conditions without the proposed action. The authors of this language must have logically assumed any proposed action would be a new occurrence, changing conditions from what they had previously been. In this case, the No-Action condition would likely be obvious, and the more difficult part of the equation would be what effects the Proposed Action might have. However, in the case of the RGSM and the MRG the Proposed Action is to continue current actions, and the unknown quantity is the No-Action condition. This seeming contradiction is becoming more common as the use of the ESA expands over the years. This BA is particularly unusual in that the "proposed action" is the continuance of activities that have been occurring to varying degrees for centuries. Thus, there is no way to calibrate the URGWOM model for the No-Action condition, since it has never been observed in historic times. A different approach is called for.

The No-action scenario to be modeled must be capable of showing the effects of the operation of existing reservoirs, and any actions that are not part of the Proposed Action condition. The No-Action condition must also demonstrate the range of flows expected through the MRG in the absence of the proposed actions, which below Cochiti reservoir is primarily the operation of MRGCD diversions for water delivery to agricultural consumers. Initial attempts using the URGWOM model were made by removing the MRGCD Demand or MRGCD Diversion from the consumptive use below Cochiti. However, these factors include consumptive uses which would continue under the No-Action scenario. The "MRGCD Demand" includes riparian consumptive use, evaporation from the river itself, and seepage to aquifer recharge, all of which would logically be expected to continue in the absence of irrigation water diversion. Similarly, "MRGCD Diversion includes a component that is not consumptively used by agriculture, but instead returns to the river or drain system, where it may be consumptively used by riparian vegetation, evaporate, become groundwater recharge, or appear again as surface flow in the RG.

A refinement to the modeled scenarios can be derived utilizing the ET Toolbox model (ETT). The ETT produces daily consumptive use values for agricultural, riparian, and open water consumptive use based on weather conditions and acreage extents. This allows for the effects of agricultural consumptive use related to the operation of MRGCD diversion dams to be removed for the No Action condition, and restored for the Proposed Action condition. Or, perhaps stated properly, the use of ETT allows the effects of open-water evaporation and riparian consumption to remain as consumptive demands upon the river under all conditions. As with any model, there are limitations to ET Toolbox. ETT does not contain a component for groundwater recharge, and this must be compensated for in another way. Prior to 2011, ET Toolbox riparian and agricultural values were based on a version of the Penman-Montieth equation (PM) that had been modified by agricultural researchers at New Mexico State University (NMSU). The NMSU PM method tended to overestimate MRG ET by about 30% ("Comparisons of ET Toolbox Reference ET with Other Methods Using Weather Data for the Period January 1 through December 30, 20110, BOR, Al Brower letter of March 20, 2012). For 2011, ETT adopted the more conservative FAO-56 PM method (Crop Evapotranspiration –Guidelines for Computing Crop Water Requirements, United Nations Food and Agriculture Organization, FAO-Irrigation and Drainage Paper 56, Richard Allen, 1998).

2.0 The Flow Model

To simulate MRG flows, a spreadsheet model was constructed (using MS EXCEL). The construction of this Flow Model (FM) is possible due to the geographic and hydrologic characteristics of the MRG. It has been said that the MRG is where the Rio Grande spreads itself out to dry. Most flow inputs to the Rio Grande occur upstream of the MRG. Most flow in the RG originates from winter snows, resulting in a pronounced and often dramatic increase in flow during the spring runoff period, and much lower flow the remainder of the year as baseflow from groundwater (also snow origin) drains from the high mountains. Within the MRG, hydrology is heavily dominated by depletion. As the RG enters the MRG area, its valley widens and its slope lessens. Tributary contributions within the MRG are limited to the Rio Jemez, and a number of arroyos that normally flow only during and immediately after precipitation events. Climatic conditions become more harsh and open-water evaporation increases. The broad valley supports an extensive riparian forest, which consumes a sizable percentage of the total flow. Riverside drains collect water from the river and from surrounding agricultural lands, and that water is either returned to the river at drain outfalls or used for agricultural irrigation. Groundwater pumping causes de-watering of both shallow and deep aquifers, which in turn draws additional water from the river corridor. And of course water is diverted from the RG, and delivered onto agricultural lands where it is consumed by agricultural use.

Within the MRG, the river system is neatly oriented north-south. It can be broken into "reaches" by creating east-west boundary lines. For URGWOM and ETT purposes, the MRG is separated into 8 distinct reaches. Not coincidentally, these reaches correspond with points of interest for water managers and for describing flow characteristics for the BA. Reaches are related to these flow points of interest as:

Reach 1-3: Cochiti reservoir outflow to Central Avenue gauge (Albuquerque)

Reach 4: Central Avenue Gauge to Isleta Diversion dam

Reach 5-6: Isleta Diversion dam to San Acacia Diversion dam

Reach 7: San Acacia Diversion dam to San Marcial Gauge

Reach 8: San Marcial Gauge to Elephant Butte Reservoir

All of these reaches experience consumptive use of water for agricultural and riparian evapotranspiration and open water evaporation, with the exception of reach 8. Reach 8 includes effectively no agricultural use, but does have extensive riparian consumption. Reach 8 also includes a large amount of open water evaporation, highly variable due to the changing pool elevation of EB reservoir. For these reasons, and since the downstream end of Reach 8 is not a flow point of interest for this BA, the FM does not include reach 8.

The underlying and simple premise of the FM is that a certain flow enters each reach, and the amount leaving that reach is determined by subtracting the known depletions in that reach from the inflow. The outflow from that reach then becomes the inflow for the next reach. There are complicating factors, primarily the interaction of water into and out of the drainage system. As noted above, some reaches are aggregated for consideration, which eases the difficulty in accounting for these complicating factors.

2.1 Model Inputs

The FM depends on an input of the flow expected to enter the MRG from the outlet works of Cochiti reservoir. This input value is derived from the previous URGWOM modeling for various conditions. The FM then uses ETT-derived depletion estimates for agricultural, riparian, and open water depletions; and an estimation of the impact of municipal groundwater pumping in the Albuquerque area (reaches 3 and 4) to estimate flows arriving at four key points in the MRG; Central Avenue gauge in Albuquerque, below Isleta Dam, San Acacia Gauge, and San Marcial Gauge. The FM is prepared to accept 10-year sequences of flows (runs). Flows at these points are evaluated in terms of number of years of successful spawn/recruitment condition during each run (Central Avenue only), days of major drying over the course of the run, days of intermittency over the course of the run, number of years during the run in which major drying occurs, and number of years during the run in which some intermittency occurs.

The FM is constructed so that the user can readily specify (or modify) values to test for spawn/recruitment conditions, major drying, or intermittency. For the runs described by this document, the following conditions were specified:

	Spawn Flow/Duration	Major Drying	Intermittency
Central Avenue	3000 cfs/7 days	10 cfs	100 cfs
Below Isleta Dam		30 cfs	100 cfs
San Acacia Gauge		10 cfs	200 cfs
San Marcial Gauge		10 cfs	50 cfs

The FM also includes a user-adjustable factor that allows the extent of agricultural consumption to be specified. This allows for full agricultural consumptive use to occur in the FM under the Proposed Action, where it should be set to 1. However, for No-Action runs, agricultural consumption may still occur in some areas even when no diversion for that purpose is occurring, due to groundwater accretion in MRGCD drains. Reaches 1-3 contain no lands which can practically be served from these drains. A considerable portion of agricultural lands in Reach 4 can be served from drains. While a lesser percentage can be served in Reach 5-6, the very large agricultural acreage in Reach 5-6 makes this an important component. In Reach 7, about a third of agricultural lands are expected to be served from drains, primarily MRGCD lands south of Socorro and on the BDA National Wildlife Refuge. The following factors are used for the No-Action conditions described here.

Reach 1-3: 0

Reach 4: 0.5

Reach 5-6: 0.25

Reach 7: 0.33

Should one wish to evaluate conditions if no agricultural consumption were to occur, and groundwater accretion to drains were routed back to the RG, these values should all be set to zero.

2.1.1. ET DATA for Depletion Input

Ag/Riparian Evapotranspiration and Open Water Evaporation should be reasonably constant year to year, though will vary substantially over the course of a year. It is practical and reasonable to establish evapotranspiration/open-water consumption curves (for our purposes, a series of steps, roughly describing a curve); similar to what was previously used in the URGWOM model for MRGCD Demand and MRGCD Diversion. This is considerably less subjective than previous efforts, since reliable estimations of evapotranspiration and open-water evaporation may be produced from mathematical evaluation of known plant/water functional relationships with climate.

ETT values used as inputs in the FM are determined through a separate set of spreadsheets:

AG_ET_Corrected_2Week.xls

RIP_ET_Corrected_2Week.xls

OW_EVAP_Corrected_2Week.xls

Each of these worksheets contains 5 years (2007-2011) of daily values from ETT. An Average value for each day is produced from the five years. Then, the average values are used to determine the average for every 2-week period beginning Jan 1. Two small exceptions occur; the last period of the year includes 15 days, and where leap years occurs (2012, 2016) Feb 29 is given the same value as Feb 28. The use of the 2-week average was found to be necessary to produce a logical and evenly distributed "curve" for ET throughout the year, damping out the effects of daily weather disturbances from seasonal climate. The five years chosen represent a fairly limited sample, and a longer record would clearly be desirable. However, ETT underwent significant changes from its inception in 2000 through 2005, and 2006 was an exceptional year due to record rains in the critical July-September period. For these reasons only the last 5 full years of ETT data were used to construct the agricultural, riparian, and open water consumptive use inputs. ETT daily values for years 2007-2010 are multiplied by 0.70 in the worksheet to adjust them to the FAO-56 method used in 2011.

Along similar lines, MRGCD diversions were also processed through an excel spreadsheet:

2.1.2. Diversions_Corrected.xls

In this worksheet, daily recorded values for the past 4 or 5 full years were culled from MRGCD records. For Isleta Diversion, years 2007-2010 were used. Similar logic was applied as with ETT data, with 2002 and earlier data representing a different MRGCD operational policy, 2003 and 2004 being years of short supply, and 2006 being the exceptional year of high rainfall. 2011 data is not yet reviewed and available, so only the four years of 2007-2010 were used to get an average value for diversion at Isleta Dam on any day. For San Acacia diversion, 2011 data are available, so a full five-year set, 2007-2011, was used for this diversion point. At present, diversions for Cochiti and Angostura are not being considered in the FM, so data from these diversions are not yet included in the spreadsheet.

2.1.3. Leakage to Groundwater

A value for seepage to groundwater use is also necessary, particularly for estimating flows through the Albuquerque reach of the river. While there are lesser groundwater withdrawals throughout the MRG, an initial estimate of this is done only for the ABCWUA withdrawal/return. Evaluation by NMISC of the present rate of loss from the river to ABCWUA groundwater recharge is approximately 60,000 AF/year. While the rate will vary slightly throughout the year, this averages out to a steady loss from the river of about 80 cfs. This loss is spread throughout the Albuquerque area, and is complicated by the fact that ABCWUA makes a substantial contribution to river flow through its surface water treatment plant. At present, this rate of return is averages about 70 cfs (NMISC). For modeling purposes, ABCWUA replaces nearly as much water as leaks from the river due to groundwater pumping. However, the return occurs midway through reach 4, while loss happens throughout reaches 3 and 4. Flow at the lower end of Reach 3 is of concern for the BA, so this must be appropriately accounted for. Accordingly, a seepage loss of 40 cfs each is assigned to Reaches 3 and 4, with and an inflow of 70 cfs to Reach 4, in an effort to accurately reflect flow at the end of each reach.

Other groundwater consumptive use is occurring in the MRG. Most notable would be Rio Rancho/Bernalillo area, the Albuquerque South valley area with its myriad of private domestic wells, and the Los Ulnas/Belen area. These consumptive uses are clearly substantial, but are impossible to incorporate into the FM at this time. In the past, these consumptive uses have tended to be masked by agricultural operations, as agricultural deliveries supply a considerable portion of the recharge to offset consumption. More precise regulation and monitoring of agricultural supply in the future will probably lead to quantification of this water use, and eventually of its incorporation into models of this type. At present however, it should be noted by the users of the FM, that the model may tend to overestimate flow at critical measuring points due to this shortcoming. As with a number of other factors which cannot be fully defined in the FM, the overestimation should be consistent across all conditions, so values between conditions should remain comparable.

2.1.4. FM Relationships

As previously mentioned, the FM begins with an input value representing flow entering the MRG. This is supplied by the user from URGWOM model outputs for a particular condition to be modeled. The FM then depletes this flow by the aggregated depletions occurring in Reaches 1-3 for Riparian evapotranspiration (column C), open–water evaporation (column D), Agricultural consumption (column E) and ABCWUA groundwater pumping (column F). These inputs are derived from the INPUT sheet in the workbook. Ag depletion is subject to the user-entered depletion factor in column AA on the INPUT sheet, allowing agricultural depletions to be switched on/off, or adjusted for partial service from drain accretions. The end result is a rate of flow arriving at the outflow from reach 3, equivalent to the Central Avenue gauge. It is important to note that outflow from Reach 3 is not (in this version) partitioned between floodway and drain, and that particularly at lower flows, an appreciable percentage of total flow may be in the drain, rather than the floodway, with the model thus tending to underestimate river drying at Central avenue.

In Reach 4, the flow at Central Avenue is depleted by Riparian evapotranspiration (column H), open–water evaporation (column I), Agricultural consumption (column J) and ABCWUA groundwater pumping (column K). Then the MRG's largest tributary, the ABCWUA return flow, is added as an input to Reach 4 in column. L. This produces the flow arriving at Isleta dam (column M). Drain flow at this point is not substantial, as most drain flow is returned just above the dam, and only minor flows bypass the structure on the west side of the Rio Grande. To arrive at the flow in the Rio Grande just below Isleta dam, The MRGCD diversion at Isleta Dam (column. N) Is subtracted from available flow (column. M). A logical test is applied in column O, preventing diversion from exceeding available supply, and the resulting flow past Isleta dam is then displayed in Col. O.

Moving downstream, aggregated depletions in Reaches 5 and 6 are deducted from the available water at Isleta Dam (Col M) for Riparian (col P), Open water (col Q), Agricultural (Col R), to produce the total available water arriving at San Acacia Dam (col S). Note that the depletions are applied to total available flow at Isleta, and not the flow in the floodway below Isleta Dam. At San Acacia Dam, the split of the flow arriving via the Unit 7 is determined through logic in column. T, and then the flow below San Acacia Dam is determined by subtracting both the MRGCD diversion at San Acacia (column U) and the flow in the Unit 7 Drain. This has the practical effect of drawing the dividing line between Reach 6 and 7 just upstream of San Acacia Dam, but downstream of the point where Unit 7 drain can re-enter the floodway. The logic in column V results in the contents of the Unit 7 drain returning to the floodway if MRGCD diversions are zero, or remaining out of the floodway and in the drain if MRGCD is diverting. Accretion to Unit 7 Drain in reaches 5/6 is based on a percentage (7%) of flow in the floodway below Isleta dam, and 50% of the MRGCD Isleta diversion less agricultural depletions. The end result is realistic values for flows below San Acacia Dam (column V).

Reach 7 calculations in the FM involve subtracting depletions for Riparian evapotranspiration (column W), open–water evaporation (column X), and agricultural consumption (column Y) from the total available water at San Acacia (column S) to produce the total available water arriving at San Marcial (column AA). As at San Acacia, the flow at San Marcial is then partitioned into the component in the LFCC (column AB) by assuming 30% of flow at San Acacia (column S) winds up as groundwater accretion to the LFCC, or MRGCD return flow. The flow in the floodway at the San Marcial Gauge (column AC) is then determined by subtracting the component of flow in the LFCC (column AB) from the total arriving at San Marcial (column AA).

2.1.5. Output Analysis

The FM spreadsheet includes a sheet titled ANALYSIS. In this sheet, the values from the FLOW MODEL sheet are compared to user test conditions. The user adjustable conditions are set in the boxes across the top of the sheet, and this then produces number of days or years that particular condition is met in the model. For Central Avenue, user-adjustable test conditions are in column C, For Isleta, they are in column K, for San Acacia, they are in column S, and for San Marcial, they are in column AA. With a little consideration, the purpose and use of these test conditions should be readily apparent to the user.

2.1.6. Using the Flow Model

Any particular set of flow conditions should begin by opening the Flow_Model_10Year_Template file. This should then immediately be saved as a new file name identifying the flow scenario to be entered, preserving the unaltered template. The newly created file should then receive appropriate inputs. All inputs should be made in the INPUTS sheet. The primary input will be column B, into which the flow entering the MRG below Cochiti Dam should be cut/pasted from URGWOM output. Columns in the INPUT sheet for depletions (columns C through S) can be changed if necessary, but presumably will remain the same for the present. For Flow scenarios where MRGCD diversions are expected to operate, no additional changes are necessary. However, columns T through U contain average MRGCD diversions at the Isleta and San Acacia diversions, so if a flow scenario includes no diversion for MRGCD, the values in these two columns should be replaced with 0's (check carefully, as the top of the columns always show zeros anyway). Finally, there are four values at the top of the sheet in column D that represent the percent of agricultural depletions that are to be met. The template contains values believed appropriate for the No-Action (MRGCD not diverting) scenario. These are user adjustable, and for scenarios where MRGCD is expected to be in normal operation, these for values should all be set to "1" (100% ag depletions met).

Column Z in the INPUT sheet was included to simulate the effects of an additional water source in Reach 7. This was specifically included so that the effects of supplemental pumping could be considered. In the absence of pumping by Reclamation from the LFCC, this column should include all zeros, or appropriate values if pumping is to be included. At present, it is simply added to the available flow arriving at San Marcial. No provisions for additional sources of water are included in the FM, though this could readily be done in the future if desired.

After providing the correct Input values, the user should switch to the ANALYSIS sheet. There, one can view the number of days, and the number of years in which the defined conditions are met. The conditions can be changed if desired. In the template, values of 10 cfs are used as condition 1 to represent major or complete drying. Since, for a variety of reasons, the FM still probably overestimates flow, 10 cfs was selected as the “dry” threshold value, though a larger number may well be appropriate. Condition 2 is used to represent some drying, or scattered intermittency, and is considerably more subjective that Condition. 1. Probably every user will have some slightly different idea of what this number should be. The template contains the values above which this author believed continuous flow was likely.

To evaluate the presence or absence of conditions believed likely to produce successful spawning, a logical test is provided for flow and duration between April 15 and June 15 of each year. The values used can be set in the same box as the flow conditions for Central Avenue. Initial values used were 3000 cfs, for a minimum of 7 days, based on conversations with Gary Dean at BOR and Mickey Porter at the Corps. However the user is free to substitute any conditions he deems appropriate for a successful spawn. The logic in column N starts a counter whenever the minimum flow is reached, which continues to increment every day the flow occurs. It resets to zero if the flow is not reached on a day, and a fresh count starts. Logic in column O evaluates whether the count has reached the value specified for minimum duration, and if so writes a “1”. Logic in column P tests to see if the value in column O is greater than zero in any year, indicating that successful spawn conditions were met that year.

2.1.6 Considerations to be aware of

At present, flow at Central Avenue is not being partitioned between drain flow and floodway. This may be producing less than the actual number of days/years drying at this point, particularly in the No-Action condition where all drain accretion would likely be routed to supply agricultural need in the South Valley area, rather than being returned to the floodway. A future iteration of the FM will attempt to correct this.

Until Cochiti and Angostura Diversions are incorporated in the model, the FM will tend to overestimate drying, since it is subtracting the full agricultural depletion for each reach, even though the diversion may not be present to meet that supply. This is apparent in the proposed action runs in some years in which the MRGCD has no supplemental storage. If URGWOM can supply information on whether MRGCD is fully supplied or not, some logic can likely be placed in the FM to proportion agricultural depletion to available supply.

The FM is does not incorporate potential rainfall inputs in the MRG. Theses tend to be unpredictable, and no reasonable methodology appeared to allow their inclusion. However, MRG rainfall inputs generally occur in the form of thunderstorms in the July-August period. These flows can and do contribute appreciable volume of water to the river system, however the duration is usually very brief. So while rainfall events might tend to reduce the number of drying days in a given year, it would probably not be a large impact. Also, while the number of days might be reduced, the drying condition for a year likely would not change. In other words in a particular year, the drying might change from 100 days to 90 days, or 40 days to 30 days, but the drying condition would still have been met in the year.

The influence of summer precipitation events is not completely absent from the FM. The URGWOM model incorporates summer precipitation inputs. As a result the flow entering the MRG used as the primary input for the FM reflects precipitation events upstream of Cochiti Reservoir. Also, precipitation events within the MRG and incorporated in the URGWOM model help to determine NM compact deliveries, and by extension storage of water in and release of water from upstream reservoirs.

Along the same lines as the earlier mentioned unquantifiable groundwater depletions, rainfall events should affect all No Action and Proposed Actions the same way, so the relative difference between conditions should be comparable.

The FM does not account for time-lag between physical points. A flow at Cochiti translates instantly into a flow at San Marcial. Of course this is not reality, but for the purposes of the FM, and especially since other factors (agricultural consumption, riparian evapotranspiration, open-water evaporation, and MRGCD diversions) are entered into the model as averages over time, this is expected to give reasonable results. The FM could be easily time-lagged if desired, but it would introduce another layer of complexity to the spreadsheets, trying to keep up with which rows corresponded, and probably would not produce significantly better results.

Numbers in the model have not been rounded. Although the formatting is set to display only integer values, most numbers are floating point with many digits to the right of the decimal.

3.0 Outputs from Flow Condition Runs.

3.1 No-Action Condition

Several different conditions have been evaluated using the FM. The first, the No-Action (or “baseline”) condition consists of 5 runs (separate spreadsheets) , representing 10-year URGWOM flow sequences selected to reflect a 10%, 30%, 50%, 70%, and 90% probability of exceedance. For the No-Action condition, reservoirs are operated under existing rules for flood operations and compliance with the Rio Grande Compact, but do not store or release water for agricultural use by the MRGCD. The ABCWUA and Buckman Direct Diversion continue to divert surface water for municipal use, and release from storage. Consumptive uses upstream of the MRG and not included in this BA, including diversions in Colorado, at Velarde, PVID, on the Rio Chama, and by innumerable small Acequia systems in Rio Grande tributaries will continue. MRGCD diversion from the Rio Grande at the diversion dams does not occur. BOR would not operate reservoirs or the SJC project to supply water to agricultural users in the MRG. Some agricultural use in the MRG will continue through uncontrolled accretions to drains, and subsequent delivery through irrigation canals. Leakage to aquifer recharge, replacing decades of past pumping, as well as ongoing modern depletions will continue. Riparian consumptive use and open-water evaporation will continue. Processing the appropriate URGWOM outputs through the FM results in in the following No-Action (or “baseline) conditions:

Central Ave.	Less than 100 cfs	Less than 100 cfs	Spawn (years out of the 10-year sequence)
	Days	Years	3000cfs/7dys
90%	47	3	3
70%	34	4	6
50%	16	3	6
30%	23	4	6
10%	31	4	8
All (50 yrs)	151	18	27

Below Isleta Dam	Drying	Drying	Intermittency	Intermittency
	Days	Years	Days	Years
90%	64	3	261	8
70%	40	4	141	4
50%	16	3	71	3
30%	25	4	68	4
10%	39	5	127	6
All (50 yrs)	184	19	668	25

Below San Acacia Dam	Drying	Drying	Intermittency	Intermittency
	Days	Years	Days	Years
90%	447	6	831	10
70%	277	4	640	10
50%	186	5	597	9
30%	175	6	460	8
10%	276	7	668	9
All (50 yrs)	1361	28	3096	46

Below San Marcial	Drying	Drying	Intermittency	Intermittency
	Days	Years	Days	Years
90%	824	10	900	10
70%	723	10	787	10
50%	670	10	730	10
30%	547	8	618	9
10%	683	10	765	10
All (50 yrs)	3447	48	3800	49

From the above table, it is apparent that flows less than 100cfs, indicative of possible intermittency downstream from that point, occasionally occur in the No-Action condition. While this represents a relatively small number of total days, it occurs in all 5 flow sequences, and in a little more than a third of all possible years (18 out of 50). Of particular interest is that conditions thought to represent successful spawning conditions occur just over half the time, 27 out of a possible 50 years in the No Action condition.

Below Isleta Dam there are 19 years in which significant to complete drying could be expected. In half the total years, at least some degree of intermittency between Isleta and San Acacia dams would occur. In the other 25 years, there would presumably be enough flow entering the MRG to prevent drying in the Isleta Reach. Both drying and Intermittency occur in all of the 10 year sequences.

Below San Acacia dam complete or nearly complete drying occurs in over half of all years; and in about half the years in each 10-year sequence. Intermittency is even more dramatic, occurring in 46 out of 50 total years. Intermittency occurs an average of 62 days per year in the San Acacia reach over the 50-year time span. The two driest sequences have drying in all 10 years.

Below the San Marcial gauge, some amount of drying would be expected in virtually every year. In only one or two years in the 2nd wettest 10 year sequence is there enough water arriving at San Marcial to make it likely that the RG would stay connected all the way through to Elephant Butte reservoir.

3.2 Proposed Action Conditions

Under the proposed action, MRGCD diversions of water would occur as normal to meet agricultural demand. Reservoirs would be operated to store water during the spring runoff, for release later in the season to meet that agricultural demand. Other operations and consumptive uses would occur upstream of the MRG as described in the No-Action condition. BOR would operate reservoirs and the SJC Project to supply water for agricultural users in the MRG. No specific conservation measures, such as Supplemental Water, are included in this condition. Processing the appropriate URGWOM outputs through the FM results in in the following Proposed Action conditions:

Central Ave.	Less than 100 cfs	Less than 100 cfs	Spawn (YRS)
	Days	Years	3000cfs/7dys
90%	411	5	3
70%	258	4	6
50%	139	3	5
30%	95	3	6
10%	122	2	8
All (50 yrs)	1025	17	27

Below Isleta Dam	Drying	Drying	Intermittency	Intermittency
	Days	Years	Days	Years
90%	1187	10	1373	10

70%	1008	10	1208	10
50%	907	10	1127	10
30%	673	9	880	10
10%	779	9	985	9
All (50 yrs)	4554	49	5573	49

Blw San Acacia Dam	Drying	Drying	Intermittency	Intermittency
	Days	Years	Days	Years
90%	1097	10	1486	10
70%	944	10	1391	10
50%	818	10	1266	10
30%	656	9	1046	10
10%	705	9	1092	10
All (50 yrs)	4220	48	6281	50

Blw San Marcial	Drying	Drying	Intermittency	Intermittency
	Days	Years	Days	Years
90%	1224	10	1296	10
70%	1155	10	1228	10
50%	1030	10	1122	10
30%	853	10	914	9
10%	907	10	980	10
All (50 yrs)	5169	50	5540	49

Comparing the above tables, with those for the No-Action condition provides an indication of the effects of the proposed action. The Proposed-Action appears to have very little influence on number of years where successful spawning conditions are met. In both cases, the threshold condition (3000 cfs, 7 days) occurs in 27 of the total 50 years. The distribution changes slightly when considering the 10 year sequences separately, with some sequences gaining a year, and others losing a year. The effect on flows is significant, but slightly contradictory. The total number of days of potential intermittency (less than 100 cfs) increases under the proposed action, but at the same time the total number of years in which intermittency can occur decreases (17).

There is a dramatic increase in drying and intermittency at the Below Isleta Dam location. Since MRGCD diverts the largest portion of irrigation water at Isleta Dam, and a primary difference between the two conditions is the absence/presence of diversion dam operation, this is an expected result. Total number of days in which drying occurs (less than 30 cfs) rises from 178 days to 4554. Dividing the number of days by the number of years produces a value of 8days/year for the No-Action condition, compared with 93 days/year for the Proposed Action condition. However it may prove to be more critical to know the number of years in which drying can be expected, rather than the length of the drying events. The number of years drying could be expected increases in the Proposed Action condition from 21 years to 48 years out of 50. Again, this is an expected result, and consistent with past experience below Isleta dam, where drying has historically occurred virtually every year.

Similarly, there are increases in both number of days and years in which drying occurs at the at the San Acacia Gauge location. Since San Acacia would be expected to experience a much greater incidence of drying under the No-Action condition, the effect of the Proposed Action is not as dramatic as at Isleta. Total number of days increases to 4220, over 48 years. This resolves to 93 days/year, compared to 48 days/year under the No-Action condition. The number of years in which drying occurs increases to 48 under the Proposed Action, compared with 28 years under the No-Action condition.

The difference is even less noticeable at San Marcial Gauge. San Marcial gauge could be expected to experience drying in 48 years under the No-Action condition, increasing slightly to 50 years for the proposed Action. Total drying days increases to 5169, compared to 3447. On a number of days per year basis, this results in a change from 71 days/year to 103 days/year.

RECLAMATION

Managing Water in the West

Joint Biological Assessment

Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico

Part II – Maintenance

Middle Rio Grande Project, New Mexico
San Juan-Chama Project, New Mexico
Upper Colorado Region

U.S. Department of the Interior
Bureau of Reclamation

July 2012 (Amended January 2013)

Mission Statements

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

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

Joint Biological Assessment

Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico

Part II – Maintenance

Middle Rio Grande Project, New Mexico
San Juan-Chama Project, New Mexico
Upper Colorado Region

Submitted to the U.S. Fish and Wildlife Service

Rio Grande Silvery Minnow	**Southwestern Willow Flycatcher**
Pecos Sunflower	**Interior Least Tern**

U.S. Department of the Interior
Bureau of Reclamation
Albuquerque Area Office
Albuquerque, New Mexico

July 2012 (Amended January 2013)

Acronyms and Abbreviations

BA	biological assessment
BDANWR	Bosque del Apache National Wildlife Refuge
BiOp	biological assessment
BLM	Bureau of Land Management
BMP	best management practice
CFR	Code of Federal Regulations
ESA	Endangered Species Act.
GIS	Geographic information system
GRF	Gradient Restoration Facilities
LFCC	Low Flow Conveyance Channel
LWD	large woody debris
MBTA	Migratory Bird Treaty Act of 1918
MRG	Middle Rio Grande
MRGCD	Middle Rio Grande Conservancy District
NMISC	New Mexico Interstate Stream Commission
Project	Middle Rio Grande Project
Reclamation	Bureau of Reclamation
RGSM	Rio Grande silvery minnow
RM	river mile
Service	U.S. Fish and Wildlife Service
SWFL	southwestern willow flycatcher
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
WDFW	Washington Department of Fish and Wildlife
%	percent

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1. Introduction

Section 7(a) (2) of the Endangered Species Act (ESA) requires Federal agencies to consult with the U.S. Fish and Wildlife Service (Service) over any discretionary actions that the agency authorizes, funds, or carries out, which may affect a listed species or adversely modify its habitat. This is Part II of the biological assessment (BA) of the Bureau of Reclamation (Reclamation) and non-Federal water management and maintenance activities on the Middle Rio Grande (MRG) focusing on maintenance activities within the MRG. Reclamation actions, as well as the actions of non-Federal entities, are described in this BA. As such, submittal of this BA constitutes a request to initiate formal consultation with the Service for these actions.

This BA analyzes the effects of Reclamation's MRG river maintenance program (river maintenance) and other MRG maintenance activities, including operation and maintenance (O&M) activities on the Low Flow Conveyance Channel (LFCC) and Project drains, on federally protected species in the project area: the Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow [RGSM)), the southwestern willow flycatcher (*Empidonax traillii extimus*; flycatcher [SWFL]), and the Pecos sunflower (*Helianthus paradoxus*, sunflower), and the interior least tern (*Sternula antillarum athalassos*, tern). The bald eagle (*Haliaeetus leucocephalus*) was removed from the Federal list of threatened and endangered species in August 2007 and is., therefore, not considered in this BA. There is no requirement to discuss de-listed species in an ESA consultation, however, activities conducted in the course of river maintenance and other MRG maintenance activities will be conducted in accordance with the Bald Eagle Protection Act and the Migratory Bird Treaty Act.

The analysis presented in this section 7 consultation is based upon anticipated river and habitat conditions over the next 10 years under the proposed action. While the analysis period is used to estimate approximate numerical values for the purpose of facilitating an ESA assessment, the analysis period duration is not a representation of the desired ESA compliance period. As with Part I, water management, for activities described in this BA, Reclamation is requested that the Service issue a Biological Opinion (BiOp) without identifying any specific expiration date. If the proposed actions are modified or affect listed species in ways not considered in this BA, or if standard reinitiation triggers are reached, additional consultation will be requested in accordance with 50 Code of Federal Regulations (CFR) 402.16.

Reclamation's objectives for maintenance through this ESA consultation process are to provide information for the Service to analyze and provide take exemptions, thereby providing ESA coverage for maintenance activities on the

MRG. In this document, three types of maintenance activities are described: river maintenance, other Reclamation MRG maintenance, and Middle Rio Grande Conservancy District (MRGCD) maintenance. The State of New Mexico also has maintenance activities that are covered by this document; but since these maintenance activities fall within the described actions and effects of river maintenance and other Reclamation MRG maintenance, a separate section describing their specific maintenance is not included.

The described river maintenance actions portray activities believed to be geomorphically and ecologically viable that maintain the biological integrity and improves conditions of the listed species. A geomorphically viable activity considers the relationship between the river's sediment transport capacity and sediment supply. It is the imbalance between sediment transport capacity and sediment supply that is a key cause of most channel and flood plain adjustments (Lane 1955; Schumm 1977; Biedenharn et al. 2008). Factors affecting the imbalance between sediment transport capacity and sediment supply can be categorized as drivers of adjustment and controls on adjustment. Important drivers on the MRG include flow frequency, magnitude and duration; and sediment supply. There are several factors than can limit or control the effects of the drivers on channel adjustment and the observed reach characteristics. Controls of channel adjustment such as bank stability, bed stability, base level, flood plain lateral confinement, and flood plain connectivity influence the extent of effect that the drivers have on the observed characteristics of a reach. The relationship between sediment transport capacity and sediment supply helps predict future changes in observed geomorphic trends and the direction of possible river responses. An understanding of the relationship between sediment transport capacity and sediment supply provides the ability to develop river management practices that work with the river's adjustments and treat causes of channel instability, rather than treating symptoms of the channel's adjustments (Schumm et al. 1984).

River maintenance activities covered in this BA include river maintenance strategies (section 3.2 and 3.6.1), priority/monitored river maintenance sites (section 3.6.1 and 5.2.1), both of which involve the utilization of river maintenance methods (section 3.3). River maintenance support activities (section 3.6.4) and processes for identifying adaptive management work (section 3.4), unanticipated work (section 3.5), interim work (section 3.6), and new site work (section 3.6.1) are also described. The river maintenance strategies presented in this BA are an example of a geomorphically viable river management practice for the MRG. The implementation of river maintenance strategies on a reach scale represents a significant shift in addressing river maintenance concerns on the MRG; one that addresses the causes and not just symptoms of the observed geomorphic trends.

The described actions for Reclamation's other MRG maintenance (section 3.7) and the MRGCD's maintenance (section 3.8) describe operation and maintenance of MRG facilities and represent ecologically viable actions that maintain the biological integrity and improves conditions of the listed species.

In the described proposed action for maintenance activities, approximate numeric values are provided to allow for an evaluation of the programmatic effect of the maintenance work. To provide the ability to achieve ESA programmatic coverage, the framework for these details is provided in this proposed action. While specific project locations are not described in this BA, estimates are made as to the general type, amount, and distribution of future maintenance needs. Reclamation expects that, while these numbers are used to derive a total acreage, Reclamation would not be limited in the new BiOp by values like the number of sites in a given year and the future distribution of sites, but rather the resultant amount of programmatic take. This may involve annual sidebars to assess and ensure actions are complying with the issued overall take statement.

2. Action Area

The project area is the immediate area involved in the proposed action, while the action area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR 402.02). The project area is within the geographic area where Reclamation has legal authorization to perform programmatic actions associated with the MRG Project (see section 5). The river mile (RM) designations used in this document, as with the Part I, water management BA component, are those developed from the 2002 controlled aerial photography within the boundaries of the MRG Project.

2.1 River Maintenance Action Area

Located in the Rio Grande Rift, the Rio Grande flows downstream through a series of valleys separated by canyons—for example, White Rock Canyon and local constrictions (e.g., Sevilleta bend or the location of Isleta Diversion Dam) (Reclamation 1977; Lagasse1980). The project and action area for river maintenance activities, under this consultation, is defined as the Rio Grande from Velarde, New Mexico, downstream to the Full Pool Elephant Butte Reservoir Level. The lateral extent of the project area generally is defined by the levees located to the east and west of the mainstem of the river. Under certain (likely limited) circumstances, the levee may be relocated to provide more area for river migration. In situations where levees on one or both sides are missing, the lateral extents are confined by the historical flood plain (geological constraints, such as terraces and rock outcroppings). Between RM 72 and RM 69, the LFCC separates from the Rio Grande, with the Rio Grande being bounded on the west by the Tiffany Levee. The area between the Tiffany Levee, up to and including the LFCC further to the west, is also a potential work area for river maintenance (an average distance of approximately [~] 7,000 ft).

For this BA, the following 10 reaches and associated river mile and landmark designations will be used as graphically shown in figure 1 and as described in table 1.

These 10 reaches have distinct geomorphic differences and characteristic attributes. These are described in more detail in the Middle Rio Grande River Maintenance Plan, Part 1 Report (Reclamation 2007). The White Rock Canyon and Cochiti Lake Reach is not discussed in this report since Reclamation has no authorized river maintenance and there are no future Reclamation planned activities in this reach. Reclamation does conduct river maintenance work from the Elephant Butte (EB) Full Pool Reservoir Level to the current EB Reservoir

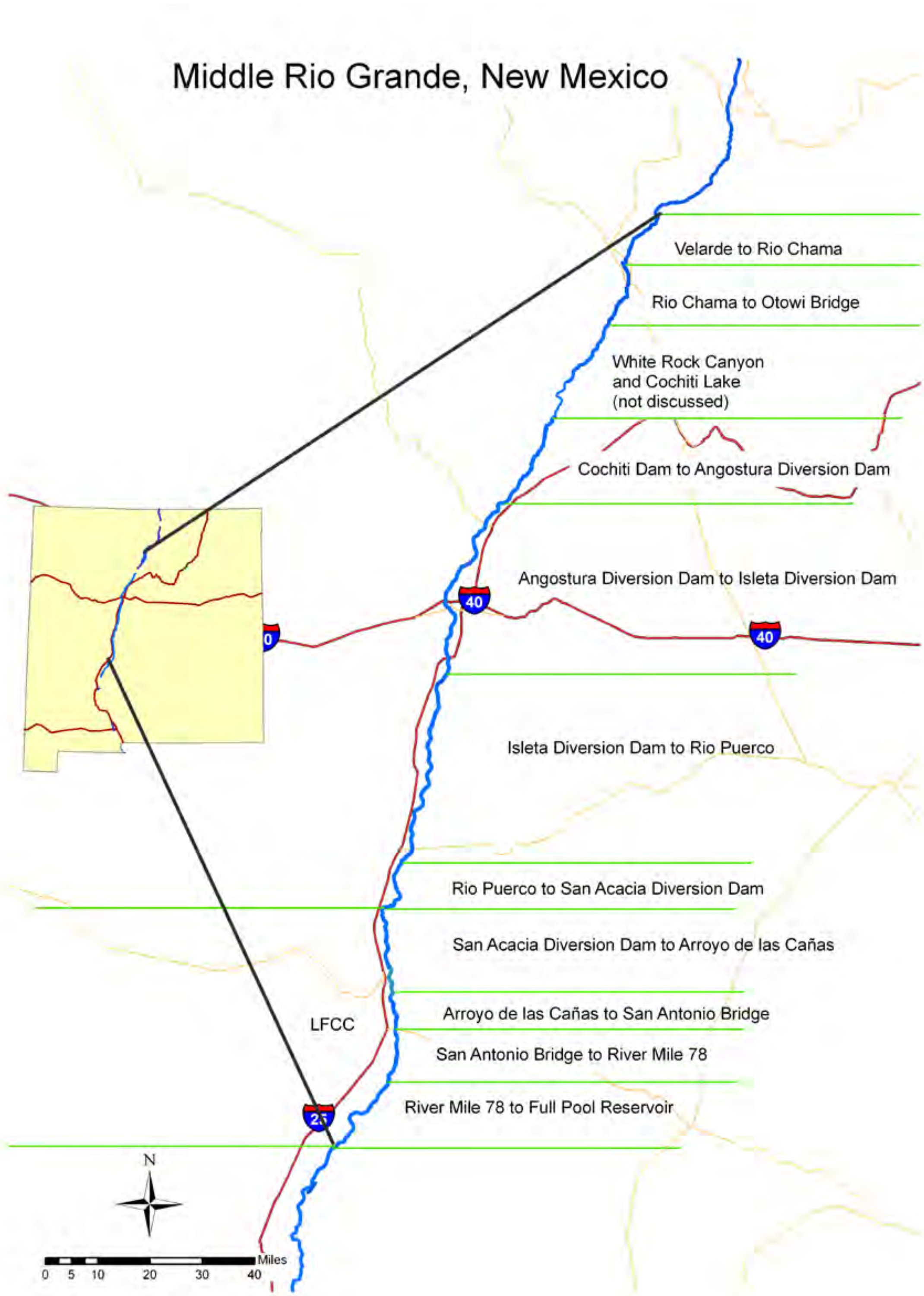

Figure 1. Geomorphic reach designation.

Table 1. Geomorphic Reaches

Geomorphic Reach Name	Description
Velarde to Rio Chama	Velarde, New Mexico (RM 285) to Rio Chama Confluence (RM 272)
Rio Chama to Otowi Bridge	Rio Chama Confluence (RM 272) to NM 502 - Otowi Bridge (RM 257.6)
Cochiti Dam to Angostura Diversion Dam	Cochiti Dam (RM 232.6) to Angostura Diversion Dam (RM 209.7)
Angostura Diversion Dam to Isleta Diversion Dam	Angostura Diversion Dam (RM 209.7) to Isleta Diversion Dam (RM 169.3)
Isleta Diversion Dam to Rio Puerco	Isleta Diversion Dam (RM 169.3) to Rio Puerco Confluence (RM 127)
Rio Puerco to San Acacia Diversion Dam	Rio Puerco Confluence (RM 127) to San Acacia Diversion Dam (RM 116.2)
San Acacia Diversion Dam to Arroyo de las Cañas	San Acacia Diversion Dam (RM 116.2) to Arroyo de las Cañas (RM 95)
Arroyo de las Cañas to San Antonio Bridge	Arroyo de las Cañas (RM 95) to San Antonio – U.S. 380 Bridge (RM 87.1)
San Antonio Bridge to River Mile 78	San Antonio – U.S. 380 Bridge (RM 87.1) to RM 78
River Mile 78 to Full Pool Elephant Butte Reservoir	RM 78 to the Elephant Butte Full Pool Reservoir Level

Level. Reclamation will consult separately on this work. Reclamation also conducts river maintenance work between the EB Dam and the I-25 Bridge south of Caballo Dam. This work is outside the current action area for MRG BA. The work in this reach has a negligible impact on endangered species since the minnow is extirpated from the reach and critical habitat for the willow flycatcher does not exist within the defined river maintenance work area for this reach (river maintenance does not conduct work within the current pool of Caballo Reservoir).

2.2 Other Reclamation MRG Activities Action Area

The project and action areas for other Reclamation MRG activities include the footprint (drain, O&M roads, spoil levees, and immediately adjacent property along the drain corridor) of the MRG Project drains (Drain Unit 7, Drain Unit 7 Extension, La Joya Drain, San Francisco Drain, San Juan Drain, Elmendorf Drain, and the Escondida Drain) and the LFCC. The LFCC is typically adjacent to the western levee, relative to the river, and maintenance activities may occur between the eastern toe of the western spoil levee and the toe drain to the west of the western O&M access road (an average distance of 230 feet, with occasional distances up to 300 feet). The LFCC, within the context of defining an action area for this BiOp, parallels the river from San Acacia downstream to the Full Pool Elephant Butte Reservoir Level. The two exceptions to the LFCC being adjacent to the levee are around RM 111 and roughly between RM 72.5 and RM 69. At RM 111, there are two additional areas (total length of about 2,200 feet) where the LFCC footprint is extended (average additional width of 250 feet) to allow space for stockpiling materials used for river maintenance activities. Between RM 72.5 and RM 69, the LFCC also separates from a spoil levee, with the Tiffany Levee further to the east.

2.3 The MRGCD MRG Activities Action Area

The project and action areas for the MRGCD MRG activities includes the footprint (facility structure, O&M roads, spoil levees, and immediately adjacent property facility structure) of irrigation and flood control structures and facilities between Cochiti Dam and the southern boundary of Bosque del Apache National Wildlife Refuge (BDANWR).

3. Description of Proposed Actions

3.1 Introduction and Background

3.1.1 Introduction

This section contains a description of the proposed actions for maintenance on the MRG above the Elephant Butte Full Pool Reservoir Level. In this document, three types of maintenance activities are described: river maintenance, other Reclamation MRG maintenance, and Middle Rio Grande Conservancy District (MRGCD) maintenance. The State of New Mexico also has maintenance activities that are covered by this document; but since these maintenance activities fall within the described actions and effects of river maintenance and other Reclamation MRG maintenance, a separate section describing their specific maintenance is not included.

Currently, the only recognized Pecos sunflower population within the defined maintenance action areas is located specifically on the Rhodes property south of Arroyo de las Cañas or on land managed by the New Mexico Department of Game and Fish. Reclamation will work with the Service to avoid impact to the sunflower populations on any maintenance activities that would affect the Pecos sunflower population.

Specific details are provided for other Reclamation MRG Project maintenance activities (see section 3.7), including the anticipated operation and maintenance on the LFCC (section 3.7.1), Project drains (see section 3.7.2), and the MRGCD MRG maintenance activities on irrigation and flood control facilities (section 3.8). It is anticipated that sufficient detail is provided in this BA and that these activities would require minimal subsequent coordination with the Service to provide ESA coverage for actions described herein.

For river maintenance, specific project details and areas are not described because exact projects are not defined at this time. Since Reclamation is seeking programmatic ESA coverage for its river maintenance program, a summary of the MRG Project's river maintenance authorization and current goals (section 3.1.2) is presented. These goals, coupled with an understanding of the current geomorphic trends within each reach, are used to develop reach-based strategies (section 3.2) to effectively accomplish river maintenance work within the context of a geomorphic/ecological process based approach. The proposed action for river maintenance describes the strategy approach formulated from coupling the river maintenance goals with the geomorphic trends. Since these strategies were developed to address the trends resulting from physical processes on a reach-basis, a more complete and encompassing view of the river is obtained, providing a broader river maintenance approach.

The proposed action for Reclamation's river maintenance consists of strategies, river maintenance methods, implementation techniques, support activities, and project details. Reclamation is proposing two types of river maintenance activities. The first type is proactive steps to minimize river maintenance activities based on the strategies that are presented in section 3.2 and described in more detail in the Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a). This type of activity involves evaluating river maintenance strategies for an entire reach and prioritizing specific sites for implementation. To implement river maintenance strategies on a reach scale, river maintenance activities are determined by need and budget, and exact projects are not defined at this time. The second type is individual sites, described as priority or monitored sites (section 5.2.1), which are designed to meet local river maintenance needs to address symptoms of an observed geomorphic trend.

River maintenance sites (section 3.6.1), within the context of this BA, may be implemented as individual sites within a reach-based river maintenance strategy or as a priority site project. Both would be considered river maintenance sites as described in this proposed action. These two types of activities may use the same river maintenance methods (section 3.3) and implementation techniques (section 3.6.4.5). They also both rely on a variety of river maintenance support activities (section 3.6.4).

Estimated river maintenance project area, footprint, duration, etc., are described conceptually for the implementation of project sites (section 3.6) by whether the estimated impact area is expected to occur in the wetted portion of the river (wet) or occur totally above the water surface at the time of project implementation (dry). Specific project details and areas are not described, because exact projects are not defined at this time. Four project descriptions, described below, are used in this document. These descriptions are used to provide further clarification of the two previously defined river maintenance project types.

- **New site work** (section 3.6.1) – describes project locations where river maintenance activities have not previously been performed.
- **Adaptive management work** – describes projects where an adaptive management process (section 3.4) is being followed to address ongoing river responses that may undermine river maintenance activities previously performed at the site.
- **Interim work** (section 3.6) – describes project locations where river maintenance activities may be needed due to threatening, but not immediate, risks to infrastructure, public health and safety, or potential for a significant loss of water.

- **Unanticipated work** (section 3.5)– describes project locations where river maintenance activities may be needed due to immediate risks to infrastructure, public health and safety, or potential for a significant loss of water.

For river maintenance, it is expected that additional future information will be shared to define river maintenance projects, including specific site locations, project footprints, implementation techniques, and river maintenance methods. It also is anticipated that additional information may be needed to define new methods that have developed via technological advances and ongoing research, changes in reach trends, and continued monitoring or adaptive management. Most of these individual project activities may be described in subsequent correspondence tiered off this programmatic maintenance BA. Reclamation expects that routine river maintenance support activities such as ongoing geomorphic data collection, and maintained existing locations of stockpile sites, storage yards, and quarry/borrow areas are presented in sufficient detail and would not need to be described further. Lastly, any new routine maintenance, tiered off this programmatic maintenance BA, would be developed with sufficient detail through coordination with the Service.

3.1.2 River Maintenance Authorization and Goals

Traditional river engineering projects often created environmental problems as a result of imposing unnatural conditions on rivers by modifying channel cross sections and length, creating lateral confinements, and altering flow and sediment supply (Thorne et. al. 1997; Gore and Petts 1989; Gore, 1985; Brookes 1988; Brookes and Shields 1996). It should be recognized that, on the MRG, much of the original channelization, flow control, and sediment load reduction were planned to reduce and reverse aggradational trends in the channel. The channel was aggrading above the adjoining lands outside the levee even into the 1960s (Lagasse 1980; Makar and AuBuchon 2012), which endangered valley residents, and local economies. These conditions formed the background for creating the MRG Project, which is authorized by the Federal Flood Control Acts of 1948 and 1950 (Public Law 858 and 516). MRG Project components are assigned to Reclamation, the U.S. Army Corps of Engineers (USACE), and the MRGCD in the House Documents (Reclamation 1947; Reclamation 2003). Additional information about the House Documents and Project authorization can be found in the Middle Rio Grande River Maintenance Plan, Part 1 Report (Reclamation 2007).

Constructed channel and reservoir works to control aggradation have been effective at alleviating some of the original authorization concerns; however, the combination of anthropogenic and natural changes over time on the MRG has altered the water and sediment supply, resulting in different trends and impacts. The major current geomorphic trends observed on the MRG, although not every trend occurs on every reach, are listed below. These trends and their applicability to the MRG are discussed in more detail in the report titled Channel Conditions and Dynamics on the MRG (Makar and AuBuchon 2012).

- Channel narrowing
- Vegetation encroachment
- Increased bank height
- Incision or channel bed degradation
- Bank erosion
- Coarsening of bed material
- Aggradation (river bed rising due to sediment accumulation)
- Channel plugging with sediment
- Perched channel conditions (river channel higher than adjoining riparian areas in the floodway or land outside the levee)
- Increased channel uniformity

River maintenance goals also have been updated to reflect the changing river conditions, the evolution of practices of river maintenance and management, and compliance with environmental statutes (Reclamation 2012a). The river maintenance goals are designed to reflect the river system as a whole, where possible, and to help implement the best methodology to achieve the original project authorization. The four river maintenance goals are:

- Support Channel Sustainability
- Protect Riverside Infrastructure and Resources
- Be Ecosystem Compatible
- Provide Effective Water Delivery

These goals are described in more detail in the Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a). The current MRG trends, identified above, and their underlying processes, create the need for channel maintenance to meet the river maintenance goals. For example, channel incision and narrowing can lead to lateral migration, which can lead to damage of riverside infrastructure and resources. River maintenance strategies and methods used to achieve the stated river maintenance goals remain consistent with the objectives specified in the MRG Project authorization and other Federal responsibilities.

3.2 River Maintenance Strategies

Strategies define reach-based management approaches to meet the river maintenance goals on the MRG, according to the physical and biological processes understood to be driving the current and predicted river trends. The proposed action for river maintenance describes the strategy approach formulated from coupling the river maintenance goals with the geomorphic trends. These strategies provide the ability to address the trends on a reach basis. In many cases, multiple strategies may be needed to work towards achieving a desired goal. The best outcome for the MRG as a whole requires a balance between desirable outcomes for individual goals and how they can best be applied given the varying reach characteristics. This is to be expected for multiple uses of a limited resource and provides a more complete and encompassing view of the river for river maintenance.

The following reach strategies were developed to address the major current trends resulting from physical processes on the MRG:

- Promote Elevation Stability
- Promote Alignment Stability
- Reconstruct/Maintain Channel Capacity
- Increase Available Area to the River
- Rehabilitate Channel and Flood Plain
- Manage Sediment

Each strategy has an array of different methods used for implementation, different geomorphic responses that affect the MRG, and varying degrees of meeting the river maintenance goals. Each reach generally has multiple constraints such as public health and safety concerns, protection of riverside infrastructure, local variations in geology, and endangered species habitat. These reach strategies are intended to better help integrate the physical processes, reflected by the observed trends, occurring on the MRG with river maintenance programmatic actions. Reach strategies, addressing currently observed trends, are briefly described below. The reach strategies are described in more detail in the Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a).

3.2.1 Promote Elevation Stability

The objective of this strategy is to reduce the extent and rate of bed elevation changes. Promote Elevation Stability has two distinct suites of methods to address the conditions of sediment transport capacity greater and less than sediment supply (i.e., raising the bed for degrading reaches and lowering the bed for aggrading reaches).

This strategy addresses all four river maintenance goals, but its applicability to the Be Ecosystem Compatible Goal is method dependent. The strategy can help address the following trends: increased bank height, incision or channel bed degradation, coarsening of bed material, and aggradation.

An example of executing this strategy on a reach basis would be the implementation of cross channel features (see section 3.3.4 for more details on this method category) throughout a reach to minimize channel bed degradation. This could involve stabilizing the bed through maintaining a preferred river channel bed elevation with more permanent features or increasing the erosion resistance of the bed material to decrease the rate of channel incision. Cross channel methods would be low structures (~2 feet high or less), with a low gradient on the downstream apron to provide fish (Rio Grande silvery minnow [RGSM]) passage. Implementing these methods provides bed stability in the immediate area and for some distance upstream; cross channel features, however, do not prevent the continuation of downstream degradation (bed lowering). If the trend of downstream channel incision (bed degradation) continues, adaptive management may be needed to provide for continued fish passage.

Aggradation is also a trend that has been observed in several reaches of the Rio Grande because of an excess sediment supply. Since this trend affects and leads to bed elevation stability concerns, this strategy also could include minimization of aggradation where appropriate. It should be noted that, to minimize the overlap between strategy methods and effects, implementing this strategy is focused on method categories that directly address incision or channel bed degradation because there are other strategies that directly address aggradation. These other strategies are Reconstruct/Maintain Channel Capacity, Increase Available Area, and Manage Sediment. The overlap in strategies means projects likely will require the combination of multiple strategies (see section 3.2.7).

3.2.2 Promote Alignment Stability

The objective of this strategy is to provide alignment protection while allowing the river channel to adjust as much as possible horizontally within the lateral constraints. If the safety or integrity of riverside infrastructure and resources is likely to be compromised within the next few years, then bank protection or re-directive flow measures are implemented to provide protection and reduce the risk of future migration in an undesirable direction. There are two basic types of lateral channel movement: migration, which generally occurs under degrading and tall bank conditions (sediment transport capacity greater than sediment supply), and avulsion, which generally occurs under aggrading and perched channel conditions (sediment transport capacity less than sediment supply).

This strategy can address all four river maintenance goals, but applicability to the Be Ecosystem Compatible Goal is method dependent. The strategy also addresses the following trends: bank erosion, perched channel conditions, and channel plugging with sediment. This strategy addresses the trend of channel plugging with sediment and perched channel conditions by providing a suitable alignment so that protection is provided to infrastructure in the event of channel relocation via a sudden avulsion.

An example of implementing this strategy on a laterally migrating reach would be the implementation of bank protection/stabilization features (see section 3.3.3 for more details on this method category) throughout the reach. This could involve direct longitudinal bank stability methods such as bank slope re-grading, stabilization with more erosion resistant material (vegetation, riprap, etc.), bank lowering, etc. It may also involve using features that redirect flow patterns, minimizing the hydraulic forces near the bank that affect bank stability.

Promote Alignment Stability also may be implemented under aggrading and perched channel conditions. Typically, under these conditions, this strategy is addressed with Reconstruct/Maintain Channel Capacity. Other strategies that also may be used to address perched river conditions include Increase Available Area to the River and the Manage Sediment.

3.2.3 Reconstruct/Maintain Channel Capacity

The objective of this strategy is to help ensure safe channel capacity and to provide effective water delivery through a reach. Capacity can be lost through gradual aggradation over time, channel narrowing through island and bar deposits or vegetation encroachment, large sediment deposits at the mouths of ephemeral tributaries, and abrupt aggradation such as sediment plugs in the active river channel. This strategy also would address conditions where the channel bed is perched, or higher than the flood plain, due to past aggradation. This strategy can involve repositioning sediment so that the river can help transport it. Maintaining or excavating a wider and/or deeper channel helps ensure that safe channel capacity requirements are met consistent with Reclamation's authorization. This strategy most likely would be implemented in reaches where sediment deposition would create unsafe channel capacities.

This strategy addresses the Protect Riverside Infrastructure and Resources and Provide Effective Water Delivery Goals. The strategy also addresses the following trends: channel narrowing, vegetation encroachment, aggradation, channel plugging with sediment, and perched channel conditions.

An example of implementing this strategy on a reach basis would be the implementation of channel modification features (see section 3.3.2 for more details on this method category) throughout a reach. This could involve changing the channel profile, plan shape, cross section, bed elevation, slope, and/or channel location to increase channel capacity.

3.2.4 Increase Available Area to the River

The objective of this strategy is to provide area for the river to evolve in response to changing conditions and to minimize the need for additional future river maintenance actions. The ideal condition would be that the river and flood plain area are large enough to accommodate more than the expected width of potential lateral migration; otherwise, the need for future channel maintenance work is more likely.

This strategy addresses the river maintenance goals of Support Channel Sustainability, Protect Riverside Infrastructure and Resources, and Be Ecosystem Compatible. Effects of this strategy on the Provide Effective Water Delivery Goal are uncertain and reach dependent. The strategy also addresses the following trends: channel narrowing, increased bank height, incision or channel bed degradation, bank erosion, coarsening of bed material, aggradation, channel plugging with sediment, perched channel conditions, and increased channel uniformity.

An example of implementing this strategy on a reach basis would be the implementation of infrastructure relocation and setback features (see section 3.3.1 for more details on this method category). This could involve moving irrigation/drainage features and accompanying spoil levees to a location further away from the river, increasing the available area for the river to adjust. Conservation easements also may be used to implement this strategy (see section 3.3.5 for more details on this method category).

3.2.5 Rehabilitate Channel and Flood Plain

The objective of this strategy is to help stabilize the channel bed elevation and slope in reaches where sediment transport capacity is greater than sediment supply. Rehabilitate Channel and Flood Plain reconnects abandoned flood plains, which reduces the sediment transport capacity of higher flows and more closely matches the existing sediment supply.

This strategy addresses the Support Channel Sustainability, Be Ecosystem Compatible, and Protect Riverside Infrastructure and Resources Goals of river maintenance, although the degree to which it speaks to these goals is method dependent. Effects of this strategy on the Provide Effective Water Delivery Goal are uncertain and reach dependent. The strategy also addresses the following trends: channel narrowing, vegetation encroachment, increased bank height, incision or channel bed degradation, bank erosion, coarsening of bed material, and increased channel uniformity.

An example of implementing this strategy on a reach basis would be the implementation of channel modification features (see section 3.3.2 for more details on this method category) throughout a reach. This often involves changing the channel cross section by lowering the banks, so that flows go over bank at a lower discharge.

3.2.6 Manage Sediment

This strategy would aid in balancing sediment transport capacity with available sediment supply. Currently, there is an excess of sediment transport capacity in most of the reaches, so this generally would involve the addition of sediment into the system. In some reaches, however, the sediment supply exceeds the sediment transport capacity and in those cases implementation of the strategy would involve the reduction of sediment supply into the system.

This strategy addresses the Support Channel Sustainability and Be Ecosystem Compatible Goals of river maintenance. The effects of this strategy on Provide Effective Water Delivery Goal are uncertain and reach dependent. This strategy also may apply to the Protect Riverside Infrastructure and Resources Goal; however, it is difficult to ensure no impact to infrastructure. The strategy also addresses the following trends: increased bank height, incision or channel bed degradation, coarsening of bed material, aggradation, channel plugging with sediment, perched channel conditions, and increased channel uniformity.

An example of implementing this strategy on a reach basis would be to change the sediment supply (see section 3.3.6 for more details on this method category) throughout a reach. For a reach with an excess sediment transport capacity, features like arroyo reconnection, sediment bypass of water storage structures, and bank destabilization would augment the sediment supply and help the channel reach a dynamic equilibrium with its sediment transport capacity. This most likely is implemented, however, through combining with other strategies (see section 3.2.7). For a reach with excess sediment supply, features such as natural or constructed sediment basins would promote dynamic equilibrium by removing sediment to match the available sediment transport capacity. Once adding or removing sediment is implemented, this would need to continue indefinitely to realize long-term benefits. It is also likely that this strategy implementation would require more adaptive management than other strategies because of the uncertainty related to sediment augmentation or withdrawal and the complexity of the potential river response.

3.2.7 Strategy Combinations

While strategies have been developed and can be implemented individually, often the combination of strategies is the most effective approach to address observed reach trends.

As an example, Promote Elevation Stability could include minimizing aggradation where appropriate. To achieve this result, Reconstruct/Maintain

Channel Capacity and Increase Available Area to the River could be combined through applicable features. For instance, changes to the channel configuration within Reconstruct/Maintain Channel Capacity could be coupled with relocating river constraints under Increase Available Area to the River. This would increase the sediment transport capacity of the channel in the short term, while at the same time providing space for the river to realign in the long term. The combination of these two strategies allows a measure of elevation stability in the affected reach, thereby also addressing a third strategy, Promote Elevation Stability. The combination of strategies allows the creation of a longer term implementation that gets incrementally closer to addressing the processes underlying the observed reach trends.

Another example can be taken from Manage Sediment. For situations with an excess sediment transport capacity, features could be implemented from Rehabilitate the Channel and Flood Plain. For instance, island and bar clearing and destabilization and flood plain creation by terrace lowering (longitudinal bank lowering) may help increase the available sediment supply, at least temporarily. If this was coupled with upstream features suitable to Manage Sediment, similar to arroyo reconnection, or other sediment augmentation, both short- and long-term impacts are addressed. Combining these two strategies may increase the alignment stability, thereby benefiting Promote Alignment Stability. Methods within this strategy also could be used to provide direct protection to critical infrastructure in concert with Manage Sediment and Rehabilitate the Channel and Flood Plain.

3.2.8 Most Likely Strategies by Reach

Using reach geomorphic trends and reach characteristics (i.e., infrastructure, habitat and presence of ESA species, population and land use, and water delivery), the most likely strategies to be implemented for each reach are identified and listed in table 2. Strategies that address reach geomorphic trends are suitable for the reach and its geomorphic tendencies, and, thus, most likely to be implemented. Strategies that do not address reach trends and those for which trends do not indicate a need are described as not suitable. While current reach trends of importance to river maintenance have been identified, future trends of the river could change so that unsuitable strategies would become suitable as well as the converse. Projects that work with reach geomorphic trends and processes more likely are to be sustainable and often address endangered species habitat needs. More information on the identification of most likely strategies by reach, and the rationale for why strategies are listed as unsuitable in a reach, can be found in the Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a).

Table 2. Summary of Most Likely Strategies by Reach

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Velarde to Rio Chama	Not Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
Rio Chama to Otowi Bridge	Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
Cochiti Dam to Angostura Diversion Dam	Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
Angostura Diversion Dam to Isleta Diversion Dam	Suitable	Suitable	Not Suitable	Not Suitable	Suitable	Suitable
Isleta Diversion Dam to Rio Puerco	Suitable	Not Suitable	Suitable	Suitable	Suitable	Suitable
Rio Puerco to San Acacia Diversion Dam	Not Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
San Acacia Diversion Dam to Arroyo de las Cañas	Suitable	Suitable	Not Suitable	Suitable	Suitable	Suitable
Arroyo de los Cañas to San Antonio Bridge	Suitable	Not Suitable	Suitable	Not Suitable	Not Suitable	Suitable
San Antonio Bridge to River Mile 78	Suitable	Not Suitable	Suitable	Suitable	Not Suitable	Suitable
River Mile 78 to Full Pool Elephant Butte Reservoir Level	Suitable	Not Suitable	Suitable	Suitable	Not Suitable	Suitable

3.3 River Maintenance Methods

River maintenance methods can be used as multiple installations as part of a reach-based strategy approach, at individual sites within the context of a reach-based approach, or at single sites to address a specific river maintenance issue that may be separate from a reach strategy. Methods are the river maintenance treatments used to implement reach strategies to meet river maintenance goals. The applicable methods for the MRG are organized into six major categories, each with similar features and objectives. Methods may be applicable, however, to more than one category because they can create different effects under various conditions. The major method categories are:

- Infrastructure Relocation or Setback
- Channel Modification
- Bank Protection/Stabilization
- Cross Channel (River Spanning) Features
- Conservation Easements
- Change Sediment Supply

Method selection is dependent upon local river conditions, reach constraints, desired environmental effects or benefits, and the inherent properties of the method. The major method categories and their corresponding individual methods are described briefly in sections 3.3.1–3.3.6 and in more detail in the River Maintenance Methods Attachment, as well as the report titled Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide, Appendix A (Reclamation 2012b). A caveat should be added that while these categories of methods are described in general, those descriptions are not applicable in all river situations, and will require more detailed, site specific, analysis and design for implementation. It is also important to note that no single method or combination of methods is applicable in all situations.

Table 3, below, contains the most applicable major method categories for each strategy. For a given strategy, more than one method category can apply. The combination of method categories used depends upon local river conditions, reach trends, reach constraints, and the specific methods employed. The Most Likely Strategies and Methods by Reach Attachment has additional information on the most likely strategies and methods that would be used in a specific reach.

Due to river channel condition variability, methods may be applicable locally in reaches where they are not considered most likely. River channel dynamics also include the probability that the designations of most likely strategies and methods by reach may change over time.

Table 3. Method Categories Associated with Strategies

Method	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Infrastructure Relocation or Setback				X		
Channel Modification			X		X	X
Bank Protection/ Stabilization		X				
Cross Channel (River Spanning) Features	X					
Conservation Easements				X	X	
Change Sediment Supply						X

3.3.1 Infrastructure Relocation and Setback

Riverside infrastructure and facilities constructed near the riverbanks may laterally constrain river migration. Relocating infrastructure provides an opportunity for geomorphic processes, especially lateral migration, to occur unencumbered by local lateral infrastructure constraints, encouraging the river towards long-term dynamic equilibrium (Newson et al. 1997; Brookes et al. 1996). Bank erosion can remove older growth riparian areas, while downstream bar deposition can create new flood plain and riparian areas. Potential facilities to be relocated include levees, dikes, access roads, canals, drains, culverts, siphons, utilities, etc. Infrastructure would need to be set back beyond the expected maximum extent of lateral migration; otherwise, bank erosion and stability problems may, in time, advance to the new infrastructure location. Thus, protection of re-located infrastructure may still be required as channel migration approaches the relocated facilities.

3.3.2 Channel Modification

Channel modifications are actions used to re-construct, relocate, and re-establish the river channel in a more advantageous alignment or shape and slope consistent with river maintenance goals. Channel modification actions potentially may result in a larger channel capacity at various flow rates and cause changes in channel shape and slope. Excavating new channel alignments and plugging existing channel entrances are part of this method category. Channel modification techniques also have been used to address geomorphic disequilibrium, thereby reducing risks of bank erosion (Washington Department of Fish and Wildlife

[WDFW] 2003). These methods include changes to channel profile, slope, plan shape, cross section, bed elevation, slope, and/or channel location.

3.3.3 Bank Protection/Stabilization

Bank protection works may be undertaken to protect the river bank against fluvial erosion and/or geotechnical failures (Hey 1994; Brookes 1988; Escarameia 1998; McCullah and Gray 2005). Bank protection methods described in the River Maintenance Methods Attachment apply to cases where bank line and toe erosion is the primary mechanism for bank failure. In situations where the bank slope is unstable due to geotechnical processes, other methods would need to be applied in addition to bank stabilization (Escarameia 1998). This could include placing additional material at the toe of the slope or removing upslope material to minimize the potential for soil instabilities that may lead to bank failure (Terzaghi et al. 1996).

3.3.4 Cross Channel (River Spanning) Features

These features are placed across the channel using variable sized rock material without grout or concrete (Neilson et al. 1991; Watson et al. 2005). The objective of cross channel or river spanning features is to control the channel bed elevation and improve or maintain current flood plain connectivity and ground water elevations. The primary focus of cross channel structures would be slowing or halting channel incision or raising the riverbed. Grade control features also have been used in cases where channel incision caused or was expected to cause excessive lateral migration and undermining of levees and riverside infrastructure (Bravard et al. 1999).

3.3.5 Conservation Easement

Conservation easements are land agreements that prevent development from occurring and allow the river to erode through an area as part of fluvial processes. Conservation easements also preserve the riparian zone and allow future evolution as determined by fluvial processes and flood plain connectivity.

This method preserves and promotes continuation of riparian forests, the ecosystem, and the river corridor (Karr et al. 2000). Conservation easements may involve infrastructure relocation or setback, which may increase the opportunity for the river to access historical flood plain areas.

3.3.6 Change Sediment Supply

Sediment transport and supply vary with discharge over time and from place to place within a river system. Where the supply of sediment is limited or has been reduced, the result is generally channel incision, bank erosion, and, on the MRG, possibly a channel pattern change from a low-flow, braided sand channel with a shifting sand substrate to a single thread, mildly sinuous channel with a coarser bed. Where sediment supply is limiting, alluvial rivers generally respond through channel width decreases, channel depth increases, local longitudinal slope decreases, and sinuosity increases (Schumm 1977). The addition of sediment supply can stabilize or reduce these tendencies.

When a river system has more sediment supply than sediment transport capacity, channel aggradation will occur. In general, aggradation results in the channel width increasing, channel depth decreasing, local longitudinal channel slope increasing, sinuosity decreasing (Schumm 1977), and in decreased channel and flood capacity. Sediment berms also can form along the channel banks (Schumm 2005). The reduction of sediment supply can slow or reverse these trends.

3.4 Adaptive Management for River Maintenance

Much of the geomorphic change on the Rio Grande is driven by variations in flow and sediment supply, especially high-flow events. These high-flow events may change the needs of the river on an annual basis. Adaptive management for river maintenance is a planned, systematic process to achieve the best set of decisions possible in the face of uncertainty and lack of knowledge as outcomes from strategy implementation and river dynamics become better understood. Adaptive management work describes projects where an adaptive management process is being followed to address ongoing river responses that may undermine river maintenance activities previously performed at the site. The intent is to adjust the river maintenance implementation in a timely manner to address any concerns that may arise and provide lessons learned to projects in the future. Adaptive management for river maintenance project sites, as described herein, has been used in the past (section 5.2.2, table 18 and tables 19–28, provides information on historical utilization) and is proposed to continue into the future at discrete sites using the current implementation philosophy, as described in the MRG maintenance baseline (see section 5.2.1) and also as part of the implementation of river maintenance sites that are part of a reach strategy. The adaptive management, as practiced for river maintenance, requires a series of steps, as described below. The intent is to adjust the implementation in a timely manner to address any concerns that may arise and provide valuable lessons learned to projects in the future.

- Defining river maintenance and ecosystem function objectives (including stakeholder involvement)
- Identifying the approach to potential alternatives
- Predicting channel response (using state-of-the-art design and analysis methods) to each alternative
- Selecting the alternative approach that best meets objectives

- Developing monitoring plans (including baseline data collection)
- Implementing the selected alternative and monitoring plans
- Comparing monitoring results to predictions and objectives
- Adjusting the strategy/project approach as needed to achieve the desired objectives
- Documenting all steps

Adaptive management within the framework of river maintenance will be performed using the U.S. Department of the Interior guidelines. Adaptive management "recognizes the importance of natural variability" (Williams et al. 2009) in river response due to dynamic river conditions and the project implementation. "It is not a trial and error process, but rather emphasizes learning by doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits" (Williams et al. 2009). This is especially true for ecosystem function because it is influenced by river maintenance actions. Monitoring and evaluating will lead to improved scientific knowledge on the effects of river maintenance implementation upon the ecosystem and ways to improve the ecosystem function. Documenting the project objectives, process, and predicted results is necessary to understand which activities work (or do not) and why. The *why* is important because success or failure can result from factors such as incorrect assumptions, inadequate design/analysis methods, poorly implemented designs, changing conditions at the project site, flawed interpretation of monitoring data, or any combination of these factors. This information is essential to improve both the current and the next project or to repeat the success.

Using an adaptive management approach for river maintenance in dynamic river systems often extends the time period of river maintenance implementation, but goals are more likely to be met. Traditional maintenance methods are implemented within one implementation season. In contrast, some river maintenance work incorporates plans for reviews and works in subsequent implementation seasons after the occurrence or in the absence of significant channel forming flows. Additional information on adaptive management, as implemented by river maintenance, is provided in the report, Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a).

On the MRG, some strategies have a stronger adaptive management component than others. Adaptive management is expected to be used for Promote Elevation Stability where cross channel features are implemented. The continuation of downstream channel incision (bed degradation) may require adaptive management to ensure continued fish (RGSM) passage. Promote Alignment Stability is intrinsically adaptive because monitoring of channel conditions is used to allow some lateral migration until infrastructure is threatened. It also is expected that Rehabilitate Channel and Flood Plain may need continued evaluation and adjustments to ensure flows go over bank at the desired discharge and frequency, the channel is stable, and to ensure infrastructure is not at risk. Manage Sediment is likely to need adjustments as the channel responds to changes in the sediment supply. Increase Available Area has an adaptive component to ensure that water deliveries are not significantly impacted. Because it is unlikely that enough space can be acquired to permanently ensure that relocated levees will not be impacted by lateral migration, monitoring will be required for this strategy. For both these reasons, Increase Available Area to the River has an adaptive component. Reconstruct/Maintain Channel Capacity requires ongoing monitoring and evaluation of available channel capacity to transport the incoming flows and sediment loads. This strategy requires ongoing maintenance; but since it recreates the same channel, there is a minimal adaptive management component.

Certain reaches have more potential for adaptive management. For instance, adaptive management may be useful in reaches that have highly variable conditions such as River Mile 78 to the Full Pool Elephant Butte Reservoir Level, with its significant changes in base level control, or Angostura Diversion Dam to Isleta Diversion Dam, where sediment supply may be increasing due to Jemez Canyon Dam operations modifications, and reaches where the cumulative effects of numerous habitat restoration projects may be significant. Other reaches where adaptive management may be useful are those that are critical to endangered species. The implementation of river maintenance projects in reaches with critical habitat may require an adaptive management process to ensure a minimal impact to desirable habitat features and/or improve the functionality of a design element to further enhance the creation of desirable habitat features.

Finally, the continuing adjustments of channel conditions may create the need for adaptive management of previously completed river maintenance projects. Because of the uncertainty and lack of knowledge associated with designing in a dynamic river environment, it is expected that many completed river maintenance projects may at some time become candidates for more intensive adaptive management. An assessment of future river maintenance adaptive management needs is provided in section 3.6.3.

3.5 River Maintenance Sites and the Interstate Stream Commission Cooperative Agreement

As previously discussed in section 3.1.2, one of the four river maintenance goals for the MRG Project is to “Provide effective water delivery” through the MRG reach. Providing effective water delivery includes conserving surface water in the Rio Grande Basin and providing for the effective transport of water to Elephant Butte Reservoir. The State of New Mexico has a common interest with Reclamation in ensuring the effective delivery of water to the Elephant Butte

Reservoir. Reclamation and the State of New Mexico have participated in a joint cooperative program for water salvage and river maintenance activities since 1956. The purpose of this program is to provide maintenance and improvements that mitigate stream flow losses and to reduce non-beneficial consumption of water by vegetation in the flood plain of the Rio Grande and its tributaries above Elephant Butte Reservoir. Projects pursued under this cooperative program fall into two general areas, one being projects that have a common river maintenance interest, and the other being projects that fall within the realm of other MRG activities.

In February 2007, a new Cooperative Agreement (07-CF-40-2627) was executed between the New Mexico Interstate Stream Commission (NMISC) and Reclamation to provide funding for water salvage work on the MRG Project. The purpose of this program is to provide maintenance and improvements that mitigate stream flow losses and to reduce nonbeneficial consumption of water by vegetation in the flood plain of the Rio Grande and its tributaries above Elephant Butte Reservoir. Work includes river maintenance, as well as other MRG Project maintenance with water salvage potential. For most river maintenance projects done under the State Cooperative Agreement, Reclamation provides funding for engineering and environmental compliance support, while NMISC provides funding for implementation and equipment maintenance.

While proposed work under this agreement may include any of the described river maintenance strategies, there is a higher likelihood of pursuing a joint collaboration with the river maintenance strategies of Promote Elevation Stability, Promote Alignment Stability and Reconstruct/Maintain Channel Capacity (section 3.2). The expected river maintenance methods (section 3.3) that would be used in pursuit of work under this cooperative agreement include those within the method categories of channel modification, bank protection/stabilization, and cross channel (river spanning) features. Maintenance work pursued jointly between Reclamation and the NMISC is covered by the description and quantity of river maintenance project details provided in section 3.6. It is expected that, for these joint maintenance projects, additional future information will be shared to define the maintenance projects, including specific site locations, project footprints, implementation techniques, and river maintenance methods.

3.6 River Maintenance – Project Details

This section presents the specific details involved with implementing river maintenance projects on the MRG. The estimated number of river maintenance sites for a given year is provided in section 3.6.1. In addition to river maintenance methods (section 3.3 and the River Maintenance Methods Attachment), river maintenance projects during implementation also have specific site locations (section 3.6.3), implementation footprints (section 3.6.2), implementation techniques (see section 3.6.4.5), and impacts from support activities (section 3.6.4). Implementation techniques describe how the work is implemented, while river maintenance methods describe the element that is being implemented. This section also provides a summary of estimated river maintenance impacts on the MRG.

Throughout section 3.6 of this document, approximate numeric values are provided to help evaluate the programmatic effect of Reclamation's river maintenance. To provide the ability to achieve ESA programmatic coverage for river maintenance, the framework for these details is provided in this proposed action. While specific project locations are not described in this BA, the relative distribution of future river maintenance projects is described in section 3.6.3 for both new sites and continued adaptive management of existing sites. Reclamation expects that, while these numbers are used to derive total river maintenance acreage, Reclamation would not be limited in the new BiOp by values like the number of sites in a given year and the future distribution of sites but rather the resultant amount of programmatic take.

3.6.1 River Maintenance Sites

Based on Reclamation's historical performance (section 5.2, table 18), it is expected that, on average, the river maintenance program would implement projects at approximately four river maintenance sites per year, with a range of one to eight sites in any given year (table 5, shown later in this document). Of the four sites, it is expected that, on average, one would be ongoing adaptive management work at a previously completed site and one would be unanticipated/interim river maintenance work (section 3.6.1.1 and 3.6.1.2). The remaining three would be considered new project implementation at a river maintenance site location. Of the three new river maintenance sites, one would be unanticipated/interim river maintenance work (sections 3.6.1.1 and 3.6.1.2). New river maintenance sites may develop at sites currently identified as river maintenance monitoring sites, be totally new river maintenance sites where changing site conditions warrant declaring a new monitoring or priority site, or be river maintenance sites that are used to implement a river maintenance strategy.

3.6.1.1 River Maintenance Unanticipated Work

River maintenance unanticipated work occurs due to variable channel response creating conditions where immediate action is needed to protect infrastructure, ensure public health and safety, or prevent excessive water loss. Because there is uncertainty in predicting the spatial and temporal timeframes of future channel changes, unanticipated work activities likely will be needed in the future. These typically are associated with bank erosion and safe channel capacity concerns. Unanticipated work would be pursued if the timeframe for finding solutions is pushed forward by an event on the river that accelerates the necessity of doing work, creating the need to address the risk immediately. Risk in the context of river maintenance refers to a threat to infrastructure or the loss of effective water delivery. These are projects where the compliance must be streamlined or Reclamation would need to label the project as an emergency and proceed using the ESA emergency protocols. The implementation of river maintenance strategies on a reach scale (see section 3.2) may reduce the amount of unanticipated work when compared historically.

River maintenance methods typically used to address unanticipated work are described below. These methods fall in the method categories of Channel Modification and Bank Protection/Stabilization. Additional information about river maintenance categories and methods can be found in section 3.3, the River Maintenance Methods Attachment, and the report, titled Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide, Appendix A (Reclamation 2012b). For areas of difficult terrain or access restrictions, it may be necessary to clear and/or create a road to the project site. Vegetation clearing is described in more detail in section 3.6.4.1. Road creation may simply involve vegetation clearing but also could include bringing in fill material, both dirt and rock, to ensure a suitable base for driving heavy equipment to the project site.

Riprap Revetments – This is a method that may be used for river maintenance unanticipated work to address erosion and flooding threats. Riprap would be brought to the site and dumped at the bank that is actively eroding until the erosion is controlled, creating a riprap revetment that protects the bank slope. Typically riprap is hauled to the site from a Reclamation riprap stockpile site using highway dump trucks. Railway cars or articulated dump trucks also may be used in certain situations for sites that are difficult to access by highway trucks.

Levee Strengthening – This is a method that may be used for river maintenance unanticipated work to address seepage and flooding threats. Levee strengthening involves bringing in fill material to increase the height and width of the levee. Levee strengthening also may involve rebuilding a levee section. Increasing the levee height provides additional freeboard to prevent floodwaters from overtopping a levee. Adding to the levee height, by default, also increases the levee width, which provides some level of protection from seepage concerns. Typically, dirt is hauled to the site from Reclamation's Valverde quarry using highway dump trucks. Articulated dump trucks also may be used in certain situations where the terrain is more difficult to maneuver around.

Riprap Windrow – This is a method that may be used for river maintenance unanticipated work to address erosion threats. Riprap would be brought to the site and dumped on dry ground in a windrow along the length of the desired protection area. The windrow is designed to self-launch into the river as the bank erosion progresses, creating a riprap revetment. Typically, riprap is hauled to the site from a Reclamation riprap stockpile site using highway dump trucks. Articulated dump trucks also may be used in certain situations where the terrain is more difficult to maneuver around.

3.6.1.2 River Maintenance Interim Work

River maintenance interim work typically is conducted at river maintenance sites where a primary solution is delayed and there are concerns caused by erosion, seepage, or flooding under certain flow scenarios. Interim work is a temporary stop gap measure, carried out in advance of immediate action to buy time until the primary solution can be constructed. Implementation of interim work can preclude the need for unanticipated work. Also, the planning timeframe for interim work is typically longer than for unanticipated work because the immediacy of the risk is less

Levee strengthening and riprap windrow methods (as discussed in section 3.6.1.1) typically are used to address interim work. For areas of difficult terrain or access restrictions, it may be necessary to clear and/or create a road to the project site. Vegetation clearing is described in more detail in section 3.6.4.1. Road creation may simply involve vegetation clearing but also could include bringing in fill material, both dirt and rock, to ensure a suitable base for driving heavy equipment to the project site.

3.6.2 River Maintenance Project Footprint During Implementation

The anticipated river maintenance project footprint, within the proposed action area, is based on an analysis of Reclamation's historical performance (see section 5.2, table 17). The average predicted river maintenance project footprint is about 12 acres, with a historical footprint range of about 1–90 acres. Of this acreage, the anticipated acreage in the wet is 5 acres, and the remaining 7 acres would occur in upland or riparian areas in the dry. Impacts in the wet, as defined for river maintenance, would consist of disturbance areas in the water at base flow levels that are directly connected (i.e., not separated by a physical barrier such as an earthen berm) to flowing river water. All other acreage is defined as occurring in the dry, including areas that may be inundated at high flows, but are dry at base flows. The approximate range of future anticipated impact acres in the wet for a single river maintenance project is between 0–65 acres, with an estimated average of 5 acres (table 6, shown later in this document). The estimated river maintenance project impact acreage in the dry ranges between 1–70 acres, with an estimated average of 7 acres (table 6).

The expected duration of river maintenance projects also is compiled from a summary of historical river maintenance work, with an average estimated duration of 6 months. The approximate range of river maintenance duration for a single project is expected to range between 1–16 months (table 7, shown later in this document).

Implementation techniques (section 3.6.4.5) used to implement a river maintenance project also may add additional impact acreage. Implementation techniques typically employed, along with other support activities for river maintenance sites are described in section 3.6.4. The river maintenance acreage impacts provided in table 14 include the impact acreage from the implementation techniques.

3.6.3 Distribution of Proposed River Maintenance Work

The uncertainty associated with predicting future channel changes makes it difficult to estimate reliably where future river maintenance actions would occur. This uncertainty, in alluvial rivers, is associated with the complex interactions among the flow, sediment supply, and channel characteristics (Einstein 1950). The interrelationship between the flow of water, the movement of sediment, and the variable character and composition of the channel boundaries over time and space contributes to the current channel morphology that we observe (Schumm 1977; Leopold et al. 1964). This channel morphology is constantly changing as rivers seek to balance the movement of sediment (sediment supply) with the energy available from the flow of water (sediment transport capacity) (Schumm et al. 1984; Biedenharn et al. 2008). Knowledge of current and expected MRG trends, coupled with an understanding of the relationships between sediment transport capacity and sediment supply and the history and effects of historical changes, both natural and anthropogenic, helps to reduce the uncertainty (Biedenharn et al. 2008). The continued process of predicting the future spatial distribution of sites and tracking where river maintenance work is done in the future may add additional reliability. However, uncertainty will always remain in any prediction of the spatial distribution of future river maintenance sites given the aforementioned factors. There is also additional uncertainty associated with specific reaches, like River Mile 78 to the Full Pool Elephant Butte Reservoir Level or Isleta Diversion Dam to Rio Puerco, because of the influence of controls or a higher uncertainty in the river's response to the drivers. Estimates provided in this section should be considered with these caveats in mind.

To estimate spatial distributions of river maintenance work, interim or unanticipated river maintenance work is considered to be encompassed by the spatial distribution of new river maintenance needs. The difference between interim/unanticipated work and new site work is the timing of the work, since interim and unanticipated work would be done at sites where time does not allow the development of a more comprehensive design. In many cases, interim and unanticipated work may be followed up with new site work, but this would not increase the number of sites; but, rather, the number of times implementation is performed at a site. The spatial distribution of new sites, therefore, would account for both interim and unanticipated work. There then remains the need to forecast the relative spatial distribution of two types of river maintenance needs: new river maintenance sites and adaptive management at previously completed river maintenance sites. The majority of the existing river maintenance sites are locations previously completed with ongoing maintenance needs, sites that are currently being implemented, or sites that could be implemented (e.g., expect to have compliance initiated or in place) before March 2013. Since these represent essentially completed river maintenance sites, for the purpose of this BA, the current existing and completed river maintenance sites are folded into the spatial distribution of adaptive management sites. This section provides the background for estimating a percent spatial distribution by reach. Section 3.6.5 uses these percent distribution estimates to provide approximate impact areas by reach. The percent distribution of both new and adaptive management river maintenance work was considered in a predictive, qualitative assessment of where work may occur given two different hydrologic scenarios. Each assessment, while not restricted to a defined time period, would best be described as covering a 10-year period. Extending the results beyond that timeframe is difficult due to the level of uncertainties associated with the geomorphic drivers and controls on the system. These assessments also assume that the drivers and controls would fluctuate within the range of historical observations. The effect of habitat restoration projects, climate change, land use, natural resource changes, or even the effects of implementing a reach-based river maintenance strategy were not considered in this analysis.

The distribution of geomorphic change in the river is correlated with the frequency, magnitude, and duration of flows, especially the spring runoff flows. Since historically it is the spring runoff flows that have created the need for river maintenance activities, two spring runoff scenarios were qualitatively "modeled." The two hydrologic scenarios considered were both high-flow scenarios, since historically geomorphic change on the MRG for base or lower flows has been slower. Trends such as channel narrowing and vegetation encroachment that develop at base or lower flows can set up conditions at local sites allowing infrastructure impacts to develop at high flows. Such channel evolution points to the continuing need for monitoring of trends. The two high-flow scenarios were based on two different decadal hydrographs that were considered to represent a reasonable range to estimate the spatial distribution of future river maintenance sites. The historical periods did not necessarily have high peak flow years (with their corresponding recurrence interval) for every year, but the sequence of events during these periods manifested itself in significant geomorphic changes when the peak flow years did occur. The first was a "normal" high spring runoff on the MRG. The distribution of peak flows and the magnitude of peak flows that occurred between 2000–2010 are an example of this decadal hydrograph. The qualitative peak flow for this scenario is in the 4,000- to 6,000-cubic-feet-per-second (cfs) flow range. The second was an "above normal" high spring runoff on the MRG. The distribution of peak flows and the magnitude of peak flows that occurred between 1980–1990 are an example of this decadal hydrograph, with multiple back to back peak flows. The qualitative peak flow for this scenario is in the 8,000- to 10,000-cfs flow range.

The relative or most likely distribution of new river maintenance sites potentially generated in each of the 10 river maintenance reaches was estimated in a collaborative effort with Reclamation staff from the Albuquerque and Denver offices. Existing or completed river maintenance priority sites were excluded from this analysis, except as how they might influence the location of new river maintenance sites. Engineering analysis and judgment were used to evaluate information from the 2010 aerial photography, historical channel alignments, geomorphic parameters (Makar and AuBuchon 2012), reach trends (listed in section 3.1), field observations, and indicator results of future conditions from the Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a). The anticipated trajectory of change for a reach and resulting potential effects were assessed considering the balance between sediment transport capacity and sediment supply; the difference between the current channel slope and the stable slope for the current conditions; planform changes such as narrowing, vegetation encroachment, and bend migration; bank height; bed and bank material size and stability; tributary effects; comparison of the calculated meander belt to river alignment and lateral constraints; base level control effects of fluctuations in Elephant Butte Reservoir pool elevation; and current channel proximity to infrastructure or other lateral constraints.

This information was integrated for each reach to estimate the relative number of new priority sites expected for both the "normal" and "above normal" flow scenarios. Table 4 lists the estimated distribution of new river maintenance sites by reach over a 10-year period for each scenario.

Table 4. Estimated Spatial Distributions of New River Maintenance Sites

Reach	Percent (%) Distribution "Normal" Scenario	Percent Distribution "Above Normal" Scenario
Velarde to Rio Chama	4%	6%
Rio Chama to Otowi Bridge	4%	8%
Cochiti Dam to Angostura Diversion Dam	15%	8%
Angostura Diversion Dam to Isleta Diversion Dam	15%	15%
Isleta Diversion Dam to Rio Puerco	8%	13%
Rio Puerco to San Acacia Diversion Dam	4%	4%
San Acacia Diversion Dam to Arroyo de las Cañas	4%	8%
Arroyo de las Cañas to San Antonio Bridge	12%	8%
San Antonio Bride to River Mile 78	15%	9%
River Mile 78 to Full Pool Elephant Butte Reservoir Level	19%	21%

The relative distribution of adaptive management sites was limited to where river maintenance work occurred in the recent past (after 2001), or where river maintenance currently has identified river maintenance priority sites. Maintenance risks to cross channel diversion structures and outfall locations, especially on the MRG between Velarde and Otowi, also were identified. The approach for the adaptive management analysis used engineering judgment to evaluate information from aerial photography, current reach trends, historical knowledge of natural and anthropogenic changes, river maintenance priority site details, and field observations.

The anticipated need for adaptive management at the site considered channel hydraulics, the balance between sediment transport capacity and sediment supply, bank stability from vegetation, and potential planform changes. Potential sites were identified as mentioned above and qualitatively rated, using professional judgment as a low, medium, or high risk for failure. A low rating represented a site where it was believed there would be negligible maintenance needed to provide protection at the site for either of the high flow scenarios. A medium rating was assigned to sites where some additional protection may be necessary to provide protection but would be minimal at the "normal" flow scenario but more likely on the "above normal" flow scenario. A high rating was assigned to sites where either of the flow scenarios likely would create the need for additional protection.

This information was integrated for each reach to estimate the relative distribution of adaptive management sites expected for both the "normal" and "above normal" flow scenarios. Because sites may be completed in the next 10 years that are not accounted for in looking at the current potential adaptive management need, some percent allocation of the new river maintenance site distribution also is needed. This would account for sites, currently unforeseen, that may be constructed in the next 10 years and for which an adaptive management need may then exist. In the last decade or so, the ratio of adaptive management projects to new river maintenance projects was 1 to 3.4. This ratio was used to obtain a percentage of new site distribution for which adaptive management would be needed. This percentage (30%), times the new river maintenance spatial distribution plus the remaining percentage (70%) times the adaptive management site distribution described above, was used to derive an estimated future spatial adaptive management site distribution. This was assumed to be a reasonable representation of the spatial distribution of adaptive management sites for this BA. The spatial distribution range by reach over a 10-year period is listed in table 5.

Table 5. Estimated Spatial Distributions of Adaptive Management River Maintenance Sites

Reach	Percent Distribution "Normal" Scenario	Percent Distribution "Above Normal" Scenario
Velarde to Rio Chama	10%	11%
Rio Chama to Otowi Bridge	6%	9%
Cochiti Dam to Angostura Diversion Dam	26%	28%
Angostura Diversion Dam to Isleta Diversion Dam	11%	14%
Isleta Diversion Dam to Rio Puerco	2%	4%
Rio Puerco to San Acacia Diversion Dam	3%	4%
San Acacia Diversion Dam to Arroyo de las Cañas	6%	9%
Arroyo de las Cañas to San Antonio Bridge	4%	2%
San Antonio Bride to River Mile 78	13%	9%
River Mile 78 to Full Pool Elephant Butte Reservoir Level	19%	10%

3.6.4 River Maintenance Support Activities

Several support activities are required to successfully and efficiently complete river maintenance actions. These activities, summarized in the following sections, provide information on data collection (section 3.6.4.4), access (section 3.6.4.1), materials essential for the completion of river maintenance actions (sections 3.6.4.2 and 3.6.4.3), and implementation techniques (section 3.6.4.5). The sections on material essential for the completion of river maintenance actions and information on data collection refer to information described in Section 5.2.4, River Maintenance Historical Baseline.

3.6.4.1 Access Roads and Dust Abatement

Part of the support process for undertaking river maintenance is providing safe access to the site. Typically, existing access routes are used; however, on a few occasions, a new route must be created to provide adequate access. It is anticipated that the average river maintenance site will impact approximately 3 acres for the temporary development of site access roads, with an estimated impact range of 0–18 acres. This impact acreage is for new or minimally used access road, like two track dirt roads, and does not account for the acreage impact on existing maintained roads. An estimated typical impact range for these new or minimally used access roads is a total clearing width of 20–30 feet per linear foot of access road. Work activities associated with creating new or improving minimally used access roads include clearing of vegetation (clearing and trimming), placing fill, grading, shaping, installing culvert pipes, graveling, and dust abatement.

Existing maintained access routes that are typically used include drain and irrigation access roads, the LFCC O&M roads, levee top roads, paved roads, and graded dirt roads. Appropriate access permission and weight limitations are obtained prior to use of these routes. Because these routes have varying maintenance cycles and some are not maintained for heavy construction equipment, there are varying levels of work required to provide safe access to the action area. The level or work required depends on the type of activity (e.g., access for data collection or project implementation) and the initial state of the access route. Activities associated with maintained access roads include clearing of vegetation (mowing and trimming), placing fill, repairing washouts, restoring drainage ditches, grading, shaping, installing culvert pipes, graveling, and dust abatement. The total range of horizontal clearing (mowing), on either side of the existing road, for a safe access road width would be approximately 5-10 feet on one side, for a total impact of around 10–20 feet wide per linear foot of access roads. The overhead height from the road surface to be cleared (trimming) varies with the type of equipment, with an estimated range of 10–20 feet per linear foot of access roads.

Vegetation clearing includes three distinct activities: clearing, mowing, and trimming; which may be used independently or in concert to ensure safe access. Clearing involves removing vegetation within the roadway with some amount of subsurface disturbance of the vegetation roots. This typically is undertaken with new or minimally used access routes. Mowing is the process of cutting vegetation in and to the sides of the access route to provide line-of-site and safe conditions for access, including increasing the reaction time to respond to wildlife and livestock within the access road corridor. Horizontal clearance provides the ability for equipment to drive without hitting and damaging equipment. This action is performed by mowing the vegetation, with the expectation that vegetation will return in a year or two. Trimming involves the selective cutting of tree branches in the vertical direction that restricts vehicular access along the route. Vegetation clearing for new and minimally used access roads involves all three actions; vegetation clearing on maintained access roads involves mowing and trimming.

Dust abatement is a support activity undertaken on those projects for which dust control is necessary for safety or public health reasons. Dust abatement typically occurs on access routes and in project areas during implementation when there is not sufficient moisture in the soil to inhibit the formation of dust. Dust abatement involves placing water onto an earthen surface. Water sources may include the Rio Grande, irrigation and drainage facilities, the LFCC, city water system, or wells. The Rio Grande will be used only when water is unavailable from other sources or is cost prohibitive. Water from an open water source typically is derived through using a pump setup similar to what is shown in figure 2. Pumping from the Rio Grande for river maintenance sites will use a 0.25-inch mesh screen at the opening to the intake hose to minimize entrainment of aquatic organisms. Typically, this would be done in areas that are clear of riparian vegetation and wetlands.

Figure 2. Typical water pump setup for dust abatement.

For areas where the depth to a level surface is too much for the pump setup, an intermediate area will be leveled to create a shelf to temporarily house the pump. Water typically is applied to the roadway using a truck-based water unit that allows for controlled and uniform spraying of the desired surface. Reclamation obtains the appropriate permits from the Office of the New Mexico State Engineer. Reclamation’s current permit (SP-04955) allows the use of 80 acre-feet per year. The quantity of water used under this permit is replenished through an associated leasing program. The expected water usage for the duration of a river maintenance project is about 4.5 acre-feet of water, with an estimated range of 2–65 acre-feet. Reclamation also ensures that applicable regulatory agencies, irrigation districts, landowners, and municipalities also are informed and that the appropriate permissions are obtained prior to procuring the water.

River maintenance activities between Velarde and Otowi would predominantly pull water for dust abatement from the Rio Grande. River maintenance projects within the vicinity of the LFCC (San Acacia Diversion Dam south) would predominantly pull water for dust abatement from the LFCC. It is anticipated that, for dust abatement purposes, river maintenance projects south of Cochiti Dam and north of the San Acacia Diversion Dam would use nearby irrigation and drainage facilities during irrigation season (March–October) and the Rio Grande from November–February. If it is not practicable (not enough flow volume, economically prohibitive, etc.) to use irrigation or drainage facilities during irrigation season, Reclamation would dig a sump in the proximate flood plain for pumping. Preparation of a sump involves digging a hole in the flood plain, away from the edge of the river. The sump would be located a minimum of 50 feet from the nearest open water in the river and excavated to about 30–35 feet square and approximately 3 feet below ground water level. The excavated material would be temporarily placed as a berm between the sump and the river. The sump is less effective for pumping water but would exclude fish eggs and larvae during the spawning season. The sump would be filled back in with the excavated material when pumping is terminated.

If water is pumped from the river for dust abatement purposes, it would likely be pumped at a rate between 1.8 and 2.2 cfs for 4–8 minutes to fill a water truck. This would be a minimal impact to river flows, equating to a decrease in flows of approximately 0.2% for river flows of 1,000 cfs and approximately 0.1% for river flows of 1,500 cfs for 4–8 minutes. A typical project may use four to six truck loads per day and on rare occasions, may use 18 truck loads per day.

3.6.4.2 Stockpiles and Storage Yards
Reclamation currently has ten established stockpile sites and two storage yards that support the MRG river maintenance needs within the defined action area. It is expected that these sites will continue to be used to support river maintenance into the foreseeable future in the same manner that they were historically described in section 5.2.4.2.

3.6.4.3 Borrow and Quarry Areas
Reclamation currently has one active borrow area (Valverde Pit) and one active quarry area (Red Canyon Mine) to support river maintenance within the defined action area. The locations are outside the river corridor. It is expected that these sites will continue to be used to support river maintenance into the foreseeable future in the same manner that they were historically described in section 5.2.4.3. The average river maintenance project disturbance for acquiring soil material from Valverde Pit is approximately 10 acres or less. It is expected that about 5–15% of river maintenance projects would require this material. The entire site acreage (18 acres) for Red Canyon Mine is expected to be used intermittently to support river maintenance, providing riprap material for river maintenance projects.

3.6.4.4 Data Collection
Data collection activities are required to support river maintenance actions and typically occur for two main purposes: specific projects and monitoring trends. It is expected that data collection will continue to be used to support river

maintenance into the foreseeable future in the same manner as historically described in section 5.2.4.4. Data collection methods may include hydrographic data collection (river cross sections, river profiles, sediment sampling [suspended sediment, bed load, and bed/bank material], gauge data, discharge and velocity measurements, etc.), surveying, subsurface investigations (borehole drilling, hand augers, test pits, geophysical tests, etc.), site visits (GPS points, site photos, bank line measurements, site observations, etc.), oblique aerial photography, and controlled aerial photography and remote sensing. Data collection efforts are conducted through the use of boats, ATVs, and pedestrian travel (walking on land and wading in the river). The majority of the data collection methods are nondestructive in nature, requiring very little disturbance and intrusion into the natural system. The main exceptions are the monitoring of rangelines, subsurface monitoring, and water or sediment sampling.

Subsurface monitoring requires disturbing the earth to collect samples or provide a soil characterization. These are done infrequently and typically on a site-by-site basis, with an average of less than 2 acres of disturbance in any given year. This acreage also includes impacts to allow access into an area for sampling, especially borehole drilling. Water and sediment sampling require a physical sample to provide a scientific characterization. Water samples, for water quality or suspended sediment analysis are typically 1-liter samples or less. The expected range of water sampling in any given year is 100–1,500 samples. Sediment samples range from approximately 1- to 100-pound samples, depending on the material being sampled. Coarser material, like gravels and cobbles, requires a larger sample size. Sediment samples may be collected from bars, island, bank side, or river beds. The expected range of sediment sampling in any given year is 50–500 samples.

Reclamation, on average, expects to clear and collect rangeline information for about 110 lines a year within the described action area, with an estimated range between 50–250 lines. Although the specific rangeline lengths vary throughout the MRG project area, a typical annual impact range for rangeline clearing is about 5–25 acres, with an average near 13 acres. With regard to rangeline clearing, the following best management practices (BMPs) would be followed.

1. Impacts to any desirable vegetation present would be minimized to the extent possible.

2. All vegetation clearing locations would be reviewed by Reclamation biologists for potential impacts prior to any brushing activity.

3. Vegetation clearing activities located near willow flycatcher habitat would not occur during the breeding season (April 15–August 15).

4. New transect endpoints would be moved upstream and downstream in the field to avoid impacts to riparian areas, including nesting sites or vegetation that is desirable to keep intact.

3.6.4.5 Typical River Maintenance Implementation Techniques

Reclamation has developed implementation techniques that are used during a river maintenance project to facilitate the field placement of river maintenance methods. Reclamation recognizes that these techniques may add additional impact acreage and has developed BMPs to minimize the impacts to the environment. Impacts of BMPs are described in the following sections by footprint area, duration used, and applicability (by percent) to river maintenance projects. Acreage impacts from these implementation techniques for river maintenance as a whole are described in section 3.6.5. These BMPs fall into two general categories. The first refers to general BMPs that are applicable to all river maintenance methods. The second are specific BMPs to a method category. These techniques have been utilized historically, as listed by project in tables 19–29 located in section 5.2.

General BMPs

1. *Management of local site water runoff* – Dirt berms, straw bales, silt fences, silt curtains or other appropriate material will be placed at strategic locations to manage water runoff in the river maintenance site in accordance with the NPDES storm water permit and plan.

2. *Minimize impact of hydrocarbons* – To minimize potential for spills into or contamination of aquatic habitat:

    a. Hydraulic lines will be checked each morning for leaks and periodically throughout each work day.

    b. All fueling will take place outside the active flood plain. Fuel will be stored onsite overnight but not near the river or any location where a spill could affect the river.

    c. All equipment will undergo high-pressure spray cleaning and inspection prior to initial operation in the project area.

    d. Equipment will be parked on predetermined locations on high ground, away from the project area overnight, on weekends, and holidays.

    e. Spill protection kits will be kept onsite, and operators will be trained in the correct deployment of the kits.

3. *Visual monitoring of water quality* – Reclamation visually monitors for water quality at and below areas of river work before and during the work day.

4. *Bird surveys* – Reclamation will avoid impacts to birds protected by the Migratory Bird Treaty Act (16 United States Code [U.S.C.] 703) by periodically conducting breeding bird surveys during the normal breeding and nesting season (approximately April 15–August 15) for most avian species.

5. *Vegetation clearing* – Vegetation clearing, required for each project site, will be completed after August 15 and before April 15. Any need for deviations from this work window would be considered on a project-specific basis in the tiered consultations for each river maintenance project at a later date. Work after April 1 would be accompanied by appropriate surveys. Reclamation coordinates monitoring and work activities with the Service, as appropriate, if bird nests are found. Nonnative vegetation at the project site will be mulched, burned, or removed offsite to an approved location. If a project requires removing native vegetation, where possible, this material will be removed or harvested at the appropriate season to use in revegetation at another location in the project area or at another project site. If it is not possible for native vegetation to be replanted, material will be mulched or temporarily stockpiled and used to create dead tree snags or brush piles in the project area upon completion.

6. *Clean material* – Riprap and other material to be placed in the water will be reasonably clean, to the extent possible. If there are large clumps of soil bigger than 1 foot within the material, those clumps will be set aside during the loading or placing operations.

7. *Implementation waste* – All project spoils and waste are disposed of offsite at approved locations. All river maintenance projects have a contract in place for the rental of porta potty facilities during the duration of the project.

8. *Water work warning* – To allow fish time to leave the area before implementation activities begins, the first piece of equipment (in the case of articulated trucks, dozers, front end loaders, scrapers, etc.) initially will enter the water slowly at the start of each work sequence in the river. If work involves placing rock or other material in the river channel from a platform, an object will be lowered and raised slowly into the water before placing the material. The object typically will be the bucket of an excavator, or similar piece of construction equipment. This will be done at the start of each work sequence in the river.

9. *Water work duration* – In water, work will be fairly continuous during work days, so that fish are less likely to return to the area once work has begun. River maintenance work in the river during spring runoff or monsoonal events greater than 1,000 cfs

will not be conducted unless a river diversion, described in the Method Category BMPs below, is constructed.

10. *Revegetation* – A variety of revegetation techniques, such as stem and pole cuttings (Los Lunas Plant Materials Center 2007b), long stem transplants (Los Lunas Plant Materials Center 2007a), upland planting with and without a polymer, zeolite, or similar compound to maximize soil water retention (Dreesen 2008), etc., may be used on river maintenance projects. Actual planting techniques may vary from site to site, using buckets, augers, stingers, water jets, etc., mounted on construction equipment to provide a hole for stem and pole plantings and long stem transplants. In some areas, a trench may be constructed to facilitate the placement of a significant number of plants, specifically stem and pole cuttings. Upland plantings like shrubs will use similar techniques. Seeding would be done using a native seed drill, where feasible, and spread with a protective covering to facilitate the gathering of moisture to the seeds.

11. *Herbicide/Chemical spraying* – The use of sprays may be necessary to control undesirable plant species around stockpile sites and storage yards and also to prevent the spread of invasive species in areas cleared for maintenance activities. It also may be necessary to spray or control for arthropods (spiders, ants, cockroaches, and crickets) that pose a safety problem or are a nuisance in buildings and facilities, birds (pigeons and swallows) roosting in building structures that are considered a nuisance, and mice that get into structures and/or equipment. Since the application of herbicides and chemical spraying is tightly controlled by State and Federal agencies, Reclamation will follow all State and Federal laws and regulations applicable to the application of herbicides, including guidelines described by White (2007). Herbicides or chemicals will not be directly applied to or near water unless they are labeled for aquatic use. Communication with the Service would occur prior to any application to sites with threatened or endangered wildlife species. An example of the processes that would be followed by Reclamation is *The* Socorro Field Division Integrated Pest Management Plan (Reclamation 2008).

Method Category BMPs

1. *River diversion* – This implementation technique places a berm across a portion or all of the river channel to re-divert the river flow away from the river maintenance site. This technique allows construction equipment to work in relatively still water, minimizing downstream turbidity concerns during maintenance activities. Typically, the diversions are temporary, lasting the majority of the project duration. The diversions, in a few cases, may be permanent where there is a need to relocate the river into a new channel location. The berm typically consists of fluvial sediment deposits available nearby; but depending on the location and desired duration, the

diversion also may include a more erosion resistant barrier, such as riprap and/or a geosynthetic/erosion control fabric. Material from the berm typically comes from the desired new channel location and is stockpiled in a suitable location to prepare for the diversion berm placement. The diversion berm is placed after the desired channel relocation had been completed and is placed from one side of the river to the other to minimize the formation of isolated pools. Typically, this is done with a dozer or other similar tracked construction equipment. A typical diversion berm would be sized to handle about a 2,000-cfs flow event, with an estimated 25-foot top width and a height that may vary from 6–12 feet. Using an assumed side slope of 2:1 (horizontal: vertical), this gives an estimated footprint range of 45–75 feet. The diversion berm length is dependent on the implementation area and whether existing features in the river channel, such as bars and islands, may be used to help isolate the project site from the main river flow. The expected diversion berm length range for river maintenance projects is approximately 100–500 feet. Temporary diversion berms are removed by breaching a section of the berm and then removing as much of the remaining material as possible. This requires some work in the wet and requires equipment to be in the river. It is expected that about 15–25% of river maintenance projects would require this technique. This technique may be used for methods within the Channel Modification, Bank Protection/Stabilization, Cross Channel Features, and Change Sediment Supply method categories.

2. *River reconnection* – This implementation technique provides the excavation to reconnect sections of the river. This technique minimizes the amount of time construction equipment needs to work in the wet. Excavation typically proceeds from downstream to upstream, allowing the existing separation to act as a diversion berm for the project. The last phase of this implementation technique is to remove this diversion berm. The majority of this technique is performed in the dry, with only the last removal phase requiring equipment to potentially be in the wet. Typically, this technique requires less than 1 week for work in the wet. It is expected that the range of river maintenance projects requiring this technique would be around 20–30%. This technique may be used for methods within the Channel Modification method category.

3. *Dewatering* –This implementation technique places dewatering wells in a hydraulically connected area of the project site to lower the water level. This technique is coupled with the river diversion technique to provide isolation of the project site from the main flow area. This technique minimizes the amount of time construction equipment needs to work in the wet. Water pumped from these wells is returned to the river downstream, with adequate protection at the return point to minimize surface erosion and the addition of sediment into the water column. Dewatering, where used, is needed for the majority of the project duration.

It is expected that the range of river maintenance projects requiring this technique would be about 1–5%. This technique may be used for methods within the Infrastructure Relocation or Setback, Channel Modification, Bank Protection/Stabilization, and Cross Channel Features method categories.

4. *River crossings* – This implementation technique facilitates moving construction materials and equipment from the side of the river opposite of the project site. If feasible, options to cross the river in the dry would be explored and acted upon first. This technique typically is employed where existing bridges have an inadequate load limitation for the construction equipment or where it is prohibitive (either from a cost or other compliance perspective) to transport material for a longer distance to the project site. This technique would be used only if no other feasible options exist. This technique minimizes disturbance acreage in the wet by defining a set path for the construction equipment to follow. Equipment moves slowly across the river and crossings are typically performed as part of an equipment caravan. River crossings also typically are grouped temporally to minimize the duration of river crossings. In areas with sufficient coarse bed material, the wetted river channel crossing will be placed, where possible, in a riffle. In areas with finer bed material, crossing platforms may be placed to facilitate the crossing of equipment, where possible, in a riffle. This is typically less of an issue with metal tracked equipment than with rubber tired equipment. Crossing platforms in areas of finer bed material may consist of areas hardened with larger sized bed material, like gravels or cobbles, or constructed mats that can be placed on the bed and driven over. Constructed mats likely would consist of cabled wooden beams but may also consist of cabled articulated, concrete blocks. Riffle crossings are preferable to the shortest distance across the river, which may have deeper water. Crossing locations also typically are located to minimize impacts of existing bank vegetation and to avoid areas of vertical slopes. The estimated range of river crossings for river maintenance projects may vary from 100–1,000 feet in length. The typical crossing width is around 20 feet. The range of river crossings for a single river maintenance project, where needed, may vary from about 2–600 trips for the duration of a project. It is expected that about 20–30% of river maintenance projects would require this technique. This technique may be used for methods within the channel modification, bank protection/stabilization, cross channel features, and change sediment supply method categories.

5. *Working platforms* – This implementation technique creates a ramp from the flood plain, typically along an upstream or downstream key or tie-back feature, to allow trucks loaded with rock to back down the ramp and dump the rock in the river or at the end of the ramp. Rock dumped from the trucks then is pushed and/or placed into the river channel to form the

lower portion of the rock layers required by the river maintenance method being implemented. As rock is placed into the river channel, larger rocks are placed and then positioned with the excavator bucket. Smaller rocks then are placed to fill voids between the larger rocks, forming a uniform layer of riprap. This lower portion of riprap forms a working platform approximately the same elevation as the flood plain and above the water surface elevation. Once working platforms are constructed, work would occur in the dry. This technique minimizes the amount of time construction equipment needs to work in the wet. This technique requires some level of work in the wet, but equipment does not work in the wet. This technique may be used for methods within the Channel Modification and Bank Protection/Stabilization method categories.

6. *Partial excavation of bank* – This implementation technique lowers the bank in the project area to allow construction equipment to reach the desired placement area and elevation without having the equipment actively in the river. If the soil is geotechnically unstable, material such as gravel, clay, or more cohesive soil may be added to this platform to provide stability. This technique requires removing vegetation in an area wide enough to support a platform for the equipment (about 30 feet) and to allow the excavation to be adequately sloped (this distance varied with depth but is typically the same, if not more than the desired platform width) to ensure compliance with Reclamation's safety standards (Reclamation 2009). Rock is placed from this excavated bank in a similar fashion as described for the working platform implementation technique. This technique minimizes the time construction equipment needs to work in the wet. This technique requires some level of work in the wet, but equipment does not work in the wet. This technique may be used for methods within the Channel Modification and Bank Protection/Stabilization method categories.

7. *Top of bank work* – This implementation technique would be used in areas where construction equipment has adequate working space. This means equipment is able to reach the desired placement area and elevation from the existing bank line without having the equipment actively in the river or needing to partially excavate the bank. This technique requires the removal of vegetation in an area wide enough to support a working area for the equipment (about 30 feet). Rock is placed from the bank line in a similar fashion as described for the working platform implementation technique. This technique minimizes the amount of time construction equipment needs to work in the wet. This technique requires some level of work in the wet, but equipment does not work in the wet. This technique may be used for methods within the Channel Modification and Bank Protection/Stabilization method categories.

8. *Amphibious construction* – This implementation technique requires construction equipment to operate in the river flows. Typically, this method is employed when minimal disturbance of the dry portion of the project area is desirable, such as to minimize the loss of bank vegetation. This technique minimizes the disturbance to bank riparian areas. Material placement or removal follows the descriptions listed for those techniques. This technique typically is used only for a portion of the project duration. For projects requiring long durations of river work, this technique is done in conjunction with placement of a river diversion, as described above, upstream of the project area, to minimize the work being performed in flowing water. This technique may be used in conjunction with a project that places a river diversion on both the upstream and downstream end of the project site. Placement of the downstream diversion berm would be done after seining to exclude the entrapment of fish. It is expected that the range of river maintenance projects requiring this technique would be around 10–15% with no river diversion, about 10–15% with an upstream river diversion, and less than 5% with both an upstream and downstream diversion. This technique may be used for methods within the Channel Modification, Bank Protection/Stabilization, Cross Channel Features, and Change Sediment Supply method categories.

9. *Material placement* – This technique involves the placement of construction material (typically rock or sediment) starting from the bank line at the upstream end of the project site and extending placement into the channel in the downstream direction. This technique helps prevent the formation of isolated pools or channels, which could trap fish or other species. If stranding occurs, Reclamation will coordinate with the Service to rescue stranded fish. This technique may be used for methods within the Channel Modification, Bank Protection/Stabilization, Cross Channel Features, and Change Sediment Supply method categories.

10. *Material removal* – This technique prescribes that materials, such as sediment, jetty jacks, woody debris, riprap, or other material, will be removed in a consistent manner to help avoid the formation of isolated pools or channels, which could trap fish or other species. If stranding occurs, Reclamation will coordinate with the Service to rescue stranded fish. This technique may be used for methods within the Channel Modification, Bank Protection/Stabilization, Cross Channel Features, and Change Sediment Supply method categories.

11. *Infrastructure relocation* – This technique provides for the setback of features like irrigation canals or drains, including the LFCC. This technique avoids, for the time being, needing to perform river maintenance activities in the river. This technique includes the following sequence of steps, which may not always follow the exact sequence of steps listed. Equipment consists of both metal tracked and rubber tired equipment.

Setback projects do not involve any work in the river. This technique may be used for methods within the Infrastructure Relocation or Setback and Conservation Easements method categories.

a. Seining the facility to be relocated and installing a fish exclusion barrier downstream from the project site.

b. Clearing vegetation in the project area.

c. Excavating new wetted channel (starting downstream and working upstream).

d. Placing new spoil berm (everywhere except across old channel).

e. Lining new wetted channel with erosion protection (if designed).

f. Connecting new wetted channel to old wetted channel.

g. Filling old wetted channel in abandoned channel sections (fill placed from upstream to downstream).

h. Connecting spoil berms.

i. Final grading of and placing road material on O&M roads, excavating bar ditches, and placing rainfall runoff erosion controls.

3.6.5 Summary of River Maintenance Proposed Actions

Tables 6–8 summarize the annual number of projects, project footprint acreage, and project duration for proposed river maintenance projects as previously described in Section 3.6, River Maintenance Project Details.

Table 6. Estimated River Maintenance Projects per Year (Number)

	Average	Minimum	Maximum
New Sites	2	1	4
Adaptive Management	1	0	3
Interim/Unanticipated Work	1	0	1
Total	**4**	**1**	**8**

Table 7. River Maintenance Project Area (Single Site) During Implementation (Acres)

	Average	Minimum	Maximum
Wet	5	0	65
Dry	7	1	70
Total	**12**	**1**	**[1]90**

[1] The total maximum acreage disturbed is less than the sum of the maximum disturbance area listed in the wet and dry rows. Based on past projects, large acreage disturbances occurred predominantly in the wet or in the dry, depending on project scope. The historical maximum was around 90 acres.

Table 8. Approximate River Maintenance Project Duration (Single Site in Months)

	Average	Minimum	Maximum
Single Site	**6**	**1**	**16**

Tables 6 and 7 were used with the following assumptions to estimate river maintenance footprint acreage for the proposed action. The total footprint impact acreage, applying these assumptions, is listed in table 8.

1. Ten-year analysis period.

2. Analysis period is used to estimate approximate numerical values to facilitate an ESA impact but is not expected to represent the desired ESA compliance period.

3. Approximately 2.5% of new sites for analysis period would be at the maximum acreage impact, both wet and total, as listed in table 7. This gives a wet impact area of 65 acres and dry impact area of 25 acres.

4. Approximately 2.5% of new sites for analysis period would be at the maximum acreage impact, both dry and total, as listed in table 7. This gives a wet impact area of 20 acres and dry impact area of 70 acres.

5. Approximately 50% of new sites for analysis period would be at the average acreage impacts stated in table 7.

6. Approximately 22.5% of new sites for analysis period will be one-half standard deviation above the average impact area. Based on the historical data, the standard deviation is 13 acres in the dry and 11 acres in the wet. This gives a wet area of 11 acres and a dry area of 14 acres.

7. Approximately 22.5% of new sites for analysis period will be one-half standard deviation below the average impact area. Based on the historical

data, the standard deviation is 13 acres in the dry and 11 acres in the wet. This gives a wet area of 0 acres and a dry area of 1 acre.

8. New site acreage has the potential to span the acreage range indicated in table 7.

9. Adaptive Management and Interim/Unanticipated Work are expected to be at or less than the average acreage listed in table 7. For this analysis, the acreage will be taken as the average.

10. Estimated number of projects for analysis period (10 years): numbers reflect 10 times the project estimates listed in table 6.

    a. Average scenario: 40 (20 new, 10 adaptive management, 10 interim/unanticipated work)

    b. Minimum scenario: 10 (10 new)

    c. Maximum scenario: 80 (40 new, 30 adaptive management, 10 interim/unanticipated work)

11. Decadal footprint acreage for new sites is calculated by taking the number of new sites in a given scenario (average, minimum, maximum), multiplying by the percent of new sites applicable and the acreage associated with one of those new sites (given in bullets above). This is repeated for each of the five scenarios listed above (bullet numbers 3–7) with all values summed together for the wet and dry cases, respectively. For example, the average scenario for wet, new sites would be the sum of the following calculations:

    a. 20 (bullet 10a)*.025*65 (percent and wet impact acreage from bullet 3) = 32.5 acres

    b. 20 (bullet 10a)*.025*20 (percent and wet impact acreage from bullet 4) = 10 acres

    c. 20 (bullet 10a)*.50*5 (percent from bullet 5, wet impact acreage from table 7) = 50 acres

    d. 20 (bullet 10a)*.225*11 (percent and wet impact acreage from bullet 6) = 49.5 acres

    e. 20 (bullet 10a)*.225*0 (percent and wet impact acreage from bullet 7) = 0

12. Decadal footprint for adaptive management and interim/unanticipated work is calculated by taking the number of sites in a given scenario

(average, minimum, maximum) from table 6 and multiplying by 10 (to adjust to the decadal time scale) and the average acreage listed in table 9 for the wet and dry impact areas..

Table 9. Approximate Decadal River Maintenance Footprint Acreage

	Average	Minimum	Maximum
Wet, New Sites	142	71	284
Dry, New Sites	185	93	370
Wet, Adaptive Management and Interim/Unanticipated Work	100	0	200
Dry, Adaptive Management and Interim/ Unanticipated Work	140	0	280
Total	**567**	**164**	**1,134**

Additional impact acreage also is incurred by river maintenance for various support activities, including implementation techniques. Table 10 lists additional annual or per project impacts from support activities, like data collection, water usage, and off river corridor areas, that are necessary for river maintenance but are indirectly related to specific project sites. Acreage for off river corridor areas and river maintenance data collection in table 11 is the sum of annual values listed in table 10. No multiplying factor is applied to extend this acreage over multiple years, since the area of disturbance is not changing from year to year.

Table 10. River Maintenance Support Activities Indirectly Related to Project Sites

	Average	Minimum	Maximum	Notes
Water Usage (acre-feet)				
Water Usage	4.5	2	65	Per project
Off River Corridor Areas (acres)				
Stockpile Sites/Storage Yards	67	67	75	Total area
Borrow Areas	10	1	114	5–15% projects utilize
Quarry Areas	18	0	18	
Data Collection				
Subsurface Monitoring (Acres)	2	0	2	Area/year
Water Samples		100	1,500	Number of 1 liter samples
Sediment Samples		1	100	Sample weight in pounds
Sediment Samples		50	500	Number
Rangelines (Lines)	110	50	250	Number lines per year
Rangelines (Acres)	13	5	25	Acres per year – 3-foot width

Table 11. Approximate Decadal River Maintenance Acreage for Indirect Project Support Activities

	Average	Minimum	Maximum
Wet, river corridor	2	1	4
Dry, river corridor	170	50	290
Dry, off river corridor	95	68	207
Total, river corridor	**172**	**51**	**294**
Total, off river corridor	**95**	**68**	**207**

Acreage for river corridor values in table 11, both wet and dry, is based on the summation of annual values listed in table 10 and then multiplied by the analysis period (10 years). Dry river corridor acreage is a summation of subsurface monitoring and rangeline acreage. Wet river corridor acreage estimates a disturbance area for water and sediment sampling. Assuming that each sample disturbs an area about 9 square feet (likely an overestimate since these are point samples), an estimate of the acreage is obtained by multiplying the number of sites by the area (converting from square feet to acres) and the number of years (10) in the analysis period. The average impact is calculated as the average of the minimum and maximum impacts. Impacts from water usage were not evaluated on an acreage basis since pumping would occur within the described river maintenance footprint acreage. The Rio Grande will be used only when water is unavailable from other sources or is cost prohibitive. If water is pumped from the river for dust abatement purposes, it likely would be pumped at a rate between 1.8 and 2.2 cfs for 4–8 minutes to fill a water truck. This would be a minimal impact to river flows, equating to a decrease in flows of approximately 0.2% for river flows of 1,000 cfs and approximately 0.1% for river flows of 1,500 cfs for 4–8 minutes. Additional impact acreage incurred by river maintenance for various support activities that are directly related to project site is listed in table 12. Estimated values in table 12 are per project. The total impact acreage for river maintenance for these activities is listed in table 13. For calculations in table 13, acreage in the dry is derived from access road impacts, while acreage in the wet is derived from impacts of implementation techniques, specifically river diversions and river crossings. Impacts from the implementation techniques of river reconnection are not included in table 13, since impacts are short in duration and would be covered under the delineated river maintenance footprint acreage from table 9. Impacts from the implementation technique of dewatering are also not included in table 13. On a spatial scale, these would fall within the river maintenance footprint acreage, and the volume of water removed would be returned to the river corridor within this footprint acreage.

Table 12. River Maintenance Support Activities Directly Related to Project Sites

	Average	Minimum	Maximum	Notes
Access Roads				
New/Minimally Used Access Roads	1	0	3	Only for new sites (acres)
Existing Roads – Width Cleared		10	20	Per foot of road (feet)
Existing Roads – Height Cleared		10	20	Per foot of road (feet)
Implementation Techniques				
River Diversions (Width in Feet)		45	75	
River Diversions (Length in Feet)		100	500	15–25% projects utilize
River Reconnection (Duration in Weeks)	1			20–30% projects utilize
Dewatering				1–5% projects utilize
River Crossings (Width in Feet)	20			
River Crossings (Length in Feet)	1000	100	600	
River Crossings (Number of Trips for Project)	300	2	600	20–30% projects utilize
River Work, No Diversions				10–15% projects utilize
River Work, with Upstream Diversion				10–15% projects utilize
River Work, Two Diversions				< 5% projects utilize

Table 13. Approximate Decadal River Maintenance Acreage for Direct Project Support Activities

	Average	Minimum	Maximum
Wet, New Sites	691	1	1,992
Dry, New Sites	133	216	865
Wet, Adaptive Management Work	345	0	1,494
Dry, Adaptive Management and Interim/Unanticipated Work	73	0	145
Total	**1,242**	**217**	**4,496**

Acreage from existing access roads was calculated by assuming each river maintenance project site would use approximately 2 miles of existing access roads. This length is then multiplied by the width ranges from table 12 for the minimum and maximum scenarios. The average of the minimum and maximum scenario was used to represent the average scenario. The height ranges from table 12 were not used because this would double count the estimated acreage impact. The access road impacts for a given project were estimated by summing the area for new access roads listed in table 12 and the calculated existing access road acreage as previously discussed. The per project access road acreage was then multiplied by the estimated number of projects for the three scenarios (average, minimum, and maximum). New access road acreage was assumed to apply only to new sites, while existing road acreage was applied to new, adaptive management, and interim/unanticipated sites.

Acreage from the river crossing and river diversion implementation techniques was calculated first on a project basis and then multiplied by a utilization percent and the estimated number of projects (adaptive management and new sites only) for the three scenarios (average, minimum, and maximum). These construction techniques are not applicable to the river maintenance methods described for interim/unanticipated projects. Utilization percent ranges are provided in table 12. The lower and upper values were assumed to represent the minimum and maximum scenarios, respectively, while the median of the range was used for the average scenario. Project acreage for river diversions is calculated from the length and width values provided in table 12. The average scenario acreage is the average of the minimum and maximum acreages. Project acreage for river crossings is calculated by multiplying the length, width, and the number of crossings for the average, minimum, and maximum scenarios.

To arrive at a total acreage impact for river maintenance (table 14), the acreage totals in tables 9, 11, and 13 were distributed to reaches using the predicted spatial distributions described and listed in section 3.5.3. Only the river corridor acreage (wet and dry) is utilized from table 11 and assumed to apply equally to the new site and adaptive management spatial distributions. The average, minimum, and maximum acreages were used with both flow scenarios, applying adaptive management spatial distributions to adaptive management work and the new site spatial distribution to new and interim/unanticipated work. This results in two sets of averages, minimum, and maximum acreages—one for the normal and one for the above normal flow scenario. To arrive at a single, estimated value by reach, it was assumed that the probability of occurrence for either flow scenario is the same, thus providing the ability to average each of the average, minimum, and maximum scenarios, respectively. Wet, dry, and total acreage per reach are listed in table 14.

Table 14. Approximate Decadal Acreage Distribution by Reach of River Maintenance Sites

Reach	Average	Minimum	Maximum
Velarde to Rio Chama, wet	84	3	283
Velarde to Rio Chama, dry	45	19	114
Velarde to Rio Chama, Total	**129**	**22**	**397**
Rio Chama to Otowi Bridge, wet	79	4	251
Rio Chama to Otowi Bridge, dry	43	21	117
Rio Chama to Otowi Bridge, Total	**122**	**25**	**368**
Cochiti Dam to Angostura Diversion Dam, wet	210	8	707
Cochiti Dam to Angostura Diversion Dam, dry	111	45	281
Cochiti Dam to Angostura Diversion Dam, Total	**321**	**53**	**988**
Angostura Diversion Dam to Isleta Diversion Dam, wet	186	11	568
Angostura Diversion Dam to Isleta Diversion Dam, dry	103	55	290
Angostura Diversion Dam to Isleta Diversion Dam, Total	**289**	**66**	**858**
Isleta Diversion Dam to Rio Puerco, wet	106	8	302
Isleta Diversion to Rio Puerco, dry	60	36	180
Isleta Diversion to Rio Puerco, Total	**166**	**44**	**482**
Rio Puerco to San Acacia Diversion Dam, wet	49	3	153
Rio Puerco to San Acacia Diversion Dam, dry	27	14	75
Rio Puerco to San Acacia Diversion Dam, Total	**76**	**17**	**228**
San Acacia Diversion Dam to Arroyo de las Cañas, wet	79	4	251
San Acacia Diversion Dam to Arroyo de las Cañas, dry	43	21	117
San Acacia Diversion Dam to Arroyo de las Cañas, Total	**122**	**25**	**368**
Arroyo de las Cañas to San Antonio Bridge, wet	96	7	275
Arroyo de las Cañas to San Antonio Bridge, dry	54	33	164
Arroyo de las Cañas to San Antonio Bridge, Total	**150**	**40**	**439**
San Antonio Bridge to River Mile 78, wet	155	9	478
San Antonio Bridge to River Mile 78, dry	85	45	240
San Antonio Bridge to River Mile 78, Total	**240**	**54**	**718**
River Mile 78 to Full Pool Elephant Butte Reservoir Level , wet	235	14	707
River Mile 78 to Full Pool Elephant Butte Reservoir Level, dry	130	71	373
River Mile 78 to Full Pool Elephant Butte Reservoir Level, Total	**365**	**85**	**1,080**
Total, wet	**1,279**	**71**	**3,975**
Total, dry	**701**	**360**	**1,951**

Tables 11 and 14 provide an estimate of the proposed river maintenance acreage impacts. While these acreages estimates are expected to be reasonable, the MRG is a dynamic river with complex adjustments that cannot be captured in an analysis such as this. It should be noted that approximate numerical values provided throughout section 3.6 are provided to allow for an evaluation of the programmatic effect of river maintenance. To provide the ability to achieve ESA programmatic coverage, the framework for these details is provided in this proposed action. While specific project locations are not described in this BA, estimates are made as to the general type, amount, and distribution of future maintenance needs. Reclamation expects that, while these numbers are used to derive a total river maintenance acreage, river maintenance would not be limited in the new BiOp by values—i.e., the number of sites in a given year and the future distribution of sites—but rather the resultant amount of programmatic take.

3.7 Other Reclamation MRG Project Proposed Maintenance Actions

There are other activities, distinct from river maintenance actions and river maintenance support activities, which help achieve Reclamation's authorization under the Flood Control Acts of 1948 and 1950. These activities, as described in the authorization, include irrigation and drainage rehabilitation (maintenance) and operation and maintenance on the Low Flow Conveyance Channel (Reclamation 1947; Reclamation 2003). Descriptions of these activities are provided in the following sections.

Throughout section 3.7 of this document, approximate numeric values are provided to evaluate the programmatic effect of other MRG Project maintenance. To provide the ability to achieve ESA programmatic coverage for Reclamation's maintenance on the LFCC and Project drains, the framework for these details is provided in this proposed action. While specific project locations are not described in this BA, the general type and annual amount of Reclamation's facility work is described. Reclamation expects that, while these numbers are used to derive a total other MRG Project maintenance acreage, Reclamation would not be limited in the new BiOp by values such as the number of sites in a given year and the future distribution of sites but rather the resultant amount of programmatic take.

The use of sprays may be necessary to control undesirable plant species on the slopes of the LFCC and Project drains and along access roadway to control aquatic vegetation in the LFCC and Project drains, and to prevent the spread of invasive species in areas cleared for maintenance activities. Since the application of herbicides and chemical spraying is tightly controlled by State and Federal agencies, Reclamation will follow all State and Federal laws and regulations applicable to applying herbicides, including guidelines described by White (2007). Herbicides or chemicals will not be directly applied to or near water unless they are labeled for aquatic use. Communication with the Service would occur prior to any application to sites with threatened or endangered wildlife species. An example of the processes that would be followed by Reclamation is The Socorro Field Division Integrated Pest Management Plan.

3.7.1 LFCC O&M Proposed Actions

Reclamation has continued to maintain the LFCC as it serves important functions, including improving drainage, supplementing irrigation water supply to MRGCD, and supplying water to the BDANWR for irrigation and other uses. Reclamation does not propose any operational changes on the LFCC from what is described as historical maintenance in the MRG Maintenance Baseline (section 5.3.1) with the exception of the distinction between safety mowing and vegetation control mowing. In many locations, the LFCC is the lowest point in the valley, and it provides drainage benefits for developed areas and protects infrastructure by collecting ephemeral storm runoff, subsurface drainage water, irrigation return flows, and seepage water from the river in some areas. The LFCC, as part of the existing baseline in the perched reaches of the river, can slightly increase seepage from the river and contribute to drying. The magnitude of this effect is likely small, especially as compared to the general infiltration of water into the river banks and bed. Furthermore, the seepage rates from the river into the LFCC appear to be largest when the river stage is high and smallest when the stage is low.

Maintenance of the LFCC includes, but is not limited to, the following activities. For all of these activities, the general BMPs described in section 3.6.4.5 are used.

- **Vegetation Control**: Vegetation control would occur within the area defined between the fence line west of the LFCC or from 20 feet west of the road (where applicable with no fence line) or the top of slope on the western edge of the LFCC channel (where no fence line or roads exist) and the eastern toe of slope on the levee between the river and the LFCC. Vegetation control, or mowing, can impact any vegetation along the 54-mile length of the LFCC. If mature cottonwoods are impacted, mitigation will take place at a ratio of 10 to 1. Vegetation control described herein is not intended for the Rio Grande channel. Mowing will typically be done with a radial blade mounted to a backhoe or other heavy equipment and can impact a maximum of 4,390 acres (670 average lateral feet between the western edge of mowing specified above to the furthest toe of slope on the eastern levee over the course of 54 LFCC miles) every 3 calendar years. In a given calendar year, only one-third of the total LFCC length will be mowed, an average of 1,472 acres per year. This one-third rotational mowing was a commitment from an earlier ESA, section 7 consultation (#2-22-96-1-069). The harvesting of vegetation is considered a subset of maintenance work done under the parameters and within the impact acreage of the described LFCC maintenance for vegetation control. Acres of impact of mowing within the LFCC corridor, related to supplemental pumping operations, also described in this BA, are not intended to be counted against the proposed mowing acreage totals outlined here. Mowing will not take place April 15–August 15 due to guidelines set forth in the Migratory Bird Treaty Act of 1918. The restrictions on mowing also benefit the willow flycatcher, because the LFCC provides a potential migration corridor. On occasion, circumstances may warrant an exception to these dates, in which case, Reclamation biologists will be consulted to ensure endangered or threatened avian species will not be disturbed as a result of mowing or other vegetative clearing.

- **Safety Mowing**: In addition to the vegetation control mowing, Reclamation will annually safety mow the eastern slope of the LFCC (between the LFCC channel and the road) from Neil Cup (RM 90) to Ft Craig (RM 64). The vegetation will be mowed level with the road to provide a safe line of sight. This will still provide some habitat as much as 9 feet high at the deepest part of the channel. Also, understory vegetation within existing cleared areas of the four outfall channels/pipeline areas (Neil Cup, North Boundary Bosque del Apache NWR, South Boundary Bosque del Apache NWR, and Ft Craig) will be cleared no greater than 100 feet away from the center of the drainage channel in the area between the river and the levee road. No native vegetation will be cleared which is either five inches or larger in diameter at its base or has obtained at least 20 feet in height. No mowing or clearing will take place between April 15 and August 15 due to guidelines set forth in the Migratory Bird Treaty Act of 1918.

- **Removal of Material**: This activity covers the removal of sediment, trash, and incidental vegetation such as gathered tumbleweeds and growing cattails from the LFCC channel to a degree that would allow adequate conveyance of water, which may be considered the original design geometry of the channel. This action would alleviate overbank flooding in areas of the LFCC where seasonal debris flows combine with large amounts of sediments in the LFCC. Proposed sediment removal can be either done with heavy excavating machinery or with vacuum-operated dredging. Reclamation proposes to remove sediment and any other material at any point along the LFCC between San Acacia Diversion Dam and Reclamation's established rangeline EB 34.5 (an approximate in-channel wetted area of 1,475 acres). Rangeline EB 34.5 is approximately 1.25 miles downstream from the San Marcial Power lines and about 0.8 mile upstream of the Elephant Butte Full Pool Reservoir Level. Sediment removal described herein is intended only in the LFCC and not the Rio Grande The area between Neil Cupp and rangeline EB 34.5 is the most frequent location where the highest amount of sedimentation in the channel and overbank flooding occurs (approximate wetted area of 920 acres). Sediment and other material removal will take place outside of the April 15–August 15 dates established in the Migratory Bird Treaty Act. When emergency work is necessary that requires the removal of sediment and/or other material from the channel, work may have to be done at any point in the calendar year. In this case, Reclamation biologists will be contacted to consult with the Service to ensure endangered or threatened avian species will not be disturbed as a result of this activity.

- **Road Maintenance:** Road maintenance on either side of the LFCC, including levee roads, will include routine grading, graveling, toe channel, and washout repairs. Maintenance of existing LFCC O&M roads and the spoil levee road is accomplished with typical heavy machinery including graders, backhoes, dump trucks, and hauling equipment. The total road acreage between the San Acacia Diversion Dam and the Full Pool Elephant Butte Reservoir Level is estimated to be 788 acres. On average, Reclamation does not intend to maintain any more than 20 lateral miles of road in any given year, typically done in the winter season. Due to fluctuations of funding and availability of personnel and equipment, Reclamation could conceivably do maintenance activities on the entire stretch between the San Acacia Diversion Dam and the Full Pool Elephant Butte Reservoir Level. While work typically is proposed to be done in the winter season, heavy precipitation during spring and summer may extensively damage any road and require immediate and extensive maintenance of the roads.

- **Structure Maintenance:** Maintenance of concrete bridges, siphons, and check structures in the LFCC corridor is only proposed as inspections dictate. Typical maintenance includes facility inspections, upkeep of metal work (painting, repairs, etc., to prevent rust), erosion protection along bridge abutments, vegetation clearing around structure, and adding material (soil and gravel) to maintain the slope of the roads approaching the structure. When foreseen maintenance is anticipated, work will be coordinated outside of the Migratory Bird Treaty Act dates of April 15–August 15. Concrete bridges on the LFCC include those at San Acacia Diversion Dam, River Mile 111, Highway 1280, Brown Arroyo, Mid-Bosque del Apache, South Boundary, Ft. Craig, and San Marcial. Routine maintenance also may include work on LFCC siphons at Brown Arroyo and the Socorro North Diversion Channel. As these structures are associated with the LFCC that contains water nearly year-round at any given point along its length, work will likely be done while water is present and under supervision of Reclamation biologists using techniques that will limit disturbance of water and sediments in the LFCC. Work done on these structures typically will be carried out with common heavy equipment such as backhoes, dump trucks, semitrucks, concrete trucks, and others.

3.7.2 Project Drain Proposed Actions

MRG project authorization provides for Reclamation (Reclamation 1947; Reclamation 2003) to perform irrigation and drain rehabilitation. The majority of these drains and irrigation facilities in the Middle Rio Grande are currently operated and maintained by MRGCD. There are a few drains, however, that MRGCD does not maintain and that benefit the State of New Mexico by increasing water salvage, thereby assisting the State in fulfilling the Rio Grande Compact requirements.

Irrigation drain improvements include routine maintenance of the following drains: Drain Unit 7, Drain Unit 7 Extension, San Francisco Drain, San Juan Drain, La Joya Drain, Escondida Drain, and Elmendorf Drain. Other drains or irrigation facilities may be added for routine maintenance as circumstances change. Maintenance activities include dredging, removing vegetation, mowing, placing riprap, maintaining earthwork on drain side slopes, repairing hydraulic structures, maintaining roads, repairing and installing culverts, repairing fences and gates, removing unauthorized crossings, and adjusting drain alignments. Drain maintenance work can occur at any time of year, although work in the vicinity of flycatcher nest sites is limited to portions of the year when the birds are not present. On occasion, circumstances may warrant an exception, in which case Reclamation biologists will be consulted to ensure endangered or threatened avian species will not be disturbed as a result of this activity. Additionally, areas near occupied Pecos sunflower habitats will be surveyed prior to any work. If Pecos sunflower are present within the needed maintenance area, Reclamation will work with the Service to avoid impact to the sunflower populations. The maintenance work typically involves the following construction equipment: mowers, excavators, scrapers, motor graders, loaders, water trucks, fuel trucks, bulldozers, and dump trucks.

Drain dimensions are shown below in table 15. The actual dimensions vary throughout the length of the drain; the dimensions stated in the table are typical of the portions of the drain that are largest.

Table 15. State Drain Dimensions

Drain	Length (feet)	Channel Width (feet)	Corridor Width (feet)
Drain Unit 7	30,000	50	150
Drain Unit 7 Extension	68,000	50	200
San Francisco	42,000	50	175
San Juan	87,000	50	150
La Joya	37,000	50	150
Escondida	18,000	40	120
Elmendorf	70,000	50	200

In a typical year, maintenance on these seven drains encompasses up to 50 acres of channel work in the wet and up to 200 acres of channel corridor (drain slope, O&M roads, spoil levees, and bar ditches) in the dry. The usual duration of maintenance is 2–4 months, but longer projects (up to 8 months) may occasionally be undertaken.

3.7.2.1 Typical Drain Maintenance Implementation Techniques

Typical implementation techniques used in drain maintenance are described below. The general BMPs described in section 3.6.4.5 are used on drain maintenance projects. Methods specific to drain maintenance are described below.

1. *Material Placement* – This technique involves placement of construction material (typically rock or earth material) along the sideslopes or invert of the drain, usually to fill in areas where erosion has occurred. The drain is thereby restored to its original geometry. Fill material is placed with an excavator or a loader.

2. *Dredging* – Sediment, aquatic vegetation, and other material is removed from the bottom of the drain and placed along the edge of the spoil levee or along the side of the maintenance road.

3. *Mowing* – Weeds and woody vegetation are removed from the sideslopes of the drain, usually by a mower that drives along the edge of the drain. Larger woody vegetation may need to be removed with chainsaws. Additional mowing can occur within the entire width of the drain corridor.

4. *Hydraulic Structure Repairs* – Damaged hydraulic structure (such as culverts, inverted siphons, and hydraulic gates) in the drains are repaired as necessary. This may involve welding, as well as removing and replacing sheet pile, concrete, and other components of the structure. Earthwork to expose portions of the structures for maintenance and then cover them afterward may be necessary. New structures occasionally may be installed, and existing structures may be removed.

5. *Fence and Gate Work* – Fences and vehicle gates within the drain corridor periodically will be repaired, removed, and installed.

6. *Removing Unauthorized Crossings* – Culverts and bridges installed by landowners without authorization from Reclamation may be removed if they are negatively affecting the function of the drain or causing an undesirable increase in public access.

7. *Alignment Adjustments* – If the drain has changed its alignment through erosional processes, the original alignment may be restored through excavation and fill placement. Additionally, short sections of the drain may be relocated within the existing right-of-way as necessary to improve functionality. Drain realignment is accomplished with excavators, bulldozers, scrapers, loaders, dump trucks, and water trucks.

8. *Road Maintenance* – Service roads along the drains are maintained to ensure public safety and continued access. Road maintenance includes grading, placing fill material, removing vegetation, and gravel surfacing. Repairs and installation of drainage culverts also occur. Road maintenance work is performed primarily using motor graders, water trucks, and mowers, with occasional use of loaders, bulldozers, excavators, and dump trucks.

3.7.3 Summary of Other Reclamation MRG Project Proposed Maintenance Actions

Table 16 summarizes the annual project footprint acreage for proposed other MRG Project maintenance activities as previously described above. Values in table 16 were calculated using the range of impact acreage described throughout section 3.7. The calculation methodology and input data are described below.

- Annual analysis period.

- Analysis period is used to estimate approximate numerical values for the purpose of facilitating an ESA impact but is not expected to represent the desired ESA compliance period.

- Minimum acreage was assumed to be 0 acres, since it is plausible that no maintenance work may be performed.

- For Project drains, the typical annual maintenance was assumed to represent the average scenario.

- For Project drains, the maximum scenario was represented by two times the typical annual maintenance. A 40-foot width for the LFCC.

- For structural maintenance on the LFCC, the following scenarios were assumed:
  - Average scenario: 1 site per year.
  - Maximum scenario: 2 sites per year.
  - Site impact area for structural maintenance: 1 acre.
  - Structural maintenance may occur in the wet or dry.

Table 16. Annual Approximate Other Reclamation MRG Project Maintenance Acreage

	Average	Minimum	Maximum
Wet, LFCC	149	0	1,477
Dry, LFCC	1,736	0	5,180
Wet, Project Drains	50	0	100
Dry, Project Drains	200	0	400
Total	**2,135**	**0**	**7,157**

3.8 The MRGCD Proposed Maintenance Actions

The MRGCD constructs, maintains, modifies, repairs, and replaces irrigation and flood control structures and facilities throughout its boundaries to ensure the proper functioning of these facilities for their intended purpose. Maintenance typically involves vegetation control or removal, debris removal, earthwork, sediment removal, concrete work, cleaning, painting, etc. Repair, replacement, and modification typically involve earthwork and concrete work. These

MRGCD activities may be divided into four broad categories as follows. These facilities may be located within, or external to, designated critical habitat for the species.

The use of sprays may be necessary to control undesirable plant species on the slopes of irrigation facilities, access roadways, right-of-ways, boundary fences, and facility buildings, to control aquatic vegetation in irrigation facilities and to prevent the spread of invasive species in areas cleared for maintenance activities. It also may be necessary to spray or control for arthropods (spiders, ants, cockroaches, and crickets) that pose a safety problem or are a nuisance in buildings and facilities—birds (pigeons and swallows) roosting in building structures that are considered a nuisance, mice that get into structures and/or equipment, and mammals, like muskrat or beavers that create plugs within irrigation facilities. Since the application of herbicides and chemical spraying is tightly controlled by State and Federal agencies, MRGCD will follow all State and Federal laws and regulations applicable to the application of herbicides, including guidelines described by White (2007).

3.8.1 Regular Ongoing Activities

These are regular functions associated with keeping the irrigation system operating properly. These activities occur regularly, and often with great frequency. They will be performed during every irrigation season; and; in many cases; they may happen daily. They typically are associated with particular locations within the MRGCD. Examples of these would be regulation of gates at diversions structures, debris and sediment removal at diversion structures, cleaning and painting of diversion structures, bank and access road maintenance at diversion structures, mowing/cleaning/debris removal from wasteway and drain outfalls, grading of access roads at wasteway and drain outfalls, grading and repair of levees, construction and maintenance of measurement stations on wasteway and drain outfalls, etc.

8.3.2 Regular as-Needed Activities

These are less regular functions associated with keeping the irrigation system operating properly. They are performed in response to observed changes over time, such as erosion happening along facilities. They may occur at anytime and anywhere throughout the MRGCD but generally are not expected to occur frequently. Examples of these would include levee repair, re-alignment of wasteway and drain outfall channels, replacement of diversion measurement or control structures, replacement of pipe crossings for access roads; etc.

8.3.3 Exceptional as-Needed Activities

These are occasional functions performed in response to an observed need or changed condition. These may occur at anytime and anywhere throughout the MRGCD but are not expected to occur frequently. Examples of these would include construction or modification of recreational facilities, construction of wildlife habitat features, construction of new outfall channels, abandonment of unused outfall channels, construction or modification of river control features, construction of access roads, etc.

8.3.4 Exceptional Emergency Activities

These are MRGCD maintenance or repair activities associated with extreme or unexpected conditions that pose an immediate risk to human life or property. These are expected to be very infrequent and, hopefully, never occur. However, should they occur, immediate response is required. Examples of these types of activities include fire suppression efforts in riparian areas, levee repair during flood events, and sediment removal when required to prevent catastrophic flooding or major damage to irrigation structures.

8.3.5 Best Management Practices

To minimize effects to species, MRGCD will designate certain geographic areas of the MRGCD where facility operation/maintenance/replacement/construction is expected to be frequent and ongoing and confine such activities to within those geographic boundaries.

Additionally, in geographic areas of the MRGCD where facility operation/maintenance/replacement/construction is expected to be less frequent, though still a part of regular operation, they will provide to the Service at the beginning of each year an inventory on the types of activities to be conducted in these areas. The MRGCD will conduct such activities in a manner designed to minimize impact to the species, will confine the footprint of activities within those geographic boundaries to the smallest practical extent, and will consider recommendations from the Service on how to best conduct these activities for the benefit of wildlife.

MRGCD will coordinate with Reclamation and the Service on exceptional activities occurring within the critical habitat to conduct these activities to produce the least possible impact to the species. When impacts are unavoidable, MRGCD will cooperate with Reclamation and the Service to provide appropriate mitigation measures.

When emergency actions are necessary to protect human life and property, MRGCD will coordinate with Reclamation and the Service as soon as is practical to minimize any potential impacts of these activities to the species.

4. Species Description, Federal Listing Status and Life History

The listed species in the project area, as well as their habitats, include the Rio Grande silvery minnow, southwestern willow flycatcher, and Pecos sunflower. Currently, the only recognized Pecos sunflower population within the action area is located specifically on the Rhodes property south of Arroyo de las Cañas or on land managed by the New Mexico Department of Game and Fish. Reclamation will work with the Service to avoid impact to the sunflower populations on any maintenance activities that would affect the Pecos sunflower population. The project area is on the outside periphery of the interior least tern's breeding range, and terns typically are not observed along the Middle Rio Grande. The analysis for this BA component focuses on the silvery minnow and the flycatcher and can be found in Chapter 4. Species Description, Federal Listing Status and Life History of the Joint Biological Assessment, Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico, Part I – Water Management.

5. MRG Maintenance Baseline

5.1 Introduction

Under section 7(a)(2) of the ESA, when considering the effects of the action on federally listed species, agencies are required to consider the environmental baseline. Regulations implementing the ESA (50 FR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions and other human activities in the action area; the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early section 7 consultation; and the impacts of State and private actions that are contemporaneous with the consultation in progress. The environmental baseline defines the current status of the species and its habitat in the action area as a point of comparison to assess the effects of the action now under consultation.

The environmental baseline describes a "snapshot in time" that includes the effects of all past and present Federal and non-Federal human activities. All existing facilities and all previous and current effects of operation and maintenance of the Project, as well as all ongoing, non-Federal irrigation activities and existing physical features such as diversion dams, storage dams, and flood control levees are part of the environmental baseline. The environmental baseline for the Part II – Maintenance is described in Chapter 5. Environmental Baseline of the Joint Biological Assessment, Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico, Part I – Water Management. Additional geomorphic and background supporting information also may be found in the Middle Rio Grande River Maintenance Plan, Part 1 Report (Reclamation 2007), the Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a), and the report titled Channel Conditions and Dynamics of the Middle Rio Grande by Makar and AuBuchon (2012).

This river maintenance baseline includes additional baseline information on river maintenance work between 2001–2013 (see section 5.2). This section was added to provide baseline information on the historical MRG work that has been done through river maintenance. The time period covers work that has been done (2001–2012) and work (2012–2013) that is expected to occur before the BiOp associated with this BA is issued. This historical perspective provides a picture of the current river maintenance practice that considers environmental resources along with the more traditional river maintenance concerns of channel sustainability, protection of riverside infrastructure and resources, and effective water delivery. Some of the methods that have been used for river maintenance projects are similar to those used for habitat restoration work on the MRG (see the

Habitat Restoration subsection of the Environmental Baseline for Reclamation's Water Management BA component). While the purposes for the work may have been different, these methods have a similar effect on the surrounding local morphology.

5.2 MRG River Maintenance Historical Perspective

5.2.1 MRG River Maintenance Priority Site Criteria

The decision process for identifying individual river maintenance projects and actions follows criteria developed to prioritize river maintenance needs (Smith 2005). A river maintenance priority site is defined as a site at which one or more of the following exist and could be addressed by river maintenance activities:

- The continuation of current trends of channel migration or morphology likely will result in damage to riverside infrastructure within the foreseeable future.
- Similar conditions have historically resulted in failures or near failures at flows less than the 2-year flood.
- Existing conditions cause significant economic loss, danger to public health and safety, or loss of effective water delivery.

Monitored sites are locations that have the potential of becoming future priority sites based on the above criteria. The river maintenance program has established a methodology for assessing existing sites and identifying new site locations. This methodology involves ongoing aerial monitoring and field reviews of river channel conditions. Factors incorporated into the priority site review methodology process include engineering analysis and judgments, river geomorphic considerations, environmental considerations, public involvement, political considerations, and economic considerations (i.e., the value of riverside infrastructure). The fundamental activities that support decisionmaking on channel maintenance needs are monitoring changes in the river channel morphology, evaluating channel stability, and modeling channel and levee capacity (Smith 2005). The priority site review methodology rates sites for maintenance implementation to determine their relative priority to each other as well as to document decisions that are made to undertake river maintenance activities for each site. Additional information about the decision process for determining river maintenance activities at priority and monitored sites can be found in the report, Middle Rio Grande River Maintenance Plan, Part 1 (Reclamation 2007).

5.2.2 MRG River Maintenance Sites: 2001–2012

A summary of acreage impacts and project durations for river maintenance projects between 2001–2012 is shown in table 17. The information in table 17 represents statistical river maintenance project information on a per project basis. These are projects that have been implemented or are in the process of being implemented. Information on the type and amount of river maintenance projects completed between 2001–2012 is shown in table 18. An illustration of the impact acreage (wet and dry) for river maintenance projects completed between 2001–2012 is shown in figure 3 as a percent exceedance curve. The projects are a combination of new project sites, completed sites where adaptive management was needed, and interim/ unanticipated work.

Table 17. 2001–2012 River Maintenance Acreage Impacts and Project Durations

	Access roads (acres)	Project impact area in the dry (acres)	Project impact in the wet (acres)	Total project impact (acres)	Project Duration (months)
Maximum	18	[1]68	[2]62	88	16
Minimum	0	0	0	1	1
Average	3	7	5	12	6

[1] See table 25 for information on the Bosque del Apache (BDA) Channel Widening river maintenance project.
[2] See table 22 for information on the Santa Ana Restoration Phase 1 river maintenance project.

Table 18. River Maintenance Projects by Year

Year	Adaptive Management Sites	New Project Sites	Interim or Emergency Work	Total
2000				0
2001		1		1
2002		2	1	3
2003		1		1
2004		1		1
2005	1	4	3	8
2006			1	1
2007	3	3	1	7
2008		4		4
2009	1	2		3
2010	1		1	2
2011		2	1	3
2012	1	2	1	4
Total	**7**	**22**	**9**	**38**
Average per year	**1**	**2**	**1**	**4**

Tables 19–26 provide an overview of river maintenance work between 2001–2012 separated by geomorphic reach (see section 2.1). The tables include the type of project (new, adaptive management, or interim/unanticipated), a brief description of the project purpose, the types of river maintenance methods used for the project, implementation techniques employed on the project, access road acreage, project impact acres in the wet and dry, project duration, habitat features created because of the project, and general observations about the project's success or failure.

Acreage for access roads describes the use area for new or minimally used access roads. Existing maintained roads that were used for access are not included in this total. The acres listed for wet and dry impact areas are the footprint or planview impact areas for the projects at low flows. The acreage listed was calculated by delineating the project footprints in geographic information system (GIS) using aerial photography during low-flow periods. The listed acreage does not account for specific river maintenance implementation techniques, such as river crossings.

Notations are added to the project duration to indicate if the project involved work in the river. Those projects requiring equipment to be working in the active portion of the river (either sitting in or touching) were designated with the notation "wet." Typically, this is the area of the river that is inundated at 1,000 cfs or less. Projects that could be implemented outside of the active portion of the river were designated as "dry." Where the channel was relocated such as the Santa Ana Project (table 23), the "wet" area included the relocated channel because these were the impacted, wetted channel areas, even though the relocation pilot channel was constructed prior to introducing river flows. Projects that did not span the entire river include only the portion of the affected channel at base flows, as designated using aerial photography (typically around 1,000 cfs). As noted in table 17, there are two projects that account for the maximum "wet" and "dry" acreages. The remaining 36 projects, in tables 19–26, have significantly less acreage. This can be seen graphically in figure 3 by noting that, between 2001–2012, less than 10% of the implemented river maintenance projects had a project footprint in the wet greater than 10 acres and in the dry greater than 20 acres. Figure 4 shows individual project footprint by reach, along with statistical trendlines (average and one-half the standard deviation). Project names for site numbers listed in figure 4 are provide in tables 19–26.

5.2.3 MRG River Maintenance Sites 2012–2013

Tables 27–29 provide an overview of anticipated river maintenance work from 2012–2013 separated by geomorphic reach (see section 2.1). The tables include the type of project (new or adaptive management) a brief description of the project purpose, the types of river maintenance methods used for the project, expected construction techniques employed on the project, access road acreage,

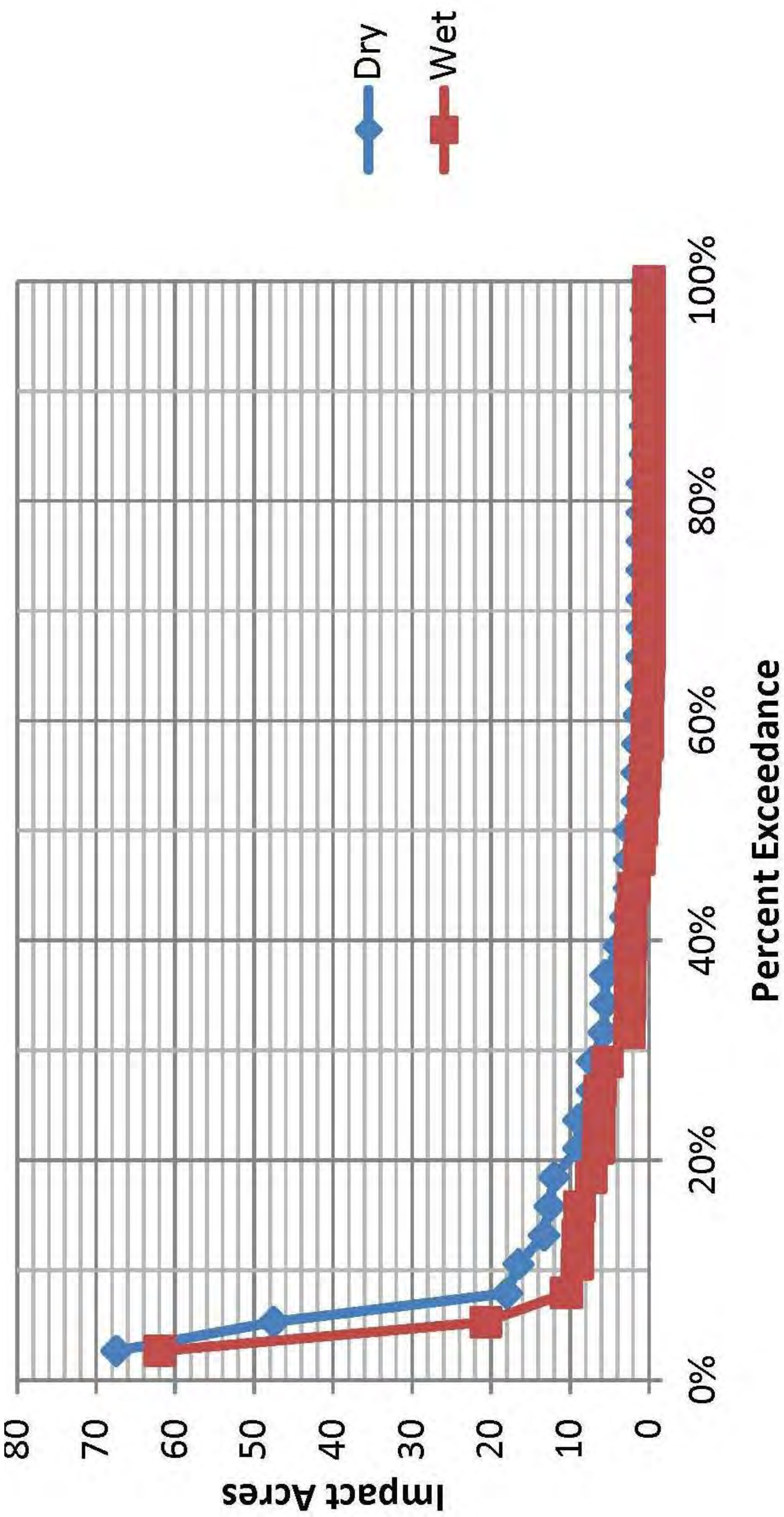

Figure 3. Percent exceedance curves for river maintenance project footprint impacts (2001–2012).

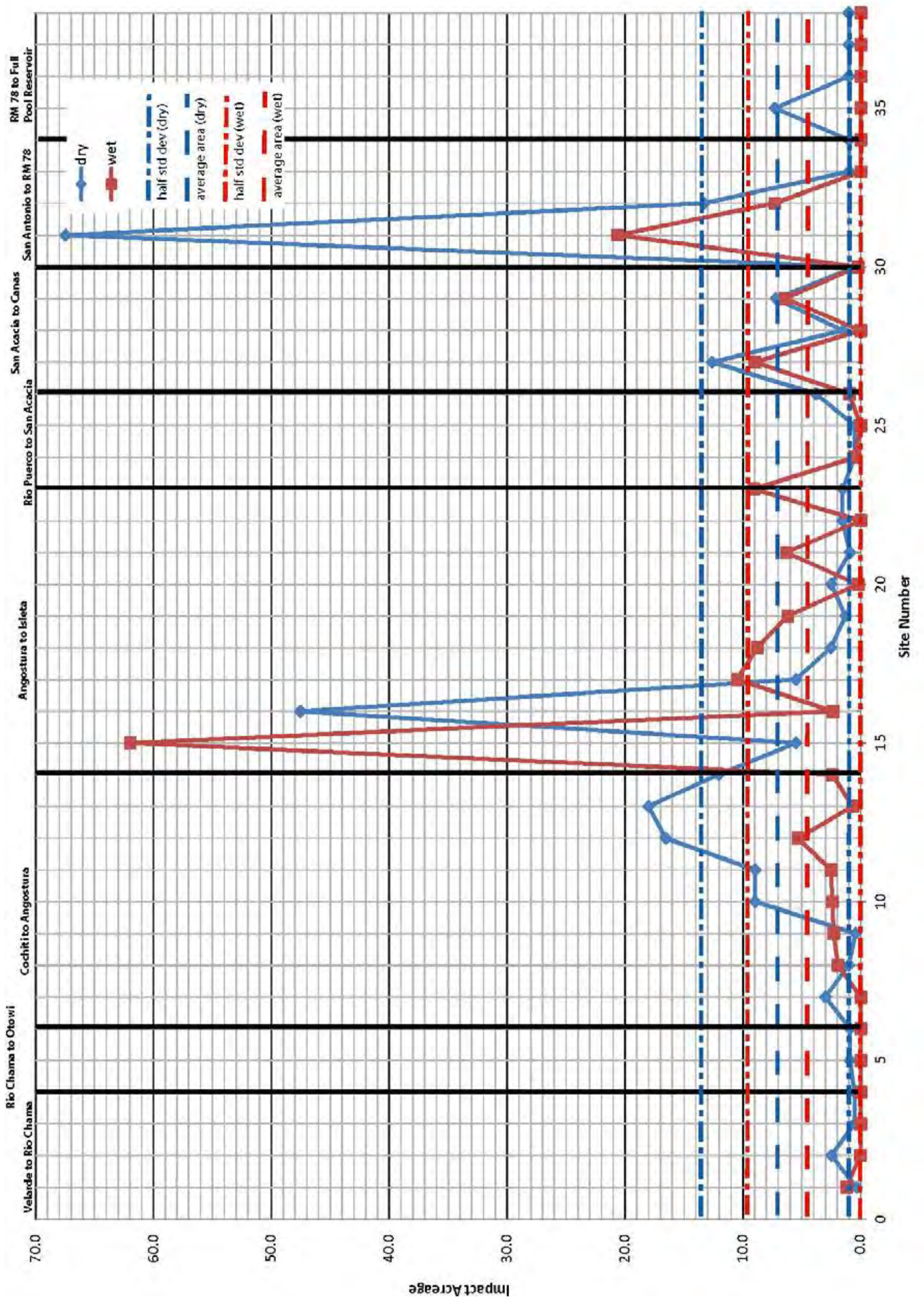

Figure 4. River maintenance project area by reach (2001–2012)

project impact acres in the wet and dry, project duration, habitat features created because of the project, and general observations about the project's success or failure. Sites designated as new sites in tables 27–29 are existing river maintenance priority site locations that potentially may be implemented (e.g., expect to have compliance initiated or in place) before March 2013.

Acreage for access roads describes the use area for new or minimally used access roads. Existing maintained roads that were used for access are not included in this total. The acres listed for wet and dry impact areas are the footprint or planview impact areas for the projects at low flows. The acreage listed was calculated by delineating the project footprints in GIS using aerial photography during low flow periods or estimated using typical project footprints. The listed acreage does not account for specific river maintenance implementation techniques, such as river crossings.

Notations are added to the project duration to indicate if the project may involve work in the river. Those projects requiring equipment to be working in the active portion of the river (either sitting in or touching) are designated with the notation "wet." Typically, this is the area of the river that is inundated at 1,000 cfs or less. Projects that may be implemented outside of the active portion of the river were designated as "dry."

5.2.4 River Maintenance Support Activities

There are several support activities for river maintenance actions that have required historic field activity to successfully and efficiently complete. These activities, summarized in the following sections, provide information on materials essential to complete river maintenance actions (sections 5.2.4.2 and 5.2.4.3) and data collection (section 5.2.6.4**).**

5.2.4.2 Stockpiles and Storage Yards

Reclamation currently has 10 established stockpile sites and two storage yards that support the MRG river maintenance needs within the defined action area. These areas are outside the flood plain of the MRG. The names and approximate acreage of these sites are listed in table 30. These sites were used on a recurring basis over the last 10 years, providing support through the storage of material, supplies, and equipment. This support activity, while useful for planned river maintenance actions, also allowed for a quicker response time in emergency situations.

Table 30. Reclamation Stockpile Sites and Storage Yards for the MRG

Stockpile Sites	Site Footprint (acres)
Velarde	5.8
Angostura	1.2
Bernalillo	13.9
Drain Unit 7	1.8
RM 111 east	6.8
RM 111 west	10.5
Escondida	2.7
San Antonio – Highway 380	1.9
Tiffany Junction	1.4
Ft. Craig	19.2
Storage Yards	
Socorro	1.1
San Marcial	1.0

Stockpile sites primarily were used to store material, typically riprap, for a particular river maintenance project or for unspecified future river maintenance work. These sites also were used on a temporary basis to store equipment and other supplies for a nearby river maintenance project. Storage yards were used for continuous storage of equipment and supplies, but were also be used to temporarily store material. Periodically, these sites required vegetation clearing (mowing and trimming), grading, graveling, drainage, and/or fencing. Appropriate land use and access permission and all necessary regulatory permits were obtained prior to initial use of the sites. All appropriate permissions and permits are kept current while these sites are being used.

5.2.4.3 Borrow and Quarry areas

Reclamation currently has one active borrow area (Valverde Pit) and one active quarry area (Red Canyon Mine) to support river maintenance within the defined action area. The locations are outside the river corridor. Valverde Pit is located near Fort Craig and is used to provide soil material for use in river maintenance actions. Soil is extracted through a process that initially requires vegetation clearing (clearing) of the area and then removing the soil for placing at river maintenance sites. The total acreage of the Valverde Pit is around 114 acres, but the typical historical river maintenance project disturbance for acquiring soil material from Valverde Pit was 10 acres or less.

The Red Canyon Mine is used to produce and process riprap of a required gradation for use on river maintenance actions. This quarry location is located in the Magdalena front range on Bureau of Land Management (BLM) land. Extracting riprap involves a process that first requires placing explosives to break apart the rock walls of the quarry to produce variable sized riprap. This is followed by processing the riprap to obtain the design gradation. If the blast was successful, the processing involved sieving the blasted material (typically done through using a grizzly) and loading the material onto transport trucks to take to a river maintenance project site or a riprap stockpile site. If the blast was not successful and produced larger than the desired size gradation, an additional processing step was necessary, requiring a rock breaker to break down the larger rock pieces. The total acreage of the Red Canyon Mine is around 18 acres. Appropriate land use and access permission and all necessary regulatory permits were obtained prior to initial use of these sites. All appropriate permissions and permits also are kept current while these sites are being used.

5.2.4.4 Data Collection

Data collection activities are required to support river maintenance actions and typically occur for two main purposes: specific projects and monitoring trends. Data collection for monitoring trends is necessary to assess changes in river bed elevation and slope, channel position, width, depth, flow velocity, sinuosity, channel capacity, and sediment. This data collection supports trend analysis and future projections of geomorphic trends, sediment transport, and hydraulic geometry; all of which are necessary and feed into river maintenance actions. Typically, these were a more spatially extensive, reach-based data collection effort. Similar types of data were collected for specific projects. Specific project data collection, however, was more localized and collected information that supported planning, design, environmental compliance, and maintenance/adaptive management implementation for specific river maintenance projects.

Rangelines were established along the river as part of Reclamation's hydrographic data collection program for river channel monitoring. These rangelines typically run perpendicular to the channel and allow collection of survey data within the channel and flood plain. For rangeline monitoring, these lines were cleared of vegetation (clearing and trimming by hand) to a width of about 3 feet to create a clear line-of-sight. Reclamation, on average, historically cleared and collected rangeline information for about 100 lines a year between 2001–2012 within the described action area. The range in any given year varied between 40–200 lines. Although the specific rangeline lengths vary throughout the MRG project area, a typical annual impact range for rangeline clearing was approximately 1–23 acres, with an average near 12 acres. A summary of the rangeline monitoring impact by reach and year is shown in tables 31 and 32.

Table 31. Historical River Maintenance Rangeline Monitoring (Number of Lines)

Reach	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average
Verlade to Rio Chama	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Chama to Otowi Bridge	0	0	0	0	9	0	0	10	6	0	0	0	2
Cochiti Dam to Angostura Diversion Dam	1	1	0	7	7	0	102	0	20	0	0	0	12
Angostura Diversion Dam to Isleta Diversion Dam	74	2	65	45	48	5	0	0	42	0	17	57	30
Isleta Diversion Dam to Rio Puerco	0	15	0	14	14	0	0	0	0	0	0	0	4
Rio Puerco to San Acacia Diversion Dam	0	0	0	0	0	8	0	0	0	0	0	15	2
San Acacia Diversion Dam to Arroyo de las Cañas	0	32	28	7	55	9	0	0	15	42	0	13	17
Arroyo de las Cañas to San Antonio Bridge	0	10	0	0	11	0	0	0	11	0	0	23	5
San Antonio Bridge to River Mile 78	5	16	3	5	17	0	5	11	10	0	0	18	8
River Mile 78 to Full Pool Elephant Butte Reservoir Level	10	44	30	49	35	27	64	47	0	0	0	0	26
Totals	**90**	**120**	**126**	**127**	**196**	**49**	**171**	**68**	**104**	**42**	**17**	**126**	**103**

Table 32. Historical River Maintenance Rangeline Monitoring (Acreage Impact)

Reach	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average
Verlade to Rio Chama	0	0	0	0	0	0	0	0	0	0	0	0	0
Rio Chama to Otowi Bridge	0	0	0	0	0.4	0	0	0.4	0.3	0	0	0	0.1
Cochiti Dam to Angostura Diversion Dam	0	0	0	0.3	0.3	0	3	0	0.6	0	0	0	0.4
Angostura Diversion Dam to Isleta Diversion Dam	3.6	0.3	3.2	2.3	2.4	0.2	0	0	1.9	0	0.8	2.7	1.5
Isleta Diversion Dam to Rio Puerco	0	1.2	0	1.1	0.9	0	0	0	0	0	0	0	0.3
Rio Puerco to San Acacia Diversion Dam	0	0	0	0	0	0.6	0	0	0	0	0	0.9	0.1
San Acacia Diversion Dam to Arroyo de las Cañas	0	4.5	1.4	0.2	4.4	0.7	0	0	1.4	4.1	0	1.1	1.5
Arroyo de las Cañas to San Antonio Bridge	0	0.5	0	0	0.6	0	0	0	0.6	0	0	1.6	0.3
San Antonio Bridge to River Mile 78	1.5	4.3	0.9	1.5	4.6	0	1.5	2.6	2.8	0	0	5.1	2.1
River Mile 78 to Full Pool Elephant Butte Reservoir Level	1.5	9.8	7.2	14.8	9	4.2	17.2	8.7	0	0	0	0	6
Totals	**7**	**21**	**13**	**20**	**23**	**6**	**22**	**12**	**8**	**4**	**1**	**11**	**12**

5.3 Other Reclamation MRG Project Historical Maintenance Actions

There are other activities, distinct from river maintenance actions and river maintenance support activities, which help achieve Reclamation's authorization under the Flood Control Acts of 1948 and 1950. These activities, as described in the authorization, include irrigation and drainage rehabilitation (maintenance) and operation and maintenance on the Low Flow Conveyance Channel (Reclamation 1947; Reclamation 2003). Descriptions of the historical maintenance activities are provided in the following sections.

5.3.1 LFCC O&M Historical Actions

The LFCC was constructed by Reclamation between 1951–1959. The LFCC was originally constructed at the site of the San Acacia Diversion Dam extending to the Narrows of Elephant Butte Reservoir, a distance of about 70 miles. The design capacity of the LFCC was originally 2,000 cfs. Its purpose was to reduce water loss due to evaporation and transpiration, by conveying Rio Grande water in a narrower, deeper channel, rather than in the wider and shallower floodway. The portion of the LFCC between the South Boundary of BDANWR and the Elephant Butte Reservoir was constructed between 1951 and 1953, with river diversions into this reach beginning in 1953 at San Marcial (Reclamation, 1953; Reclamation, 1956). The LFCC between San Acacia Dam and the South Boundary BDANWR was constructed between 1956 and 1959, with diversions from San Acacia Dam beginning in 1959 (Reclamation 1959). High reservoir levels at Elephant Butte in the 1980s resulted in the lower 8 miles of the LFCC filling in with sediment (Klumpp and Baird 1995), so that, by March 1985, the LFCC was forced out of operation (Reclamation 1985). While it was estimated that between 50,000–70,000 acre-feet of water were salvaged annually by operation of the LFCC (Reclamation 1985), diversions have been minimal after 1985. The only diversion has been into a 9-mile section of the LFCC (San Acacia Dam to the Escondida outfall), which also was used between 1997–2004 to conduct experimental operations (Tetra Tech 2004) to explore rehabilitation options for the LFCC (Reclamation 2001). It should be noted that between RM 111 and RM 114, the LFCC and the protecting spoil levee have been relocated. The relocated LFCC has a riprap-lined capacity of 500 cfs. It also should be noted that no LFCC operational changes from the status quo are proposed as part of this BA. Since the 1980s, the LFCC has functioned much in the same manner as an irrigation drain, collecting and transporting return flows.

Reclamation has continued to maintain the LFCC as it does serve important functions, including improving drainage, supplementing irrigation water supply to MRGCD, and supplying water to BDANWR for irrigation and other uses. In many locations, the LFCC is the lowest point in the valley, and it provides essential drainage benefits by collecting ephemeral storm runoff, subsurface drainage water, irrigation return flows, and in some areas seepage water from the river.

Historical maintenance of the LFCC has included the following activities: vegetation control, removal of material, road maintenance, and structure maintenance. For all of these activities, equipment that was used on a given job underwent high-pressure spray cleaning and inspection prior to initial operation in the project area. Spill kits are kept with equipment to contain accidental releases of fluid.

5.3.2 Project Drain Past Actions

MRG project authorization provides for Reclamation (Reclamation 1947; Reclamation 2003) to perform irrigation and drain rehabilitation. The majority of drains and irrigation facilities in the MRG are currently operated and maintained by MRGCD. There are a few drains, however, that MRGCD does not maintain and that benefit the State of New Mexico by increasing water salvage, thereby assisting the State in fulfilling the Rio Grande Compact requirements. Historically, Reclamation usually performed drain maintenance under a cost-sharing arrangement in which Reclamation provided engineering, environmental compliance, and inspection, while a partner agency (most commonly NMISC) contributed funding to cover the cost of Reclamation's construction crew and equipment. Until about the year 2000, Reclamation regularly maintained the Project drains using the implementation techniques described in section 3.7.2.1. During 2000–2010, drain maintenance was greatly reduced because of a sharp decrease in available funding from cooperating agencies. Activities during that period consisted of occasional mowing, road maintenance, and repairs to heavily damaged portions of the drains as necessary to maintain public safety.

5.4 The MRGCD MRG Historical Maintenance Actions

The MRGCD operates and maintains the diversion dams and its irrigation, drainage, recreation, and flood control facilities pursuant to the 1923 New Mexico Conservancy Act, Federal Congressional Acts of 1928 and 1935, Office of the State Engineer Permit No. 0620, and the 1951 Contract[1] to meet the following requirements:

[1] Contract No. 178r-423, dated September 24, 1951, between MRGCD and Reclamation for Rehabilitation and Construction of Project Works and Repayment of Reimbursable Construction Costs.

- Diverting and delivering water stored in and released from El Vado Dam and native Rio Grande water to satisfy the needs of private property holders and users of water within its service area and newly reclaimed lands of the Six Middle Rio Grande Pueblos.

- Diverting and delivering native Rio Grande water for lands of the six MRG pueblos with federally designated prior and paramount water rights, through the Cochiti Heading and Angostura and Isleta Diversion Dams, as requested by the Bureau of Indian Affairs designated engineer.

- Re-diverting the MRGCD's contracted San Juan-Chama Project water, which, by statute, cannot be used by the United States for ESA purposes, except upon a willing seller basis.

- Maintaining the diversion dams.

- Operating and maintaining the MRGCD water delivery system (canals/drains) throughout the MRG.

The MRGCD constructs, maintains, modifies, repairs, and replaces irrigation and flood control structures and facilities throughout its boundaries to ensure the proper functioning of these facilities for their intended purpose. Maintenance typically has involved vegetation control or removal, debris removal, earthwork, sediment removal, concrete work, cleaning, painting, etc. Repair, replacement and modification involved earthwork and concrete work. These MRGCD activities may be divided into four broad categories as follows.

The MRGCD is comprised of four divisions: Cochiti, Albuquerque, Belen, and Socorro, serving irrigated lands from Cochiti Dam to the BDANWR. The full description of MRGCD facilities is located in the Joint Biological Assessment, Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico, Part I – Water Management.

5.4.1 MRGCD Measurement

The MRGCD operates and maintains a system of measurement stations, or gauges, along its canal and drain network. These gauges report water level and rates of flow back to the MRGCD on 30-minute intervals. Data is collected via FM radio telemetry, processed (converted from raw electronic signals to usable values and units), then through file transfer protocol, sent to three separate computer databases (MRGCD, Reclamation, and USACE). This entire process occurs automatically, 24 hours a day, throughout the year.

At present, the MRGCD provides data from about 130 sites on its system, and continues to add several new locations each year. In addition, the MRGCD collects, processes, and distributes data from Reclamation's RGSM pumping sites in Socorro County, and the NMISC's RGSM Atrisco habitat project in Bernalillo

County. The MRGCD maintains its gauge network through periodic calibration measurements using a variety of flow measuring devices. In addition, MRGCD makes flow measurements in ungauged areas of its system, and along the Rio Grande itself.

6. Analysis of Effects of Proposed Actions

The discussion of effects in this document is divided into several sections. The first section is general in nature and attempts to broadly define the effects of river maintenance (sections 6.1 and 6.2) large scale, reach basis. The effects of implementing river maintenance strategies on a reach level are discussed in section 6.1. The implementation of river maintenance strategies (see section 3.2) within a reach is designed to address observed trends resulting from underlying physical processes. The general geomorphic effects of implementing the six river maintenance strategies are described in section 6.1.1 and in the Strategy Effects Attachment, with additional reach implementation geomorphic details provided in section 6.1.2. The biological effects on the silvery minnow and the flycatcher are described in section 6.1.3 based on the known channel dynamics (observed geomorphic channel trends) and the anticipated channel responses to strategy implementation. The anticipated channel responses and conditions may change if the observed geomorphic trends adjust in the future.

River maintenance sites, within the context of this BA, may be implemented as individual sites within the context of a reach-based river maintenance strategy or as a priority site project. These two types of activities may use the same river maintenance methods (section 3.3) and implementation techniques (section 3.6.4.5). They also both rely on a variety of river maintenance support activities (section 3.6.4). The implementation of individual river maintenance site projects have localized effects on geomorphology, endangered species, and habitat conditions. The localized geomorphic effects of river maintenance methods are described in section 6.2. Biological effects for both silvery minnow and flycatchers are estimated based on the amount and distribution of work that has been performed historically or as predicted by the river maintenance Proposed Action. These effects are analyzed throughout section 6.2. Currently, the only recognized Pecos sunflower population within the defined river maintenance action area is on the Rhodes property south of Arroyo de las Cañas. Reclamation will work with the Service to avoid impact to the sunflower populations on any river maintenance activities that would affect the Pecos sunflower population.

Section 6.3 describes the biological and geomorphic effects from operation and maintenance of Project drains and the LFCC. Pecos sunflower effects are analyzed in conjunction with the Project drain near La Joya State Wildlife Area (section 6.3.2.3), since there are currently no known Pecos sunflower populations within the flood plain of the Rio Grande.

MRGCD MRG maintenance proposed actions are analyzed within section 6.4. A summary of all MRG biological effects is provided in section 6.5.

6.1 River Maintenance Strategy Effects on Geomorphology

Strategies define reach-scale management approaches to meet the river maintenance goals (see section 3.2). Strategies were assessed by geomorphic suitability for a reach. More information on the identification of the most likely strategies by reach and the rationale for why strategies are listed as unsuitable in a reach can be found in the Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide (Reclamation 2012a). Only strategies that were determined to be suitable are described in this document. The following general (section 6.1.1) and reach by reach (section 6.1.2) sections describe the effects of suitable river maintenance strategies given the current geomorphic reach trends. Estimated effects on silvery minnow and flycatcher habitat due to implementation of these strategies are outlined in table 34 (later in this chapter). It should be noted that future geomorphic trends of the river could change, and the selection of suitable strategies could be different.

General strategy effects on the geomorphology are described based on the expected outcome of the change in the balance between sediment transport capacity and sediment supply within a reach after implementation. Where the probable magnitude of an effect is known, it is stated. The balance between sediment transport capacity and sediment supply affects channel processes and strongly influences geomorphic changes and conditions. An imbalance between sediment transport capacity and sediment supply is the key cause of most channel and flood plain adjustments. These are evinced in the river through changes in trends. Complementary strategies are those that create similar changes, relative to the balance between sediment transport capacity and sediment supply and could be used to address the same trends. Complementary strategies are also strategies that more likely are to be used in combination. Effects of multiple strategy combinations are not described explicitly, but the use of combinations from complementary strategies generally would produce the same described effects.

Reaches where sediment transport capacity is generally less than sediment supply are the reaches between Arroyo de las Cañas and the Full Pool Elephant Butte Reservoir Level. For these reaches, changes and corresponding strategies that bring sediment transport capacity closer to sediment supply include the following:[2]

- Increase sediment transport capacity – Reconstruct/Maintain Channel Capacity

[2] Promote Elevation Stability is an applicable strategy for aggrading reaches; however, the actual implementation would be through the complementary strategies of Reconstruct/Maintain Channel Capacity, Increase Available Area to the River, Manage Sediment, and/or Promote Alignment Stability.

- Reduce sediment supply – Manage Sediment

- Allow channel realignment to lower bed elevation – Increase Available Area to the River, Promote Alignment Stability

- Initiate channel realignment to lower elevation – Reconstruct/Maintain Channel Capacity

- Levee strengthening/raising to allow realignment – Reconstruct/Maintain Channel Capacity

Reaches where sediment transport capacity is generally greater than sediment supply are the reaches between Velarde and Otowi Bridge and those between Cochiti Dam and Arroyo de las Cañas. For these reaches, changes and corresponding strategies that bring sediment transport capacity closer to sediment supply include the following:

- Increase length of channel – Promote Alignment Stability, Increase Available Area to the River

- Limit bank erosion – Promote Alignment Stability

- Add sediment supply – Manage Sediment

- Reduce sediment transport capacity of high flows – Rehabilitate Channel and Flood Plain

- Reduce or control future channel bed lowering – Promote Elevation Stability

Additional information may be needed to better define a future specific project and its effects based upon its planned methods, changes in reach trends, and necessary monitoring or adaptive management. As needed, additional details tiered off this programmatic river maintenance BA would be developed and coordinated with the Service.

6.1.1 General River Maintenance Geomorphic Effects

The geomorphic effects of implementing river maintenance strategies (section 3.2 provides a description of the strategies) are estimated through an analysis of the expected physical changes in a reach as a result of strategy implementation. While the effects are described qualitatively, several tools were developed and used to aid in understanding the observed river trends and the strategy implementation effects on these trends on a reach by reach basis. These tools include mobile and fixed bed modeling (Varyu et al. 2011), meander belt analysis (Varyu et al. 2011), and the MRG planform evolution model (Massong et al.

2010). Results from these tools helped provide a qualitative understanding of the existing conditions and expected trajectory of reach adjustments without maintenance. The results also provided a means to assign and evaluate the effects of strategy implementation through a comparison of modeled physical results, such as:

- Bed elevation changes
- Flood plain inundation changes
- Bed material size changes
- Channel length changes
- Lateral mobility and its relationship with existing lateral constraints
- Sediment load changes
- Geomorphic planform changes

For the reaches between Cochiti Dam and the Full Pool Elephant Butte Reservoir Level; the modeling and analysis tool results (Varyu et al. 2011; Reclamation, 2012a) were coupled with professional judgment and individual reach geomorphology to provide a qualitative description of the reach implementation effects of river maintenance strategies. This description relies on the different methods that will be used to implement reach based strategies (see River Maintenance Methods Attachment for a description of localized methods associated with a strategy and a description of those methods and their general effects). The general method effects are combined with strategy characteristics to create a general description of the effects. These general effects are then refined to reach specific effects (see section 6.1.2). Professional judgment and an understanding of reach trends were used to provide a qualitative description of the geomorphic effects of river maintenance strategies for the 10 reaches (see figure 1 for a map of the reach designations).

The Strategy Effects Attachment provides a list, by strategy, of the general reach trends addressed (not in order of importance), the effects of implementing each strategy in a reach, additional potential complementary strategies that address the same trends, and effects of strategy implementation in downstream and upstream reaches. Strategies address observed geomorphic trends through four primary actions: stopping, reducing, reversing, and making it a non-issue. The first three are straightforward actions related to the strategy effect on the trend, given the current understanding on the MRG. The last one allows the trend to continue, while reducing the need for river maintenance. The Strategy Effects Attachment provides a further separation of strategy implementation and ensuing effects by the relationship between sediment transport capacity and sediment supply, since the outcomes are different if the sediment transport capacity is greater than or less than the sediment supply. If a strategy only lists one condition, such as sediment transport capacity less than sediment supply for Reconstruct and Maintain Channel Capacity, then it can be assumed that this strategy is not applicable to the other condition—in this case, sediment transport capacity greater than sediment supply. These are general reach effects; so there may be uncertainty in the magnitude of physical effect. Where the probable magnitude of physical effect is known, it is so stated.

6.1.2 Most Likely Geomorphic Strategy Effects by Reach

Strategies that address geomorphic trends and, thus, the most likely to be implemented, have been identified in the Proposed Action by reach (section 3.2.8). Where potential future geomorphic trends influence the effect of strategy implementation, they are included in each reach effects description. These potential future trends are identified through analysis of patterns of historical changes, results from Varyu et al. (2011), the planform evolution model (Massong et al. 2010), and professional judgment. Where the probable magnitude of an effect is known, it is stated. Where the magnitude of effect is uncertain, more information is needed to estimate it; and this would be developed, tiered off this programmatic river maintenance BA and coordinated with the Service.

Some general strategy effects are included in each reach strategy effects discussion where they are of much more significance than other general effects. It is possible that future geomorphic trends of the river could change so that additional strategies would become suitable for a reach or the converse. The 10 reaches are identified and shown graphically in section 2.1. Estimated effects on silvery minnow and flycatcher habitat due to implementation of these strategies in each reach are outlined in tables 33 and 34 (shown later in this document).

6.1.2.1 Velarde to Rio Chama – RM 285 to 272

6.1.2.1.2 Trends

This reach has been influenced by historical activity and past variability in the sediment and hydrology, resulting in a flood plain that is absent or disconnected from the main channel. Historical conditions and current hydrological inputs upstream and sediment inputs from tributaries located within this reach have contributed to the following trends currently observed in this reach.

- Channel narrowing
- Vegetation encroachment
- Bank erosion
- Coarsening of bed material
- Increased channel uniformity

6.1.2.1.2 Promote Elevation Stability

This strategy is not suitable because there is a low potential for new degradation.

6.1.2.1.3 Promote Alignment Stability

Reach Effects.—In general, this strategy addresses the trend of bank erosion through stabilizing the banks and preventing additional bank erosion that would harm or endanger public infrastructure, such as roads, irrigation facilities, houses, etc. The narrowness of this reach and the proximity of infrastructure likely would result in using a more direct and permanent bank protection method. Field observations show bank erosion opposite some new tributary deposits in the main channel. The general effects of this method implemented on a reach scale, for the sediment transport capacity greater than sediment supply case, are described in table 1 of the Strategy Effects Attachment. However, in this reach, the contribution of sediment from bank erosion is relatively low due to low rates of bend migration. Therefore, a decrease in sediment supply is not expected to have significant effects. This strategy likely would keep the current conditions for sinuosity and overbanking wetted area. Within this reach, there are numerous diversion dams that provide vertical stabilization through their effect on the river bed elevation. These diversion dams, to some extent, also help provide local alignment stability as, typically, bank protection is provided in close vicinity to the dams, upstream and downstream, to prevent flanking.

Upstream and Downstream Effects.—The general upstream and downstream effects are listed in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The sediment supply for the Rio Chama to Otowi Bridge Reach may decrease slightly, but effects are expected to be minimal. For the reach north of Velarde, it is not expected that there would be significant upstream effects.

6.1.2.1.4 Reconstruct and Maintain Channel Capacity

This strategy is not suitable because a reach-wide loss of channel capacity is not expected.

6.1.2.1.5 Increase Available Area to the River

Reach Effects.—In general, this strategy addresses channel narrowing, increased bank height, and bank erosion. The effects of this strategy would be to increase the degrees of freedom on the channel, as described in table 4 of the Strategy Effects Attachment, for the sediment transport capacity greater than sediment supply case. This allows for the possibility to increase the sinuosity and the overbanking wetted area by allowing the channel to migrate and create new depositional features. This channel evolution also may create the opportunity to decrease high-flow energy that may have the effect of decreasing the bed material size.

Upstream and Downstream Effects.—Implementing this strategy will provide additional area for future river migration but will not immediately affect current downstream or upstream reach trends. The general upstream and downstream effects are listed in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The Rio Chama to Otowi Bridge Reach has an existing sediment transport capacity greater than sediment supply, so the Rio Chama to Otowi Bridge Reach effects of adding sediment are expected to be minimal. If the bank material is fine enough, this strategy may deliver increased sediment load to the Cochiti Reservoir pool and have an impact on its serviceable life. Over time as the channel evolves nearer to dynamic equilibrium, downstream sediment supply from lateral migration will decrease. It is expected that the reduced sediment supply in the long term would have minimal effect on channel trends in the Rio Chama to Otowi Bridge Reach. The reach north of Velarde is outside the MRG Project area and is strongly influenced by geologic controls. Actions in the Velarde to Rio Chama Reach are expected to have minimal upstream effects for the reach north of Velarde. Near the upstream boundary on the Velarde to Rio Chama Reach is the Los Chico and La Canova Diversion Dam that effects bed elevation and river location and further limits effects upon the reach north of Velarde.

6.1.2.1.6 Rehabilitate Channel and Flood Plain

Reach Effects.—In general, this strategy addresses channel narrowing, vegetation encroachment, and bank erosion. This strategy would increase the overbanking wetted area and may increase the channel sinuosity. This strategy also would have the general effects as described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This strategy also may increase the braiding within the reach; however, sediment loads are relatively small, so this effect is expected to be minimal. In the long term, this strategy may reduce the high-flow sediment transport capacity.

Upstream and Downstream Effects.—Implementing this strategy has the general upstream and downstream effects as described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The Rio Chama to Otowi Bridge Reach has an existing transport capacity greater than supply, so the downstream reach effects of the addition of sediment are expected to be minimal. If the bank material is fine enough, this strategy may deliver increased sediment load to the Cochiti Reservoir pool, although the increase to the sediment supply is expected to be small and would be expected to have only a minimal impact on the reservoir pool's serviceable life. Some methods also may induce sediment deposition, thereby decreasing downstream sediment supply. In comparison to downstream reaches, the sediment load in the Velarde to Rio Chama Reach is small, so this effect on the Rio Chama to Otowi Bridge Reach is expected to be minimal. It is expected that the reduced sediment supply in the long term would have minimal effect on channel trends in the Rio Chama to Otowi Bridge Reach. The upstream reach effects, for the reach north of Velarde, are expected to be minimal as described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case.

6.1.2.1.7 Manage Sediment

This strategy is not suitable because there is no reach-wide imbalance in sediment transport capacity and sediment supply.

6.1.2.2 Rio Chama to Otowi Bridge – RM 272 to 257.6

6.1.2.2.1 Trends

This reach has been influenced by historical activity and past variability in the sediment and hydrology, resulting in the abandonment of a once relatively large flood plain. Historical conditions and current hydrological inputs upstream and sediment inputs from tributaries located within this reach have contributed to the following trends currently observed in this reach:

- Channel narrowing
- Vegetation encroachment
- Bank erosion
- Coarsening of bed material
- Increased channel uniformity

6.1.2.2.2 Promote Elevation Stability

Reach Effects.—In general, this strategy addresses the trends of increased bank height, incision or channel bed degradation, and coarsening of bed material. The general effects of this method implemented on a reach scale are described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This strategy is expected to maintain the status quo for overbanking wetted area and sinuosity, although there is the possibility, depending on how the strategy is implemented, to increase the overbanking wetted area. The additional overbanking wetted area likely would be small since the expected maximum increase in bed elevation through implementing this strategy is 1–2 feet. In local areas where the bed elevation is below riparian vegetation root zone, additional bank erosion could occur. This strategy would help stabilize the bed in the reach and also may provide additional bank stability.

Upstream and Downstream Effects.—The general upstream and downstream effects are as described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This strategy may decrease the amount of sediment available for the river to transport through the White Rock Canyon Reach. This reach has considerable geological controls, and effects from this strategy in the White Rock Canyon Reach are expected to be minimal. For the Velarde to Rio Chama Reach, this strategy may temporarily lower the sediment transport capacity. The bed through the Velarde to Rio Chama Reach may rise slightly, especially on the southern end of the downstream reach, with a minimal change expected in channel morphology and flood plain connectivity. The effects of implementing this strategy in the Rio Chama to Otowi Bridge Reach also may have the effect of a short-term bed material fining in the Velarde to Rio Chama Reach.

6.1.2.2.3 Promote Alignment Stability

Reach Effects.—In general, this strategy addresses the trend of bank erosion through stabilizing the banks and preventing additional bank erosion that would harm or endanger public infrastructure, such as roads, irrigation facilities, recreational facilities, houses, etc. The general effects of this method implemented on a reach scale are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. However in this reach, due to low rates of lateral migration, the contribution of sediment from bank erosion is relatively low. Therefore, a decrease in sediment supply from bank erosion is not expected to have significant reach geomorphic effects. This strategy likely would keep the status quo for sinuosity and overbanking wetted area.

Upstream and Downstream Effects.—The general upstream and downstream effects are as described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The sediment supply to the White Rock Canyon Reach may decrease slightly, but effects are expected to be minimal due to the extent of geological controls in the downstream reach. The downstream reach also feeds into the Cochiti Reservoir pool, so implementing this strategy in the Rio Chama to Otowi Bridge Reach may help to lengthen the reservoir life. It is not expected that there would be significant effects in the Velarde to Rio Chama Reach.

6.1.2.2.4 Reconstruct and Maintain Channel Capacity

This strategy is not suitable because a significant loss of channel capacity is not expected.

6.1.2.2.5 Increase Available Area to the River

Reach Effects.—In general, this strategy addresses channel narrowing, bank erosion, and increased channel uniformity. The effects of this strategy would be to increase the degrees of freedom on the channel, as described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This allows for the possibility to increase the sinuosity and the overbanking wetted area by allowing the channel to migrate and create new depositional features. This channel evolution also may create the opportunity to decrease high-flow energy that may have the effect of decreasing the bed material size.

Upstream and Downstream Effects.—Implementing this strategy will provide additional area for future river migration but will not immediately affect current downstream or upstream reach trends. The general upstream and downstream effects are as described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This strategy may increase the sediment supply to the White Rock Canyon Reach as the channel lengthens. Over time and as the channel evolves nearer to dynamic equilibrium, the White Rock Canyon Reach sediment supply from lateral migration will decrease. The White Rock Canyon Reach has significant geological controls, so minimal changes are expected in the local channel morphology or flood plain connectivity. If the bank material is fine enough, this strategy may deliver a small increase in sediment load to the Cochiti Reservoir pool and would be expected to have only a minimal impact on the reservoir pool's serviceable life. In the Velarde to Rio Chama Reach, there is the potential for this strategy to decrease the channel sediment transport capacity and/or reduce bed material size. However, this potential change is expected to have minimal effect on the channel morphology and flood plain connectivity.

6.1.2.2.6 Rehabilitate Channel and Flood Plain

Reach Effects.—In general, this strategy addresses channel narrowing, vegetation encroachment, bank erosion, and increased channel uniformity. This strategy would increase the overbanking wetted area and may increase the channel sinuosity. This strategy also would have the general effects as described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This strategy may increase the braiding within the reach. In the long term, this strategy may reduce the high-flow sediment transport capacity, but the effect may diminish as sediment deposits in the overbank area and the high-flow channel becomes narrower.

Upstream and Downstream Effects.—Implementing this strategy has the general upstream and downstream effects as described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The White Rock Canyon Reach has significant geological controls, so the downstream reach effects of the addition of sediment are expected to be minimal. The White Rock Canyon Reach geology has a controlling effect on the bed elevation and river location of this reach. If the bank material is fine enough, this strategy may deliver increased sediment load to the Cochiti Reservoir pool, although the increase to the sediment supply is expected to be small and would be expected to have only a minimal impact on the reservoir pool's serviceable life. Some methods also may induce sediment deposition, thereby decreasing the White Rock Canyon Reach sediment supply. In comparison to downstream reaches, the sediment load in the Rio Chama to Otowi Bridge Reach is small, so the effect in the White Rock Canyon Reach is expected to be minimal. In the Velarde to Rio Chama Reach, the potential exists for this strategy to decrease the channel sediment transport capacity and/or reduce the bed material size; however, the effect upon channel morphology and flood plain connectivity is expected to be minimal.

6.1.2.2.7 Manage Sediment

This strategy is not suitable because there is not a reach-wide imbalance in sediment transport capacity and sediment supply.

6.1.2.3 Cochiti Dam to Angostura Diversion Dam – RM 232.6 to 209.7

6.1.2.3.1 Trends

This reach is strongly influenced by the storage of the upstream sediment load in Cochiti Reservoir and coarse bed material sizes that have retarded incision. Bed material sediment load primarily is supplied from ephemeral tributaries and bank erosion. These sand and gravel sediments are mobilized at higher flows and deposit downstream on active mid-channel and bank-attached bars. The historical flood plain is hydrologically disconnected from the river because of reduced flow peaks and channel bed lowering. Cochiti Dam will continue to reduce sediment supply and high-flow peaks in this reach. Channel evolution due to the closure of Cochiti Dam has largely already occurred, and the following trends likely are to continue but potentially at a slower rate than other reaches of the Middle Rio Grande:

- Channel narrowing
- Vegetation encroachment
- Bank erosion
- Coarsening of bed material
- Increased channel uniformity

6.1.2.3.2 Promote Elevation Stability

Reach Effects.—The general effects of this method implemented on a reach scale are as described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This strategy addresses the trends of incision or channel bed degradation, increased bank height, and coarsening of bed material. This strategy indirectly addresses bank erosion where a potential exists for the degradation to continue below the riparian root zone. Some additional channel incision and bed degradation is possible in this reach. This reach has well defined riffles that would become the boundary of sediment deposition above the structure. Sinuosity would remain the same as prior to implementation. Bed material size downstream from these structures is not expected to change. Sand and fine gravel sizes from ephemeral tributaries could initially deposit upstream, but this effect is expected to be temporary.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The upstream reach is White Rock Canyon, and Cochiti Dam prevents any upstream effects from occurring. Sediment delivery to downstream reaches would remain about the same as pre-implementation. Bed material size would not be affected downstream from this reach.

6.1.2.3.3 Promote Alignment Stability

Reach Effects.—In general, Promote Alignment Stability addresses the trend of bank erosion through stabilizing the banks where riverside infrastructure is threatened. The general effects of this method implemented on a reach scale are as described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The width of the flood plain bounded by infrastructure in this reach is relatively narrow in some locations (Varyu et al. 2011), increasing the number of potential sites where this strategy could be implemented. The amount of sediment available from bank erosion would be reduced, with potential local bed coarsening. Where split channels exist, the effect of locally increasing the velocity and depth should affect the channel where implemented, while the other channel would not be influenced. Within the reach, upstream alignment stability can help downstream infrastructure by reducing the approach angle, influencing the channel alignment.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Strategies implemented in this reach do not impact upstream reaches since the reach is bounded on the north by Cochiti Dam. Angostura Diversion Dam confines the lateral location of this reach's downstream boundary. Reduced bank erosion could cause a relatively small decrease in sediment supply to the Angostura Diversion Dam to Isleta Diversion Dam Reach.

6.1.2.3.4 Reconstruct and Maintain Channel Capacity

This strategy is not suitable because a significant loss of channel capacity is not expected.

6.1.2.3.5 Increase Available Area to the River

Reach Effects.—This strategy addresses the trends of channel narrowing, coarsening of bed material, bank erosion, and increased channel uniformity. The general effects of this method implemented on a reach scale area as described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Lateral confinement is significant in this reach (Varyu et al. 2011), and providing an opportunity for the river to migrate across a larger portion of its historical flood plain would allow current geomorphology processes to continue. The small amount of channel lengthening and sinuosity increase would reduce or eliminate the potential for additional bed degradation. The size of active mid-channel and bank-attached bars throughout this reach likely would increase creating more depositional surfaces that are hydrologically connected.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Strategies implemented in this reach does not impact upstream reaches since the reach is bounded on the north by Cochiti Dam. The downstream reach boundary is Angostura Diversion Dam that controls the bed elevation and river location. A small increase in channel length may result in a lower amount of sediment being supplied to the Angostura Diversion Dam to Isleta Diversion Dam Reach downstream when the slope decreases and the size of mid-channel and bank-attached bars increases.

6.1.2.3.6 Rehabilitate Channel and Flood Plain

Reach Effects.—This strategy addresses channel narrowing, vegetation encroachment, coarsening of bed material, and increased channel uniformity. The general effects of this method implemented on a reach scale are as described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Excavation of the channel banks to establish a lower elevation flood plain decreases the flow required to go over bank, and increases high-flow channel width. High-flow sediment transport rates would be reduced. Vegetation re-growth would occur in the excavated flood plain and on the channel margins. Due to the relatively low suspended sediment load from ephemeral tributaries and bank erosion, inundating flows will have a lower tendency to deposit sediment in the excavated flood plain than in reaches with greater load.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Strategies implemented in this reach do not impact upstream reaches since the reach is bounded on the north by Cochiti Dam. Angostura Diversion Dam exercises influence on the bed elevation and river location at the downstream reach boundary. The reduction in high-flow sediment transport capacity and overbank sediment deposition could result in a lower sediment supply to the Angostura Diversion Dam to Isleta Diversion Dam Reach. This could result in bed lowering downstream from existing grade control structures resulting in decreased flood plain connectivity and a narrower, deeper channel. These effects are expected to be small because the Jemez River supplies sediment to the Rio Grande about 1.5 miles downstream from the diversion dam, and the sediment supply in this reach is relatively smaller than downstream reaches.

6.1.2.3.7 Manage Sediment

This strategy is not suitable because modeling results show both aggradation and degradation within the reach.

6.1.2.4 Angostura Diversion Dam to Isleta Diversion Dam – RM 209.7 to 169.3

6.1.2.4.1 Trends

The storage of sediment and reduced high-flow peaks as a result of Cochiti Reservoir continue to affect this reach. Sediment is supplied to the reach by the Jemez River and other tributaries. Operational changes to increase sediment pass through at Jemez Canyon Dam will reduce the imbalance in sediment transport capacity and load, but the effects are not well known at this time. The reach is also affected by the formation of mid-channel and bank-attached bars that are becoming stabilized with vegetation. Three subreaches have been evolving as identified in the geomorphology baseline section 5.5.2.4. The upstream subreach largely has become a fairly narrow, single thread, gravel-dominated channel. The central subreach is a transition reach in which the percentage of gravel in the bed is increasing, and the downstream subreach is still sand dominated. In each of the three subreaches, the following reach-wide trends are present:

- Channel narrowing
- Vegetation encroachment
- Increased bank height
- Incision or channel bed degradation
- Bank erosion
- Coarsening of bed material
- Increased channel uniformity

The way in which each strategy affects these reach-wide trends can vary between subreaches.

6.1.2.4.2 Promote Elevation Stability

Reach Effects.—This strategy addresses the trends of incision or channel bed degradation, increased bank height, and coarsening of bed material. This strategy also may indirectly influence bank erosion where there is potential for the degradation to continue below the riparian root zone. The general effects of this method implemented on a reach scale are described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. When the river bed is raised about 1–2 feet, the water surface elevation is increased upstream to the next riffle or higher bed elevation location, promoting greater flood plain connectivity. In the downstream subreach (Bridge Street Bridge to Isleta Diversion Dam), there likely will be greater potential for increased flood plain connectivity when compared to the gravel-dominated bed reach that has already experienced some channel incision and degradation. Upstream of the structures in the sand-dominated bed subreach, sediment deposition would potentially occur faster than in the gravel bed dominated subreach because sand sizes are mobilized at lower discharges than gravel bed sizes. Sediment deposition upstream of the structures could become vegetated on the channel margins without sufficient flows to periodically mobilize sediment deposits, requiring maintenance/adaptive management to maintain channel hydraulic capacity. Sinuosity would remain the same as prior to implementation. The Albuquerque-Bernalillo County Water Authority low-head inflatable dam exerts a bed level controlling effect within this reach.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Sediment delivery to downstream reaches would remain about the same as pre-implementation. There may be a temporary short period of time where the sediment supply is slightly reduced as the upstream river bed establishes its post implementation elevation. However, this is likely a small amount of the total annual sediment load. The bed material size in the downstream reach is expected to remain the same. Bed elevations are controlled at the upstream and downstream reach boundaries by Angostura Diversion Dam and Isleta Diversion Dam, respectively.

6.1.2.4.3 Promote Alignment Stability

Reach Effects.—In general, Promote Alignment Stability addresses the trend of bank erosion, through stabilizing the banks where the laterally constraining infrastructure is threatened. The general effects of this method implemented on a reach scale are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This strategy is most applicable currently in the gravel-dominated bed subreach that has already experienced more bed degradation and lateral migration than the transition and sand-dominated bed subreaches. Should the bed material coarsen and/or incision and lateral migration occur in the future in the transition and sand-dominated bed subreaches, this strategy is likely to become more applicable. This is especially true since a significant amount of the calculated potential future meandering channel length is outside the current lateral constraints (Varyu et al. 2011). After implementation, the amount of sediment available from bank erosion potentially would be reduced, leading to local bed coarsening. Due to sediment inflow from the Jemez River and the numerous ephemeral tributaries, the reduction of sediment supply from bank erosion may be relatively small. Sinuosity would increase as the channel lengthens until lateral migration threatens the integrity of riverside infrastructure.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The bed elevation and river location upstream of this reach are strongly influenced by Angostura Diversion Dam; thus, any effects upon the bed elevation as a result of potential channel lengthening from lateral migration will not affect the upstream reach. Isleta Diversion Dam exerts a controlling effect upon the bed elevation and river location at the downstream boundary of this reach. There could be a small reduction in the portion of the total sediment supply derived bank erosion. However, given the number of tributaries, including the Jemez River, providing sediment supply, this effect is expected to be small.

6.1.2.4.4 Reconstruct and Maintain Channel Capacity

This strategy is not suitable because a significant loss of safe channel hydraulic capacity is not expected.

6.1.2.4.5 Increase Available Area to the River

This strategy is not suitable because urban development makes implementation so expensive as to be unfeasible.

6.1.2.4.6 Rehabilitate Channel and Flood Plain

Reach Effects.—This strategy addresses channel narrowing, vegetation encroachment, increased bank height, incision or channel bed degradation, coarsening of bed material, and increased channel uniformity. The general effects of this method implemented on a reach scale are described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The reduced tendency for future bed coarsening would have the greatest effect on the sand-dominated bed subreach and should reduce or eliminate the tendency to develop a gravel dominated bed. Vegetation re-growth would occur in the excavated flood plain and on the channel margins. Inundating flows will likely deposit sediment in the vegetated overbank at a higher rate than in the Cochiti Dam to Angostura Diversion Dam subreach, due to the higher sediment load from tributaries.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The bed elevation and river location upstream of this reach are strongly influenced by Angostura Diversion Dam; thus, any effects upon the implementation reach will not affect the upstream reach. Reduction in high-flow sediment transport capacity and increased overbank sediment deposition could result in a lower amount of sediment being supplied to the Isleta Diversion Dam to Rio Puerco Reach. This effect is more pronounced during higher overbank flow peaks with longer durations and could result in downstream bed lowering, decreased flood plain connectivity, and a narrower, deeper channel.

6.1.2.4.7 Manage Sediment

Reach Effects.—The increased bank height, incision or bed degradation, coarsening of bed material, and increased channel uniformity trends are addressed by this strategy. The general effects of managing sediment in this reach consist of those due to increasing sand size sediment supply, as described in table 6 of the

Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The potential for future bank erosion caused by bed degradation below the root zone would be reduced. Depositional bars and islands may form downstream from augmentation sites. The potential change in bed material size would be greatest in the gravel dominated bed reach where the sand size portion of the bed material gradation would increase.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects of sediment augmentation are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The bed elevation and river location upstream of this reach are strongly influenced by Angostura Diversion Dam; thus, any effects upon the implementation reach will not affect the upstream reach. Deposition of bars and islands will likely occur in the Isleta Diversion Dam to Rio Puerco Reach unless the increased sediment supply can be transported through this reach. The bed elevation at Isleta Diversion Dam would be expected to remain the same. There is potential for additional sediment deposition upstream of the dam.

6.1.2.5 Isleta Diversion Dam to Rio Puerco – RM 169.3 to 127

6.1.2.5.1 Trends

Historically, the bed and alignment have been relatively stable except near the Rio Puerco. This reach is influenced by island and bar vegetation growth that has stabilized these once transient features, thereby narrowing the channel and encouraging new deposition along the bank. Current trends occurring in this reach are the following:

- Channel narrowing
- Vegetation encroachment
- Increased bank height
- Coarsening of bed material
- Increased channel uniformity

Continuation of these trends may cause additional trends to develop in the future:

- Incision or channel bed degradation
- Bank erosion

6.1.2.5.2 Promote Elevation Stability

Reach Effects.—This strategy addresses the trends of increased bank height and coarsening of bed material. This strategy can address increased bank height but only in the case where it is due to degradation. Since it is very possible that bed degradation and incision will become a future trend, similar to other reaches of the Middle Rio Grande that have narrowed, this strategy has been identified as suitable. The general effects of this method implemented on a reach scale are described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Channel narrowing as a result of future channel incision would be reduced or slowed by bed elevation control. When the river bed is raised about 1–2 feet, the water surface elevation is increased upstream to the next riffle or high point in the bed, promoting greater flood plain connectivity and increased depth and velocity variability at high flows. Sediment deposition upstream of the structures could become vegetated on the channel margins without sufficient flows to periodically mobilize sediment deposits, requiring maintenance/adaptive management to maintain channel capacity. Sinuosity would remain the same as prior to implementation.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are as described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Sediment delivery to Rio Puerco to San Acacia Diversion Dam Reach would remain about the same as pre-implementation. Bed material size would not be affected downstream from the structures. The upstream bed elevation is controlled by Isleta Diversion Dam and would not change with this strategy.

6.1.2.5.3 Promote Alignment Stability

This strategy is not suitable because analysis results show the meander belt is expected to continue to fit between constraints.

6.1.2.5.4 Reconstruct and Maintain Channel Capacity

Reach Effects—This strategy addresses trends of channel narrowing and vegetation encroachment. The trend of increase bank height due to sediment deposition could potentially reduce high-flow floodway capacity. The general effects of this method implemented on a reach scale are described in table 3 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Where increased bank height has cut off side channels and backwaters, these may be reconnected. Vegetation encroachment could continue on the channel margins without sufficiently high flows to mobilize bed sediments after channel reconstruction. Potential bank erosion due to bed degradation and channel narrowing likely would decrease. No change in sinuosity is likely. The bed elevation may increase, and bed size may decrease due to reduced peak flow channel velocity and depth.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are as described in table 3 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. The upstream bed elevation and river location are influenced by Isleta Diversion Dam. Reduction in high-flow sediment transport capacity could result in lower downstream sediment supply. This could result in bed lowering, decreased flood plain connectivity, and a narrower, deeper channel in the Rio Puerco to San Acacia Diversion Dam Reach. The potential amount of these changes is not known.

6.1.2.5.5 Increase Available Area to the River

Reach Effects.—This strategy addresses the trends of channel narrowing, coarsening of bed material and increased channel uniformity. The general effects of this method implemented on a reach scale are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Allowing the river more space for lateral erosion and bar deposition could result in the formation of a larger flood plain with increases in overall flood plain connectivity and increased channel width. Bed degradation tendencies would be reduced or eliminated as the channel lengthens. Potential for bank erosion increases with the development of migrating channel bends; however, there would be more space to accommodate that migration.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Relocating riverside infrastructure will provide additional area for future river migration but will not immediately effect current reach trends. If channel lengthening occurs, there would be a reduced tendency for upstream bed lowering. The upstream sediment supply/transport capacity relationship would remain about the same; thus, channel width and flood plain connectivity would be essentially unchanged. The sediment supply to the Rio Puerco to San Acacia Diversion Dam Reach could be reduced if channel lengthening reduces degradation potential. The potential amount of this reduction is an unknown at this time.

6.1.2.5.6 Rehabilitate Channel and Flood Plain

Reach Effects.—This strategy addresses channel narrowing, vegetation encroachment, increased bank height, coarsening of bed material, and increased channel uniformity. The general effects of this method implemented on a reach scale are described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Excavation of the channel banks to establish a lower elevation flood plain decreases the flow required to go over bank, and leads to increased high flow channel width. High flow sediment transport rates would be reduced, lowering the likelihood of future bed degradation and the tendency for the bed to coarsen. Vegetation re-growth would occur in the excavated flood plain, and on the channel margins. Inundating flows will likely deposit sediment in the vegetated overbank.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are as described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The potential for continued upstream bed degradation would be reduced. Reduction in high-flow sediment transport capacity and overbank sediment deposition could result in a lower downstream sediment supply. This could result in bed lowering, decreased flood plain connectivity, and a narrower, deeper channel in the Rio Puerco to San Acacia Diversion Dam Reach. The potential amount of these changes is not known.

6.1.2.5.7 Manage Sediment

Reach Effects.—Increased bank height, coarsening of bed material, and increased channel uniformity are trends addressed by this strategy. The general effects of managing sediment in this reach consist of those due to increasing sediment supply are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The potential for future bank erosion caused by bed degradation below the root zone would be reduced. Downstream from augmentation sites, bars and islands may form due to sediment deposition.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects of sediment augmentation are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. No additional trends are expected in addition to these general upstream and downstream effects.

6.1.2.6 Rio Puerco to San Acacia Diversion Dam – RM 127 to 116.2

6.1.2.6.1 Trends

The uncontrolled, large, ephemeral tributaries of the Rio Puerco and Rio Salado strongly influence this reach through both peak flows and sediment load. The historically high load from the Rio Puerco has significantly decreased because that channel has evolved. Recent MRG evolution includes the development of small inset flood plains. Located between the tributary confluences is Sevilletta bend ,which is a 2½-mile-long geologic constriction in the center of the reach. Above the bend, the channel is narrowing with vegetation encroachment. The Rio Salado enters immediately below Sevilletta bend. It contributes sediment that is coarser than the Rio Grande, and the Rio Salado delta tends to act as a grade control. From here downstream to San Acacia Diversion Dam, the channel is currently moving laterally and degrading. The delta deposits upstream of the diversion dam have become heavily vegetated and confine the channel north against the Drain Unit 7 Levee. The current reach trends are:

- Channel narrowing
- Vegetation encroachment
- Increased bank height
- Incision or channel bed degradation – local
- Coarsening of bed material
- Increased channel uniformity

6.1.2.6.2 Promote Elevation Stability

Reach Effects and Effects on Upstream and Downstream Reaches.—As modeling results (Varyu et al. 2011) show, this reach is expected to mildly aggrade, so this strategy is suitable but would be implemented by methods falling primarily under the other strategies suitable for this reach—Reconstruct and Maintain Channel Capacity and Manage Sediment.

6.1.2.6.3 Promote Alignment Stability

Reach Effects.—For much of the reach, there appears to be adequate space for lateral migration at the 2006 channel widths. Of note is that channel narrowing could set in motion a geomorphic shift toward channel migration and the Drain Unit 7 extension and other infrastructure may be threatened as the channel position changes. The trend of bank erosion that threatens infrastructure is addressed through armoring the bank line or deflecting the main flow path away from the area of concern. Effects are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Modeling results (Varyu et al. 2011) don't show channel lengthening at the 2006 widths, but narrowing could change the stable slope to a condition where channel migration becomes an active process. Sinuosity could then increase because there is space available for lateral migration. Bed material could continue to coarsen as the supply of fines from bank erosion is reduced.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The downstream reach boundary is San Acacia Diversion Dam that controls bed elevation and puts boundaries on the lateral location of the river. There could be a relatively small decrease in sediment supplied to the San Acacia Diversion Dam to Arroyo de las Cañas Reach because of reduced bank erosion. Isleta Diversion Dam to Rio Puerco Reach effects are expected to be small.

6.1.2.6.4 Reconstruct and Maintain Channel Capacity

This strategy is not suitable because a significant loss of channel capacity is not expected.

6.1.2.6.5 Increase Available Area to the River

Reach Effects.—The trends of channel narrowing increased bank height, incision or channel bed degradation, coarsening of bed material, and increased channel uniformity are addressed by setting aside space for the channel to evolve. The general effects of this strategy in this reach are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Land use outside the infrastructure constraints is agricultural or wildlife refuges and the AT&SF Railroad. Altering land use in agricultural or wildlife areas may be more implementable than changing the railroad alignment. Potential for bank erosion increases with the development of migrating channel bends; however, there would be more space to accommodate that migration. There is uncertainty on how significant the process of migration will become in this reach.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The downstream reach boundary is San Acacia Diversion Dam that controls the bed elevation and puts bounds on river location. A longer channel could result in lower sediment supply to the San Acacia Diversion Dam to Arroyo de las Cañas Reach when the slope decreases and the size of mid-channel and bank-attached bars increases; but modeling results (Varyu 2011) show that the channel is not expected to lengthen at the 2006 channel widths. Isleta Diversion Dam to Rio Puerco Reach effects are expected to be small.

6.1.2.6.6 Rehabilitate Channel and Flood Plain

Reach Effects.—The trends of channel narrowing, vegetation encroachment, increased bank height, incision or channel bed degradation, coarsening of bed material, and increased channel uniformity are addressed by decreasing high-flow energy through lowering the bank height that increases flow area at lower discharges. New riparian vegetation will grow, and then sediment deposition is expected in the lowered overbank areas. The effects listed in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case would apply, but specific effects will depend on the type of implementation.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. San Acacia Diversion Dam controls bed elevation and puts bounds on river location at the downstream reach boundary. Reduction in high-flow sediment transport capacity and overbank sediment deposition could result in a lower downstream sediment supply. This could then result in bed lowering, decreased flood plain connectivity, and a narrower, deeper channel in the San Acacia Diversion Dam to Arroyo de las Cañas Reach. The effect is not expected to be large.

6.1.2.6.7 Manage Sediment

This strategy is not suitable because modeling showed only a mild reach-wide imbalance in sediment transport capacity and sediment supply.

6.1.2.7 San Acacia Diversion Dam to Arroyo de las Cañas – RM 116.2 to 95

6.1.2.7.1 Trends

This reach is influenced by a large reduction in finer grain sizes from the Rio Puerco, but the Salado contributes coarser grain sizes. Additional influences include channel incision, formation of abandoned terraces, and width reduction.

San Acacia Diversion Dam prevents upstream migration of channel bed degradation. Many of the ephemeral tributaries junctions now act effectively as grade controls as described in the geomorphology baseline section 5.5.2.7. Current trends in this reach are the following:

- Vegetation encroachment
- Increased bank height
- Incision or bed degradation
- Bank erosion
- Coarsening of bed material
- Increased channel uniformity

Near San Acacia Diversion Dam, the amount of bed material coarsening and channel degradation is the greatest, decreasing in the downstream direction. From Escondida to Arroyo de las Cañas, the bed is predominantly sand with intermittent gravel deposits. Several smaller tributaries have been reconnected, increasing sediment supply within the reach.

6.1.2.7.2 Promote Elevation Stability

Reach Effects.—This strategy addresses the trends of increased bank height, incision or channel bed degradation, and coarsening of bed material. This strategy also may address bank erosion where there is potential for the degradation to continue below the riparian root zone. This strategy addresses increased bank height from the condition of channel bed degradation. The general effects of this method implemented on a reach scale are described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. This reach has natural grade controls from ephemeral tributary sediment deposits that could become the boundary of the relatively small amount of sediment deposition upstream of each structure. Channel narrowing as a result of future channel incision would be reduced or slowed by bed elevation control. Sediment deposition upstream of the structures likely would occur more quickly where the bed material load is largely sand sized. The upstream sediment deposits could become vegetated on the channel margins without sufficient flows to periodically mobilize sediment deposits, requiring maintenance/adaptive management to maintain channel capacity. Sinuosity would remain the same as prior to implementation. The lateral location of the river is fixed for most methods. Bed material size is not expected to change.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 1 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The upstream bed elevation is controlled by San Acacia Diversion Dam and would not change. Sediment delivery to the Arroyo de las Cañas to San Antonio Bridge Reach would remain about the same as pre-implementation. Bed material size would not be affected downstream from this reach. Bed elevation in the Arroyo de las Cañas to San Antonio Bridge is not likely to be affected by this strategy because sediment supply is not likely to change.

6.1.2.7.3 Promote Alignment Stability

Reach Effects.—This strategy addresses the trend of bank erosion by stabilizing banks where infrastructure is threatened by river bank migration. The general effects of this method implemented on a reach scale are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Sinuosity would increase as the channel lengthens until lateral migration threatens riverside infrastructure. Additional lateral migration would likely allow the river to increase the size of its inset flood plain. If the bed material size continues to coarsen in the downstream portion of this reach, and lateral migration were to occur in the future, this strategy will become more applicable.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 2 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The bed elevation and river location at the upstream boundary of this reach are controlled by San Acacia Diversion Dam, thus any potential changes in bed elevation as a result of channel lengthening from lateral migration will not affect the upstream reach. The bed elevation in the Arroyo de las Cañas to San Antonio Bridge Reach is not likely to be influenced by a small reduction in sediment supplied by bank erosion because Arroyo de las Cañas appears to be acting as a grade control. The downstream lateral location could be influenced by the alignment of this strategy.

6.1.2.7.4 Reconstruct and Maintain Channel Capacity

This strategy is not suitable because a significant loss of channel capacity is not expected.

6.1.2.7.5 Increase Available Area to the River

Reach Effects.—This strategy addresses the trends of channel narrowing, increased bank height, incision or bed degradation, coarsening of bed material, bank erosion, and increased channel uniformity. The general effects of this method implemented on a reach scale, are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Allowing the river more space for lateral erosion and bar deposition could result in the formation of a larger inset flood plain, increasing overall flood plain connectivity and channel width. Bed degradation tendencies would be reduced or eliminated as the channel lengthens, except where controlled by ephemeral tributary sediment deposits.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Relocating riverside infrastructure will provide additional area for future river migration. The presence of San Acacia Diversion Dam prevents any upstream reach channel changes. The downstream channel bed elevation most likely will not be affected due to Arroyo de las Cañas deposits in the river appearing to act as a grade control, even if the downstream sediment supply decreased. Sediment supply to the Arroyo de las Cañas to San Antonio Bridge Reach is likely to decrease because channel lengthening reduces degradation potential and sediment could be stored on forming point bars. Downstream sediment supply could be reduced if channel lengthening reduces degradation potential. The downstream reach has a sediment depositional trend, so this effect would potentially reduce the rate of aggradation.

6.1.2.7.6 Rehabilitate Channel and Flood Plain

Reach Effects.—This strategy addresses channel narrowing, vegetation encroachment, increased bank height, incision or channel bed degradation, bank erosion, coarsening of bed material, and increased channel uniformity. The general effects of this method implemented on a reach scale for the transport capacity greater than supply case are described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Excavation of the channel banks to establish a lower elevation flood plain, in the abandoned river terraces, decreases the flow required to go over bank and leads to increased high-flow channel width. High-flow sediment transport rates would be reduced, lowering the likelihood of future bed degradation and the tendency for the bed to coarsen. Vegetation regrowth would occur in the excavated flood plain and on the channel margins. Inundating flows likely will deposit sediment in the vegetated overbank since there can be significant amounts of sediment in suspension particularly during Rio Puerco and Rio Salado flow events.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 5 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Upstream bed elevation is controlled by San Acacia Diversion Dam and would not be affected by this strategy. Reduction in high-flow sediment transport capacity and overbank sediment deposition could result in a lower sediment supply to the Arroyo de las Cañas to San Antonio Bridge Reach. This could result in slowing the aggradational trend in the downstream Arroyo de las Cañas Reach. It is not likely that this strategy would alter the downstream lateral channel location.

6.1.2.7.7 Manage Sediment

Reach Effects.—The increased bank height incision or bed degradation, coarsening of bed material and increased channel uniformity trends are addressed by this strategy. The general effects of managing sediment in this reach consist of those due to increasing sediment supply, as described in table 6 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. The potential for future bank erosion caused by bed degradation below the root zone would be reduced. Sediment deposition likely could occur on inset flood plain features, decreasing the frequency of inundation, downstream from augmentation sites.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects of sediment augmentation are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity greater than sediment supply case. Sediment augmentation would have no effect upon the upstream bed elevation or channel location controlled by San Acacia Diversion Dam. It is likely that this strategy would increase sediment supply to the Arroyo de las Cañas to San Antonio Bridge, potentially exacerbating the aggradational trend. The amount of potential sediment supply is an unknown.

6.1.2.8 Arroyo de las Cañas to San Antonio Bridge – RM 95 to 87.1

6.1.2.8.1 Trends

This reach has experienced less change in bed elevation and average channel width since channelization than most other reaches of the MRG. Recent trends, which appear to be declining in effect, include:

- Channel narrowing
- Vegetation encroachment

Aggradation is extending into this reach, but on a smaller in scale than historically documented in the San Antonio Bridge to River Mile 78 and River Mile 78 to River Mile 60 Reaches. Recent arroyo reconnections and aggradation in the San Antonio to River Mile 78 Reach contribute to these trends:

- Aggradation
- Increased channel uniformity

Sediment storage in the channel is key to the recent trends observed in this reach. Strategies that address the channel filling (related to both narrowing and aggradation) would be appropriate, but the recent narrowing could increase sediment transport, move more sediment through the reach, and, thus, change the aggradation-related trends in this reach, potentially increasing bend migration.

6.1.2.8.2 Promote Elevation Stability

Reach Effects and Effects on Upstream and Downstream Reaches.—As recent observations and modeling results (Varyu et al. 2011) show, this reach is expected to aggrade, so this strategy is suitable but would be implemented by methods falling primarily under the other strategies suitable for this reach—Reconstruct and Maintain Channel Capacity and the Manage Sediment.

6.1.2.8.3 Promote Alignment Stability

This strategy is not suitable because modeling shows a low potential for lateral migration.

6.1.2.8.4 Reconstruct and Maintain Channel Capacity

Reach Effects.—The current reach trends of channel narrowing, vegetation encroachment, and aggradation are addressed by directly removing sediment from the channel, increasing sediment transport capacity through confining high flows, or reducing impacts from channel realignment through levee strengthening/ raising. Since the excess incoming sediment supply is not modified and sediment transport capacity is not likely to exceed previous levels, sediment excavation could require continued maintenance. The effects as described in table 3 of the Strategy Effects Attachment because the sediment transport capacity less than sediment supply case would apply in this reach. Bed material is expected to remain sand-dominated except in the upstream riffles. Sinuosity is not expected to change much, but the wetted area of the overbank at high flows is expected to decrease and discharge needed to go over bank increases, at least temporarily.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 3 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Downstream effects include increased water and sediment delivery to the San Antonio Bridge to River Mile 78 Reach. Significant coarsening of bed material in the downstream reach is not expected. Arroyo de las Cañas deposits in the channel, at the upstream end of this reach, appear to be controlling degradation at current peak flows, but aggradation and bed material fining extending into the San Acacia Diversion Dam to Arroyo de las Cañas Reach is possible. The likelihood and magnitude of this effect is unknown at this time.

6.1.2.8.5 Increase Available Area to the River

This strategy is not suitable because modeling shows a low potential for lateral migration.

6.1.2.8.6 Rehabilitate Channel and Flood Plain

This strategy is not suitable because of historically stable bed and modeling show aggradation.

6.1.2.8.7 Manage Sediment

Reach Effects.—The reach trends of aggradation and increased channel uniformity can be addressed by this strategy. The general effects of this method implemented on a reach scale are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Implementation would consist of reducing sediment supply. The reduction in sediment supply would reduce flooding and water losses.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Reducing sediment supply in this reach should reduce the effects of sediment supply being greater than transport capacity in the upper portion of the San Antonio Bridge to River Mile 78 Reach. A reduction in aggradation in this reach might reduce aggradation in the San Acacia Diversion Dam to Arroyo de las Cañas Reach upstream.

6.1.2.9 San Antonio Bridge to River Mile 78 – RM 87.1 to 78

6.1.2.9.1 Trends

This reach is influenced by the pool elevation of Elephant Butte Reservoir. Under the current water and sediment loads, the pool is quite low and not expected to rise far in the near term. This base level lowering has led to the following current trends in the lower portion of the reach that are anticipated to be temporary (Makar and AuBuchon, 2012). :

- Increased bank height
- Incision or channel bed degradation
- Bank erosion
- Coarsening of bed material – minor

Three trends currently are observed that may or may not reverse when water and sediment loads increase and the pool fills:

- Channel narrowing
- Vegetation encroachment
- Increased channel uniformity

Under historically more frequent conditions, there is an excess of sediment supply as compared to transport capacity and long-term trends of:

- Aggradation
- Channel plugging with sediment
- Perched channel conditions

The dependence on pool elevation makes conditions of this reach variable in the long term. Given the wide variation in trends and the need to preserve peak flow channel capacity, valley drainage, and capacity in Elephant Butte Reservoir, strategies that address the long-term aggradation trends are appropriate for this reach and have been addressed herein.

6.1.2.9.2 Promote Elevation Stability

Reach Effects and Effects on Upstream and Downstream Reaches.—As this is a long-term aggrading reach, this strategy is suitable but would be implemented by methods falling under the other strategies suitable for this reach—Reconstruct and Maintain Channel Capacity, the Increase Available Area to the River, and the Manage Sediment.

6.1.2.9.3 Promote Alignment Stability

This strategy is not suitable because the reach over the long term is aggrading, and only localized lateral migration is expected.

6.1.2.9.4 Reconstruct and Maintain Channel Capacity

Reach Effects.—This strategy addresses the trends of channel narrowing, vegetation encroachment, aggradation, channel plugging with sediment, and perched channel conditions by directly removing sediment from the channel, increasing transport capacity through confining high flows, or reducing levee impacts from channel realignment. Since the excess incoming sediment load is not modified and transport capacity likely will not exceed previous levels, sediment excavation likely will require continued maintenance. The effects are described in table 3 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Bed material is expected to remain sand. Sinuosity is not expected to change much, but wetted area of the overbank at high flows is expected to decrease and discharge needed to go over bank increase, at least temporarily.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 3 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Downstream effects include increased water and sediment delivery to the River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach and potentially to Elephant Butte Reservoir increasing the rate of storage capacity loss. Significant coarsening of the bed material in the River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach is not expected. It is possible the Arroyo de las Cañas to San Antonio Bridge Reach aggradation could be reduced as channel filling in this reach is reduced.

6.1.2.9.5 Increase Available Area to the River

Reach Effects.—This strategy addresses the trends of channel narrowing, increased bank height, incision or channel bed degradation, bank erosion, coarsening of bed material, increased channel uniformity, aggradation, channel plugging with sediment, and perched channel conditions through allowing natural channel processes to cause channel evolution. The trends of aggradation, channel plugging with sediment, and perched channel conditions are addressed through allowing space for channel relocation to lower bed elevations. The general effects of this method implemented on a reach scale are described in table 4 of the

Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. The majority of the surrounding land in this reach is federally owned. Sinuosity, wetted area, and discharge needed to go over bank are not expected to change significantly. However, it is possible that after natural channel realignment, the new channel bed elevation within the reach could be lowered far enough so that upstream effects could include channel degradation with higher flows required to go over bank and lowered water tables. This effect may be temporary unless the strategy is extended into the River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach. Water delivery may be reduced until a continuous competent channel is formed. The magnitude of this effect is dependent on the increase in wetted area.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. It is possible that water delivery to the River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach may be reduced, but the effect is expected to be small. Significant changes in the River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach bed material size or sediment load are not expected. It is possible that effects due to lowered bed elevation, as discussed under reach effects, could extend into the Arroyo de las Cañas to San Antonio Bridge Reach. The extent and magnitude of the effect is dependent on the change in bed elevation.

6.1.2.9.6 Rehabilitate Channel and Flood Plain

This strategy is not suitable because the reach over the long term is aggrading.

6.1.2.9.7 Manage Sediment

Reach Effects.—The general effects of this method implemented on a reach scale are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. The trends of aggradation, channel plugging with sediment, perched channel conditions, and increased channel uniformity are addressed through storage of excess sediment supply in basins or by channel relocation to a lower elevation alignment. In either case, the sediment load transported and/or the perched condition where the elevation of the channel bed is higher than the flood plain should be reduced. Channel relocation would allow sediment storage in low lying areas, but maintenance may be required to sustain a continuous channel downstream in the new alignment. Sinuosity, local ground water table, wetted area, and discharge needed to go over bank are dependent on locations selected for implementation.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. It is possible that water delivery downstream may be reduced, but the effect is expected to be small and may be temporary depending upon the method used. Sediment load to the

River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach would, of course, be reduced; and it is possible that the effect may extend to Elephant Butte Reservoir. Significant coarsening in the River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach is not expected. Sediment deposition in low areas may temporarily reduce Arroyo de las Cañas to San Antonio Bridge Reach aggradation.

6.1.2.10 River Mile 78 to Full Pool Elephant Butte Reservoir Level – River Mile 78 to Elephant Butte Full Pool Reservoir Level

6.1.2.10.1 Trends

This reach is strongly influenced by the pool elevation of Elephant Butte Reservoir. Historically an aggrading and perched reach, the channel has degraded significantly. This is primarily due to the base level lowering effect of recent pool elevations. Under the current water and sediment loads, the pool is quite low and not expected to rise far in the near term. This base level lowering has led to the following current trends that are anticipated to be temporary:

- Increased bank height
- Incision or channel bed degradation
- Bank erosion
- Coarsening of bed material
- Increased channel uniformity

Two trends are currently observed that may or may not reverse when water and sediment loads increase and the pool fills:

- Channel narrowing
- Vegetation encroachment

Under historically more frequent conditions, there is an excess of sediment supply as compared to transport capacity and long-term trends of:

- Aggradation
- Channel plugging with sediment
- Perched channel conditions

The dependence on pool elevation makes conditions of this reach highly variable in the long term. Given the wide variation in trends and the need to preserve peak flow channel capacity, valley drainage and capacity in Elephant Butte Reservoir, strategies that address the long-term aggradation trends are appropriate for this reach. Loss of a continuous channel to the reservoir in this reach can impair water delivery.

6.1.2.10.2 Promote Elevation Stability

Reach Effects and Effects on Upstream and Downstream Reaches.—As this is a long-term aggrading reach, this strategy is suitable but would be implemented by methods falling under the other strategies suitable for this reach—Reconstruct and Maintain Channel Capacity, Increase Available Area to the River, and Manage Sediment.

6.1.2.10.3 Promote Alignment Stability

This strategy is not suitable because the reach over the long term is aggrading, and only localized lateral migration is expected.

6.1.2.10.4 Reconstruct and Maintain Channel Capacity

Reach Effects.—This strategy addresses the trends of channel narrowing, vegetation encroachment, aggradation, channel plugging with sediment, and perched channel conditions by removing sediment from the channel. Sediment transport capacity is increased by confining high flows that can increase flow capacity within the levee system. Building on the discussion in the trends section above, the duration of the effects of increasing the sediment transport capacity through partial or complete channel reconstruction (see table 4 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case) are likely to be shorter than in other reaches if the base level control of pool elevation rises and longer if it remains low. A continued need for maintenance is expected if this strategy is implemented. Partial reconstruction via a pilot channel through sediment plugs can restore channel capacity. Confining over bank flows can increase local transport capacity and may prevent plug formation. Levee raising and strengthening can reduce concerns of levee failure during plugs and high-flow events. Little change is expected in sinuosity or the discharge required to go over bank and the resulting wetted area.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 3 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Downstream effects include increased water and sediment delivery to Elephant Butte Reservoir resulting in an increased rate of reservoir capacity loss. The downstream bed material size is likely to increase if the pool remains low but is expected to remain in sand sizes. The San Antonio Bridge to River Mile 78 Reach effects could be channel degradation and longer duration of increased channel capacity, again dependent on Elephant Butte pool elevation. Higher flows required to go over bank and lowered water tables may accompany the degradation.

6.1.2.10.5 Increase Available Area to the River

Reach Effects.—This strategy addresses the trends of channel narrowing, increased bank height, incision or channel bed degradation, bank erosion, coarsening of bed material, and increased channel uniformity through allowing natural channel processes to cause channel evolution and increased length. The trends of aggradation, channel plugging with sediment, and perched channel conditions are addressed by allowing space for channel relocation. The San Marcial Railroad Bridge locally limits application of this strategy; but since the majority of the surrounding land is federally owned, implementation could be easier than in other reaches. There appears to be enough land available to realize the effects listed in table 4 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. Wetted area of high flows would increase when channel filling resumes. Sinuosity could increase if the pool remains low and the channel migrates. The discharge needed to go over bank is not expected to change until the pool elevation comes up; and, then, the discharge needed to spill out of the channel will decrease.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 4 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. The increased area available for overbank deposition could reduce the sediment load reaching Elephant Butte Reservoir, extending its useful capacity life. The bed material size downstream is expected to remain about the same. The San Antonio Bridge to River Mile 78 Reach aggradation, which has historically occurred over the long term, is expected to be reduced (at least temporarily) because there would be more area for future sediment deposition.

6.1.2.10.6 Rehabilitate Channel and Flood Plain

This strategy is not suitable because the reach over the long term is aggrading.

6.1.2.10.7 Manage Sediment

Reach Effects.—The effects of managing sediment on a reach basis consist of those due to reducing sediment supply as described in table 6 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. The trends of aggradation, channel plugging with sediment, perched channel conditions, and increased channel uniformity are addressed through storage of excess sediment supply. Federal land ownership of the majority of surrounding land means there is space available for constructed or natural basins. Wide variations in topography mean that using existing low spots is possible, minimizing implementation. If the deepest of the low spots are selected for implementation, higher discharges will be required for flows to go over bank, at least temporarily. Sinuosity will be a function of the locations selected for implementation.

Effects on Upstream and Downstream Reaches.—The general upstream and downstream effects are described in table 6 of the Strategy Effects Attachment for the sediment transport capacity less than sediment supply case. The increased sediment deposition will reduce the sediment load reaching Elephant Butte Reservoir, extending its useful capacity life. Bed material size downstream from the deposition basins is expected to coarsen but remain in sand sizes. The downstream channel bed is likely to degrade because of basin sediment storage within this reach. The San Antonio Bridge to River Mile 78 Reach aggradation, which has historically occurred over the long term, is expected to be reduced (at least temporarily) because there would be more space for future sediment deposition in this reach. The channel bed upstream may aggrade in the future depending upon the rate basins fill with sediment and how often they are relocated. Channel lowering may occur in upstream reaches if the elevation difference between the current channel bed and the new alignment through the basins is great enough.

6.1.3 Most Likely Biological Effects of River Maintenance Strategies on Silvery Minnows and Flycatchers by Reach

Tables 33 and 34 display the general reach by reach analysis of effects to silvery minnows, flycatchers, and their associated habitats from changes expected by implementing actions to achieve river maintenance strategies identified in the Proposed Action (section 3.2.8). The effects are general in nature and evaluate whether the river maintenance strategy would indicate a positive or negative outcome for the reach. Where the probable magnitude of an effect is known, it is analyzed. As needed, additional details of the effects, tiered off this programmatic river maintenance BA, would be developed and coordinated with the Service. The effects of these strategies on critical habitat of silvery minnow and flycatchers would be variable depending on the design and location of the project. Most types of projects are expected to have a temporary adverse effect to critical habitat through disturbance to the water quality or riparian vegetation. Long-term indirect effects may be adverse or beneficial.

6.2 River Maintenance Project Site Effects

The long-term geomorphic effects on the river and species habitat of a river maintenance site project are local in nature. There are short-term impacts for each of these method types that are related to the size of the impact area, the location or the project, implementation techniques and duration. The estimated effects are described by method in section 6.2.1. Effects from river maintenance support activities and unanticipated and interim work are described in sections 6.2.2 and 6.2.3. Effects predictions of specific acreages of impacts are analyzed in section 6.2.4.

6.2.1 Effects of River Maintenance Methods

River maintenance methods, and their expected local geomorphic effects, are described in the River Maintenance Methods Attachment. A summary of predicted species and habitat changes are outlined in table 35. These changes are dependent on project location and scope. Project specific analysis for river maintenance will be completed for all proposed projects and tiered off this

Table 33. Predicted Effects to Silvery Minnow Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Velarde to Rio Chama		No effects to silvery minnow or silvery minnow critical habitat.		No effects to silvery minnow or silvery minnow critical habitat.	No effects to silvery minnow or silvery minnow critical habitat.	
Rio Chama to Otowi Bridge	No effects to silvery minnow or silvery minnow critical habitat.	No effects to silvery minnow or silvery minnow critical habitat.		No effects to silvery minnow or silvery minnow critical habitat.	No effects to silvery minnow or silvery minnow critical habitat.	
Cochiti Dam to Angostura Diversion Dam	The current distribution of silvery minnow and habitat within the Cochiti Dam to Angostura Diversion Dam Reach is unknown. Though current conditions are not favorable to silvery minnow, any activity to promote elevation stability should maintain current conditions. The proposed action will not change current conditions. Channel spanning features to promote elevation stability would be constructed to facilitate movement of silvery minnow.	The current distribution of silvery minnow and habitat within the Cochiti Dam to Angostura Diversion Dam Reach is unknown. Methods to promote alignment stability may reduce the rivers potential to maintain habitat complexity.		Implementing projects to increase the channel area are likely to have a positive impact on habitat diversity for silvery minnow by increasing sinuosity and hydrologically connected surfaces. Downstream effects are minimized by Angostura Diversion Dam.	Implementation of methods intended to reconnect the flood plain at lower discharge levels are likely to have positive effects on silvery minnow habitat by creating high productivity larval fish habitats that are inundated more often than existing conditions. There is the possibility that silvery minnow may become entrained on the flood plain when inundation subsides, which may result in take.	

Table 33. Predicted Effects to Silvery Minnow Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Angostura Diversion Dam to Isleta Diversion Dam	This reach is currently occupied by silvery minnow. Any activity to promote elevation stability should maintain or improve current conditions for silvery minnow. Channel spanning features to promote elevation stability would be constructed to facilitate movement of silvery minnow.	This reach is currently occupied by silvery minnow. Strategies to promote alignment stability may reduce habitat complexity.			Methods to rehabilitate the channel and flood plain are generally designed to help the river function more naturally and benefit silvery minnow. There is the possibility that silvery minnow may become entrained on the flood plain when inundation subsides, which may result in take.	Likely would maintain current conditions within the reach.
Isleta Diversion Dam to Rio Puerco	This reach is currently occupied by silvery minnow. Any activity to promote elevation stability should maintain or improve current conditions for silvery minnow. Channel spanning features to promote elevation stability would be constructed to facilitate movement of silvery minnow.		Depending on the method used, long term effects may be positive or negative. Methods that decrease complexity are negative, strategies that allow for reconnection of abandoned side channels and backwaters would be positive.	Implementing projects to increase the channel area are likely to have a positive impact on habitat diversity for silvery minnow by increasing sinuosity and hydrologically connected surfaces.	Methods to rehabilitate the channel and flood plain are generally designed to help the river function more naturally and benefit silvery minnow. There is the possibility that silvery minnow may become entrained on the flood plain when inundation subsides, which may result in take.	Likely would maintain current conditions within the reach. Depositional bars and islands may form downstream of augmentation sites. This may increase habitat complexity for silvery minnow.

Table 33. Predicted Effects to Silvery Minnow Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Rio Puerco to San Acacia Diversion Dam	This reach is currently occupied by silvery minnow. Any activity to promote elevation stability should maintain or improve current conditions for silvery minnow. Channel spanning features to promote elevation stability would be constructed to facilitate movement of silvery minnow	This reach is currently occupied by silvery minnow. Strategies to promote alignment stability may reduce habitat complexity.		Implementing projects to increase the channel area are likely to have a positive impact on habitat diversity for silvery minnow by increasing sinuosity and hydrologically connected surfaces.	Methods to rehabilitate the channel and flood plain are generally designed to help the river function more naturally and benefit silvery minnow. There is the possibility that silvery minnow may become entrained on the flood plain when inundation subsides that may result in take.	
San Acacia Diversion Dam to Arroyo de las Cañas	This reach is currently occupied by silvery minnow. Any activity to promote elevation stability should maintain or improve current conditions for silvery minnow. Channel spanning features to promote elevation stability would be constructed to facilitate movement of silvery minnow	This reach is currently occupied by silvery minnow. Strategies to promote alignment stability may reduce habitat complexity.		Implementing projects to increase the channel area are likely to have a positive impact on habitat diversity for silvery minnow by increasing sinuosity and hydrologically connected surfaces.	Strategies to rehabilitate the channel and flood plain are generally designed to help the river function more naturally and benefit silvery minnow. There is the possibility that silvery minnow may become entrained on the flood plain when inundation subsides that may result in take.	Likely would maintain current conditions within the reach.
Arroyo de las Cañas to San Antonio Bridge	Suitable strategy, likely to be implemented by methods falling under the other strategies identified for this reach.		Overbank area is expected to decrease temporarily.			Likely would maintain current conditions within the reach.

Table 33. Predicted Effects to Silvery Minnow Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
San Antonio Bridge to River Mile 78	Suitable strategy, likely to be implemented by methods falling under the other strategies identified for this reach.		Overbank area is expected to decrease. Increased water and sediment delivery to lower reaches may change likelihood of drying in those reaches.	Implementing projects to increase the channel area are likely to have a positive impact on habitat diversity for silvery minnow by allowing avulsions to occur, increasing hydrologically connected surfaces.		Likely would maintain current conditions within the reach.
River Mile 78 to Full Pool Elephant Butte Reservoir Level	Suitable strategy, likely to be implemented by methods falling under the other strategies identified for this reach.		Overbank area is expected to decrease temporarily.	Implementing projects to increase the channel area are likely to have a positive impact on habitat diversity for silvery minnow by increasing sinuosity and hydrologically connected surfaces.		Likely would maintain current conditions within the reach. May cause less aggradation in upstream reaches

Table 34. Predicted Effects to Flycatcher Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Velarde to Rio Chama		This reach has minimal flycatcher territories and suitable habitat. This strategy decreases the erosion and deposition ability of the river, from lateral erosion, in turn decreasing the opportunity for a variety of successional stages needed for flycatcher habitat. However, deposition and erosion processes may still continue on bars and islands.		This reach has minimal flycatcher territories and suitable habitat. Positive impacts to flycatcher habitat with this strategy and habitat availability in this reach likely would increase with the added area the river could potentially meander.	This reach has minimal flycatcher territories and suitable habitat. This strategy would increase overbank wetted area and may increase the channel sinuosity. Minimal effects are expected upstream of and downstream from this reach. Flycatcher habitat may improve.	
Rio Chama to Otowi Bridge	Minimal flycatcher territories and suitable habitat in this reach. No impact on flycatcher. If anything, positive, as it would not let further incision occur in this reach.	Minimal flycatcher territories and suitable habitat in this reach. Alignment stability decreases erosion and deposition for regenerating flycatcher habitat from lateral erosion. However, deposition and erosion processes may still continue on bars and islands.		Minimal flycatcher territories and suitable habitat in this reach. Allowing the river to meander over a greater flood plain could create new and younger age classes of vegetation for flycatcher through erosion and deposition of sediments. Flycatcher habitat could improve with a meandering river.	Minimal flycatcher territories and suitable habitat in this reach. This strategy could have a positive impact on flycatcher habitat from the increased likelihood of overbank flooding and greater sinuosity.	

Table 34. Predicted Effects to Flycatcher Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Cochiti Dam to Angostura Diversion Dam	This reach does not have flycatchers or flycatcher suitable habitat. Stabilizing the bed elevation would at least prevent further degradation of flycatcher habitat in this reach.	This reach does not have flycatchers or flycatcher suitable habitat. Reduced ability for erosion and deposition from lateral erosion needed for flycatcher habitat. However, deposition and erosion processes may still continue locally on bars and islands.		This reach does not have flycatchers or flycatcher suitable habitat. Allowing the river to meander over a greater flood plain could create new and younger age classes of vegetation for flycatcher through erosion and deposition of sediments.	This reach does not have flycatchers or flycatcher suitable habitat. Flycatcher habitat within this reach would not be affected as there really is none, or the potential for habitat creation would be slightly improved.	
Angostura Diversion Dam to Isleta Diversion Dam	Minimal flycatcher territories and suitable habitat. Current suitable habitat becoming over mature and declining in value for flycatchers. Preventing channel incision would help prevent further decrease in flycatcher habitat.	Minimal flycatcher territories and suitable habitat. Current suitable habitat becoming over mature and declining in value for flycatchers. No significant change to flycatcher habitat would occur.			Minimal flycatcher territories and suitable habitat. Current suitable habitat becoming over mature and declining in value for flycatchers. Flycatcher habitat within this reach would not be affected or would be slightly improved with an increased likelihood of flooding.	Minimal flycatcher territories and suitable habitat. Current suitable habitat becoming over mature and declining in value for flycatchers. Sediment management may build desirable point bar habitat for fly-catcher. However, the patch size may not be large enough for flycatcher. This reach has a low sediment supply and increasing the sediment supply could create islands and increased shoreline habitats.

Table 34. Predicted Effects to Flycatcher Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Isleta Diversion Dam to Rio Puerco	Promoting elevation stability in this reach likely would not have a great impact on flycatcher habitat as there is not much currently present. However, this strategy would prevent future channel incision in this reach.		Minimal flycatcher habitat or territories within this reach. Overall, this strategy would not change flycatcher habitat significantly from existing conditions. If management activities are taken that allows bed elevation increases and reconnection of side channels and backwaters, benefits to flycatcher habitat would occur.	Minimal flycatcher territories and suitable habitat in this reach. Current suitable habitat becoming over mature and declining in value for flycatchers. Impacts to flycatcher habitat from this strategy could be positive if the river were to migrate to occupy the newly available area.	Minimal flycatcher territories and suitable habitat in this reach. Flycatcher habitat may benefit from increasing overbank flooding.	Minimal flycatcher territories and suitable habitat in this reach. Impacts for flycatcher depend on the type of sediment management.
Rio Puerco to San Acacia Diversion Dam	No impact on flycatcher. If anything, positive as it would not let further incision occur in this reach and allow a continuation of overbank flooding.	This reach has historically had populations of flycatchers and suitable habitat. This strategy decreases the river's abilities for erosion and deposition from lateral migration and, thus, decreases regenerating flycatcher habitat.		Allowing the river to meander over a greater flood plain could create new and younger age classes of vegetation through erosion and deposition, potentially improving and regenerating flycatcher habitat.	This reach has had localized populations of flycatchers and areas of suitable habitat. Habitat for flycatcher in this reach likely would be improved by this strategy by providing increased overbank flooding.	

Table 34. Predicted Effects to Flycatcher Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
San Acacia Diversion Dam to Arroyo de las Cañas	No impact on flycatcher as there are very few areas with suitable habitat or historic flycatcher territories. If anything, positive as it would not let further incision occur in this reach.	The river's ability for erosion and deposition would decrease, decreasing the potential for creating flycatcher habitat.		By increasing the space available for river movement, the potential for suitable conditions for seed establishment and creation of new flycatcher habitat would increase.	This strategy could have a positive impact on future potential flycatcher habitat from the increased likelihood of overbank flooding. Minimal areas of suitable or occupied habitat exist presently within this reach.	This reach likely would require the addition of sediment which would allow for some aggradation that would be beneficial for any potential flycatcher habitat creation in the future.
Arroyo de las Cañas to San Antonio Bridge	This strategy within this reach would involve stabilizing a rising bed, which would be achieved primarily through the Reconstruct/ Maintain Channel Capacity and Manage Sediment Strategies.		Overall, this strategy would not change the minimal flycatcher habitat existing currently within this reach. This reach currently has an aggrading channel and attached side channels; main-taining that trend would increase the possibility of flycatcher habitat creation. However, the maintenance of channel capacity in this reach may cause a reduction in potential overbank flooding and may reduce the possibility in habitat creation.			This strategy would not change flycatcher habitat significantly from existing conditions as there are minimal areas of suitable habitat or historic territories within this reach. However, the reduction in sediment in this reach may cause a reduction in potential overbank flooding and may reduce the possibility in habitat creation.

Table 34. Predicted Effects to Flycatcher Habitat from River Maintenance Strategies in Various Reaches

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
San Antonio Bridge to River Mile 78	This strategy within this reach would involve stabilizing a rising bed, which would be achieved primarily through the Reconstruct/ Maintain Channel Capacity, Increase Available Area to the River, and Manage Sediment Strategies.		There is a large population of flycatchers and an abundance of suitable habitat within this reach. Flycatcher impacts will depend on site locations and need site assessments.	This strategy would be beneficial to the abundance of currently existing flycatcher habitat by allowing the river to aggrade and potentially move into a larger flood plain, expanding habitat in the future.		Impacts would be site-specific for the large flycatcher population, but decreasing aggradation and the potential for occurrence of sediment plugs would negatively impact existing and developing flycatcher habitat.
River Mile 78 to Full Pool Elephant Butte Reservoir Level	No impact on the moderate amount of flycatcher habitat and territories mainly located in the northern extent of this reach. This strategy within this reach would involve stabilizing a rising bed, which would be achieved primarily through the Reconstruct/ Maintain Channel Capacity, Increase Available Area to the River, and Manage Sediment Strategies.		Removing sediment and preventing overbank flooding would be a detriment to flycatcher habitat. In instances where the channel would be relocated, if done so with a minimal bank height and an opportunity for overbank flooding, creation of flycatcher habitat may be possible.	Generally positive for flycatcher but needs to be accompanied by sediment management that promotes aggradation and the formation of potentially suitable flycatcher habitat, particularly in the severely degraded downstream portion of this reach. In areas where the bed degradation is currently below the root zone, the collapse of the bank may allow the formation of potentially suitable flycatcher habitat within the channel to occur.		Sediment augmentation may improve current flycatcher habitat in downstream portions of this reach, but settling basins would have the opposite effect. This strategy is very site-specific and depends on the Elephant Butte Reservoir level, and the incoming sediment supply in some areas the basin may create habitat, but require higher flows to allow for overbank flooding in other areas.

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
Infrastructure relocation or setback	Generally out of flood plain; can be positive for silvery minnow habitat by allowing sinuosity and habitat diversity. Generally positive for flycatcher habitat by allowing for a wider as opposed to deeper river system. A greater likelihood of overbank flooding.	Can encourage current geomorphic processes to continue, such as bend migration, and the creation of new flood plain and riparian areas. Opportunity to connect to historical channels and oxbows. For incised channels, may provide an opportunity to establish new inset flood plain and riparian zone. Bank erosion should also result in deposition of sediment downstream and potentially establish bars and low surfaces. Bend migration can erode banks causing riparian vegetation to fall into the channel.	Bend migration river movement creates broader flood plain and more favorable riparian zone habitat. Inset flood plain increases overbank flooding and riparian zones which creates variable depth and velocity habitat types including potential spring runoff silvery minnow nursery habitat. The lateral and down valley migration of the river provides more opportunity for successional age classes of potentially native vegetation for flycatcher habitat. Longer meander bends may establish greater pool depth and eroding banks providing additional complexity.
CHANNEL MODIFICATION			
Complete Channel Reconstruction and Maintenance	Depends on project design and scope. Generally negative for silvery minnow habitat due to decrease in low velocity habitats. Projects may be designed to have less impact on silvery minnow habitat. Generally negative for flycatchers if channel decreases potential for overbank flooding and/or acts as a drain, decreasing ground water level that could cause stress for vegetation and eventually encourage exotic encroachment.	Increased sediment transport through a delta or reconstructed channel. Decreases upstream channel aggradation. Can lead to channel bed lowering upstream of the project site, and low-flow alternate bars can form within the excavated channel. Relatively uniform width, depth, and velocity. Reduces braiding and split delta channels. Can lower the ground water table, and reduce the size of river bars. If medial and alternate bars are not removed as part of ongoing maintenance, then the amount of shallower, lower velocity areas should increase.	Can have more uniform width, depth, and velocity. Limited amount of low or no velocity habitat; low amount of cover. Reduces braiding and distributary channels and, thus, provides less opportunity for riparian growth. Lowers ground water table and reduces the size of river bars. If medial and alternate bars are not removed as part of ongoing maintenance, then the amount of smaller depth and velocity habitat increases.
Channel Relocation Using Pilot Channels or Pilot Cuts	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat or may decrease habitat diversity by creating a monotypic channel for water conveyance. Projects may be designed to improve flycatcher habitat or may decrease habitat suitability if channel takes too long to widen and incision and lowering of the water table occurs.	Lengthening can bring sediment transport capacity more in balance with sediment supply in supply-limited reaches. Re-establishes meanders, increases channel stability, and initiates new areas of bank erosion and deposition. Can provide overbank flooding and can create connected flood plain/ wetted areas.	Depending on project design and scope, can provide overbank flooding and establish new areas of riparian vegetation. Can increase the complexity of habitat by creating connected flood plain/wetted areas for silvery minnow egg entrainment and larval development.

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
Island and Bank Clearing and Destabilization	Generally positive for silvery minnow, reduces flow needed to inundate overbank habitat. Projects may be designed to improve flycatcher habitat or may decrease habitat suitability if channel takes too long to widen and incision and lowering of the water table occurs.	Promotes a wider channel with greater flood plain connectivity, and better transport capacity/supply balance. New sediment balance may be temporary unless increased supply is maintained. Reduces further degradation of the channel and lowering of the water table. learing and destabilization would result in the lowering and/or loss of islands and bars, but sediments from destabilized areas may deposit in new bars, which would be more connected to the main channel and suitable for vegetation growth. Cleared areas may become zones of sediment deposition and vegetation may re-grow, making re-clearing necessary for benefits to continue.	Islands/bars that are more connected to the main channel can provide silvery minnow with a greater variety of depth and velocity habitat types. Provides low velocity habitat during high flows for adult fish. Increased overbank flooding creates variable depth and velocity habitat types including silvery minnow nursery habitat during spring runoff and aids in increasing egg and larval entrainment. Loss of habitat may be temporarily negative depending on site specific details and proximity to flycatcher territories, however, sediment accumulation forming new bars or islands could promote new seed source establishment and potentially young native successional stands to develop into flycatcher habitat. By reducing further degradation of the channel and lowering of the water table, the flood plain has a better chance of connectivity which is better overall for the flycatcher.
Bank Line Embayment	Depends on project design and scope. May be positive for silvery minnow by providing more low velocity habitat for silvery minnow. Depends on project design and scope. May provide more surface water for vegetation and possibly attract flycatchers establishing territories.	Historical areas of channel slow water velocity and shallow bank line are restored/rehabilitated. Bank line embayments are zones of sediment deposition and have a finite lifespan without periodic re-excavation.	Slow water velocity and shallow depth bank line habitat. Increase in egg retention and availability of nursery larval habitat during high flow. Increases probability of native vegetation growth and potential for flycatcher habitat.
Pilot Cuts Through Sediment Plugs	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat or may decrease habitat diversity by creating a monotypic channel for water conveyance. Projects may be designed to improve flycatcher habitat via berm placement techniques that encourage sediment	Connecting small channels through sediment plugs results in plug material being transported downstream to re-establish preplug riverine conditions. Restores flow velocity and depth conditions found in the main river channel. Allows sediment transport to continue, which may possibly provide new bars and islands downstream.	Allows sediment transport to continue, which may possibly provide new areas for riparian vegetation establishment. While the sediment plugs block main channel flows, silvery minnow do utilize overbank channels through the riparian corridor created by the plug. There is increased potential for silvery

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
	transport and deposition downstream for example, or may decrease habitat diversity by creating a monotypic channel for water conveyance that would decrease the chance of overbank flooding potential.		minnow stranding during receding flow conditions.
Side Channels (High Flow, Perennial, and Oxbow Re-establishment)	Generally positive for silvery minnow, provides greater habitat diversity. Generally positive for flycatcher, provides greater vegetation potential and increases water surface elevation. During construction, vegetation may need to be cleared, but long-term benefits could outweigh the disadvantages.	Important to natural systems for passage of peak flows. Sediment tends to fill in high-flow side channels over time. Can decrease peak-flow water surface elevation and may decrease sediment transport capacity until sediment blocks the side channel. Periodic inlets and outlet sediment removal may be needed to maintain project benefits. Side channels result in raising the ground water table and can supply surface flows to overbank and flood plain areas. Can reconnect the flood plain to the channel, creating areas with variable depth and velocity.	Can result in higher ground water table, increasing the health of the riparian zone. Can reconnect the flood plain to the channel, creating nursery habitat for silvery minnow with variable depth and velocity habitats. Provides low velocity habitat during high flows for adult fish and developing larvae. Increase in retention of eggs and larvae during high flows. Raising the ground water table to provide water to developing riparian areas increases vegetation health. Periods of increased surface flows, particularly during mid-May to mid-June, increases probability of flycatcher territory establishment in areas with suitable habitat.
Longitudinal Bank Lowering or Compound Channels	Generally positive for silvery minnow, reduces flow needed to inundate overbank habitat. Generally positive for flycatchers and flycatcher habitat, reduces flow needed to inundate overbank habitat.	Lowered bank line can promote increases in channel width and decreases in main channel velocity, depth, shear stress, and sediment transport capacity. Reduces potential for channel degradation, thereby maintaining a higher water table and more connectivity with backwaters, side channels and flood plain. Increases overbank flooding, creating areas of variable depth and velocity.	Promotes overbank flooding favorable for establishment of riparian vegetation as well as creating variable depth and velocity habitat. Reduces potential for channel degradation, thereby maintaining a higher water table and more connectivity with backwaters and side channels. Increased overbank flooding creates variable depth and velocity habitat types including silvery minnow nursery habitat during spring runoff. Increased overbank flooding maintains moist soil conditions during flycatcher territory establishment. Growth of native riparian vegetation can enhance habitat conditions for the flycatcher.

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
Longitudinal Dikes	Generally negative for silvery minnow habitat, reduces habitat complexity and sinuosity. Generally negative for flycatcher habitat, reduces habitat complexity and sinuosity. Construction activity is very intensive and requires a high amount of maintenance.	Can create a zone of higher main channel velocity resulting in increased sediment transport capacity. This can potentially cause the channel to deepen and create a sediment depositional zone downstream. Can decrease overbank flow area and can result in more uniform channel velocity and depth.	Can decrease overbank flows, reducing the health of riparian zone. This can be partially mitigated by providing culverts for wetting the riparian zone. Can result in more uniform channel velocity and depth.
Levee Strengthening	No change for silvery minnow, maintains current conditions. Depends on project design, scope and location. Projects would typically be in areas away from flycatchers as flycatchers are typically located away from pre-existing levees and closer to the river or other water sources, and projects would also allow increased infrastructure capability to handle overbank flooding between the river and the levee. Maintenance activity would be invasive to nearby vegetation	The geomorphic response associated with levee installation has already occurred for the levee strengthening method. Initial levee construction generally resulted in flood plain narrowing. Raising or enlarging the levee causes very minor or no geomorphic effects. Small amounts of clearing may be required to enlarge the levee and reduce the side slope. May allow channel relocation nearer to levee.	Initial levee construction and the accompanying flood plain narrowing affect the habitat. Raising or enlarging the levee causes very minor o no habitat effects. Small amounts of clearing may be required to enlarge the levee and reduce the side slope.
Jetty/Snag Removal	Generally positive for silvery minnow, allows for bank migration and flood plain connectivity. Depends on project design and scope. By destabilizing the bank, could increase the possibility of lateral migration of the river or channel widening.	Jetty removal may result in channel widening and increased flood plain connectivity. Channel widening is less likely to occur where the riparian vegetation root zone provides more bank stability than the jetties. Channel widening (unless hampered by existing vegetation) could reduce channel flow depth and velocity.	The habitat may not change if the existing vegetation has more effect on bank stability than the jetties themselves. Otherwise, channel widening could reduce channel flow depth and velocity and create more bank line habitat.
Bank Protection/Stabilization			
Longitudinal Features			
Riprap Revetment	Generally negative for silvery minnow habitat, reduces habitat complexity and sinuosity. Rip rap structures may provide habitat for predatory fishes. Depends on project design, scope and location. Bank protection would protect suitable habitat if present, but vegetation may already be declining in value in reaches	Eliminates bank erosion; causes local scour and channel deepening. Studies about longer reach response are contradictory. Can be susceptible to flanking if upstream channel migration occurs. Prevents bend migration and the establishment of new depositional zones. Eliminates sediment supplied from local bank erosion. The point bar can remain connected to the main	Prevents bend migration and the establishment of new depositional zones where vegetation could become established. Eliminates sediment supplied from local bank erosion. The steep bank angle on the outside of the bend limits fish cover, except for the riprap interstitial spaces. The point bar remains connected to the

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
	where incision is to the point where lateral migration is occurring to such an extent that riprap revetment is necessary.	channel. The flow velocity, depth, and bank angle would be greater than typically found in natural channels along the outside bank of a river bend. Interstices within the riprap could host low-energy "pockets" along the bank.	main channel and remains static. The flow velocity and depth are greater than typically found in natural channels along the outside bank of a river bend.
Other Type of Revetments	Effects are essentially the same as riprap revetments.	Effects are essentially the same as riprap revetments.	Effects are essentially the same as riprap revetments
Longitudinal Stone Toe with Bioengineering	Effects are essentially the same as riprap revetments.	Similar to riprap revetment.	Same as riprap revetment. Bioengineering provides very minimal benefits to riparian community.
Trench Filled Riprap	Effects are essentially the same as riprap revetments.	Bank erosion processes continue until erosion reaches the location of the trench. After launching, response is the same as for riprap revetment.	Same as riprap revetment.
Riprap Windrow	Effects are essentially the same as riprap revetments.	Same as trench filled riprap.	Same as riprap revetment.
Deformable Stone Toe/Bioengineering and Bank Lowering	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat or may decrease habitat diversity by creating a high velocity area with little habitat diversity. Projects may be designed to improve flycatcher habitat and lowering the banks on terraced locations could promote overbank flooding potential.	The design is intended to allow bend migration at a slower rate than without protection. River maintenance may still be required in the future. Water surface elevations could be lower with bank lowering. After installation, and before the toe of the riprap becomes mobile, the channel bed may scour along the deformable bank line. Bank erosion occurs during peak-flow events, which mobilizes the small-sized riprap along the bank toe. Future bank migration would allow new depositional surfaces to be established.	If flood plain is created behind the stone toe and vegetation becomes established before the toe is lost, an expanded riparian area could develop. Future bank migration would allow new depositional surfaces to establish, which would become new riparian areas.
Bioengineering	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat or may decrease habitat diversity by creating a high velocity area with little habitat diversity. Bioengineering would not be a standalone method, and further analysis would need to be completed on a project specific description. May have long-term benefits to flycatchers.	Vegetation has the lowest erosion resistance of all available methods. Plantings require time to become established before any bank protection is realized. Lateral and down-valley bank line movement can continue because bioengineering does not permanently fix the bank location. Allows more natural movement of river channel.	If the technique is successful, it could promote the establishment and development of riparian vegetation without significant armament to the bank line. Allows more natural movement of river channel.

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
Riparian Vegetation Establishment	Effects of this type of project may be mixed. Initially vegetation may provide low velocity refuge areas during overbank periods. Long-term establishment of vegetation may add to channel narrowing which is negative for silvery minnow. Generally positive for flycatchers and flycatcher habitat. Encouraging new native growth could provide suitable habitat once mature.	Can cause sediment deposition in overbank areas due to increased flow resistance. Sediment deposition in the overbank can increase main channel sediment transport capacity by raising the bank height.	Directly adds to the amount of riparian vegetation. Increased growth of riparian vegetation in overbank areas can enhance habitat conditions for both the flycatcher and the silvery minnow. Encroachment of mature vegetation may eventually lead to a narrower and more confined channel which is negative for silvery minnow habitat.
Transverse Features or Flow Deflection Techniques	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat since they tend to create variable depth and velocity habitat, which increases complexity. In general, transverse features decrease bank erosion and deepen the main channel locally.	These methods may cause local sediment deposition between structures and/or local scalloping along the bank line. Flow is deflected away from the bank line, thereby altering secondary currents and flow fields in the bend. Eddies, increased turbulence, and velocity shear zones are created. Methods induce local channel deepening at the tip. Shear stress increases in the center of the channel, which maintains sediment transport and flow capacity. Sediment deposition between structures may allow establishment of islands, bars, and backwater areas. Channel deepening and tip scour could occur locally	Sediment deposition between structures may allow establishment of riparian vegetation and backwater areas. Channel deepening and tip scour could occur locally. Depending on site specific details, bendway weirs would allow for overbank flooding conditions for flycatchers. Local scour could provide habitat diversity and deep habitat during low flow conditions.
Bendway Weirs	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat since they tend to create variable depth and velocity habitat, which increases complexity. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	The location of the thalweg is shifted away from the outer bank line. Local scour at the tip occurs because of the three-dimensional flow patterns. Secondary currents are interrupted, and flows are redirected away from the bank. The outer bank can become a zone of lower velocity. The combined effect of the tip scour and lower velocity along the bank line creates a flow condition of variable depth and velocity. Scalloping also can occur along the bank line or sediment deposition between structures depending upon local conditions and bendway weir geometry. Can reduce local sediment supplied from bank erosion because the current river alignment is maintained.	Same as transverse features or flow deflection techniques above.

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
Spur Dikes	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat since they tend to create variable depth and velocity habitat, which increases complexity. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	Spur dikes block the flow up to bank height, thus shifting the thalweg alignment to the dike tips. Peak flow capacity can be reduced initially until the channel adjusts. The channel adjusts to the presence of spur dikes by forming a deeper, narrower cross section with additional scour downstream of each spur dike. Sediment deposition can occur between spur dikes. There is a greater tendency for sediment deposition between spur dikes than the other transverse features.	Same as transverse features or flow deflection techniques above. There is a greater tendency for sediment deposition between spur dikes than the other transverse features.
Vanes or Barbs	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat since they tend to create variable depth and velocity habitat, which increases complexity. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	These structures redirect flow from the bank toward the channel center and reduce local bank erosion while providing a downstream scour hole. Sediment deposition or bank scalloping can occur along the outer bank, depending upon spacing.	Same as transverse features or flow deflection techniques above.
J-Hook	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat since they tend to create variable depth and velocity habitat, which increases complexity. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	Redirects flow away from eroding banks, the same as vanes or barbs, with an added downstream-pointing "J" configuration. The J-hook creates an additional scour hole pool and can produce a local downstream riffle. Remainder of the geomorphic response is the same as for vanes.	Same as transverse features or flow deflection techniques described above. Additional pool habitat is created by the J-hook.
Trench Filled Bendway Weirs	Depends on project design and scope. Projects may be designed to improve silvery minnow habitat since they tend to create variable depth and velocity habitat, which increases complexity. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	Once the bank erosion reaches the bendway weir tips, the flow is redirected away from the eroding bank. The location of the thalweg is shifted away from the outer bank line. Local scour at the tip occurs because of the three-dimensional flow patterns. Secondary currents are interrupted. The outer bank can become a zone of lower velocity.	Provided the bendway weirs constructed in a trench remain intact, the habitat characteristics will be about the same as bendway weirs constructed in the channel.
Boulder Groupings	Generally projects are designed to provide refuge areas for silvery minnow during low flow. Projects may be designed to also provide	Creates a zone of local scour immediately downstream of the boulders. Creates areas of variable depth and velocity. Creates velocity shear zones.	Can provide structure and habitat for fish.

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
	some level of bank protection. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	Effects are localized to the immediate vicinity of the boulders. Increases channel roughness at high flows. Adds complexity to the system.	
Rootwads	Generally, projects are designed to create refuge areas for silvery minnow during low flow. Projects may be designed also to provide some level of bank protection. Silvery minnow response to past projects has been mixed. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	Creates local scour pools and areas of variable velocity. Increases flow resistance along the bank line, which dissipates energy, traps and retains sediments, and creates turbulence that can move the main current away from the bank line. Adds complexity to the system. Variable depth and velocity conditions can be created. Some potential for creating areas of sediment deposition (depending on specific placement). Cottonwood tree rootwads have a design span of about 5 years; therefore, this method has been used with many other methods to create habitat.	Adds complexity to the system. Variable depth and velocity conditions can be created. Some potential for creating areas of sediment deposition (depending on specific placement), which is generally beneficial for establishing and developing riparian vegetation. Can provide structure and habitat for silvery minnow. Isolated pools are often maintained in scour pools caused by debris, including rootwads. This can serve as refugia habitat for silvery minnow during low-low periods. Similar to large woody debris (LWD). Could trap sediment and encourage new native vegetative growth.
Large Woody Debris	Generally, projects create refuge areas for silvery minnow during low flow. Projects may be designed also to provide some level of bank protection. Silvery minnow response to past projects has been mixed. Could trap sediment and encourage new vegetation growth. No significant effect on flycatcher habitat.	LWD can provide local stream cover and scour pool formations, deflect flows, and increases depth and velocity complexity. Can promote side channel formation and maintenance. LWD in the Middle Rio Grande can lead to sediment deposition, including formation of islands, in reaches with large sand material loads. Could establish new sediment deposition areas. LWD constructed from cottonwood trees last about 3–5 years.	Adds complexity to the system. Sediment deposition can create areas where new riparian vegetation becomes established. Can create variable depth and velocity habitat. Can provide structure and habitat for fish. May provide for habitat diversity in areas with monotypic flow patterns and refugia habitat during low flows. These habitats also may provide refuge for predatory fishes. Increased areas of moist or flooded soil conditions could assist in flycatcher territory establishment and native vegetation recruitment.
CROSS CHANNEL (RIVER SPANNING) FEATURES			
Grade Control	Depends on project design and scope. Sediment deposition upstream of the structure may provide backwater habitat for silvery minnow and willow flycatcher. In general, river spanning grade control methods would not prevent the trend of	Grade control can reduce the gradient upstream by controlling the bed elevation and dissipating energy in discrete steps. At least during low flows, the upstream water surface is raised, depend-ing on structure height above the bed. Upstream velocity is reduced. There can be a local	Increased upstream connectivity with side channels at low flows, creating variable depth and velocity habitat. By preventing future upstream local degradation, the current level of flood plain connectivity can continue. Increased upstream water

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
	continued downstream incision in degrading reaches, which may cause issues with upstream fish passage requiring adaptive management. Channel spanning features would be designed to provide for upstream fish passage.	effect on sediment transport, scour, and deposition, depending on the structure characteristics. For low-head structures (1–2 feet), the amount of up-stream sediment storage is low and usually does not cause downstream bed level lowering as a result of upstream sediment storage. In supply-limited reaches, channel degradation downstream of the structure will continue as a result of excessive sediment transport capacity. The slope of the down-stream apron would be designed to provide fish passage and prevent local scour downstream from the structure. Due to the potential for the con-tinuation of the downstream channel incision trend, adaptive management may be necessary to provide for continued fish pas-sage. Reduces channel degra-dation upstream of this feature and can promote overbank flooding and raise the water table. Backwater areas could develop upstream, which also would raise the water table. If downstream degradation continued, the water table would be lowered.	levels (except for peak flows) likely would increase vegetative health and could attract flycatchers, particularly if overbank flooding conditions occurred during territory establishment. Low downstream apron slopes would be designed for fish passage
Deformable Riffles	Same as grade control above.	During low-flow conditions, where these structures are fixed, the effects upon channel morphology are described in the "grade control" response above. When the riprap material forming the riffle launches or deforms downstream, the bed can lower a relatively small amount.	Same as grade control above.
Rock Sills	Same as grade control above.	Riverbed elevation is held constant, while rock launches into the downstream scour hole. Since the bed is fixed, the effects on geomorphology are the same as for grade control.	Same as grade control above.
Riprap Grade Control (With or Without Seepage)	Same as grade control above.	Riprap is flexible and deforms into a scour hole. Can be at bed level or above. Can have short or long low-slope apron. Because the bed is fixed, the effects upon geomorphology are the same as for grade control.	Same as grade control above.

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
Gradient Restoration Facility (GRF)	Same as grade control above.	Bed is fixed. The effects upon geomorphology are the same as for grade control.	Same as grade control above.
Low-Head Stone Weirs (Loose Rock)	Same as grade control above. Provides pool habitat which could become low flow silvery minnow refugia.	These structures typically are constructed above the bed elevation without grout. During low flows, there is an abrupt change in the water surface elevation through the structures, creating an upstream backwater effect. Generally, these structures do not raise the water surface during high flows. Sediment continuity can be re-established after the scour pool and tailout deposit are formed. A series of structures can dissipate energy and reduce channel degradation. Can interrupt secondary currents and move main current to the center of the channel if constructed in bendways.	Same as grade control above. Can provide pool habitat. Fish usually can pass through the interstitial spaces between weir stones.
Conservation Easements	Similar to effects of infrastructure relocation or setback.	Allows space for existing fluvial processes to continue, which can preserve flood plain connectivity. Allows more natural river movement with variable depth and velocity and promotes greater area of undisturbed streamside terrain.	Allows more natural river movement and promotes greater area of undisturbed habitat.
CHANGE SEDIMENT SUPPLY			
Increase Sediment Supply	Generally positive for silvery minnow habitat in downstream reaches, to find sediment equilibrium and control degradation. Within project area, reach effects would depend on project design and scope. Perched river channels have greater connectivity with flood plain but may be more prone to channel drying at low-flow conditions. Generally positive for flycatchers as it would provide a greater likelihood of overbank flooding.	Where the river is lacking in sediment, adding sediment can stabilize or even reverse channel incision. Adding sand-sized sediment can reduce bed material size, especially where coarser material is available in an incising channel. May result in sand deposits in pools, reduction of gravel riffle height, decreased depth, and increased width-to-depth ratio. Additional sediment could result in the establishment of river bars and terraces. Could increase the potential for overbank flooding and raise the water table elevation.	Additional sediment could result in establishing river bars and terraces, which would be conducive to establishing and developing riparian areas. Could increase the potential for overbank flooding and raise the water table elevation.
Decrease Sediment Supply	Effects would depend on current status of sediment supply. Within project area, reach effects would depend on project design and scope.	Where the river has excess sediment supply, reducing or removing the sediment supply can stabilize or reverse aggradational trends. Reduction	In general, more uniform depth and velocity habitat would result, which decreases habitat complexity for the silvery minnow. The

Table 35. Predicted Endangered Species, Geomorphic and Habitat Effects for River Maintenance Methods Proposed on the MRG

Method	Endangered Species Effects	Geomorphic Effects	Habitat Effects
	Perched river channels have greater connectivity with flood plain but may be more prone to drying. Projects that decrease sediment supply are generally negative for flycatchers as it may change the aggadational trend that promotes overbank flooding.	of sediment supply could cause the bed material to coarsen. In general, a more uniform channel depth and velocity would result. In addition, the tendency for the channel to braid and form split delta channels would be reduced. Water table may fall.	opportunity for the channel to braid and form distributary channels would be reduced, providing less opportunity for riparian growth.

consultation. The morphology changes from a specific method in an isolated location are expected to be local in nature and have a negligible effect on the reach morphology. It is anticipated that river maintenance projects at multiple site locations, implemented as part of a river maintenance strategy for a reach, may have a cumulative effect and a noticeable impact on the dynamics of the reach. It is expected that the reach effects of multiple river maintenance projects could be similar to the geomorphic effects of the river maintenance strategy that best describes the projects (see section 6.1.1). Reach monitoring would be accomplished to determine the actual geomorphic and biological effects. Monitoring also will help determine the threshold for the number of projects, for both a reach and a given river maintenance strategy, needed to be implemented for the cumulative geomorphic effects to affect changes in the morphology on a reach basis. The coupling of different methods together at specific project sites would need to be analyzed on a case-by-case basis, since the number of possible variations would be too numerous to list in this BA. This would be additional information that would be provided to better define a project and its effects. As needed, additional details of the effects tiered off this programmatic river maintenance BA would be developed and provided to the Service.

6.2.2 Effects of River Maintenance Support Activities

6.2.2.1 Roads and Dust Abatement

This activity primary involves vegetation removal for access to sites and watering of the roads and construction area. Access roads are generally out of the wetted area. Impacts to silvery minnow would be specific to pumping locations for the dust abatement. Pumping of water directly from the portions of the Rio Grande occupied by silvery minnow will be avoided in times when it is very likely that larval fish or eggs would be entrained into the pump. Screening of the pump intake and prioritizing pumping from irrigation/drain facilities, when possible, minimizes this take. If water is pumped from the river for dust abatement purposes, it would likely be pumped at a rate between 1.8 and 2.2 cfs for 4–8 minutes to fill a water truck. This would be a minimal impact to river flows, equating to a decrease in flows of approximately 0.2% for river flows of 1,000 cfs and approximately 0.1% for river flows of 1,500 cfs for 4–8 minutes. This activity has an insignificant effect on the silvery minnow and habitat for flycatchers.

Creation and maintenance of access roads have a bigger impact on flycatchers due to the destruction of established habitat. Reclamation biologists will work with the project lead to minimize the acreage of roads that would be within suitable habitats. Any work that involves vegetation clearing would be scheduled outside of times when flycatchers may be in the area.

6.2.2.2 Stockpiles and Storage Yards

Reclamation is proposing to continue using existing stockpile and storage locations. These are all located outside of the flood plain. Periodically, these sites require vegetation clearing (mowing and trimming), grading, graveling, drainage, and/or fencing. There are no impacts to silvery minnow due to stockpiles and storage yards. There are no impacts to flycatchers as there is no suitable habitat within existing storage yards and storage yards as they are located outside the flood plain.

6.2.2.3 Borrow and Quarry Areas

Reclamation is proposing to continue using existing borrow and quarry locations. These are all located outside of the flood plain and outside of critical habitat for either species. There are no impacts to silvery minnow or flycatchers; there is no suitable habitat within existing quarries.

6.2.2.4 Data Collection Activities

Data collection efforts are conducted through using boats, all terrain vehicles, and pedestrian travel (walking on land and wading in the river). The majority of the data collection methods are nondestructive in nature, requiring only short-term impacts of human presence within the area. The main exceptions are monitoring rangelines, subsurface monitoring, and water or sediment sampling. Subsurface monitoring requires disturbing the earth to collect samples or provide a soil characterization. Reclamation is proposing to continue using existing rangelines. Periodically these sites require vegetation clearing (mowing and trimming). There are no impacts to silvery minnow due to rangeline clearing or soil collections in the dry. There would be negative impacts to silvery minnow due to sampling in the wet, though impacts would be minimal due to the small area generally affected (less than 1 acre annually). Impacts to flycatchers will be minimal near rangelines or soil collection sites, and coordination between the Reclamation biologist and project lead would ensure ground crews keep their distance from territories during the summer. Any work that involves vegetation clearing would be scheduled outside of times when flycatchers may be in the area. Annually, the average total area affected for all data collection activities (wet and dry) is less than 16 acres. Impacts may include disturbance due to activity within the river and disturbance of sediment, which may affect turbidity and dissolved oxygen.

6.2.2.5 River Maintenance Implementation Techniques

There are various techniques that have been developed by river maintenance as the standard way (BMPs) to implement the methods that are designed for river maintenance project sites. All construction has negative impacts to endangered species. However, the benefits of using the described implementation techniques may help minimize the impact for the project overall. The benefits and construction impacts of the techniques are described in table 36. Project-specific documents will describe which of these techniques may be implemented to reduce impacts to species.

Table 36. Standard Implementation Techniques Used in Middle Rio Grande River Maintenance Projects

	Implementation Technique	Benefits of Implementation Techniques	Construction Impacts to Silvery Minnow	Construction Impacts to Willow Flycatcher
1	River diversion	Minimizes downstream turbidity impact during construction.	During berm construction minnows may be affected directly by construction equipment and the placement of material.	Generally no vegetation impacts.
2	River reconnection	Minimizes the amount of time construction equipment needed to work in the wet.	During construction, minnows may be affected directly by construction equipment.	Minimal vegetation impacts; work is done outside the active channel area.
3	Dewatering	Coupled with the river diversion technique to provide isolation of the project site from the main flow area. This technique minimizes the amount of time construction equipment needs to work in the wet.	During construction, minnows may be affected directly by construction equipment and drying of the river bed that may desiccate silvery minnow. This technique would be done in conjunction with river diversions, which may minimize the impacts to silvery minnow.	Depends on project design and scope. Short-term dewatering should have few impacts to established vegetation.

Table 36. Standard Implementation Techniques Used in Middle Rio Grande River Maintenance Projects

	Implementation Technique	Benefits of Implementation Techniques	Construction Impacts to Silvery Minnow	Construction Impacts to Willow Flycatcher
4	River crossings	Minimizes disturbance acreage in the wet by defining a set path for the construction equipment to follow. Equipment moves slowly across the river and are part of an equipment caravan. River crossings also are typically grouped temporally to minimize the time of disturbance for river crossings.	Minnows may be impacted by equipment crossing the river.	Generally no vegetation impacts.
5	Working platforms	Once working platforms are constructed, work occurs in the dry. This technique minimizes the amount of time construction equipment needs to work in the wet.	During working platform construction, minnows may be affected directly by construction equipment and being crushed by material placement. Water work warning should minimize this risk.	Generally no vegetation impacts.
6	Partial excavation of banks	This technique minimizes the amount of time construction equipment needed to work in the wet.	During construction in wet, minnows may be affected directly by construction equipment and being crushed by material placement in construction area. Water work warning should minimize this risk.	This may require removing vegetation that may impact flycatcher habitat.
7	Top of bank work	This means equipment was able to reach the desired placement area and elevation from the existing bank line without having the equipment actively in the river or needing to partially excavate the bank.	During construction in wet, minnows may be affected directly by construction equipment and being crushed by material placement construction area. Water work warning should minimize this risk.	This may require removing vegetation that may impact flycatcher habitat.

Table 36. Standard Implementation Techniques Used in Middle Rio Grande River Maintenance Projects

	Implementation Technique	Benefits of Implementation Techniques	Construction Impacts to Silvery Minnow	Construction Impacts to Willow Flycatcher
8	Amphibious construction	Typically, this method is employed when minimal disturbance of the dry portion of the project area is desirable, such as to minimize the loss of bank vegetation. This technique minimizes the disturbance to bank riparian areas.	During construction, minnows may be affected directly by construction equipment.	Generally no vegetation impacts.
9	Material placement	This technique helps prevent the formation of isolated pools or channels, which could trap fish or other species.	During construction, minnows may be affected directly by construction equipment and being crushed by material placement construction area. Water work warning should minimize this risk. Prevent-ing the formation of isolated pools decreases the like-lihood of stranding.	This may require removing vegetation that may impact flycatcher habitat.
10	Material removal	This technique helps prevent the formation of isolated pools or channels, which could trap fish or other species.	During construction, minnows may be affected directly by construction equipment and being stranded within the construction area. Preventing the formation of isolated pools decreases the likelihood of stranding.	This may require removing vegetation that may impact flycatcher habitat.
11	Infrastructure relocation	This technique may avoid the need to perform river maintenance activities in the river.	Work is generally out of the river channel and would have minimal impacts to silvery minnow.	This may require removing vegetation that may impact flycatcher habitat.

6.2.3 Unanticipated and Interim Work

The methods that are used for unanticipated and interim work for river maintenance are described within the river maintenance methods used (table 35). These include riprap revetments, levee strengthening, and riprap windrows. The effects of these methods would be similar to that described in table 35 for each method except that there may not be flexibility in the timing of the work that is needed and so may have greater effects on endangered species.

6.2.4 River Maintenance Site Size and Distribution Effects

Two general types of effects (direct and indirect) were evaluated for endangered species and their habitat from MRG river maintenance activities. Direct effects from implementation of river maintenance projects have been described in the previous subsection of section 6.2 and are dependent on project design and scope. Indirect or long-term effects for endangered species are geared more towards the long-term changes that may occur within a reach or upstream and downstream. Indirect effects are expected to be local for the implementation of individual river maintenance projects and related to the river maintenance methods used (section 6.2.1). The indirect effects from the implementation of multiple river maintenance projects within a river maintenance strategy are described in section 6.1. Effects to the silvery minnow and willow flycatcher are described, respectively, in sections 6.2.4.1 and 6.2.4.2.

6.2.4.1 Silvery Minnow

An estimated direct impact on silvery minnow from river maintenance activities occurring in the wet area of the river was developed by using information presented in section 3.6. Section 3.6.5 predicts future acreage impacts for river maintenance projects within each occupied reach. Density of silvery minnow (tables 37 and 38) is provided from Rio Grande population monitoring survey data (Dudley and Platania 2012). The mean density estimates for the slivery minnow from population monitoring data are presented for each month. Highest densities of silvery minnow generally occur in late spring and summer months (May and June) when maintenance work in the river historically has been restricted due to the occurrence of higher water depths associated with the snow melt runoff. Silvery minnow are presumed to be absent, and no critical habitat is associated with the Velarde to Rio Chama and Rio Chama to Otowi Bridge Reaches.

No survey data is available for Cochiti Dam to Angostura Diversion Dam, so that reach is not analyzed for density impact effects. All work in the wet is anticipated to have a direct effect and is likely to adversely affect silvery minnow and silvery minnow critical habitat.

Table 37. Mean Monthly Catch Rate (Silvery Minnow per 100 Square Meters [m^2]) from Rio Grande Population Monitoring Survey Data 1993–2011
(Not all reaches or months had equal numbers of surveys.)

	Angostura Diversion Dam		Isleta Diversion Dam to Rio Puerco		Rio Puerco to San Acacia Diversion Dam		San Acacia Diversion Dam to Arroyo de las Cañas		Arroyo de las Cañas to San Antonio Bridge		San Antonio Bridge to RM 78		RM 78 to Full Pool Elephant Butte Reservoir Level	
Month	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
1	**2.2**	1.5	**17.4**	14.9	**2.0**	1.4	**8.0**	5.7	**5.3**	2.7	**14.2**	13.6	**2.9**	2.2
2	**2.0**	0.5	**2.9**	1.0	**2.1**	0.5	**14.9**	4.9	**21.1**	11.2	**20.4**	11.5	**6.1**	1.8
3	**3.2**	1.3	**1.4**	0.7	**2.1**	1.1	**2.6**	1.0	**6.8**	4.9	**4.0**	3.4	**6.4**	4.8
4	**2.0**	0.7	**21.9**	16.8	**5.2**	3.3	**10.3**	4.3	**4.6**	2.2	**0.8**	0.3	**1.0**	0.3
5	**8.6**	6.3	**1.9**	0.6	**44.9**	43.4	**8.3**	3.9	**5.2**	2.5	**4.2**	3.2	**4.9**	2.9
6	**12.4**	4.0	**27.8**	9.0	**11.5**	4.6	**13.8**	5.7	**5.1**	1.8	**8.1**	4.1	**7.2**	2.2
7	**22.1**	9.0	**29.1**	10.5	**97.5**	45.3	**49.4**	17.3	**22.8**	9.2	**44.1**	30.2	**31.0**	18.2
8	**10.9**	2.9	**9.4**	2.7	**14.3**	9.2	**20.8**	8.4	**27.2**	11.2	**14.7**	12.3	**12.3**	4.7
9	**5.7**	1.7	**8.5**	2.9	**5.6**	3.0	**14.6**	5.8	**11.0**	4.8	**2.5**	1.9	**5.3**	1.7
10	**4.5**	1.1	**10.6**	4.0	**5.1**	1.7	**15.5**	4.7	**21.1**	9.1	**14.8**	8.1	**9.6**	4.2
11	**7.4**	3.7	**13.5**	5.6	**3.2**	1.6	**13.9**	9.8	**28.8**	22.3	**8.7**	8.6	**1.3**	0.9
12	**3.9**	1.4	**26.5**	15.1	**2.6**	0.7	**10.5**	2.4	**7.0**	2.0	**7.9**	6.0	**12.8**	5.6

Table 38. Estimated 10-year Total Impact to Rio Grande Silvery Minnow and Their Habitat from Average Acreage River Maintenance Work Occurring Within the Wet for Each Reach

10-year Average Estimated Impacts	Number Acres	Number m^2	Mean RGSM/100 m^2	Standard Error	Anticipated Decadal Impact (Number RGSM)
Angostura Diversion Dam to Isleta Diversion Dam	186	752,723	8.2	1.8	61,347
Isleta Diversion Dam to Rio Puerco	106	428,971	13.1	4.2	56,024
Rio Puerco to San Acacia Diversion Dam	49	198,298	27.8	12.9	55,206
San Acacia Diversion Dam to Arroyo de las Cañas	79	319,705	20.4	3.9	65,220
Arroyo de las Cañas to San Antonio Bridge	96	388,502	19.3	6.3	74,826

San Antonio Bridge to River Mile 78	155	627,270	12.7	3.6	79,600
River Mile 78 to Full Pool Elephant Butte Reservoir Level	235	951,022	9.7	1.9	91,774
10-year impact (number silvery minnows) based on mean density and average project size					483,997

Impacts from projects in the wet that are conducted outside of the summer months would have less impact on silvery minnows due to densities being lower. During times of high silvery minnow densities, the amount of take that would be estimated during a specific project would be higher. The proportional impact to the population at large is the same and related to the acreage, whether densities of silvery minnow are high or low when the project is taking place.

Using the average acreage of work within the wet and population numbers extrapolated for 10 years, approximately half a million silvery minnow may be impacted due to river maintenance activities in a 10-year timeframe (see table 37). If the maximum estimated acreage is used, this number increases to around 1.5 million minnows that would be impacted by river maintenance projects. It is unlikely that this full amount would be lethally impacted due to their ability to sense and avoid construction activity. Additionally, BMPs (section 3.6.4.5) would minimize the amount of take during construction.

6.2.4.2 Effects on Flycatchers

Estimates on flycatcher habitat directly impacted by river maintenance proposed activities over the 10-year analysis period were completed by comparing the average acreage of 'dry' potential area to be impacted within the reach by river maintenance activities (table 14 in section 3.7) to the approximate acreage of suitable flycatcher habitat using data from vegetation mapping and reconnaissance work completed in 2002 and 2008.

The river maintenance area between Velarde and Cochiti Reservoir has minimal areas of suitable flycatcher habitat patches. According to Southwestern Willow Flycatcher Habitat Reconnaissance – Upper Rio Grande from the Colorado State Line to Cochiti Reservoir, New Mexico, by Ahlers 2009, the most suitable habitat within this entire stretch is located just north of Cochiti Reservoir. In total, from the New Mexico State line to Cochiti Reservoir (excluding areas that were not accessible), 89 river miles and approximately 5,334 total acres were evaluated, and 11.9% of the area was considered either suitable or marginally suitable for flycatchers. Some areas were not quantified, either because they were on tribal property or because they were inaccessible.

Using the 11.9% average of suitable/marginally suitable habitat and the average of 60 acres of flood plain area per river mile, the following was assumed. Flood plains are defined in this context as being areas typically confined within the levees or natural geographic constraints. The one exception is in the San Marcial area, where flood plain also includes riparian vegetation to the west of the levees.

- Velarde to Rio Chama Reach (dry) (13 river miles) had an estimated 780 acres of flood plain area or potentially 92 acres of suitable habitat in 2008.

- Rio Chama to Otowi Bridge Reach (dry) (14 river miles) had an estimated 840 acres of flood plain area or potentially 100 acres of suitable habitat in 2008.

Because suitable habitat within the Cochiti Dam to Angostura Diversion Dam and Angostura Diversion Dam to Isleta Diversion Dam Reaches have not been quantified, the assumptions used to describe the Velarde to Rio Chama and Rio Chama to Otowi Bridge Reaches were also used for these reaches and resulted in the following:

- Cochiti Dam to Angostura Diversion Dam (dry) (23 river miles) has 1,380 acres of flood plain area or potentially 164 acres of suitable habitat.

- Angostura Diversion Dam to Isleta Diversion Dam (dry) (41 river miles) has 2,460 acres of flood plain area or potentially 292 acres of suitable habitat.

In 2002, a mapping effort (Callahan and White 2004) was conducted by Reclamation's Denver Technical Service Center staff based on the vegetation classification system done by Hink and Ohmart (1984). The 2002 vegetation codes were compared to the 2008 codes for further classification of suitability for flycatchers. Polygons that did not match up to the 2008 codes were excluded to maintain consistency, so the total flood plain acreage is likely underestimated for this reach. Using this system for this area, it was determined that:

- Isleta Diversion Dam to Rio Puerco (dry) area consists of 42 miles and 5,893 acres of flood plain area and potentially 826 acres of suitable or marginally suitable habitat. This area (in 2002) had a higher potential for flycatcher establishment considering roughly 14% of the area had either suitable or marginally suitable areas and a wider flood plain when compared to those reaches farther north.

Using the 2008 vegetation classification system from Southwestern Willow Flycatcher Habitat Suitability 2008 – Highway 60 Downstream to Elephant Butte Reservoir, New Mexico by Ahlers et al. in 2010, the potential suitable or marginally suitable habitat values were determined for the remaining reaches. These values indicate that:

- Rio Puerco to San Acacia Diversion Dam (dry) (11 miles) has 2,513 acres of flood plain area or potentially 640 acres of suitable or marginally suitable habitat. Approximately 25% of the area was considered either suitable or marginally suitable for flycatchers.

- San Acacia Diversion Dam to Arroyo de las Cañas (dry) (21 miles) has 3,930 acres of flood plain area and 377 acres of suitable or marginally suitable habitat. Approximately 10% of the area was considered either suitable or marginally suitable for flycatchers.

- Arroyo de las Cañas to San Antonio Bridge (dry) (8 miles) has 2,247 acres of flood plain area and 115 acres of marginally suitable habitat (no polygons within this reach were considered suitable). Approximately 5% of the area was considered either suitable or marginally suitable for flycatchers.

- San Antonio Bridge to River Mile 78 (dry) (9 miles) has 4,049 acres of flood plain area and 492 acres of suitable or marginally suitable habitat. Approximately 12% of the area was considered either suitable or marginally suitable for flycatchers.

- River Mile 78 to River Mile 62 (dry) (16 miles) has 11,006 acres of flood plain area and 925 acres of suitable or marginally suitable habitat. Approximately 8% of the area was considered either suitable or marginally suitable for flycatchers.

Given the two independent variables of construction area (using the average in the dry) and flycatcher suitable or marginally suitable habitat, the percent probability of the river maintenance project site implementation impacting flycatcher habitat was derived assuming the variables are random in nature and independent of each other within the total possible flood plain area. This exercise essentially provided an approximate acreage with the probability that the implementation effort would overlap the suitable or marginally suitable habitat for flycatchers. The percent probability and total acreage of flycatcher habitat that may be impacted is listed in table 39. It is also important to note that. due to best management practices (section 3.6.4.5), areas of suitable habitat would be intentionally avoided if possible; so this exercise is likely an overestimate of habitat that would be impacted by river maintenance activities. Obviously, consistency in data varies due to the timeframe differences as well as the methodology in determining the suitability. However, this analysis attempts to provide a rough estimate of potential flycatcher habitat that may be impacted by river maintenance (including rangeline maintenance) over the next 10 years.

6.2.4.3 Effects on Pecos Sunflower

Currently the only recognized Pecos Sunflower population within the river maintenance action area is located specifically on the Rhodes property south of Arroyo de las Cañas. Reclamation will survey areas to determine if Pecos sunflower is present in the area prior to work and will design projects to avoid impacts that may affect the Pecos sunflower population.

Table 39. Average Estimated Impacts to Flycatcher Suitable Habitat from River Maintenance Projects Occurring in the Riparian Area of the Rio Grande

Reach	Average River Maintenance Impact Acreage Over 10-Year Period	Acreage Suitable or Marginally Suitable Derived from 2008 or 2002 Reconnaissance or Vegetation Mapping	Total Possible Flood Plain Acreage Derived from 2008 or 2002 Reconnaissance or Vegetation Mapping	Percent Probability that Construction Efforts Would Occur Within Suitable Habitat	Total Acreage of Suitable Habitat Directly Impacted by Construction Activities Over 10-Year Period
Velarde to Rio Chama, dry	45	92	780	0.68%	5.31
Rio Chama to Otowi Bridge, dry	43	100	840	0.61%	5.12
Cochiti Dam to Angostura Diversion Dam, dry	111	164	1,380	0.96%	13.19
Angostura Diversion Dam to Isleta Diversion Dam, dry	103	292	2,460	0.50%	12.23
Isleta Diversion Dam to Rio Puerco, dry	60	826	5,893	0.14%	8.41
Rio Puerco to San Acacia Diversion Dam, dry	27	640	2,513	0.27%	6.88
San Acacia Diversion Dam to Arroyo de las Cañas, dry	43	377	3,930	0.10%	4.12
Arroyo de las Cañas to San Antonio Bridge, dry	54	115	2,247	0.12%	2.76
San Antonio Bridge to River Mile 78, dry	85	492	4,049	0.26%	10.33
River Mile 78 to Full Pool Elephant Butte Reservoir Level, dry	130	925	11,006	0.1%	10.93

6.3 Effects from Other Reclamation MRG Project Proposed Maintenance Activities

The geomorphic effects to the MRG of the other described MRG Project maintenance actions are expected to be insignificant. There is a small hydrologic effect of work associated with other MRG Project maintenance actions, when compared to existing condition, by improving the conveyance of water to the MRG. The drainage benefits are to developed areas, meaning that they benefit human activities and infrastructure. They do not necessarily benefit listed species. Two general types of effects (direct and indirect) were evaluated for endangered species and their habitat from other MRG Project maintenance activities. The specific impacts for each species are described below. Direct effects from implementation of other MRG Project maintenance activities are dependent on types of activities performed. Long-term effects for endangered species (indirect effects) also may occur due to the long-term changes that may occur within a reach or upstream and downstream. Effects from the LFCC O&M and Project drain maintenance are described in section 6.3.1 and 6.3.2, respectively.

6.3.1 LFCC O&M

6.3.1.1 Silvery Minnow

There are sporadic captures of silvery minnow within the LFCC. Reclamation opportunistically sampled the LFCC in 2010 and 2012. Silvery minnow were detected at 5 of the 26 sites sampled (figure 5). A total of 12 silvery minnow were collected in over 1,700 m^2 sampled. This equates to 0.7 silvery minnow per 100 m^2 or roughly 42,700 minnows within the LFCC from San Acacia Diversion Dam to RM 60. Sediment removal within this section is likely to adversely affect silvery minnow with direct effects due to dredging operations and indirect effects due to less suitable habitat within the LFCC with the removal of shallow, low velocity areas that silvery minnow use. Vegetation control and road maintenance would have little impact on silvery minnow due to it being conducted in the dry along the banks of the LFCC. Maintenance of the structure itself may or may not have adverse impacts because some of the projects may be able to be conducted in the dry. Those that require work within the channel may have adverse impacts to silvery minnow.

The LFCC is not considered part of critical habitat. Dredging of the LFCC near to the river may have a small hydrologic effect on the water in the river if the level of the LFCC is lower than the riverbed. This effect is likely very small but may adversely affect silvery minnow critical habitat. The existence of the LFCC may slightly increase seepage from the river in the reaches where there are perched channel conditions and contribute to drying, but the magnitude of this effect is likely small. Furthermore, the seepage rates from the river into the LFCC would be largest when the river stage was high and smallest when the stage was low. The proposed maintenance will not significantly change the elevation of the LFCC. Water levels within the LFCC are also a driver of this seepage; these water levels are controlled by pumping of water by the Bosque del Apache and Reclamation and operations of the check dams within the LFCC.

6.3.1.2 Willow Flycatcher

Flycatchers have been known to migrate through less desirable habitat, including the narrow growth around the LFCC, or to nest in areas in close proximity to roads. For this reason and to be in compliance with the Migratory Bird Treaty Act (MBTA) of 1918, areas would not be mowed within the April 15–August 15 period. Because mowing activities would ensure a 3-year rotation or mowing of about one-third of the area along the banks, habitat would remain for migration activity. Maintenance of the LFCC would have minimal impacts to flycatchers north of RM 62. The maintenance could be beneficial to flycatchers to ensure efficient delivery of water reaching flycatchers occupying habitat in areas south of the action area described in this BA. Dredging of the LFCC has a small hydrologic effect on the nearby vegetation. This effect is likely very small but may adversely affect flycatcher critical habitat.

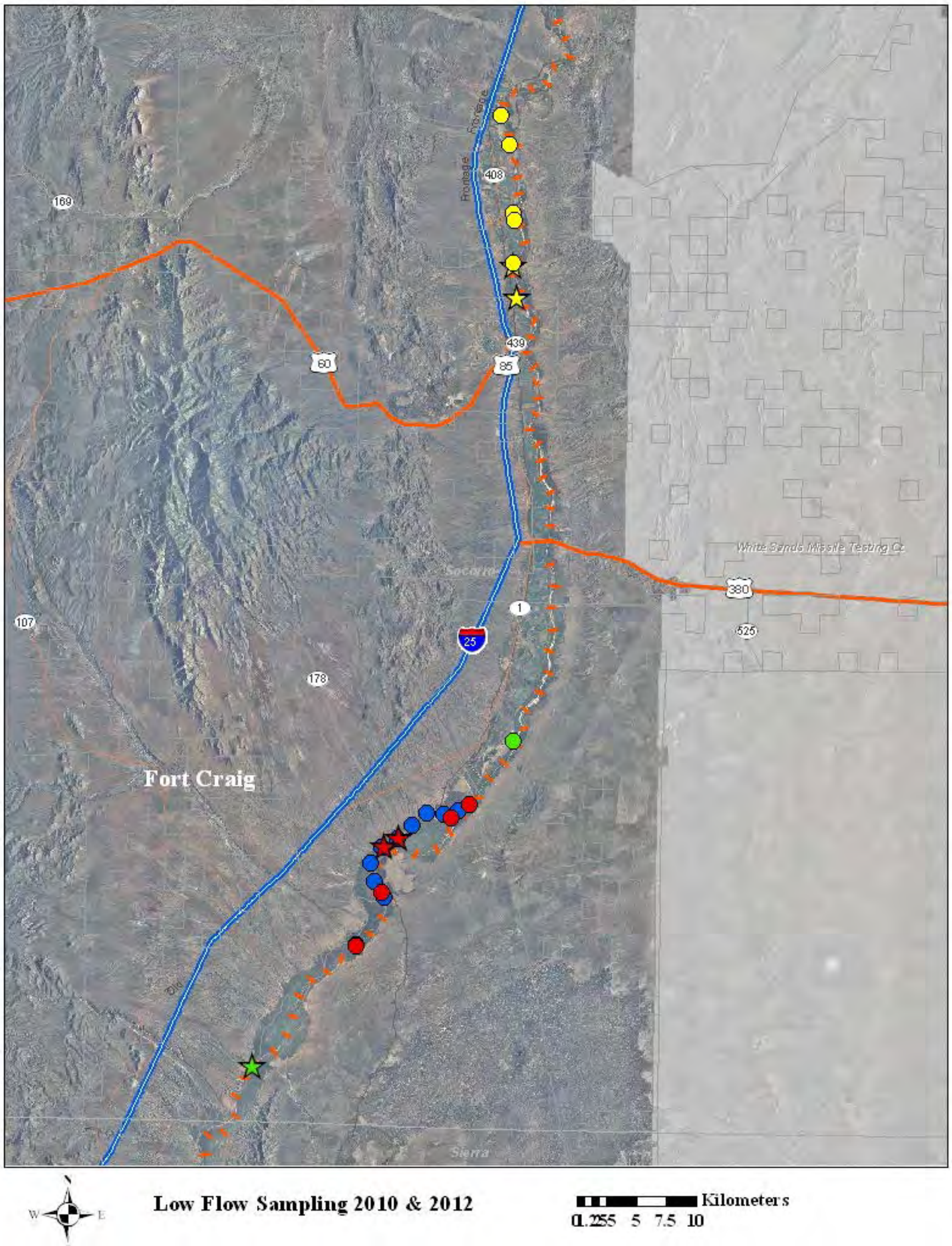

Figure 5. Presence/absence of silvery minnow at LFCC sites in 2010 and 2012. Stars indicate silvery minnow present at site. Green – February 2010, Yellow – March 2010, Red – September 2010, Blue – February 2012.

6.3.2 Project Drain Maintenance

6.3.2.1 Silvery Minnow

There have been no recent surveys for silvery minnow within the Project drains. Cowley et al. (2007) surveyed within the Peralta Canals that are on the east side of the river. They found that silvery minnow were present within the drainage system, especially during irrigation season and dry periods in the river. It is expected that many of the drains in the MRG would contain low levels of silvery minnow. Work within the wet portions of the drains is likely to adversely affect silvery minnow with direct effects due to dredging operations and indirect effects due to less suitable habitat within the Project drains with the removal of shallow, low velocity areas that silvery minnow use.

Using the estimated density of silvery minnow developed for the LFCC, we would estimate that, on average, 1,500 silvery minnow would be impacted annually by work within the Project drains. It appears that, during non-irrigation season, densities of silvery minnow are lower. Work conducted during this season would have a smaller impact on the species. These drains are not considered part of the critical habitat. Dredging of the drains near the river may have a small hydrologic effect on the water in the river if the level of the drain is lower than the riverbed. This effect is likely very small but may adversely affect silvery minnow critical habitat.

6.3.2.2 Willow Flycatcher

Flycatchers have been known to migrate through less desirable habitat, including the narrow growth around the State drains or nest in areas in close proximity to roads. For this reason and to be in compliance with the MBTA, areas would not be mowed within the April 15–August 15 period. Most drains are located outside of suitable flycatcher habitat, but maintenance on the San Juan Drain, for example, would have more of an impact to flycatcher habitat because there are flycatcher territories in close proximity to the drain. Coordination between the Reclamation biologist and the project lead for drain maintenance would need to take place to ensure maintenance actions would not have any effect to flycatchers. Dredging of the drains has a small hydrologic effect on the nearby vegetation. This effect is likely very small but may adversely affect flycatcher critical habitat.

6.3.2.3 Pecos Sunflower

The population of Pecos sunflower (figure 6) located on La Joya State Wildlife Area exists along the La Joya Drain. Water from the drain augments the wetlands on the wildlife area from direct irrigation and possibly from seepage. Any maintenance that would affect flow or seepage of water from this drain may have an adverse affect on the Pecos sunflower population. Project areas near occupied

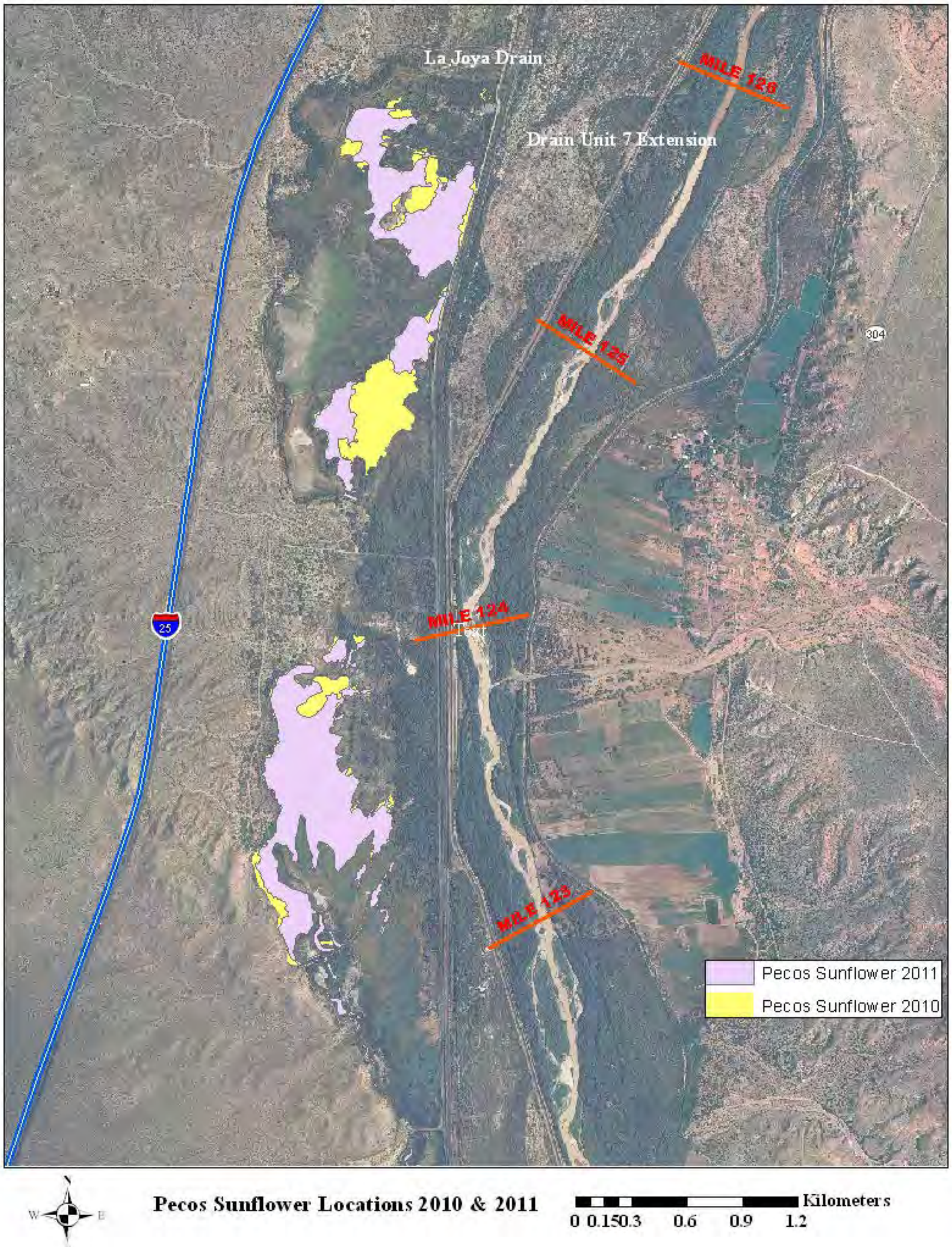

Figure 6. Extant of area occupied by Pecos sunflower on La Joya State Wildlife Management Area.

Pecos sunflower habitats will be surveyed prior to any work. If Pecos sunflower are present within the needed maintenance area, Reclamation will develop a plan to avoid impact to the sunflower populations. Work on specific project sites on the La Joya Drain System would need to be analyzed on a case-by-case basis. The Rhodes population is not affected by work along the LFCC or the Project drains.

6.4 Effects from the MRGCD Proposed Maintenance Activities

The MRGCD constructs, maintains, modifies, repairs, and replaces irrigation and flood control structures and facilities throughout its boundaries to ensure the proper functioning of these works for their intended purposes. These activities may have effects to the listed species.

Regular ongoing activities occur in specific geographic areas and may occur quite frequently (often daily), for example, the presence of men and equipment in these areas. However, these are previously disturbed and regularly accessed areas, so it is unlikely that listed species will be present; therefore, effects to the listed species will be minimal.

Regular, as-needed activities occur throughout the MRGCD with similar effects as above but occur with lesser frequency. Although these areas also are previously disturbed or modified, reduced frequency of access increases the possibility that listed species may be present.

Some activities are performed with much less frequency, dictated by changing needs or conditions. These may occur at anytime and anywhere throughout the MRGCD but are not expected to occur frequently. Due to the infrequent nature, there often is considerable planning in advance of these activities. These activities may affect listed species; specific projects that are beyond the scope of regular maintenance may need project specific consultation tiered off this BA to fully determine and mitigate for these effects. Certain activities may occur under extreme or unexpected conditions that pose an immediate risk to human life or property. Should this situation occur, an immediate response is required.

The effects of all the types of activities are similar and are mainly due to the physical presence of men/machinery and the associated noise as well as modification of habitat due to vegetation control/removal and confinement of the channel to existing infrastructure.

6.4.1 Silvery Minnow

Cowley et al. (2007) performed a fish survey within the Peralta Canals that are on the east side of the river. They found that silvery minnow were present within the drainage system, especially during irrigation season and dry periods in the river. Work within the wet portions of the drains and canals is likely to adversely affect silvery minnow with direct effects due to dredging operations and indirect effects due to less suitable habitat within the MRGCD drains and canals with removing shallow, low velocity areas that silvery minnow use. It appears that, during non-irrigation season, densities of silvery minnow are lower. Work conducted during this season would have less impact on the species. The MRGCD's drains and canals are not considered part of critical habitat. Dredging of the MRGCD's drains and canals near to the river may have a small hydrologic effect on the water in the river if the level of these facilities is lower than the riverbed. This effect is likely very small but may adversely affect silvery minnow critical habitat.

6.4.2 Willow Flycatcher

Flycatchers have been known to migrate through less desirable habitat, including the narrow growth around the drains and other canals as well as nest in areas in close proximity to roads. Coordination between MRGCD and the Service for maintenance actions involving removal of established vegetation would need to take place to ensure maintenance actions would not have any effect to flycatchers. Dredging of the MRGCD's drains and canals has a small hydrologic effect on the nearby vegetation. This effect is likely very small but may adversely affect flycatcher critical habitat.

6.4.3 Pecos Sunflower

The population of Pecos sunflower located on La Joya State Wildlife Area exists along the La Joya Drain. Water from the drain augments the wetlands on the wildlife area from direct irrigation and possibly from seepage. Any maintenance that would affect flow or seepage of water from this drain may have an adverse effect on the Pecos sunflower population. Maintenance near occupied Pecos sunflower habitats will be surveyed prior to any work. If Pecos sunflower are present within the needed maintenance area, Reclamation will work with the Service to develop a plan to avoid impact to the sunflower populations. Work on specific project sites near the La Joya Drain System would need to be analyzed on a case-by-case basis. The Rhodes population is not affected by work on MRGCD facilities.

6.5 Summary of Effects Analysis

In summary, two general types of effects (direct and indirect) were evaluated for endangered species and their habitat from MRG maintenance activities. Direct effects from implementation of river maintenance projects were described in section 6.2 and are dependent on project design and scope. Direct effects from maintenance on the LFCC and Project drains were described in section 6.3 and depend on types of activities performed.

Indirect effects for endangered species are geared more towards the long-term changes that may occur within a reach or upstream and downstream. Indirect effects are expected to be local for the implementation of individual river maintenance projects and dependent on the river maintenance methods used. These are described in section 6.2.1. The indirect effects from the implementation of multiple river maintenance projects within a river maintenance strategy are described in section 6.1. The indirect effects from other MRG Project maintenance actions are expected to be negligible. The determinations for all maintenance activities and proposed actions to the slivery minnow, willow flycatcher, and Pecos Sunflower are described, respectively, in sections 6.5.1, 6.5.2, and 6.5.3.

6.5.1 Silvery Minnow

6.5.1.1 Direct Effects

Direct effects are caused by activities that occur within occupied portions of the river, LFCC, or State drains, and MRGCD facilities. Best management practices have been and will continue to be used to minimize negative effects to silvery minnow. Analysis from sections 6.2 and 6.3 indicates that the potential acreage of impacted silvery minnow habitat would *likely adversely affect approximately 500,000 silvery minnows and 905 acres of their critical habitat over a 10-year timeframe.*

6.5.1.2 Indirect Effects

These are effects that occur after maintenance activities are complete and are due to geomorphic changes in the river as a result of the maintenance activities. Indirect effects are expected to be localized from implementation of individual river maintenance projects and dependent on the river maintenance methods used and location of the project. These are described in section 6.2.1. The indirect effects from the implementation of projects as part of a river maintenance strategy within a reach are described in section 6.1. The long-term effect of implementing river maintenance strategies on the habitat within the river are expected as a whole to be positive to the silvery minnow because they were designed to minimize future river maintenance needs and direct impacts to the river. Local indirect effects at river maintenance project sites may have positive and negative impacts to silvery minnow depending on the river maintenance methods used. For example, river maintenance methods that strive to create more complexity in the river or reconnect the flood plain may have long-term benefits to silvery minnow. However, river maintenance methods that create a deep, fast channel that may be more efficient for water delivery would have negative consequences for silvery minnow habitat. Reclamation is not proposing specific river maintenance projects at this time, but indirect effects caused by river maintenance activities do have the potential to be beneficial, but also may *adversely affect silvery minnow and silvery minnow critical habitat.*

The indirect effects from other MRG Project maintenance actions are expected to be negligible but may adversely affect silvery minnow and their habitat.

6.5.2 Willow Flycatcher

6.5.2.1 Direct Effects

Direct effects are caused by activities that occur within existing or developing suitable habitat or in close proximity to historic flycatcher territories. Best management practices (as described in section 3.6.4.5, 3.7.1, and 3.7.2) have been and will continue to be used to minimize negative effects to flycatchers. BMPs to note include, but may not be limited to, avoiding construction from April 15–August 15, conducting annual surveys to ensure flycatcher territories are identified, and ensuring at least a one-fourth-mile 'buffer' between construction activities and known flycatcher territories. Analysis from section 6.6 indicates that the likely potential acreage of impacted flycatcher habitat would be minimal in the next 10 years. However, direct effects caused by construction activities do have the potential to *likely to adversely affect flycatchers or flycatcher critical habitat.*

6.5.2.2 Indirect Effects

These are effects due to maintenance activities that occur away from historical flycatcher territories or existing or developing suitable habitat and/or while flycatchers have not arrived to their breeding grounds. They also include effects that occur due to geomorphic changes in the river as a result of the maintenance activities. Indirect effects are expected to be local for the implementation of individual river maintenance projects and dependent on the river maintenance methods used. These are described in section 6.2.1. The indirect effects from the implementation of multiple river maintenance projects within a river maintenance strategy are described in section 6.1. The long-term effect of implementing river maintenance strategies on the habitat within the river corridor are expected, as a whole, to be positive to the flycatcher because they were designed to minimize future river maintenance needs and direct impacts to the river. Local indirect effects at river maintenance project sites may have positive and negative impacts to flycatcher depending on the river maintenance methods used. For example, river maintenance methods that modify the river channel tend to change overbank flooding occurrences, frequency or locations, and also vegetation composition over time. These effects can occur upstream of or downstream from the site as well. Implementing these methods can be positive or negative depending on characteristics at the specific location. In some instances, like channel relocation for example, over the long term, it may actually be beneficial for the flycatchers because this activity mimics the historically ever changing and meandering river system and the dynamic system of vegetation being created in a new area, as the old vegetation matures. In general, river maintenance methods that reduce channel incision, promote flood plain connectivity, and provide a greater potential for overbank flooding are more beneficial for flycatchers than river maintenance methods that would increase the flood-flow capacity within the channel and lower the water table. Similar to direct effects, indirect effects from maintenance activities do have the potential to be beneficial but also may *adversely affect flycatchers or flycatcher critical habitat.*

6.5.3 Pecos Sunflower

Impacts to Pecos sunflower are possible due to maintenance actions, specifically Project drain maintenance on the La Joya Drain that occurs within occupied habitat or in close proximity to Pecos sunflower populations or changes in water delivery to those areas. Project areas near occupied Pecos sunflower habitats will be surveyed prior to any work. If Pecos sunflower are present within the needed maintenance area, Reclamation will work with the Service to develop a plan to avoid impact to the sunflower populations.

6.5.3.1 Direct and indirect effects

With these measures in place, maintenance activities are *not likely to adversely affect Pecos sunflower*.

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River Maintenance Methods Attachment

1. Introduction

Each strategy can be implemented using a variety of potential methods. The selection of methods depends upon local river conditions, reach constraints, and environmental effects. Method categories are described in section 3.2.3.

Methods are the river maintenance features used to implement reach strategies to meet river maintenance goals. Methods can be used as multiple installations as part of a reach-based approach, at individual sites within the context of a reach-based approach, or at single sites to address a specific river maintenance issue that is separate from a reach strategy. The applicable methods for the Middle Rio Grande (MRG) have been organized into categories of methods with similar features and objectives. Methods may be applicable to more than one category because they can create different effects under various conditions. The method categories are:

- Infrastructure Relocation or Setback
- Channel Modification
- Bank Protection/Stabilization
- Cross Channel (River Spanning) Features
- Conservation Easements
- Change Sediment Supply

A caveat should be added that, while these categories of methods are described in general, those descriptions are not applicable in all situations and will require more detailed, site-specific, analysis for implementation. It also should be noted that no single method or method combination is applicable in all situations. The suitability and effectiveness of a given method are a function of the inherent properties of the method and the physical characteristics of each reach and/or site. It is anticipated that new or revised methods will be developed in the future that also could be used on the Middle Rio Grande. The description of any new or revised methods developed in the future, tiered off this programmatic river maintenance biological assessment (BA), would be developed with sufficient detail and provided in coordination with the U.S. Fish and Wildlife Service (Service).

2. Infrastructure Relocation or Setback

This method also has been referred to as "Removal of Lateral Constraints." Riverside infrastructure and facilities constructed near the riverbanks may laterally constrain river migration. By re-locating infrastructure, an opportunity is provided for geomorphic processes, especially lateral migration, to occur unencumbered by local lateral infrastructure constraints encouraging the river towards long-term dynamic equilibrium (Newson et al. 1997; Brookes et al., 1996). Bank erosion can remove older growth riparian areas, while deposition can create new flood plain and riparian areas. Potential facilities to be relocated include levees, dikes, access roads, canals, drains, culverts, siphons, utilities, etc. Infrastructure would need to be set back beyond the expected maximum extent of bend migration; otherwise, bank erosion and stability problems may, in time, relocate to the new infrastructure location. Thus, protection of re-located infrastructure still may be required as channel migration approaches these facilities.

3. Channel Modification

Channel modifications are actions used to reconstruct, relocate, and re-establish the river channel in a more advantageous alignment or shape and slope consistent with river maintenance goals. Channel modification actions may potentially result in a larger channel capacity at various flow rates and cause changes in channel shape and slope. Excavating new channel alignments and plugging existing channel entrances are part of this method category. Channel modification techniques also have been used to address geomorphic disequilibrium thereby reducing risks of bank erosion (Washington Department of Fish and Wildlife [WDFW] 2003). These methods include changes to channel profile, slope, plan shape, cross section, bed elevation, slope, and/or channel location.

3.1 Complete Channel Reconstruction and Maintenance

This method would allow for reconstructing the channel when tributary sediment deposition significantly decreases channel capacity, or the channel fills with sediment in aggrading reaches. This method functions to re-establish sediment transport capacity resulting in lower upstream bed elevations. Mechanical removal of sediment deposits involves excavation using buckets and depositing spoil along the channel margins. After dredging, the channel capacity would be about 5,000 cubic feet per second (cfs) or larger design discharge.

3.2 Channel Relocation Using Pilot Channels or Pilot Cuts

Channel relocation can be used to move the river away from an eroding bank line (WDFW 2003); create a more sinuous, longer channel; and reduce channel slope and channel incision (Bravard et al. 1999; Watson et al., 2005). Creating a longer channel can bring sediment transport capacity more in balance with sediment supply in supply-limited, degrading rivers. Pilot channels are excavated to a narrower width than the current main channel to reduce construction costs and reduce the size of sediment disposal requirements. Excavated sediments typically form the banks of the relocated channel. By constructing a narrower channel than exists in the reach, the excavated sediments lining both banks will transport downstream as the channel establishes its dynamic equilibrium width. Excavated sediments along the pilot channel banks may need to be repositioned over time to be fully transported downstream by high flows. The sediment available for transport downstream provides a small amount of sediment enrichment.

The method generally includes vegetation clearing so that the pilot channel widens to the equilibrium width. Bank lowering also can aid in establishing the new channel width. Bank lowering could include creating a compound channel section and widening the channel.

3.3 Island and Bank Clearing and Destabilization (Includes Channel Widening)

In river channels that are experiencing incision, flood plain disconnection, channel narrowing, and are sediment supply limited, clearing and destabilizing islands can be a means to provide flood plain connectivity, reduce vegetated island area, promote channel widening, and provide a small increase in sediment supply. Islands and banks can be cleared of vegetation and root plowed for destabilization to occur. Jetty removal may be necessary depending upon local site conditions. Two-stage channel or lowered terraces or flood plains can be created with this method. Excavation (lowering) of islands or bars may be necessary to lower their elevation and provide destabilization. Excavated sand material can be placed in the areas where river flows will transport spoil downstream, thus providing a small amount of sediment enrichment. Excavated sediments also can be placed on terraces or in overbank areas.

3.4 Bank Line Embayment

Bank line embayments have several different names including shelves, scallops, inlets, backwater areas, and swales. These habitat features are excavated into banks at a range of elevations that allows riverflows to enter during high-flow events such as spring runoff and summer thunderstorms. They are excavated into the bank lines with sufficient width and distance into the bank to provide a drift zone or slack water area of very low velocity for Rio Grande silvery minnow (RGSM) habitat, while allowing inflow and outflow at the inlet mouth. These features generally have a sloping bed surface that can be inundated at a variety of discharges during which RGSM spawning occurs. Discharges at which the invert is wetted can range from 500–1,000 cfs (Bauer 2005). Willows can also be planted (willow swales) in the excavated area.

3.5 Pilot Cuts Through Sediment Plugs

This method consists of excavating a narrow width channel (20–30 feet) through areas where sediment deposits have completely obliterated or plugged the river channel. The action of excavating a small width channel through the sediment plug provides a hydraulic connection between the upstream and downstream river channels, which encourages flows to transport sediments forming the plug downstream, thereby opening the channel back up to the main river flows.

3.6 Side Channels (High Flow, Perennial, and Oxbow Re-establishment)

Side channels consist of channels that can be accessed by river waters during peak flow events (high flow) or perennially, which are adjacent to the main river in the flood plain, bars, and islands. Side channels may be created by excavation. Excavation can consist of creating completely new side channels or enlarging natural topographic low areas on bars or abandoned flood plains when the channel has incised. Side channels also can be created by reconnecting topographic low areas that were former channel locations (abandoned oxbows). This method can reduce the main channel flow velocity and decrease sediment transport.

3.7 Longitudinal Bank Lowering or Compound Channels

This method allows the active flood plain to expand and the river channel to reconnect to the flood plain. In reaches where the river channel is incised, high-flow sediment transport capacity is reduced. The inner channel generally has a capacity for the range of normal flows, while flood flows expand to the larger channel constructed above the mean annual or 2-year return period flow (U.S. Army Corps of Engineers [USACE] 1989; Haltiner et al. 1996). Enlarging the channel using this method can be accomplished along one or two banks (Brookes 1988). The peak flow water surface elevation can be reduced, allowing higher discharges to pass safely. Flood flow storage is increased; and main channel depth, velocity, and shear stress can be reduced leading to reduced bank erosion (McCullah and Gray 2005). Excavated material can be placed in locations where river flows will transport spoil downstream, thus enriching sediment supply, or on terrace or upland areas.

3.8 Longitudinal Dikes

Longitudinal dikes are constructed more or less parallel to the channel to guide and contain high flows (up to the 2-year return period discharge with some freeboard). However, these dikes do not furnish flood protection as is provided by riverside levees. Another purpose is to concentrate high flows to a narrower width of the flood plain, thereby increasing the main channel velocity, sediment transport rates, and channel capacity (Brookes 1988). This can reduce the likelihood of future plug formation in aggrading areas of the Middle Rio Grande. These dikes can be along the riverbank or set back to avoid toe erosion and can be associated with bank protection/stabilization methods. Culverts generally are placed through these dikes to either provide passage of surface runoff or to provide flow into the adjoining flood plain during peak discharges depending upon local conditions and habitat needs. Depressions in the dikes lined with variably sized rock (low water crossings) to allow controlled overtopping also can be a means to provide flows into the adjoining flood plain.

3.9 Levee Strengthening

Levee strengthening includes raising, widening, and reducing the levee side slopes for increased stability and to prevent overtopping. Widening and reducing the side slopes also can reduce the ground pressure underneath the structure to prevent bearing/foundation and slope failures. Generally, levees are designed for a 50- to 100-year return period flood. Other return period floods also can be used based upon economic considerations (Przedwojski et al. 1995). Depending upon local site conditions and needs, levee strengthening is sometimes accomplished for a lower flood peak, such as the 2-year return period flow plus 2–3 feet of freeboard on the Middle Rio Grande in the reach south of San Antonio, New Mexico. Levee strengthening functions to protect land and facilities outside of the flood plain from inundation.

3.10 Jetty/Snag Removal

This method performs the removal of jetty jacks from areas where their function is no longer necessary as a means to protect the bank lines or where the jetties have been moved into main river channel as a result of erosional processes and may pose a hazard. Snags (trees, vehicles, trash, ice, etc.) may be removed from the river in rare occasions to prevent them from posing a serious public hazard. They also may be removed in instances where they are deflecting flows into a bank line causing significant bank erosion.

4. Bank Protection/Stabilization

Bank protection works may be undertaken to protect the riverbank against fluvial erosion and/or geotechnical failures (Hey, 1994; Brookes, 1988; Escarameia, 1998; McCullah and Gray, 2005). Bank protection methods described in this section apply to cases where bank line and toe erosion are the primary mechanism for bank failure. In situations where the bank slope is unstable due to geotechnical processes, other methods would need to be applied in addition to bank stabilization (Escarameia 1998). These methods could include placing additional material at the toe of the slope or removing upslope material to eliminate rotational failure potential (Terzaghi et al. 1996).

4.1 Longitudinal Features

Longitudinal methods involve the placement of stone—variably sized rock material—along the bank line to provide erosion protection. Variably sized rock also may be placed on the top of the bank or in a trench set back from the bank line. Some bank shaping generally is required as part of construction.

4.1.1 Riprap Revetments

Typically, revetments are constructed from variably sized rock material that is placed along the entire bank height or from the toe to an elevation of a design water surface elevation to resist and prevent further erosion. Variably sized rock material generally is used in revetments, due to its ability to self-adjust (filling of scour holes through the self-launching initiated from gravity), preventing failure due to bed scour.

4.1.2 Other Types of Revetments

Revetments also may be constructed using stabilized soil, manufactured revetment units, and cellular confinement systems. Treatment of soils makes them less susceptible to erosion; the most common soil treatment is soil cement. Soil and cement are mixed and compacted to make an erosion-resistant material. Soil cement cannot be constructed under water and is applicable only in unusual circumstances. Several types of manufactured units are available for revetment construction. These units typically are made of concrete and are designed to be placed on the bank in interlocking patterns. The high cost of these systems would limit their use to very special cases. Plastic grid systems, designed to limit movement of soils, also can be used to prevent erosion. These systems use a honeycomb cell sheet anchored to the bank to contain fill material. These systems may be practical in conditions where erosion potential is small. Gabions or wire enclosing variably sized rock also can be used to prevent bank erosion, but structural difficulties arise when construction occurs in the water. The type of material used in a particular application determines the range of applicability—for example, materials or structures, such as gabions or stabilized soil that will fail with vertical movement, would be applicable only in stable bed situations.

4.1.3 Longitudinal Stone Toe with Bioengineering

Longitudinal stone toe with bioengineering involves placing stone variably sized rock material from the toe of the slope up to an elevation where riparian vegetation normally grows. Vegetation is used to protect the remainder of the slope up to the top of the bank or a peak flow design discharge. Bioengineering also can include biodegradable fabrics, wattles, mats, Bio-D Blocks, etc., to assist with vegetation growth and bank stability. Most commonly, willows and cottonwood poles, willow bundles/mats/fascines, or other planting methods would be used. Plantings also can be along the top of the bank or on terraces along the bank line to prevent overland erosion to the bank line.

4.1.4 Trench-Filled Riprap and Riprap Windrows

Trench filled riprap is a stone armor revetment with a large stone toe that is constructed in an excavated trench behind the bank line. A windrow revetment is rock placed on the flood plain surface landward from the existing, eroding riverbank. For both trench-filled riprap and riprap windrow, the river erodes to the predetermined location, and the riprap material launches into the river that forms an armored bank line (Biedenharn et al. 1997; McCullah and Gray 2005). For both applications, additional riprap material may need to be applied due to non-uniform launching along the bank line.

4.1.5 Deformable Stone Toe with Bioengineering and Bank Lowering

This method involves stone toe protection, an internal gravel filter (if needed), soil lifts wrapped in biodegradable coir fabric or other bioengineering, and an aggressive re-vegetation plan (Miller and Hoitsma 1998). The stone toe protection in this method is designed to be moved by the flows, becoming bedload after the vegetation is established, and gradually becomes part of the bed material in the river as the bank deforms. The method also can be used in conjunction with overbank lowering when the channel is incised. This will increase flood plain connectivity and provide a large, vegetated area through which the river may migrate, to achieve a better balance between sediment supply and sediment transport capacity for incising channels. The vegetation in the lowered area will provide some bank stability by virtue of natural root structure, while allowing bank erosion and mobility.

Stone toe protection is sized to erode during the 5- to 10-year frequency flood (relatively small rock). The toe elevation of the stone toe protection generally is placed where vegetation naturally grows in the river reach. The soil lifts, wrapped in biodegradable fabric, provide a series of distinct soil lifts or terraces that are subsequently vegetated and are placed above the stone toe. The biodegradable fabric would have an expected life span of 3–5 years; over which time, the vegetation would be firmly established. The fabric protects the soil lifts and vegetation plantings from erosion during high-flow events. The soil lifts wrapped in biodegradable fabric are called “fabric encapsulated soil” (FES). This method functions to provide a stabilized bank using toe rock, which becomes mobile after vegetation has firmly established along the bank line. Once the variably sized rock toe becomes mobile, the vegetation root structure provides some bank stability while still allowing bank erosion and channel migration.

4.1.6 Bioengineering

This method involves planting vegetation along the bank line for limited erosion resistance. Most commonly, willows and cottonwood poles, willow bundles/mats/fascines, or other planting methods would be used. Plantings also can be along the top of the bank or on terraces along the bank line to prevent overland erosion to the bank line. Vegetation has the lowest erosion resistance of all available methods (Hey 1994), and plantings require time to establish, and bank protection is not immediate (National Resources Conservation Service

[NRCS], 1996). Biodegradable fabrics wattles, mats, Bio-D Blocks, fascines, etc., may be used to assist with vegetation growth and bank stability until vegetation becomes well established (Fischenich 2000).

Few plants grow below the base level flow, except for their roots. Establishing plants to prevent undercutting of the bank due to toe scour is difficult (NRCS 1996); therefore, the use of living vegetation as a bank protection material is generally limited to the bank elevations above a base level of flow (Fischenich, 2000). This base level of flow could be the mean annual water surface, bank full elevation, or at the elevation of depositional bars and bank line surfaces where natural vegetation grows in the river system. Most bioengineering methods have some longitudinal toe protection component included (NRCS 1996; Fishenich 2000). This method may be used in situations where the bank line is slowly eroding near infrastructure without channel incision and active meandering.

4.1.7 Riparian Vegetation Establishment

This method involves planting vegetation in the flood plain or active channel areas to reduce velocity and create zones of sediment deposition; it also is used in conjunction with other methods to provide habitat benefits along the river channel as well as along structures such as levee/berms and deformable bank lines. Potential ways to establish vegetation have been described in "Stone Toe with Bioengineering" and "Bioengineering" methods.

4.2 Transverse Features or Flow Deflection Techniques

Transverse features are structures that extend into the stream channel and redirect flow so that the bank line velocity and shear stress are reduced to nonerosive levels. They generally are constructed using variably sized rock with little or no bank shaping being necessary unless an alignment change is necessary. Design guidelines based upon hydraulic performance measurements do not exist at this time. Reclamation and Colorado State University's Engineering and Research Center currently are working to develop suitable design guidelines. Boulder groupings, rootwads, and large woody debris are included in the section because they deflect flow.

4.2.1 Bendway Weirs

Bendway weirs are features constructed with variably sized rock that extend from the bank line out into the flow. They have horizontal crests that are submerged at high flows and are angled upstream. Bendway weirs are designed to control and redirect currents away from the bank line throughout the bend and immediately downstream from the bend, thus reducing local bank erosion. During low river discharges, the flow is captured by the weir and all directed to the center of the channel. At high flows, secondary currents are redirected which reduces near bank velocity. They also re-align or relocate the river thalweg through the weir field and downstream. Some bank scalloping (erosion) between weirs can occur. A downstream scour hole can occur.

4.2.2 Spur Dikes

Spur dikes are a series of individual structures that are placed transverse to the flow projecting from the riverbank with a horizontal crest, usually at the elevation of the top of bank or design flow water surface elevation. They are placed either perpendicular to the bank or oriented downstream. Spurs deflect flow away from the bank, reducing the near bank velocity and, thus, preventing erosion of the bank in critical areas. L-head, "hockey stick," or T-head added to the spur tip can move scour away from the dike (Biedenharn et al. 1997).

4.2.3 Vanes or Barbs

Vanes, also known as barbs, are discontinuous, transverse structures angled into the flow. They can be used for bank protection, as well as for providing variable depth and velocity habitat. Instream tips are usually low enough to be overtopped by nearly all flows; the crest slopes upward generally to the bank line or bank-full stage elevation at the bank. The tip is inundated at most low flows. They are angled upstream to redirect overtopping flows away from the protected bank. The sloping top redirects flow and reduces local bank erosion, while providing a downstream scour hole. Flow redirection causes the velocity and shear stress along the bank to decrease while creating a secondary circulation cell that transfers energy to the center of the channel (Fischenich 2000), creating a new thalweg location.

Some sediment deposition may occur upstream of and downstream from the structures, resulting from the redirected flows. In situations where sediment deposition occurs between the structures, additional bank protection can develop over time. In certain situations, bank scalloping between weirs may occur.

4.2.4 J-Hooks

J-hooks are vanes (barbs) with a tip placed in a downstream pointing "J" configuration. The "J" tip is partially embedded in the riverbed, so it is submerged during low flows. The "J" tip is intended to create a scour pool downstream from the "J" tip, especially in gravel to cobble substrates (McCullah and Gray 2005). They provide the same bank protection as vanes or barbs and have potential for initiating sediment deposition or bank scalloping between structures.

4.2.5 Trench-Filled Bendway Weirs

Trench-filled bendway weirs are bendway weirs extending transverse to the anticipated future flow direction and are buried in excavated trenches behind the riverbank. The river erodes to the predetermined weir locations, and the erosion resistant weir tips become exposed. The trench bottom elevation usually will be below the high-flow water surface elevation, placed ideally at the channel thalweg elevation; but due to seepage, issues may have to be raised to above the low-flow water surface elevation. Bendway weir stones would launch from the bottom of the trench to the thalweg elevation. After launching, additional rock may need to be added, and the weir tips may need to be reshaped to provide the same hydraulic effect as typical bendway weir installations. After the bank erosion process (and with additional rock placement and reshaping), bendway weirs would provide the same function described above in the bend way weir section.

4.2.6 Boulder Groupings

Boulder groupings are strategically placed, large, immobile boulders and groupings of boulders placed within a channel to increase or restore structural complexity and variable depth and velocity habitat (Saldi-Caromile et al. 2004). If the channel lacks these features, adding boulder groupings can be an effective and simple way to improve aquatic habitat. High-flow events interacting with boulder groupings create and maintain downstream scour pools and provide bed sorting. Large boulders are placed individually, in clusters, or in groups to improve habitat.

4.2.7 Rootwads

Rootwads are trees embedded into the banks or bed of the channel with the root mass or root ball placed in the flow. Rootwads provide some flow redirection; and, if placed close together, they can move the current line away from the bank (McCullah and Gray 2005). They can create additional habitat value, such as local scour pools and substrate sorting when the bed is gravel, and variable velocity habitat (McCullah and Gray 2005; Sylte and Fischenich 2000).

4.2.8 Large Woody Debris

Large woody debris (LWD) structures are made from felled trees and may be used to redirect, deflect, or dissipate erosive flows. LWD also can be used to enhance the effectiveness and mitigate the impacts of other treatments such as variably sized rock, revetments, longitudinal stone toes, and transverse features (WDFW 2003). LWD can be used to enhance the creation of side channels by the formation of medial bars with a pool downstream of the LWD (Saldi-Caromile et al. 2004). Downstream scour can create perennial pools and variable depth and velocity habitat conditions.

5. Cross Channel (River Spanning) Feature

These methods are placed across the channel using variable-sized rock material without grout or concrete (Nielson et al. 1991; Watson et al. 2005). The objective of cross channel or river spanning features is to control the channel bed elevation or grade, which may improve or maintain current flood plain connectivity and ground water elevations. The primary focus of cross channel structures would be slowing or halting channel incision or raising the riverbed. Grade control features also have been used in cases where channel incision has or will cause excessive bend migration and undermining of levees and riverside infrastructure (Bravard et al. 1999).

5.1 Deformable Riffles

This method is new and untested. The goal is to:

- Establish a channel with a stable grade
- Allow some vertical channel bed movement
- Enrich sediment supply by adding a small amount of gravel/small cobble bed material load

This method is more natural than other grade control methods. In this conceptual deformable riffle method, a trench would be constructed across the channel and filled with material that would be stable during most flows, while becoming slightly mobile during less frequent high-flow events, to provide a small amount of sediment enrichment. The trenches also would extend in the longitudinal downstream direction the length of typical stable riffles and with a stable riffle slope. Rock material also could be placed on the bed.

Fluvial entrainment of the deformable riffles would be estimated to take place between 5- and 10-year peak flow events. The gradation of imported variably sized rock would also contain sizes less than the median size, which would be mobile at the 2-year event. Natural riffles may be used to help construct the shape and help determine the particle size, if there is knowledge about the flow range for which the particles are mobilized as bed load.

Riffles could be installed in a single location or in series along the river, spaced at about five to seven river widths apart. Each riffle would contain a supply of material, enough to be mobilized during several 5- to 10-year events; thus, a small amount of gravel/cobble size material would be supplied as bed load to the river during each event. Also, during each 5- to 10-year event, a small amount of erosion of the riffles would occur; but since the material is sized to move as bedload at the higher flows, providing erosional resistance, slope increases across the structure due to erosion is expected to be minimal.

5.2 Rock Sills

Rock sills involve placing stones directly on the streambed that resist erosion within a degradational or incising river zone (Whittiker and Jaeggi 1986; Watson et al. 2005). This method differs from the deformable riffle because rock sills are intended to be constructed of immobile stones, while deformable riffles have smaller stones that are transported during certain high-flow events. The rock sill would deform as the channel establishes small pools and scour between each sill. These can be implemented as a single structure or sequentially in the downstream direction.

5.3 Riprap Grade Control

Variably sized rock grade control structures are constructed by excavating a trench across the streambed which is filled with rock, with the top elevation being the river bed (Biedenharn et al. 1997). The structure is flexile in that as the channel degrades and downstream scour occurs, a portion of the variably sized rock in the trench will launch. In cases where seepage is an issue at low flows, an upstream impervious layer of fill material or a sheet pile wall can be constructed.

5.4 Gradient Restoration Facility

This method raises the river bed about 1-2 feet, and has a long low slope downstream apron to facilitate fish passage. Gradient restoration facilities (GRF) consist of an upstream sheet pile wall, with or without a concrete cap or stable grouted variably sized rock section. The downstream apron location of the structure is also often fixed by a sheet pile wall. Scour protection is added to protect the downstream sheet pile wall from downstream scour. GRFs are designed to replicate long, low slope riffles where fish already pass through and to raise the river bed up to improve flood plain connectivity. These low structures can raise the water surface during low flows and do not generally raise the water surface during higher flows.

5.5 Low Head Stone Weirs

Low head stone weirs can be used to protect banks, stabilize the bed of incising channels, activate side channels, reconnect flood plains, and create in-channel habitat. The structures are most commonly constructed with individually placed stones or smaller variably sized rock; span the river width; and have “U,” “A,” “V,” or “W” shapes. The apex of the “V” weir is pointing upstream while the apexes of the “W” weir can be pointing both upstream and downstream. During low flows, there is a change in water surface elevation through the structures, although some fish can pass through the interstitial spaces between stones. These structures also can be oriented to align the flow toward the center of the downstream, promoting a pool while directing currents away from the bank line and, thereby, limiting bank erosion.

6. Conservation Easements

Conservation easements are land agreements that prevent development from occurring and allow the river to erode through the area as part of fluvial processes. Conservation easements also preserve the riparian zone in its current and future states as determined by fluvial processes and flood plain connectivity.

This method preserves and promotes continuation of riparian forests, ecosystem, and river corridor conservation (Karr et al. 2000). Conservation easements may or may not involve infrastructure relocation or setback. Similar to infrastructure relocation or setback, it may be possible to use conservation easements as an opportunity for the river to access historical flood plain areas.

7. Change Sediment Supply

Sediment transport and supply vary with discharge over time and in space within a river system. Where the supply of sediment is limited or has been reduced, the result is generally channel incision, bank erosion, and possibly a channel pattern change from a low-flow, braided sand channel with a shifting sand substrate to a single-thread, mildly sinuous channel with a coarser bed. In general, the channel width decreases, channel depth increases, local slope decreases, and sinuosity increases (Schumm 1977). The addition of sediment supply can stabilize these tendencies.

When a river system has more sediment supply than sediment transport capacity, channel aggradation (i.e., bed raising due to sediment accumulation) will occur. In general, aggradation results in the channel width increasing, channel depth decreasing, local slope increasing, and sinuosity decreasing (Schumm 1977), and in decreased channel and flood capacity. Sediment berms also can form along the channel banks (Schumm 2005). The reduction of sediment supply can slow or reverse these trends.

7.1 Sediment Augmentation (Sand Sizes)

Sediment augmentation involves adding sediment supply to the river. The objective of this method is to slow or halt the effects of channel incision due to a reduced sediment supply. The timing, magnitude, and location of sediment re-introduction can be adaptively managed. Sediment sources can be from bank/bar/island clearing, destabilization, and lowering, arroyo reconnection, and/or sediment bypass of water storage structures. Bank/bar/island clearing and destabilization involves clearing vegetation and root plowing to loosen sediment for removal by high flows. This is practical if the elevations are low enough to be inundated frequently with erosive flow velocities.

Bank/bar/island lowering involves clearing vegetation, excavating bank material, and placing the excavated material in erosional zones so that river flows will transport sediments downstream during high flows. Bank lowering provides increased flood plain connectivity. Bank/bar/island lowering enables the sediment supply to be increased for incised reaches where the elevation of these surfaces is not frequently inundated with erosive flow velocities. Imported sediment also can be used; but for economic reasons, this is not likely.

7.2 Natural or Constructed Sediment Basins

The reduction of sediment supply can reverse downstream aggradational trends by "controlling sediment delivery to a downstream channel and to localize sediment accumulation" (Sear 1996). The objective of this method is to reduce downstream aggradation and promote sediment storage at strategic locations, such as natural topographic low areas or constructed sediment basins.

Initiating the river to deposit sediment in natural topographic low areas would involve relocating the channel periodically.

Channel relocation and associated actions are described in Section 3.2, "Channel Relocation Using Pilot Channels or Pilot Cuts," in this attachment. Constructed sediment basins provide wide lower velocity conditions that initiate localized sediment deposition. Basins eventually fill with sediment requiring either local dredging and disposal of sediment or relocating the basin to another area that is conducive to sediment storage. Sediment basins would involve constructing flow containment berms and inlet and outlet structures to control flow. Inlet and outlet structures most likely would be variably sized rock guide berms and sills. Sills are variably sized rock structures that raise the outlet channel to a set elevation, and are perpendicular to the flow direction to prevent erosion of the containment berms.

8. Method Combinations

A combination of methods most likely will be used at all river maintenance sites on the Middle Rio Grande to provide multipurpose benefits. For a given strategy, many combinations of methods may be used to provide an effective river maintenance solution. The relationship between individual methods and strategies is shown in the following table 1.

For example the Promote Elevation Stability strategy methods include Grade Control, Deformable Riffles, Rock Sills, GRFs, etc. (table 1). Options such as changing channel slope through adjustments in channel length (Channel Relocation Using Pilot Channels, or Pilot Cuts), flood plain reconnection (Longitudinal Bank Lowering), and sediment augmentation (Increase Sediment Supply) also can promote elevation stability in reaches with excess sediment transport capacity; so combinations of methods, suitable to different strategies, could be used to provide multipurpose benefits.

Table 1. Methods Associated with Strategies

Strategy / Method	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
INFRASTRUCTURE RELOCATION OR SETBACK				X		
CHANNEL MODIFICATION						
Complete Channel Reconstruction and Maintenance			X		X	
Channel Relocation using Pilot Channels or Pilot Cuts					X	X
Island and Bank Clearing and Destabilization					X	X
Bank Line Embayment					X	
Pilot cuts through sediment plugs			X			
Side Channels (High Flow, Perennial, and Oxbow Re-establishment)					X	
Longitudinal Bank Lowering or Compound Channels					X	
Longitudinal Dikes			X			
Levee Strengthening			X			
Jetty/Snag Removal[1]						
BANK PROTECTION/STABILIZATION						
Longitudinal Features						
Riprap Revetment		X				
Other Type of Revetments		X				
Longitudinal Stone Toe with Bioengineering		X				
Trench-Filled Riprap		X				
Riprap Windrow		X				
Deformable Stone Toe/Bioengineering and bank lowering		X				
Bio-Engineering		X				
Riparian Vegetation Establishment		X				

[1] This method can be used with all strategies, and there is not a predominate strategy.

Table 1. Methods Associated with Strategies (continued)

Strategy / Method	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Transverse Features or Flow Deflection Techniques						
Bendway Weirs		**X**				
Spur Dikes		**X**				
Vanes or Barbs		**X**				
J-Hook		**X**				
Trench Filled Bendway Weirs		**X**				
Boulder Groupings		**X**				
Rootwads		**X**				
Large Woody Debris		**X**				
CROSS CHANNEL (RIVER SPANNING) FEATURES						
Grade Control						
Deformable Riffles	**X**					
Rock Sills	**X**					
Riprap Grade Control (with or without Seepage)	**X**					
Gradient Restoration Facility (GRF)	**X**					
Low-Head Stone Weirs (Loose Rock)	**X**					
CONSERVATION EASEMENTS				**X**	**X**	
CHANGE SEDIMENT SUPPLY						
Sediment Augmentation (Sand Sizes)						**X**
Natural or Constructed Sediment Basins						**X**

9. Methods Level of Confidence, Geomorphic and Habitat Responses

For each method there is a level of confidence, geomorphic, and habitat effect. The confidence that a method will perform its intended purpose is based upon whether the local response is well known; and the amount, level, and type of information known. The definitions for confidence levels are:

- **Level 3.** Well established, widely used, well documented performance, reliable design criteria, numerous case studies, well known local geomorphic response that is well documented.

- **Level 2.** Often used but lacks the level of detail, quality of information and reliability that characterizes Level 3, little or no long-term monitoring, limited design criteria, limited knowledge about the local geomorphic response, and limited documentation.

- **Level 1**. Emerging promising technique that does not have a track record, field or lab data, or design or test data; has few literature citations; has sparse documentation; and where little is known about local geomorphic response, etc.

Many of the methods have promise for successful implementation but do not have design guidelines based upon hydraulic and engineering performance. If design guidelines exist, they are qualitative and based upon anecdotal information that is not applicable to most river systems. Methods that need additional development of criteria and design guides include: longitudinal bank lowering, transverse features, deformable riffles, and low-head stone weirs.

A geomorphic and habitat effect has been identified. Method level of confidence together with these effects for each method is shown in table 2. A more complete description of confidence level, and method geomorphic and habitat effects can be found in Reclamation (2012).

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
INFRASTRUCTURE RELOCATION OR SETBACK	Level 3 (Infrastructure) and Level 2 (Limited Postproject Field Studies – River Response)	Can encourage current geomorphic processes to continue, such as bend migration and the creation of new flood plain and riparian areas. Opportunity to connect to historical channels and oxbows. For incised channels, may provide an opportunity to establish new inset flood plain and riparian zone. Bank erosion also should result in deposition of sediment downstream and potentially establish bars and low surfaces. Bend migration can erode banks causing riparian vegetation to fall into the channel.	Bend migration river movement creates broader flood plain and more favorable riparian zone habitat. Inset flood plain increases overbank flooding and riparian zones that create variable depth and velocity habitat types, including potential spring runoff silvery minnow nursery habitat. The lateral and down valley migration of the river provides more opportunity for successional age classes of potentially native vegetation for flycatcher habitat. Longer meander bends may establish greater pool depth and eroding banks providing additional complexity.
CHANNEL MODIFICATION			
Complete Channel Reconstruction and Maintenance	Level 3	Increased sediment transport through a delta or reconstructed channel. Decreases upstream channel aggradation. Can lead to channel bed lowering upstream of the project site, and low-flow alternate bars can form within the excavated channel. Relatively uniform width, depth, and velocity. Reduces braiding and split delta channels. Can lower the ground water table, and reduce the size of river bars. If medial and alternate bars are not removed as part of ongoing maintenance, then the amount of shallower, lower velocity areas should increase.	Can have more uniform width, depth, and velocity. Limited amount of low or no velocity habitat; low amount of cover. Reduces braiding and distributary channels and, thus, provides less opportunity for riparian growth. Lowers ground water table and reduces the size of river bars. If medial and alternate bars are not removed as part of ongoing maintenance, then the amount of smaller depth and velocity habitat increases.
Channel Relocation using Pilot Channels or Pilot Cuts	Level 2 (Construction and Hydraulics) and Level 1 (Limited Postproject Field Studies)	Lengthening can bring sediment transport capacity more in balance with sediment supply in supply-limited reaches. Re-establishes meanders, increases channel stability, and initiates new areas of bank erosion and deposition. Can provide overbank flooding and can create connected flood plain/wetted areas.	Can provide overbank flooding and establish new areas of riparian vegetation. Can increase the complexity of habitat by creating connected flood plain/wetted areas for RGSM egg entrainment and larval development.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Island and Bank Clearing and Destabilization	Level 1	Promotes a wider channel with greater flood plain connectivity and better transport capacity/supply balance. New sediment balance may be temporary unless increased supply is maintained. Reduces further degradation of the channel and lowering of the water table. Clearing and destabilization would result in the lowering and/or loss of islands and bars, but sediments from destabilized areas may deposit in new bars, which would be more connected to the main channel and suitable for vegetation growth. Cleared areas may become zones of sediment deposition, and vegetation may re-grow, making reclearing necessary for benefits to continue.	Islands/bars that are more connected to the main channel can provide RGSM with a greater variety of depth and velocity habitat types. Provides low velocity habitat during high flows for adult fish. Increased overbank flooding creates variable depth and velocity habitat types including silvery minnow nursery habitat during spring runoff and aids in increasing egg and larval entrainment. Loss of habitat may be temporarily negative depending on site-specific details and proximity to flycatcher territories; however, sediment accumulation forming new bars or islands could promote new seed source establishment and potentially young native successional stands to develop into flycatcher habitat. By reducing further degradation of the channel and lowering of the water table, the flood plain has a better chance of connectivity that is better overall for the flycatcher.
Bank Line Embayment	Level 1 Rehab Channel and Flood Plain	Historical areas of channel, slow water velocity and shallow bank line are restored/rehabilitated. Bank line embayments are zones of sediment deposition and have a finite lifespan without periodic re-excavation.	Slow water velocity and shallow depth bank line habitat. Increase in egg retention and availability of nursery larval habitat during high flow. Increases probability of native vegetation growth and potential for flycatcher habitat.
Pilot Cuts Through Sediment Plugs	Level 2	Connecting small channels through sediment plugs results in plug material being transported downstream to re-establish preplug riverine conditions. Restores flow velocity and depth conditions found in the main river channel. Allows sediment transport to continue, which may possibly provide new bars and islands downstream.	Allows sediment transport to continue, which may possibly provide new areas for riparian vegetation establishment. While the sediment plugs block main channel flows, RGSM do utilize overbank channels through the riparian corridor created by the plug. There is increased potential for RGSM stranding during receding flow conditions.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Side Channels (High Flow, Perennial, and Oxbow Re-establishment)	Level 2 (Design Methods Available) and Level 1 (Limited Postproject Field Studies)	Important to natural systems for passage of peak flows. Sediment tends to fill in high-flow side channels over time. Can decrease peak-flow water surface elevation and may decrease sediment transport capacity until sediment blocks the side channel. Periodic inlets and outlet sediment removal may be needed to maintain project benefits. Side channels result in raising the ground water table and can supply surface flows to overbank and flood plain areas. Can reconnect the flood plain to the channel, creating areas with variable depth and velocity.	Can result in higher ground water table, increasing the health of the riparian zone. Can reconnect the flood plain to the channel, creating nursery habitat for RGSM with variable depth and velocity habitats. Provides low velocity habitat during high flows for adult fish and developing larvae. Increase in retention of eggs and larvae during high flows. Raising the ground water table to provide water to developing riparian areas increases vegetation health. Periods of increased surface flows, particularly during mid-May to mid-June, increases probability of flycatcher territory establishment in areas with suitable habitat.
Longitudinal Bank Lowering or Compound Channels	Level 2 (Design Methods Available) and Level 1 (Limited Postproject Field Studies)	Lowered bank line can promote increases in channel width and decreases in main channel velocity, depth, shear stress, and sediment transport capacity. Reduces potential for channel degradation, thereby maintaining a higher water table and more connectivity with backwaters, side channels, and flood plain. Increases overbank flooding, creating areas of variable depth and velocity.	Promotes overbank flooding favorable for establishment of riparian vegetation as well as creating variable depth and velocity habitat. Reduces potential for channel degradation, thereby maintaining a higher water table and more connectivity with backwaters and side channels. Increased overbank flooding creates variable depth and velocity habitat types including silvery minnow nursery habitat during spring runoff. Increased overbank flooding maintains moist soil conditions during flycatcher territory establishment. Growth of native riparian vegetation can enhance habitat conditions for the flycatcher.
Longitudinal Dikes	Level 3 (Fixed Bed Design Methods Available) and Level 2 (Few Sets of Field or Lab Data and Limited Information On Mobile Bed Applications)	Can create a zone of higher main channel velocity resulting in increased sediment transport capacity. This potentially can cause the channel to deepen and create a sediment depositional zone downstream. Can decrease overbank flow area and can result in more uniform channel velocity and depth.	Can decrease overbank flows, reducing the health of riparian zone. This can be partially mitigated by providing culverts for wetting the riparian zone. Can result in more uniform channel velocity and depth.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Levee Strengthening	Level 3 (Fixed Bed Design Methods Well Established) and Level 2 (Less Knowledge on Elevation for Mobile Bed Cases)	The geomorphic response associated with levee installation has already occurred for the levee strengthening method. Initial levee construction generally resulted in flood plain narrowing. Raising or enlarging the levee causes very minor or no geomorphic effects. Small amounts of clearing may be required to enlarge the levee and reduce the side slope. May allow channel relocation nearer to levee.	Initial levee construction and the accompanying flood plain narrowing affect the habitat. Raising or enlarging the levee causes very minor to no habitat effects. Small amounts of clearing may be required to enlarge the levee and reduce the side slope.
Jetty/Snag Removal	Level 1	Jetty removal may result in channel widening and increased flood plain connectivity. Channel widening is less likely to occur where the riparian vegetation root zone provides more bank stability than the jetties. Channel widening (unless hampered by existing vegetation) could reduce channel flow depth and velocity.	The habitat may not change if the existing vegetation has more effect on bank stability than the jetties themselves. Otherwise, channel widening could reduce channel flow depth and velocity and create more bank line habitat.
BANK PROTECTION/ STABILIZATION			
Longitudinal Features			
Riprap Revetment	Level 3	Eliminates local bank erosion; causes local scour and channel deepening. Studies about longer reach response are contradictory. Can be susceptible to flanking if upstream channel migration occurs. Prevents local bend migration and the establishment of new depositional zones. Eliminates sediment supplied from bank erosion. The point bar can remain connected to the main channel. The flow velocity, depth, and bank angle would be greater than typically found in natural channels along the outside bank of a river bend. Interstices within the riprap could host low-energy "pockets" along the bank.	Prevents bend migration and the establishment of new depositional zones where vegetation could become established. Eliminates sediment supplied from local bank erosion. The steep bank angle on the outside of the bend limits fish cover, except for the riprap interstitial spaces. The point bar remains connected to the main channel and remains static. The flow velocity and depth are greater than typically found in natural channels along the outside bank of a river bend.
Other Type of Revetments	Level 2	Effects are essentially the same as riprap revetments.	Effects are essentially the same as riprap revetments

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Longitudinal Stone Toe with Bioengineering	Level 3 (Riprap Design, Scour, and Longitudinal Extent of Placement Are Well Known) and Level 2 (Elevation of the Top of the Stone Toe and Bioengineering in Arid Climates is Less Known)	Similar to riprap revetment.	Same as riprap revetment. Bioengineering provides very minimal benefits to riparian community.
Trench-Filled Riprap	Level 2	Bank erosion processes continue until erosion reaches the location of the trench. After launching, response is the same as for riprap revetment.	Same as riprap revetment.
Riprap Windrow	Level 2	Same as trench-filled riprap.	Same as riprap revetment.
Deformable Stone Toe /Bioengineering and Bank Lowering	Level 2 (Riprap Sizing) and Level 1 (Lack of Design Guidelines and Postproject Studies)	The design is intended to allow bend migration at a slower rate than without protection. River maintenance still may be required in the future. Water surface elevations could be lower with bank lowering. After installation, and before the toe of the riprap becomes mobile, the channel bed may scour along the deformable bank line. Bank erosion occurs during peak-flow events, which mobilize the small-sized riprap along the bank toe. Future bank migration would allow new depositional surfaces to be established.	If flood plain is created behind the stone toe and vegetation becomes established before the toe is lost, an expanded riparian area could develop. Future bank migration would allow new depositional surfaces to establish, which would become new riparian areas.
Bioengineering	Level 1	Vegetation has the lowest erosion resistance of all available methods. Plantings require time to become established before any bank protection is realized. Lateral and down-valley bank line movement can continue because bioengineering does not permanently fix the bank location. Allows more natural movement of river channel.	If the technique is successful, it could promote the establishment and development of riparian vegetation without significant armament to the bank line. Allows more natural movement of river channel.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Riparian Vegetation Establishment	Level 2	Can cause sediment deposition in overbank areas due to increased flow resistance. Sediment deposition in the overbank can increase main channel sediment transport capacity by raising the bank height.	Directly adds to the amount of riparian vegetation. Increased growth of riparian vegetation in overbank areas can enhance habitat conditions for both the flycatcher and the silvery minnow. Encroachment of mature vegetation eventually may lead to a narrower and more confined channel that is negative for silvery minnow habitat.
Transverse Features or Flow Deflection Techniques	Level 2 (Limited Design Guidelines Available) and Level 3 (Lack of Quantitative Design Guidelines and Postproject Studies)	These methods may cause local sediment deposition between structures and/or local scalloping along the bank line. Flow is deflected away from the bank line, thereby altering secondary currents and flow fields in the bend. Eddies, increased turbulence, and velocity shear zones are created. Methods induce local channel deepening at the tip. Shear stress increases in the center of the channel, which maintains sediment transport and flow capacity. Sediment deposition between structures may allow establishment of islands, bars, and backwater areas. Channel deepening and tip scour could locally lower the riverbed and the ground water table.	Sediment deposition between structures may allow establishment of riparian vegetation and backwater areas. Channel deepening and tip scour could occur locally. Depending on site specific details, bendway weirs would allow for overbank flooding conditions for flycatchers. Local scour could provide habitat diversity and deep habitat during low-flow conditions.
Bendway Weirs	Level 2 (Limited Design Guidelines Available) and Level 1 (Lack of Quantitative Design Guidelines and Postproject Studies)	The location of the thalweg is shifted away from the outer bank line. Local scour at the tip occurs because of the three-dimensional flow patterns. Secondary currents are interrupted, and flows are redirected away from the bank. The outer bank can become a zone of lower velocity. The combined effect of the tip scour and lower velocity along the bank line creates a flow condition of variable depth and velocity. Scalloping also can occur along the bank line or sediment deposition between structures, depending upon local conditions and bendway weir geometry. Can reduce local sediment supplied from bank erosion because the current river alignment is maintained.	Same as transverse features or flow deflection techniques above.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Spur Dikes	Level 2	Spur dikes block the flow up to bank height, thus shifting the thalweg alignment to the dike tips. Peak flow capacity can be reduced initially until the channel adjusts. The channel adjusts to the presence of spur dikes by forming a deeper, narrower cross section with additional scour downstream from each spur dike. Sediment deposition can occur between spur dikes. There is a greater tendency for sediment deposition between spur dikes than the other transverse features.	Same as transverse features or flow deflection techniques above. There is a greater tendency for sediment deposition between spur dikes than the other transverse features.
Vanes or Barbs	Level 2 (Limited Design Criteria) and Level 1 (Very Little Design Test Data)	These structures redirect flow from the bank toward the channel center and reduce local bank erosion while providing a downstream scour hole. Sediment deposition or bank scalloping can occur along the outer bank, depending upon spacing.	Same as transverse features or flow deflection techniques above.
J-Hook	Level 2 (Limited Design Criteria) and Level 1 (Does not Have a Documentable Track Record and Very Little Design Test Data)	Redirects flow away from eroding banks, the same as vanes or barbs, with an added downstream-pointing "J" configuration. The J-hook creates an additional scour hole pool and can produce a local downstream riffle. Remainder of the geomorphic response is the same as for vanes.	Same as transverse features or flow deflection techniques described above. Additional pool habitat is created by the J-hook.
Trench Filled Bendway Weirs	Level 1	Once the bank erosion reaches the bendway weir tips, the flow is redirected away from the eroding bank. The location of the thalweg is shifted away from the outer bank line. Local scour at the tip occurs because of the three-dimensional flow patterns. Secondary currents are interrupted. The outer bank can become a zone of lower velocity.	Provided the bendway weirs constructed in a trench remain intact, the habitat characteristics will be about the same as bendway weirs constructed in the channel.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Boulder Groupings	Level 2 Cross Channel Because Constructed Out into the Channel	Creates a zone of local scour immediately downstream from the boulders. Creates areas of variable depth and velocity. Creates velocity shear zones. Effects are localized to the immediate vicinity of the boulders. Increases channel roughness at high flows. Adds complexity to the system.	Can provide structure and habitat for fish.
Rootwads	Level 2 Bank Stab Bank Line Feature	Creates local scour pools and areas of variable velocity. Increases flow resistance along the bank line, which dissipates energy, traps and retains sediments, and creates turbulence that can move the main current away from the bank line. Adds complexity to the system. Variable depth and velocity conditions can be created. Some potential for creating areas of sediment deposition (depending on specific placement). Cottonwood tree rootwads have a design span of about 5 years; therefore, this method has been used with many other methods to create habitat.	Adds complexity to the system. Variable depth and velocity conditions can be created. Some potential for creating areas of sediment deposition (depending on specific placement), which is generally beneficial to the establishment and development of riparian vegetation. Can provide structure and habitat for silvery minnow. Isolated pools often are maintained in scour pools caused by debris, including rootwads. This can serve as refugia habitat for silvery minnow during low-flow periods. Similar to LWD. Could trap sediment and encourage new native vegetative growth.
Large Woody Debris	Level 2	LWD can provide local stream cover and scour pool formations, can deflect flows and increase depth and velocity complexity. Can promote side channel formation and maintenance. LWD in the Middle Rio Grande can lead to sediment deposition, including formation of islands, in reaches with large sand material loads. Could establish new sediment deposition areas. LWD constructed from cottonwood trees last about 3–5 years.	Adds complexity to the system. Sediment deposition can create areas where new riparian vegetation becomes established. Can create variable depth and velocity habitat. Can provide structure and habitat for fish. May provide for habitat diversity in areas with monotypic flow patterns and refugia habitat during low flows. These habitats also may provide refuge for predatory fishes. Increased areas of moist or flooded soil conditions could assist in flycatcher territory establishment and native vegetation recruitment.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
CROSS CHANNEL (RIVER SPANNING) FEATURES			
Grade Control (Grade Control Methods Are Shown Below. Effects that Are Common for Cross Channel Methods Are Included Here)		Grade control can reduce the gradient upstream by controlling the bed elevation and dissipating energy in discrete steps. At least during low flows, the upstream water surface is raised, depending on structure height above the bed. Upstream velocity is reduced. There can be a local effect on sediment transport, scour, and deposition, depending on the structure characteristics. For low-head structures (1–2 feet), the amount of upstream sediment storage is low and usually does not cause downstream bed level lowering as a result of upstream sediment storage. In supply-limited reaches, channel degradation downstream from the structure will continue as a result of excessive sediment transport capacity. The slope of the downstream apron would be designed to provide fish passage and prevent local scour downstream from the structure. Due to the potential for the continuation of the downstream channel incision trend, adaptive management may be necessary to provide for continued fish passage. Reduces channel degradation upstream of this feature and can promote overbank flooding and raise the water table. Backwater areas could develop upstream, which also would raise the water table. If downstream degradation continued, the water table would be lowered.	Increased upstream connectivity with side channels at low flows, creating variable depth and velocity habitat. By preventing future upstream local degradation, the current level of flood plain connectivity can continue. Increased upstream water levels (except for peak flows) likely would increase vegetative health and could attract flycatchers, particularly if overbank flooding conditions occurred during territory establishment. Low downstream apron slopes would be designed to provide for fish passage.
Deformable Riffles	Level 3	During low-flow conditions, where these structures are fixed, the effects upon channel morphology are described in the "grade control" response above. When the riprap material forming the riffle launches or deforms downstream, the bed can lower a relatively small amount.	Same as grade control above.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
Rock Sills	Level 2	Riverbed elevation is held constant, while rock launches into the downstream scour hole. Since the bed is fixed, the effects on geomorphology are the same as for grade control.	Same as grade control above.
Riprap Grade Control (With or Without Seepage)	Level 2	Riprap is flexible and deforms into a scour hole. Can be at bed level or above. Can have short or long low-slope apron. Because the bed is fixed, the effects upon geomorphology are the same as for grade control.	Same as grade control above.
Gradient Restoration Facility	Level 3 (Hydraulic Design Is Well Documented) and Level 2 (Limited Postproject Field Studies)	Bed is fixed. The effects upon geomorphology are the same as for grade control.	Same as grade control above.
Low-Head Stone Weirs (Loose Rock)	Level 2 (Limited Design Criteria and Level 1 (Limited Postproject Field Studies and Design Test Data)	These structures typically are constructed above the bed elevation without grout. During low flows, there is an abrupt change in the water surface elevation through the structures, creating an upstream backwater effect. Generally, these structures do not raise the water surface during high flows. Sediment continuity can be re-established after the scour pool and tailout deposits are formed. A series of structures can dissipate energy and reduce channel degradation. Can interrupt secondary currents and move main current to the center of the channel if constructed in bendways.	Same as grade control above. Can provide pool habitat. Fish usually can pass through the interstitial spaces between weir stones.
CONSERVATION EASEMENTS	Level 2	Allows space for existing fluvial processes to continue, which can preserve flood plain connectivity. Allows more natural river movement with variable depth and velocity and promotes greater area of undisturbed streamside terrain.	Allows more natural river movement and promotes greater area of undisturbed habitat.

Table 2. Methods Level of Confidence, Geomorphic and Habitat Effects

Method	Level of Confidence	Geomorphic Effects	Habitat Effects
CHANGE SEDIMENT SUPPLY			
Increase Sediment Supply	Level 2 (Examples Exist of the Benefits of Adding Sediment to Rivers) and Level 1 (Middle Rio Grande is a Non-equilibrium River Where Changes in Sediment Supply Could have large effects)	Where the river is lacking in sediment, the addition of sediment can stabilize or even reverse channel incision. Addition of sand-sized sediment can reduce bed material size, especially where coarser material is available in an incising channel. May result in sand deposits in pools, reduction of gravel riffle height, decreased depth, and increased width-to-depth ratio. Additional sediment could result in the establishment of river bars and terraces. Could increase the potential for overbank flooding and raise the water table elevation.	Additional sediment could result in the establishment of river bars and terraces, which would be conducive to the establishment and development of riparian areas. Could increase the potential for overbank flooding and raise the water table elevation.
Decrease Sediment Supply	Level 2 (Examples Exist of the Benefits of Reducing Sediment Supply to Some Rivers) and Level 1 (Middle Rio Grande Is a Non-equilibrium River Where Changes in Sediment Supply Could Have Large Effects)	Where the river has excess sediment supply, the reduction or removal of sediment supply can stabilize or reverse aggradational trends. Reduction of sediment supply could cause the bed material to coarsen. In general, a more uniform channel depth and velocity would result. In addition, the tendency for the channel to braid and form split delta channels would be reduced. Water table may fall.	In general, more uniform depth and velocity habitat would result, which decreases habitat complexity for the RGSM. The opportunity for the channel to braid and form distributary channels would be reduced, providing less opportunity for riparian growth.

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Most Likely Strategies and Methods by Reach Attachment

This attachment shows which strategies are suitable in each reach, the method categories, , how they are associated with each strategy, and the most likely methods for each reach. The most likely methods by reach are based upon the most likely strategies and the methods most commonly used to implement each strategy. Methods can be used as part of a reach strategy or to address site-specific river maintenance purposes. The suitability and effectiveness of a given method are a function of the inherent properties of the method, the physical characteristics of the reach, and the reach strategy. As such, there is no single method that applies to all situations; and while the most commonly used methods have been identified for each reach, other methods also may be used. In addition, new methods are likely to be developed in the future that will be described in future reach or site-specific biological assessments. Table 1 shows which strategies are most suitable for each reach. Additional information may be found in the report entitled, *Middle Rio Grande River Maintenance Program Comprehensive Plan and Guide, Appendix A* (Reclamation 2012).

Table 2 contains the most applicable method category for each strategy. For a given strategy, more than one method category can apply.

Table 3 is the most applicable methods for each reach. For a given strategy and reach, more than one method can apply. The combination of methods used depends upon local river conditions, reach trends, reach constraints, and the inherent properties of the method.

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Table 1. Summary of Most Likely Strategies by Reach

	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Velarde to Rio Chama	Not Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
Rio Chama to Otowi Bridge	Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
Cochiti Dam to Angostura Diversion Dam	Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
Angostura Diversion Dam to Isleta Diversion Dam	Suitable	Suitable	Not Suitable	Not Suitable	Suitable	Suitable
Isleta Diversion Dam to Rio Puerco	Suitable	Not Suitable	Suitable	Suitable	Suitable	Suitable
Rio Puerco to San Acacia Diversion Dam	Not Suitable	Suitable	Not Suitable	Suitable	Suitable	Not Suitable
San Acacia Diversion Dam to Arroyo de las Cañas	Suitable	Suitable	Not Suitable	Suitable	Suitable	Suitable
Arroyo de las Cañas to San Antonio Bridge	Suitable	Not Suitable	Suitable	Not Suitable	Not Suitable	Suitable
San Antonio Bridge to River Mile 78	Suitable	Not Suitable	Suitable	Suitable	Not Suitable	Suitable
River Mile 78 to Full Pool Elephant Butte Reservoir Level	Suitable	Not Suitable	Suitable	Suitable	Not Suitable	Suitable

Table 2. Method Categories Associated with Strategies

Method	Promote Elevation Stability	Promote Alignment Stability	Reconstruct/ Maintain Channel Capacity	Increase Available Area to the River	Rehabilitate Channel and Flood Plain	Manage Sediment
Infrastructure Relocation or Setback				X		
Channel Modification			X		X	X
Bank Protection/ Stabilization		X				
Cross Channel (River Spanning) Features	X					
Conservation Easements				X	X	
Change Sediment Supply						X

Table 3. Most Likely Methods for Each Reach[1]

Method	Velarde to Rio Chama	Rio Chama to Otowi Bridge	Cochiti Dam to Angostura Diversion Dam	Angostura Diversion Dam to Isleta Diversion Dam	Isleta Diversion Dam to Rio Puerco	Rio Puerco to San Acacia Diversion Dam	San Acacia Diversion Dam to Arroyo de lasCañas	Arroyo de las Cañas to San Antonio Bridge	San Antonio Bridge to River Mile 78	River Mile 78 to Full Pool Elephant Butte Reservoir Level
Infrastructure Relocation or Setback	X	X	X		X	X	X		X	X
Channel Modification										
Complete Channel Reconstruction and Maintenance					X			X	X	X
Channel Relocation Using Pilot Channels or Pilot Cuts	X	X	X	X	X	X	X	X	X	X
Island and Bank Clearing and Destabilization	X	X	X	X	X	X	X			
Bankline Embayment			X	X	X	X	X			
Pilot Cuts Through Sediment Plugs								X	X	X
Side Channels (High Flow, Perennial, and Oxbow Re-establishment)	X	X	X	X	X	X	X			
Longitudinal Bank Lowering or Compound Channels	X	X	X	X	X	X	X			
Longitudinal Dikes					X			X	X	X
Levee Strengthening								X	X	X
Jetty/Snag Removal	X	X	X	X	X	X	X	X	X	X
Bank Protection/Stabilization										
Longitudinal Features-										
Riprap Revetment	X	X	X	X		X	X			
Other Type of Revetments	X	X	X	X		X	X			

Table 3. Most Likely Methods for Each Reach[1]

Method	Velarde to Rio Chama	Rio Chama to Otowi Bridge	Cochiti Dam to Angostura Diversion Dam	Angostura Diversion Dam to Isleta Diversion Dam	Isleta Diversion Dam to Rio Puerco	Rio Puerco to San Acacia Diversion Dam	San Acacia Diversion Dam to Arroyo de lasCañas	Arroyo de las Cañas to San Antonio Bridge	San Antonio Bridge to River Mile 78	River Mile 78 to Full Pool Elephant Butte Reservoir Level
Longitudinal Stone Toe with Bioengineering	X	X	X	X		X	X			
Trench Filled Riprap	X	X	X	X		X	X			
Riprap Windrow	X	X	X	X		X	X			
Deformable Stone Toe /Bioengineering and bank lowering		X	X	X		X	X			
Bioengineering	X	X		X		X	X			
Riparian Vegetation Establishment	X	X	X	X		X	X			
Transverse Features or Flow Deflection Techniques										
Bendway Weirs		X	X	X		X	X			
Spur Dikes		X	X	X		X	X			
Vanes or Barbs		X	X	X		X	X			
J-Hook		X	X	X		X	X			
Trench Filled Bendway Weirs		X	X	X						
Boulder Groupings	X	X	X	X		X	X			
Rootwads	X	X	X	X		X	X			
Large Woody Debris	X	X	X	X		X	X			
Cross Channel (River Spanning) Features										
Grade Control										
Deformable Riffles		X	X	X	X		X			
Rock Sills		X	X	X	X		X			
Riprap Grade Control (With or Without Seepage)		X	X	X	X		X			

Table 3. Most Likely Methods for Each Reach[1]

Method	Velarde to Rio Chama	Rio Chama to Otowi Bridge	Cochiti Dam to Angostura Diversion Dam	Angostura Diversion Dam to Isleta Diversion Dam	Isleta Diversion Dam to Rio Puerco	Rio Puerco to San Acacia Diversion Dam	San Acacia Diversion Dam to Arroyo de lasCañas	Arroyo de las Cañas to San Antonio Bridge	San Antonio Bridge to River Mile 78	River Mile 78 to Full Pool Elephant Butte Reservoir Level
Gradient Restoration Facility (GRF)		X	X	X	X		X			
Low-Head Stone Weirs (Loose Rock)		X	X	X	X		X			
Conservation Easements	X	X	X	X	X	X	X		X	X
Change Sediment Supply										
Sediment Augmentation (Sand Sizes)					X		X			
Natural or Constructed Sediment Basins								X	X	X

[1]This table identifies the most likely methods to be used in each reach. Due to river channel variability, every method may be used in each reach.

Geomorphic Strategy Effects Attachment

Tables 1–6 provide a list, by strategy, of the general reach geomorphic trends addressed (not in order of importance), the geomorphic effects of implementing each strategy in a reach, additional potential strategies that address the same geomorphic trends (complementary strategies), and the geomorphic effects of strategy implementation in downstream and upstream reaches. Observed geomorphic trends may be directly addressed by a strategy through stopping the trend, reducing the trend, reversing the trend, and allowing the trend to continue while reducing the need for river maintenance. The tables describe the geomorphic effects from strategy implementation based on the currently observed relationship between sediment transport capacity and sediment supply. The addressed strategy changes are different if the sediment transport capacity is greater than or less than the sediment supply. If a strategy only lists one condition, such as sediment transport capacity less than sediment supply for Reconstruct and Maintain Channel Capacity, then it can be assumed that this strategy is not applicable to the other condition—sediment transport capacity greater than sediment supply. These are general reach effects; therefore, uncertainty may exist in the magnitude of physical effect. Where the probable magnitude of physical effect is known, it is so stated. In tables 1–6, method categories are used for some strategies where effects of methods within a method category have essentially the same reach effects. For some strategies, specific methods are included where there are dissimilar effects of methods within a method category. Where possible, the effects relating to a common geomorphic response are grouped together. Method categories and methods associated with strategies are described in the River Maintenance Methods Attachment.

Table 1. Promote Elevation Stability Strategy: Trends Addressed and Geomorphic Effects

Trends Addressed	Increased bank height Incision or channel bed degradation Coarsening of bed material Aggradation
Reach Effects *Sediment transport capacity greater than sediment supply (erosional)*	**General** • Strategy maintains or raises bed elevation, but effects upon channel capacity are expected to be small. • Effects evaluation is based upon cross channel features ~ 2 feet high or less. • Fixes local lateral channel location and width (to prevent flanking, except deformable; see below). • Reduces the probability of additional future bed material coarsening. • Stabilizes current bed elevation (except deformable; see below). • Could increase bank erosion if bank stability below erosion threshold. This effect could be local when the future potential channel slope change is small. • Downstream degradation is expected to continue and may create possible fish passage issues. This can be addressed through adaptive management. • Can prevent lateral migration by preventing erosion below root zone or beyond geotechnically stable height. This effect could be local when the future potential slope change is small. *Cross channel features* At bed – Maintain upstream water surface elevation (WSE) at same discharge. • No effect on bed elevation downstream—sediment passes through structure; does not halt downstream channel degradation. • Current slope and upstream bed elevation maintained. Above bed – Raise WSE at same discharge (effects evaluation is based upon low height cross channel structures ~ 2 feet high or less). • Long-term effect is raise bed upstream, ~ height of structure tapering to the next upstream riffle or high point in the bed. • No long-term effect on bed elevation downstream—sediment passes through structure, but local initial degradation possible that would fill in later. • Previous upstream slope is generally recreated. • Temporary – Aggradation from back water effect. • Can promote increased flood plain connectivity and greater velocity and depth variability depending upon the amount of past channel incision. Deformable – Maintain upstream water surface elevation at same discharge. Reduces and slows bed erosion—structure is mobile at design discharge.

Table 1. Promote Elevation Stability Strategy: Trends Addressed and Geomorphic Effects

Reach Effects (continued) *Sediment transport capacity greater than sediment supply (erosional)*	• Effects are similar to at bed or above bed structures when cross channel feature is intact, except that lateral channel location and width may not be fixed. **Complementary strategies:** • Promote Alignment Stability, Increase Available Area to the River– – Increases length of channel. • Manage Sediment – Increases sediment supply. • Rehabilitate Channel and Flood Plain – Reduces sediment transport capacity.
Effects on Upstream/ Downstream Reaches *Sediment transport capacity greater than sediment supply (erosional)*	*Cross channel features* At bed • Upstream effects: Because future channel bed degradation is reduced or halted, there may be a reduced tendency for degradation in the upstream reach. This would most likely result in the bed material size remaining the same, or coarsening at a reduced rate. • Downstream effects: There could be a small reduction in the downstream sediment supply since future degradation is reduced or halted. This is likely to have only a minimal effect upon the downstream reach bed elevation and potential future channel evolution. Bed material size is not likely to be affected in the downstream reach. Above bed • Upstream effects: The bed would be raised to the nearest riffle or high point in the bed upstream of the structures. Sediment fills the reach upstream at about the previous slope, which is determined by channel width, hydrology, sediment load and size, bed and bank material size, and any geologic controls, etc. Thus, there would be little, if any, additional effects upon upstream bed elevation, bed material size, or channel slope from those listed for the at bed condition. • Downstream effects: Initially, sand sizes or finer gravel sizes could deposit upstream of these structures depending upon the size of the supplied sediment. This could reduce downstream sediment supply for a temporary period of time. During this temporary period of time, there could be a small amount of downstream channel degradation; however, this effect would be minimal, because the amount of sediment storage upstream of these structures is small. After this temporary period of time, sediment delivery to the downstream reaches would be about the same as pre-implementation. Bed material size is not likely to be affected in the downstream reach. Deformable • Effects are similar to the above bed and at bed structures when cross channel feature is intact, except that lateral channel location and width may not be fixed.

Table 1. Promote Elevation Stability Strategy: Trends Addressed and Geomorphic Effects

Reach Effects *Sediment transport capacity less than sediment supply (depositional)*	**Addressed through complementary strategies:** Reconstruct/Maintain Channel Capacity – Increases sediment transport capacity. Manage Sediment – Reduces sediment supply. Increase Available Area to the River – Increases area for sediment deposition.
Effects on Upstream/ Downstream Reaches *Sediment transport capacity less than sediment supply (depositional)*	See complementary strategy effects on upstream/ downstream reaches for the sediment transport capacity less than sediment supply case.

Table 2. Promote Alignment Stability: Trends Addressed and Geomorphic Effects

Trends Addressed	Bank erosion Channel plugging with sediment Perched channel conditions

Reach Effects
Sediment transport capacity greater than sediment supply (erosional)
	General
	• Strategy allows lateral migration until infrastructure is threatened.
	• Some increase in sinuosity with potential for new deposition.
	Bank Protection/Stabilization
	Longitudinal features: Fixed bank
	• Bank line does not move.
	• No sediment supply from banks.
	• No new depositional zones.
	• Increase in local flow velocity and depth.
	Longitudinal features: Mobile bank - degree of mobility varies with method.
	• Moves to a fixed location—then effects same as above.
	  o Either fixed in advance or when needed.
	  o Temporary sediment supply from banks.
	  o Temporary continuation of lateral migration channel process.
	• Reduces sediment supply from banks.
	• Reduces new depositional zones.
	• Temporary increase in local flow velocity and depth.
	Transverse Features or Flow Deflection Techniques.
	• Fixed bend – Constructed from bank line into channel.
	• Mobile Bend – Constructed in channel bank.
	  o New location either fixed in advance or as needed.
	  o Moves to a fixed location—then effects same as above.
	  o Temporary sediment supply from banks.
	• Reduces sediment supply from banks.
	• Potential for local bank sediment deposition and/or scalloping between structures.
	• Reduces new depositional zones on opposite bank.
	• Creates local eddies, with variable turbulence and velocity shear zones.
	• Local channel deepening with greater deepening at tip.
	• Creates local scour pools.
	• Variable depth and velocity effects are reduced at higher flows.
	• Local sediment deposition upstream and along scour pool.
	• May help form and maintain side channels.
	• May form bars and islands.

Table 2. Promote Alignment Stability: Trends Addressed and Geomorphic Effects

Reach Effects (continued) *Sediment transport capacity greater than sediment supply (erosional)*	**Complementary strategies:** • Promote Elevation Stability – Reduces channel incision through cross channel structures which could either increase or reduce bank erosion. • Reconstruct/Maintain Channel Capacity – Keeps the channel in the same location or a selected relocated alignment. • Rehabilitate Channel and Flood Plain – Reduces sediment transport capacity. • Increase Available Area to the River – Moves infrastructure. • Manage Sediment – Increases sediment supply.
Effects on Upstream/ Downstream Reaches *Sediment transport capacity greater than sediment supply (erosional)*	Upstream and downstream effects are expected to be similar within the Bank Protection/Stabilization method category. Upstream – As the channel lengthens, sediment transport capacity is reduced, lowering the tendency for channel bed degradation. If the upstream reach is degrading then this tendency could be reduced. A less degrading upstream bed could result in the bed material sizes remaining about the same or become smaller. Potential changes in flow velocity and channel depth are expected to be minimal. Downstream – To the extent that the sediment supply from bank erosion of the affected reach is reduced, there could be possible impacts to the downstream reach. These impacts could be incision or bed degradation, slope reduction and increased bed material size depending upon the portion of the sediment load being supplied by lateral migration. Depending upon reach sediment supply from tributaries, this effect could be small.
Reach Effects *Sediment transport capacity less than sediment supply (depositional)*	When the trends of channel plugging with sediment or perched channel conditions are present, channel avulsion or relocation is possible. This strategy reinforces the new bank and has the same effects as listed under sediment transport capacity greater than sediment supply **Complementary strategies:** Reconstruct and Maintain Channel Capacity – Removes sediment, relocates channel, or raises/strengthens levees. Increase Available Area to the River – Moves infrastructure. Manage Sediment – Reduces sediment supply.
Effects on Upstream/ Downstream Reaches *Sediment transport capacity less than sediment supply (depositional)*	Upstream – No change is expected. Downstream – If active bank erosion within the affected reach adds significantly to the sediment supply, and this is reduced, than this may bring the sediment supply of the affected reach and the downstream reach more into a dynamic equilibrium with the sediment transport capacity. This may help to minimize deposition within the channel downstream.

Table 3. Reconstruct and Maintain Channel Capacity: Trends Addressed and Geomorphic Effects

Trends Addressed	Channel narrowing Vegetation encroachment Aggradation Channel plugging with sediment Perched channel conditions

Reach Effects
 	
Sediment transport capacity less than sediment supply (depositional)
	General
	Since the implementation reach is experiencing loss of channel capacity, maintenance of this strategy is likely. Implementation effects are described below. Maintenance would not incur additional geomorphic strategy effects beyond those listed below. This strategy may help reduce future differential between bed and valley elevation.
	Channel Modification (for applicable methods, see River Maintenance Methods Attachment)
	Complete Channel Reconstruction and Maintenance
	• Generally more uniform width, depth, and velocity.
	• Low-flow bars can form within excavated channel with increased local depth and velocity variation. Adaptive management can allow more variation.
	• Reduces braiding and split delta channels.
	• Reduces water surface area.
	• Lowers ground water table.
	Pilot Cuts Through Sediment Plugs
	• Temporary increase in velocity and bed lowering.
	• Temporary increase in sediment load delivered downstream.
	• Generally less uniform width, depth, and velocity than complete reconstruction.
	• Extent of sediment removal is flow peak and duration dependent.
	  o Channel width may be narrower than existed before sediment plugging with increase in depth and velocity.
	  o Spoil piles may disconnect flood plain, but adaptive management could reduce this effect.
	• Effects which occur at a slower rate:
	  o Reduces braiding and split delta channels.
	  o Reduces water surface area and evapotranspiration losses.
	  o Lowers ground water table.
	Longitudinal Dikes
	• Can create zone of increased main channel flow velocity and depth.
	  o Created at high flows and may remain for low flows.
	• Can increase uniformity of channel dimensions.
	  o Created at high flows and may remain for low flows.

Table 3. Reconstruct and Maintain Channel Capacity: Trends Addressed and Geomorphic Effects

Reach Effects (continued) *Sediment transport capacity less than sediment supply (depositional)*	• Decreases surface area of overbank flow. o Adaptive management can reduce this effect. • Can cause local bed lowering. Levee Strengthening • Increased high-flow capacity. • May allow channel relocation closer to levee. **Complementary strategies:** • Increase Available Area to the River – Moves infrastructure. • Manage Sediment – Decreases sediment supply.
Effects on Upstream/ Downstream Reaches *Sediment transport capacity less than sediment supply (depositional)*	Upstream and downstream effects are expected to be similar for the applicable methods within the Channel Modification method category. Upstream – Bed degradation could occur which would increase sediment transport capacity. Higher flows would be required to go over bank and lowered groundwater tables may accompany degradation. Sediment supply could increase temporarily during the degradational process. Bed material size may coarsen. Since the implementation reach is experiencing aggradation, maintenance of this strategy is likely. As the channel fills between periods of river maintenance, the upstream reach could begin to aggrade and then degrade after river maintenance, with this cycle potentially being repeated. Downstream – Increased sediment supply, because the sediment transport capacity is restored to its previous condition. This could steepen the channel slope in the downstream reach due to sediment deposition and channel aggradation. The bed material could become finer. It is likely that maintenance of this strategy will be needed since the channel is aggrading in the implementation reach. As the channel fills between maintenance events, there could be a decrease in sediment supply to the downstream reach causing channel bed degradation. There would then be an increase in the sediment supply in the downstream reach after periods of river maintenance in the implementation reach. This cycle could potentially be repeated with each river maintenance action.

Table 4. Increase Available Area: Trends Addressed and Geomorphic Effects

Trends Addressed	*Sediment transport capacity greater than sediment supply* (allows evolution and/or increased length): Channel narrowing Increased bank height Incision or channel bed degradation Bank erosion Coarsening of bed material Increased channel uniformity *Sediment transport capacity less than sediment supply (*allows channel relocation): Aggradation Channel plugging with sediment Perched channel conditions
Reach Effects *Sediment transport capacity less than or greater than sediment supply (depositional or erosional)*	**General** *Infrastructure relocation or setback/Conservation Easements* • Wider area for natural channel processes. • Encourages new flood plain areas and side channels. • Provides opportunity to reconnect historical flood plain and side channels. • Encourages variability in channel dimensions and velocity. • Provides opportunity to increase bank erosion and new deposition. • Preserves flood plain connectivity. • Possible temporary change in sediment supply. For reaches with sediment transport capacity less than sediment supply, this would likely be a reduction through deposition. For reaches with sediment transport capacity greater than sediment supply, this would likely be an increase through bank/bed erosion. • Reduces future maintenance. Extent of reduction depends upon the area needed versus. the area acquired. **Complementary Strategies (Transport capacity greater than supply)** • Reconstruct/Maintain Channel Capacity – Strengthens/raises levee to allow channel migration closer to levee and reduce area needed. **Complementary Strategies (Transport capacity less than supply)** • Manage Sediment – Sediment removal

Table 4. Increase Available Area: Trends Addressed and Geomorphic Effects

Effects on Upstream/ Downstream Reaches *Sediment transport capacity greater than sediment supply (erosional)*	Upstream –The channel slope in the implementation reach would likely decrease as the channel lengthens. If the upstream reach is degrading, then this tendency could be reduced resulting in bed material sizes to remain about the same or become smaller than the current size. This may also cause a slight reduction in the sediment supply. Downstream – There may be a short-term effect of increased sediment supply from bank erosion, but the long-term effect downstream would likely be reduced sediment supply as the channel lengthening lowers sediment transport capacity. In addition, there would likely be new depositional features such as bars, or an inset flood plain, which would form and/or grow in size during lateral migration. These sediment storage areas could also lower downstream sediment supply. Reduced sediment supply could initiate channel incision or bed degradation, coarsen the bed material, increase channel discharge capacity, and increase flows necessary to go over bank.
Effects on Upstream/ Downstream Reaches *Sediment transport capacity less than sediment supply (depositional)*	Upstream –The upstream reach effect depends upon whether or not there is a change in the water surface elevation in the area where the river migrates or avulses to. For the case where the water surface elevation in the implementation reach decreases, then the upstream bed will degrade increasing the sediment transport capacity and the discharge to go over bank. Bed material size would likely increase but remain sand-sized in sand-dominated reaches. Upstream degradation will continue until such time as the relocated channel bed fills with sediment. Then, the upstream bed elevation could increase to the previous or higher level. For the case where the water surface elevation does not change, then the upstream effect would be minimal. Downstream – Sediment deposition could occur in the area where the river migrates or avulses to, which would decrease downstream sediment supply. This could cause bed degradation, bed coarsening, increased channel capacity, and increased flow necessary to go over bank. Over time the area available for sediment deposition may fill, during which time downstream sediment supply would increase potentially leading to channel aggradation and finer bed material sizes.

Table 5. Rehabilitate Channel and Flood Plain: Trends Addressed and Geomorphic Effects

Trends Addressed	Channel narrowing Vegetation encroachment Increased bank height Incision or channel bed degradation Bank erosion Coarsening of bed material Increased channel uniformity
Reach Effects *Sediment transport capacity greater than sediment supply (erosional)*	**General** This strategy applies to implementation reaches that are experiencing channel degradation or incision associated with channel narrowing. Implementation of this strategy would reduce channel erosion, and encourage sediment deposition by increasing flood plain connectivity. Maintenance may be needed that would not incur additional geomorphic effects beyond those listed below. Conservation easements could provide additional area for river relocation and side channel development. *Channel Modification* Complete construction – Longitudinal bank lowering and channel reconstruction flow goes overbank at lower discharge—greater flood plain connectivity. • Can increase high flow capacity. • Wider surface area at high flows. • More depth and velocity variation at high flows. • Decrease high-flow velocity and depth because reduces energy of higher flows that could reduce future incision, bank erosion, or induce overbank deposition. • Could increase braiding. • Promotes increased connectivity with backwaters and side channels. • Preserves ground water table. Partial construction – Clearing, destabilizing, encouraging sediment movement. • Takes longer, only applicable where there is some flood plain connection already. • May induce temporary bank erosion until transport/load balanced. • Same effects as complete construction above but to lesser degree. Partial channel realignment – Clearing, pilot cut, encourage channel widening along new alignment. • May reduce high- flow energy, which reduces incision and/or migration. • May change channel length. • Promotes increased connectivity with backwaters and other side channels (if close enough to bank line). • Temporary decrease in velocity and depth variability. • Temporary increase in sediment supply downstream.

Table 5. Rehabilitate Channel and Flood Plain: Trends Addressed and Geomorphic Effects

Reach Effects (continued) *Sediment transport capacity greater than sediment supply (erosional)*	Side channel construction • May raise ground water table. • Promotes increased connectivity with backwaters and other side channels (if close enough to bank line). • May reduce high-flow energy which reduces incision and /or migration. • Increase velocity and depth variability. • May reduce high-flow water surface elevations. • Increase high-flow water surface area. **Complementary strategies:** • Promote Elevation Stability – Reduces channel incision. • Manage Sediment – Increases sediment supply. • Increase Available Area to the River – Allows space for river to readjust.
Effects on Upstream/ Downstream Reaches *sediment transport capacity greater than sediment supply (erosional)*	Upstream and downstream effects are expected to be similar for the Change Sediment Supply and applicable methods within the Channel Modification method category. Upstream: This strategy may allow the reach of implementation to experience sediment deposition. This may have the effect on upstream reaches of also causing a slope reduction that, in turn, may cause the sediment supply to decrease and the bed material to become finer. This sediment deposition could also result in lower discharges to go over bank. Downstream: There may be a short-term effect of increased sediment supply depending upon the method and where the excavated material is placed. But the long-term effect downstream would likely be reduced sediment supply, potentially resulting in channel degradation and coarsening of bed material. The slope of the channel could decrease. Channel degradation would likely result in a higher discharge being needed to go over bank and increased sediment transport capacity.

Table 6. Manage Sediment: Trends Addressed and Geomorphic Effects

Trends Addressed	*Transport Capacity greater than Supply* • Increased bank height • Incision or channel bed degradation • Coarsening of bed material • Increased channel uniformity *Transport Capacity less than Supply* • Aggradation • Channel plugging with sediment • Perched channel conditions • Increased channel uniformity
Reach Effects *Sediment transport capacity greater than sediment supply (erosional)*	**General** Once sediment is added, this would need continue indefinitely for benefits to be realized in the long term. *Change Sediment Supply* Sediment Augmentation • Effects are dependent on volume of sediment, and sediment volume depends upon high-flow discharge amount and duration. • Flow goes overbank at lower discharge. • May have wider surface area at high flows. • May increase depth and velocity variation at high flows. • May decrease high-flow velocity and depth. • Could induce overbank deposition. • Could increase braiding. • Promotes increased connectivity with backwaters and side channels. • Preserves groundwater table. • Likely to require adaptive management (continuing adjustment of augmentation volume and location). • Could reduce bed material size (dependent on size supplied). • May fill in pools and/or create bars. • May increase width-depth ratio. *Channel Modification* Some methods within this method category provide indirect sediment augmentation—clearing, destabilization, encouraging sediment movement. • Effects are similar to direct augmentation • Slower rate of additional sediment supply **Complementary Strategies** Increase Available Area – potential area to increase channel length thus decreasing sediment transport capacity. Rehabilitate Channel and Flood Plain – Reduces sediment transport capacity.

Table 6. Manage Sediment: Trends Addressed and Geomorphic Effects

Effects on Upstream/ Downstream Reaches *Sediment transport capacity greater than sediment supply (erosional)*	Upstream and downstream effects are expected to be similar for the applicable methods to augment sediment supply Upstream – If the augmentation results in the river bed elevation increasing, then the downstream portion of the upstream reach bed elevation could increase potentially resulting in a reduced channel slope. It is expected that the augmentation rate and location can be planned and adaptively managed in the implementation reach so that the upstream bed elevation remains at about the current elevation. Downstream – The effects downstream are dependent on the amount of sediment augmentation, but an increase in the sediment supply may be possible. This would have the effect of increasing the channel slope through deposition/aggradation of the bed elevation in the implementation reach increases. Deposition in local subreaches of the downstream reach could result in a local flatter slope. The bed material size could reduce depending upon the size of augmentation sediments. The downstream channel bed elevation could increase resulting in lower discharge to go over bank. The effects can be adaptively managed.

Reach Effects
 	
Sediment transport capacity less than sediment supply (depositional)
	General
	Once sediment is removed, this will need to continue indefinitely for benefits to continue in the long term.
	
	Change Sediment Supply
	Constructed basins
	• Slows or reverses aggradational trends.
	• Could increase discharge necessary to go over bank.
	• Could cause downstream bed size coarsening.
	• Reduce braiding potential.
	• Provide new areas of deposition.
	• In-Channel – Dredging low area in the channel bed, then allowing deposition to occur and re-dredge.
	  o Local widening and subsequent dredging or movement to new area.
	  o Provides new areas of deposition.
	• Flood plain (berm enclosed basin with inlet and outlet channel).
	  o Similar to In-channel.
	  o More likely to relocate when full than tributary.
	  o More vegetation clearing than tributary or channel.
	• Tributary – More likely to dredge than flood plain.

Table 6. Manage Sediment: Trends Addressed and Geomorphic Effects

Reach Effects (continued) *Sediment transport capacity less than sediment supply (depositional)*	Natural topography basins • Similar effects to constructed basins. • Becomes the new channel alignment. • In-Channel – May relocate when full and provides new areas of deposition. • Flood plain similar effects to in-channel but more vegetation clearing than channel. **Complementary Strategies** Increase Available Area – Potential area for sediment deposition.
Effects on Upstream/ Downstream Reaches *Sediment transport capacity less than sediment supply (depositional)*	Upstream and downstream effects are expected to be similar for the applicable methods within the Change Sediment Supply. Upstream • Constructed Basins- Depending upon the method used, the subsequent maintenance, and the sediment deposition area volume relative to the incoming sediment supply, upstream aggradation or channel bed raising could occur. This could result in lower discharges being needed to go overbank, decreased bed sediment size, and increased tendency for braiding. • Natural topography basins – Effects would be similar to upstream effects for the Increase Available Area strategy for the sediment transport capacity less than sediment supply case. Downstream • Constructed Basins – No change expected unless amount of sediment reduced is significant. If the sediment load reduction is significant, there may be channel degradation or bed lowering, which would cause a higher discharge to go over bank, less velocity, depth variability, and bed material coarsening. The amount of bed lowering is not expected to increase bank erosion rates or lead to significant lateral migration. • Natural topography basins – Effects would be similar to downstream effects for the Increase Available Area strategy for the sediment transport capacity less than sediment supply case.

RECLAMATION
Managing Water in the West

Joint Biological Assessment

Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico

Part III – Water Management: State of New Mexico

Middle Rio Grande Project, New Mexico
San Juan-Chama Project, New Mexico
Upper Colorado Region

U.S. Department of the Interior
Bureau of Reclamation

September 2012 (Amended January 2013)

Mission Statements

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

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

Joint Biological Assessment

Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico

Part III – Water Management: State of New Mexico

Middle Rio Grande Project, New Mexico
San Juan-Chama Project, New Mexico
Upper Colorado Region

Submitted to the U.S. Fish and Wildlife Service

Rio Grande Silvery Minnow | **Southwestern Willow Flycatcher**

Pecos Sunflower | **Interior Least Tern**

U.S. Department of the Interior
Bureau of Reclamation

September 2012 (Amended January 2013)

Reclamation makes the following amendment to Part III, chapter 6, sections 1 and 2 of its Biological Assessment (BA). In its initial submittal; Reclamation stated that the Middle Rio Grande Recovery Implementation Program (RIP) would be included as the conservation measure serving as the means for ESA compliance. In this amended BA, Reclamation provides that the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) will serve as the means for including non-Federal actions in its Section 7 consultation, and that conservation measures proposed by Reclamation, MRGCD, the State and the Authority, together with the conservation actions currently taken by and through the Collaborative Program will serve to offset the adverse impacts of the proposed actions described in this BA. Inclusion of proposed non-Federal actions is also supported through the involvement of non-Federal entities in Reclamation's annual river maintenance work. References to the RIP and the associated Cooperative Agreement apply to the expected future inclusion of the RIP as the conservation measure in the effects analysis of the Biological Opinion during the formal consultation process.

**STATE OF NEW MEXICO, INTERSTATE STREAM COMMISSION
AND
OFFICE OF THE STATE ENGINEER**

PROPOSED ACTIONS AND CONSERVATION MEASURES IN THE RIO GRANDE BASIN UPSTREAM OF ELEPHANT BUTTE RESERVOIR

SUPPLEMENT TO JULY 2012 JOINT BIOLOGICAL ASSESSMENT, BUREAU OF RECLAMATION AND NON-FEDERAL WATER MANAGEMENT AND MAINTENANCE ACTIVITIES ON THE MIDDLE RIO GRANDE, NEW MEXICO; PART I – WATER MANAGEMENT, MIDDLE RIO GRANDE PROJECT, NEW MEXICO, UPPER COLORADO REGION

Draft Submitted: August 15, 2012
Final Proposed Actions Submitted: August 23, 2012
Conservation Measures Submitted: September 14, 2012

Table of Contents

1. Introduction

This supplement is provided by the State of New Mexico, Interstate Stream Commission, Office of the State Engineer and New Mexico Attorney General's Office (State) pursuant to US Bureau of Reclamation's (Reclamation) request for information to supplement its July 31, 2012 Joint Biological Assessment, Bureau of Reclamation and Non-Federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico; Part I – Water Management, Middle Rio Grande Project, New Mexico, Upper Colorado Region (Reclamation MRG BA). This supplemental information reflects substantial coordination with Reclamation, and includes updated baseline information, a description of additional actions to be included as part of the Proposed Action under consultation, and an analysis of hydrologic and species effects. We request that it be forwarded to the Service as a supplement to the Reclamation MRG BA.

In developing this document, for the reasons articulated below, the State has not included water related actions of the Middle Rio Grande Conservancy District (MRGCD), the six Middle Rio Grande Pueblos, the Albuquerque Bernalillo County Water Utility Authority (ABCWUA), and Buckman Direct Diversion Project (BDD). The Middle Rio Grande Conservancy District and six Middle Rio Grande Pueblos are not included in this supplement because they are separately seeking coverage for their and their members' specific water related actions. Further, the State understands that the water related actions of the ABCWUA and BDD are covered by their respective existing biological opinions. The State is supportive of the efforts of the MRGCD, six MRG Pueblos, ABCWUA, and BDD.

By requesting this coverage and proposing conservation measures, the State does not concede that the water-related actions described herein adversely affect the listed species nor that requirements of the ESA necessarily apply to all of the described actions.

2. Background and Baseline Information

Under New Mexico law, water rights are established by the beneficial use of water. Many water rights were established prior to State Engineer jurisdiction. Rights established under State Engineer jurisdiction are only established through the permitting process. Except for small domestic, livestock, and temporary water uses, the State Engineer conditions all permits in the Rio Grande Basin (which extends from the Colorado state line to the headwaters of Elephant Butte Reservoir) to require full offset of the maximum diversion amount. State water policy and guidelines for the region are designed and applied in order to protect existing water rights and to preserve compliance with the Rio Grande Compact by ensuring that delivery of Rio Grande water into Elephant Butte Reservoir, and the flows of the Rio Grande at the Otowi gage, are not diminished.

For the above reasons, the State baseline information in this document is not directly comparable to the baseline information in Reclamation's July 31, 2012 Joint Biological Assessment. This document summarizes information for 60 plus years of water administration in the basin while Reclamation uses the previous 10 years as baseline for much of its analysis. Therefore, the effects of many activities are not comparable.

2.1 The Rio Grande Compact

The 1938 Rio Grande Compact (53 Stat. 785) (Compact) is both a Federal and State law that poses significant restrictions on water management, most specifically reservoir management, in the Middle Rio Grande (MRG). The Compact apportions the native waters of the Rio Grande among the states of Colorado, New Mexico, and Texas, and is administered by the Rio Grande Compact Commission. For purposes of the Compact, "New Mexico" is the reach between the state line with Colorado and Elephant Butte Dam , which is roughly equivalent to the area encompassed by the Middle Rio Grande Endangered Species Collaborative Program (Program). For purposes of this document, the Upper Rio Grande (URG) is defined as the reach from the Colorado-New Mexico state line to Otowi gage including the Rio Chama, and the Middle Rio Grande (MRG) is defined as the reach from Otowi gage to Elephant Butte Reservoir. New Mexico has an explicit but variable annual delivery requirement to the State of Texas at Elephant Butte Dam. New Mexico's depletion entitlement for the MRG is based upon the recorded annual native Rio Grande flow at the Otowi gage. For New Mexico, the explicit annual allocation requires that a minimum of 57% of the annual native Rio Grande flow at Otowi be delivered to Elephant Butte Dam. The allocation to Texas excludes tributary inflows between the Otowi gage and Elephant Butte Dam. Tributary inflows in this reach are highly variable and, generally, unpredictable but these inflows may be fully consumed by New Mexico.

The Compact does not require the State of Colorado or New Mexico to deliver the exact amount of water scheduled annually each and every year, but allows for the accumulation of over-deliveries (credit) and under-deliveries (debit). It is up to each state to decide how its water is used. In New Mexico, any new use of water has to be approved by the State Engineer and must be balanced by reduction of an existing use unless it is an imported source of water, such as San Juan-Chama (SJC) Project water. Approval of new uses is required because the Compact puts an upper limit on basin-wide water depletions.

Regardless of how wet a period may be, New Mexico's depletions between the Otowi gage and Elephant Butte Dam are capped at 405,000 acre-feet per year (AF/year) plus the local tributary inflows. In wet years (anything above about 1 million acre-feet at the Otowi gage), the higher flows must be passed through the MRG and delivered to Elephant Butte, and associated carriage losses must be made up from New Mexico's allocation. In very wet years, these carriage losses can deplete a large portion of New Mexico's annual allocation. For this reason, wet years are more likely than dry years to result in a Compact debit. In many cases, debits accrued in wet years must be made up for in dry or average years.

Several Compact restrictions affect reservoir operations in post-Compact reservoirs (reservoirs upstream of Elephant Butte that were constructed after 1929) and associated surface water management. All the reservoirs operated by the U.S. Army Corps of Engineers (USACE) and Reclamation are subject to these restrictions. However, Reclamation's Heron Reservoir and Nambe Falls Reservoir are excluded from these restrictions because they only store imported trans-basin SJC Project water.

Under Article VI of the Compact, New Mexico remains in compliance with the Compact if its accrued debit is less than 200,000 AF. If New Mexico is in debit status and is holding native Rio Grande water in storage in a post-1929 reservoir, New Mexico must retain the water in storage to the extent of its accrued debit. If and when a spill occurs from Elephant Butte Reservoir, the accrued credits for Colorado or New Mexico, or both, are reduced in proportion to their respective credits by the amount of the actual spill. Colorado or New Mexico may release accrued credits in part, or in full, in advance of an actual spill. Following a spill, all accrued debits for Colorado or New Mexico, or both, are cancelled.

Under Article VII of the Compact, whenever Usable Water in Rio Grande Project storage at Elephant Butte and Caballo reservoirs is less than 400,000 AF, New Mexico and Colorado may not increase the storage of native Rio Grande Basin water in upstream reservoirs constructed after 1929. Usable water is defined as water in Elephant Butte and Caballo reservoirs that is available for release to the Rio Grande Project. In New Mexico, the primary impacts of Article VII storage prohibitions are experienced at El Vado and Nichols and McClure reservoirs. Article VII also provides that, upon acceptance by Texas, New Mexico may relinquish all or part of its accrued credits so that New Mexico may store, at any time, an equivalent amount of water in post-1929 upstream reservoirs when storage restrictions are in effect. Additionally, for the City of Santa Fe, during times that Article VII is in effect, it may elect to store native water when otherwise prohibited and release a like amount of SJC Project water (an exchange) to the Rio Grande.

Article XVI of the Compact states, “Nothing in this Compact shall be construed as affecting the obligations of the United States of America to Mexico under existing treaties, or to the Indian Tribes, or as impairing the rights of the Indian Tribes.” SJC Project water is imported trans-basin water, is accounted as such, and is not subject to the Rio Grande Compact.

2.2 Credit Water Relinquishment

Since signing the Emergency Drought Water Agreement (EDWA) in 2003, the State has made relinquishment credit available as follows: 91,000 AF for Reclamation to use in its Supplemental Water Program; 171,000 AF for the MRGCD for irrigation purposes; and 8,500 AF to the City of Santa Fe for municipal and industrial uses. As a result of implementing the EDWA, a total of 192,750 AF of relinquishment water was stored on the Rio Chama during the snowmelt runoff periods of 2003 to 2011 and the remainder, some 77,700 AF was available for storage in 2012 and beyond. All of this water was stored during periods when it would otherwise not have been allowed because the Article VII storage restrictions were in effect. All 192,750 AF of water stored pursuant to the EDWA and subsequent releases are described in some detail in Chapters 2 and 5 of Reclamation’s Joint Biological Assessment.

The water stored and made available pursuant to the EDWA has been released during low natural flow periods enabling the MRGCD to meet irrigation demand and to help meet the 2003 Biological Opinion (BiOp) Albuquerque gage flow targets for a longer time period. Consequently, during those time periods, Reclamation did not have to release stored water to meet the Albuquerque gage flow targets. Reclamation has also used water allotted to it under the EDWA to meet 2003 BiOp flow targets at other times. Provided the right circumstances are present, the State would likely continue to propose relinquishments in the future. However, New Mexico's ability to relinquish accrued credit water depends on its Compact credit status and the constraints of the Compact.

2.3 State Administration of Water Rights

The State Engineer (SE) administers surface water and groundwater sources conjunctively in the waters of the Rio Grande Basin to prevent impairment to valid existing water rights by regulating depletions, thereby maintaining the overall hydrologic system balance. The SE executes his statutory duties in accordance with State law, adjudications, and court orders.

Under New Mexico law, water rights are established by beneficial use of water. Many water rights were so established prior to SE jurisdiction (1907 for surface water rights, 1931 and subsequent basin declaration date for groundwater rights). Rights established under State Engineer jurisdiction follow a permitting process.

Administration is a term that encompasses numerous actions by the SE in oversight of the exercise of existing water rights, the permitting process for changes in water use, and enforcement of New Mexico water law in the case of illegal water use. Examples of administration include:

1) Enforcement of offset requirements associated with permits (discussed in detail below).
2) Enforcement of diversion limits associated with permits, licenses and adjudications of the court.
3) Enforcement against waste of water and illegal water use.
4) Facilitation of the development of Alternative Administration and enforcement of Alternative Administrative conditions. Alternative Administration is based upon agreements by water right owning parties that resolve water disputes under conditions of shortage without the necessity for priority administration and curtailment of junior water rights. Examples of Alternative Administration in the MRG and URG include:

    a. The alternative administration program on the Rio Chama, in which diversions by the Rio Chama acequias downstream of Abiquiu Reservoir in excess of their very senior right to native water are repaid by exchange to MRGCD through purchase of SJC Project water.
    b. An alternative administration mechanism that has been developed for the Taos Valley as part of the Abeyta Adjudication, in which 1) the Taos Pueblo has agreed to limit exercise of its senior irrigation water rights until junior Acequia rights are retired, and 2) it has been agreed that major groundwater users can deal with their tributary impacts by making offsets directly to the Rio Grande, while contributing to a tributary mitigation system involving augmentation wells and a recharge project for the Buffalo Pastures wetland.
    c. An alternative administration on the Jemez River that is based on an agreement adopted on July 2, 1996 between the United States, the Pueblo of Jemez, the Pueblo of Zia, and the Jemez River Basin Water Users Association. Under this agreement, a priority call may be made by the Pueblos of Jemez and Zia during

5) Granting of licenses for pre-basin declared water rights limited to the historic legal maximum diversion amount.
6) Evaluating and acting upon applications to appropriate water (and thus obtain water rights) and/or modify water use associated with existing water rights.
   a. The Office of the State Engineer (OSE) does not accept applications to develop new water rights in most of the Rio Grande Basin. Surface water has been considered fully appropriated since 1907, and any additional groundwater use in the hydrologically connected aquifers of the Rio Grande must be fully offset (as described in more detail below).
   b. Applications accepted by the OSE are evaluated, as per Statute, and in accordance with applicable OSE rules, guidelines and policies (such as the 2006 Surface Water Transfer Requirement to Offset Effects on the Rio Grande, the 2009 Return Flow and Discharge Credit, and the 2011 Depletion Offsetting for Habitat Restoration Projects within the Middle Rio Grande Project policies). The OSE evaluates the potential for impairment of other water rights, and whether granting the application would be contrary to conservation within the State or detrimental to the public welfare of the State.
   c. If the State Engineer approves an application, conditions are applied to ensure water use does not exceed the legal extent of the water rights, and to ensure full offset of impacts to the Rio Grande (as described in more detail below).

Further, in the Rio Grande Basin, the following specific constraints related to protection of the flows of the Rio Grande are generally applied in approval of such applications:

a) In order to maintain compliance with the Rio Grande Compact, depletions to the Rio Grande above the Otowi gage must be maintained at or below pre-Compact levels (1929).
b) Water rights are not transferable from above Otowi gage to below Otowi gage, or vice versa.
c) There can be no net increase of impact to the Rio Grande stream system (including tributaries). All surface-water impacts occurring at a new location as the result of a transfer must be offset by a decrease in surface-water depletion at the move-from location. Exceptions to the offset requirement apply to small domestic, livestock and temporary-use wells approved under NMSA 1978 §§ 72-12-1 *et. seq.*
d) Water rights are not transferable from above Elephant Butte Dam to below Elephant Butte Dam, or vice versa.

2.4 Surface Water

Most surface water uses in the MRG and URG were initiated prior to enactment of the March 17, 1907 Surface Water Code. These uses were not established through any permitting process. Exceptions include diversions of permitted MRGCD rights, diversions of Bosque del Apache rights, and diversions of contracted San Juan Chama Project Water.

2.5 Groundwater

The State Engineer first declared jurisdiction over a large corridor along the main stem of the MRG and URG in 1956. The State Engineer expanded this jurisdictional area to most of the outlying areas of the MRG and URG during the 1960's, 1970's and 1980's. Groundwater rights established by beneficial use prior to 1956, and later in the extended areas (i.e., established prior to the declaration of the groundwater basins), are referred to as "pre-basin" groundwater rights. In general, there are no offset requirements associated with the exercise of pre-basin rights.

Groundwater rights established after a basin was declared require a permit from the State Engineer. In addition, the transfer or other significant modification of a water right also requires a permit from the State Engineer. As specified in statute, the State Engineer shall grant applications if he finds that the proposed activity would not impair existing water rights, would not be contrary to conservation of water within the State and would not be detrimental to the public welfare of the State.

2.6 Permitted Groundwater Pumping Offset Programs (Offset Program)

The State Engineer calculates groundwater pumping impacts to the Rio Grande by means of numerical models or by an analytical technique (Glover-Balmer method). Groundwater in the MRG and URG is pumped primarily from deep basin-fill aquifers that are in hydrologic connection with the Rio Grande. In general, all groundwater pumping from these aquifers will eventually be felt as impacts to the Rio Grande, but this may take hundreds of years.

In addition, in issuing groundwater permits, the State Engineer requires that impacts to tributaries to the Rio Grande are offset (this includes numerous streams, including the Rio Chama, the tributaries to the Rio Chama, and the numerous Rio Grande tributaries located in the Taos, Pojoaque, Espanola and other valleys). In general, depletions to a tributary stream must be offset on the affected tributary itself in order to prevent impairment of existing water rights associated with the tributary. In some cases an alternative method for offset and mitigation can be developed such as has occurred in the Taos Valley as part of the Abeyta Settlement, which allows tributary impacts to be offset on the Rio Grande, as long as mitigation is provided to the acequias on the tributaries.

Originally, the State Engineer issued permits that required offsets to be obtained and applied at the time when the surface water impacts were calculated to occur. Since the adoption of the Middle Rio Grande Administrative Area (MRGAA; Turney, 2000) Guidelines in 2000, groundwater users in that area are required to obtain offsets up front. That is, permits in the MRGAA are conditioned to require that the maximum permitted diversion be limited to the amount of valid surface rights transferred, plus the amount returned directly to the river. Surface water rights obtained in excess of currently calculated impacts may be leased back for use on the farm in the interim until the impacts are calculated to reach the Rio Grande. Similar conditions are also applied to permits throughout the Rio Grande Underground Water Basin, from the Colorado state line to Elephant Butte. The result of these offset requirements is that groundwater right owners must provide offsets to the Rio Grande equal to the total groundwater diversion amount, which is the maximum surface water impact that could be created by their diversions.

Offsets to stream depletions are accomplished by a combination of the three mechanisms described below:

1) Transfer of valid surface water rights
    a. Only valid pre-1907 water rights may be used for this purpose. In the MRG this is determined by a rigorous historical land use evaluation process.
    b. In cases where surface water used for irrigation is transferred to a different use, only a fraction of the actual diversion may be transferred to offset the groundwater use—the part generally corresponding to the calculated consumptive irrigation requirement. The carriage-water component of the diversion is not transferrable, and remains in the surface water system.
    c. The OSE routinely provides the MRGCD with geospatial data that identifies all those lands from which pre-1907 surface water rights have been severed.
2) Actual return flow of surface water to the Rio Grande, pursuant to an OSE approved return flow plan.
3) The OSE "Letter Water Program" for the release and/or storage by exchange of SJC Project water under contract by the permitted groundwater rights owners, to offset their impacts.

Each of these mechanisms is described in more detail below.

2.7 Transfer of Pre-1907 Water Rights

The primary water rights that the OSE accepts for offset purposes are valid pre-1907 surface water rights. The State Engineer has a rigorous historical-use evaluation process to determine valid pre-1907 surface-water rights in the MRG. This is necessary because some lands are irrigated with relatively junior rights associated with the creation of the MRGCD. Such rights are not acceptable for offset of groundwater-pumping impacts on surface water, and thus need to be distinguished from pre-1907 rights. Another class of water right that may be deemed acceptable for offset purposes are pre-basin groundwater rights established before the Rio Grande Compact was adopted in 1939.

When water rights are transferred from one use to another in the MRG, only a portion of the water right is allowed to be transferred. For irrigation rights, this transferrable portion of the water right is the consumptive irrigation requirement of 2.1 acre-feet per acre. An estimated total of 7.5 acre-feet per acre (2.1 acre-feet per acre divided by an estimated MRGCD project efficiency of 0.28) must be diverted from the river to supply irrigated move-from lands with the transferrable portion of the water right. When MRGCD is using natural river flow to meet irrigation demand, and transfers have occurred, less water needs to be diverted to meet irrigation demand, and the river and MRGCD benefit by the amount of conveyance water that is left in the river as a result of the transfers.

2.8 Actual Return Flow

Certain OSE groundwater permits allow permitted users to use return flow to the Rio Grande to offset their river impact pursuant to an OSE approved return flow plan (Sizemore, 2009). Return flow offsets the effect on the river resulting from groundwater pumping. While the exact number varies from year to year, approximately 67,000 acre-feet of diverted water is directly returned annually to the river in the MRG between the Otowi gage and Elephant Butte Dam. Approximately, 58,000 AF of that return flow is returned by the ABCWUA. In general, such return flows are composed of municipal wastewater, and the return flows are used to offset the impacts of groundwater pumping on surface water supplies. Return flows associated with municipal water use occur on a year-round basis.

2.9 The Letter Water Program

The OSE accepts SJC Project water to offset the hydrologic impacts of groundwater pumping on the water supply of the Middle Valley water users and to offset impacts on the State's delivery of water to Elephant Butte Reservoir under the Rio Grande Compact.

Offsets to the middle valley water users take the form of an exchange of SJC Project water in reservoir storage from a SJC Project contractor to the MRGCD. MRGCD is the only entity that diverts surface water from the Rio Grande in the middle valley for irrigation purposes and it supplies the water to its constituents and others (such as the La Joya Acequia). This additional SJC Project water gives the MRGCD the ability to release sufficient water to overcome the impacts associated with the groundwater pumping.

Offsets to the State's delivery of water to Elephant Butte are generally accomplished through the State's release of the SJC Project offset water ("Letter Water") during the winter (normally November or December) when no river diversions are occurring. That is to ensure that the vast majority of the released SJC Project water is physically delivered to Elephant Butte Reservoir before the end of a particular calendar year.

The OSE provides Reclamation with letters describing, for each groundwater pumper with SJC Project water that needs or chooses to release SJC Project water for offset purposes, the volume of SJC Project water that must be released by Reclamation or provided to MRGCD, and a deadline to do so. The impacts are described by the OSE as cumulative effects on Elephant Butte Reservoir (and therefore to New Mexico's deliveries under the Compact) and cumulative effects on the Rio Grande in the MRG due to impacts above and/or below the Otowi gage.

In addition, on occasion, SJC Project water is stored by exchange in Nichols and McClure Reservoirs by the City of Santa Fe. In such instances, Santa Fe stores water in Nichols and McClure reservoirs when they otherwise would be prohibited from doing so (such as when Article VII of the Compact is in effect). After the storage operations are complete, the amount of water stored is accounted and the SE sends a letter to Reclamation directing the release of the same amount of SJC Project water to the Rio Grande. Additionally, on occasion andusually during the winter months, the ABCWUA or City of Santa Fe, after coordination with the State and Reclamation, release some of their SJC Project water from upstream reservoirs and deliver it to Elephant Butte Reservoir.

Water operations associated with the Letter Water Program are described by Reclamation in its July 2012 Joint Biological Assessment and are included in the Upper Rio Grande Water Operations Model (URGWOM) simulations used to inform water deliveries for development of the Joint Biological Assessment.

3. Action Area

The action area is defined as all areas to be affected directly or indirectly by the State actions and not merely the immediate area involved in the actions. The action area for the State's actions covers the Rio Grande Basin from the New Mexico state line with Colorado to the full pool of Elephant Butte Reservoir (Figure 1). This BA supplement covers the effects of actions proposed by the State on the Rio Grande silvery minnow, southwestern willow flycatcher, and Pecos sunflower within the Middle Rio Grande riparian area and not localized effects to other species that may exist in upstream tributary area. We are not seeking coverage for local effects to other federally listed or candidate species that may occur outside of the Middle Rio Grande

The action area is divided into two major sections:

Upper Rio Grande

This section covers the Rio Grande basin and its tributaries from the New Mexico state line to the Otowi gage.

Middle Rio Grande

This section covers the Rio Grande basin and its tributaries from the Otowi gage to the full pool of Elephant Butte Reservoir.

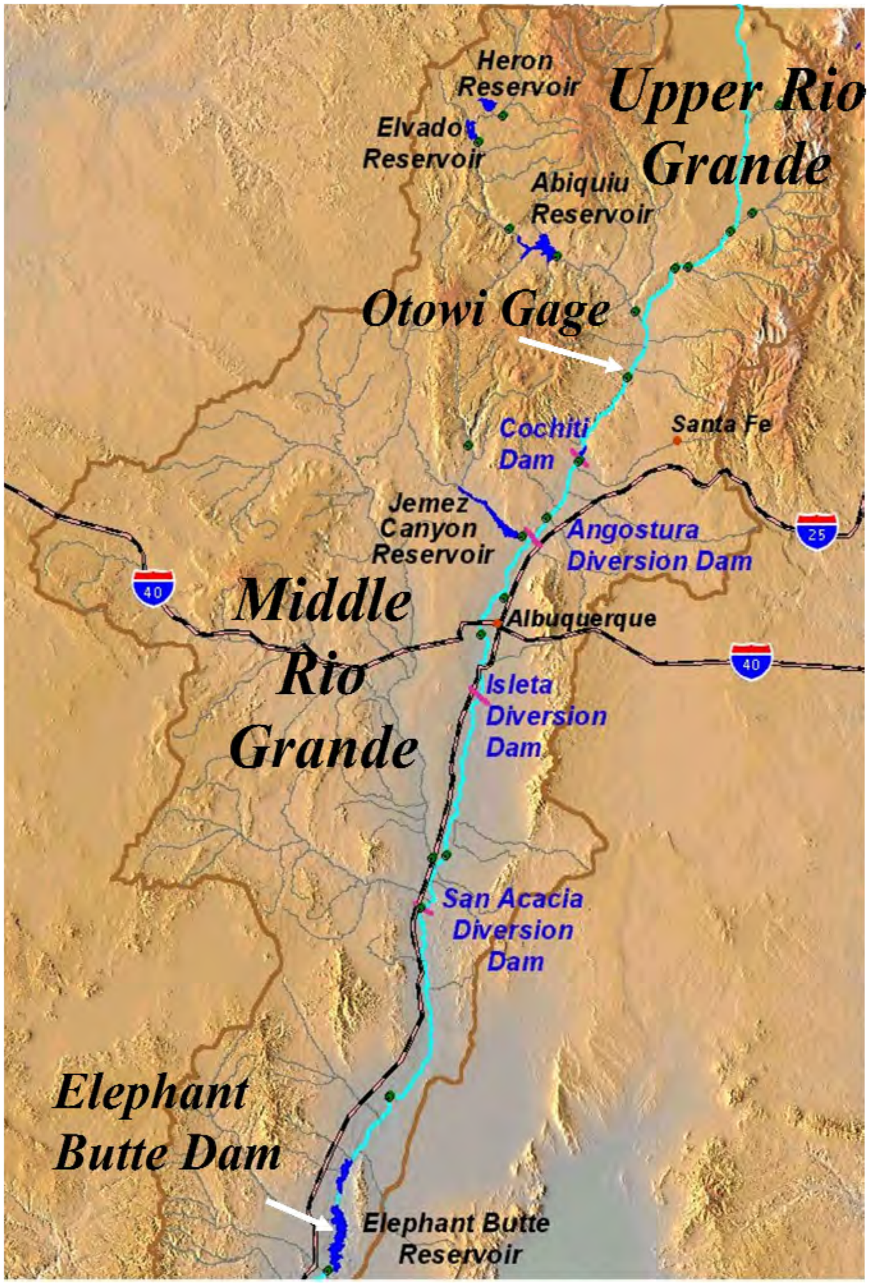


Figure-1: State Action Area: Upper Rio Grande and Middle Rio Grande

4. Description of the Proposed Actions

The New Mexico Interstate Stream Commission (ISC) and the New Mexico Office of the State Engineer (OSE) and the Office of the Attorney General (AGO) (collectively, the State) conduct State water-related actions described below and seek Endangered Species Act (ESA) coverage for the effects of all lawful actions within the outlined parameters in the action area. The proposed state actions are as follows:

4.1 Discretionary Actions Related to Administration of the Rio Grande Compact

Actions:

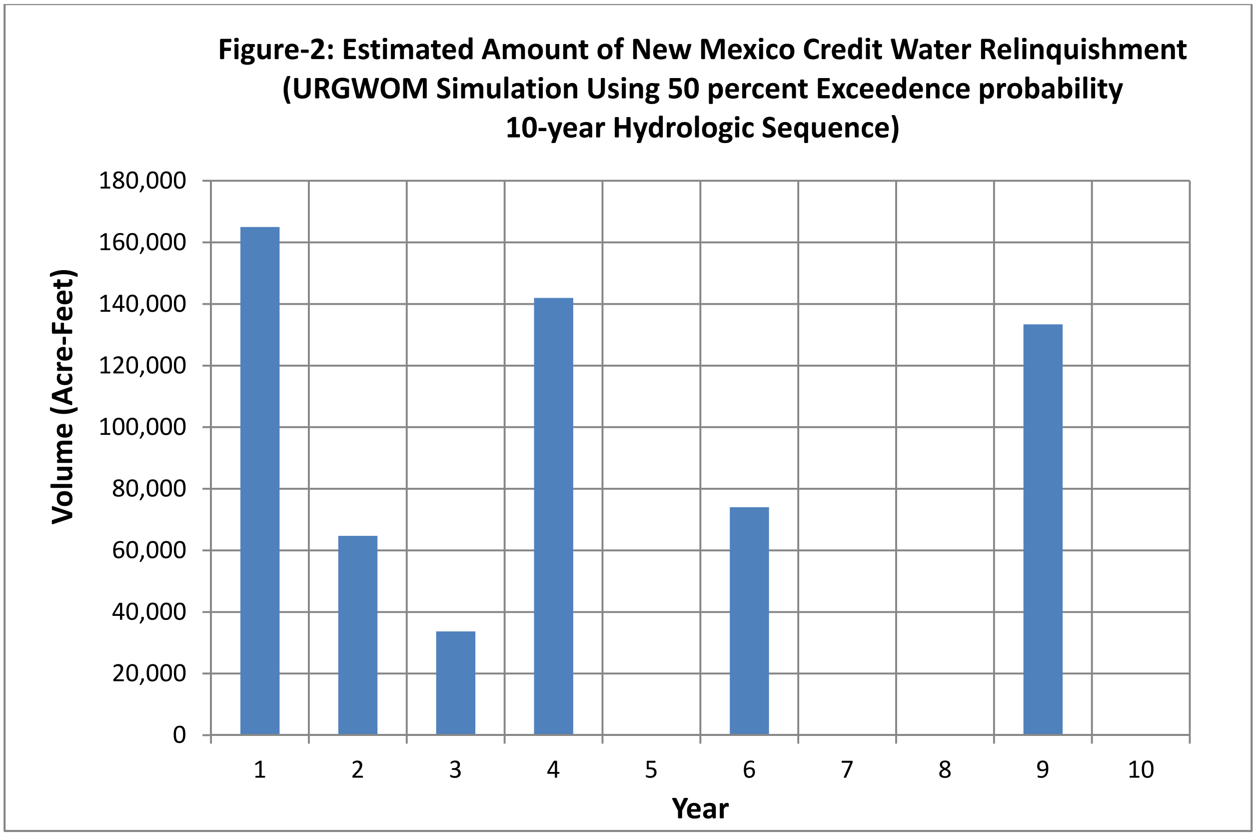
The ISC is charged with the administration of all interstate stream compacts to which the State is a party, including the Rio Grande Compact of 1938 (Compact). The ISC proposes to continue its compact related activities. The ISC proposes to continue to administer relinquishment of accrued compact credits and associated storage in post-1929 reservoirs.

Hydrologic Effects:

Analysis of the URGWOM simulations used in development of the Reclamation and USACE current Biological Assessments indicates that relinquishment of New Mexico accrued credit water, and the related ability to store relinquishment water upstream during the snowmelt runoff and release it later, allows an extended MRG irrigation season and provides storage water to help Reclamation and the USACE meet their 2003 Biological Opinion (2003 BiOp, U.S. Fish and Wildlife) flow targets. Article VII of the Compact restricts storage of native Rio Grande water in reservoirs upstream of Elephant Butte Reservoir constructed after 1929 when there are less than 400,000 acre feet (AF) of Usable Water in Rio Grande Project Storage in Elephant Butte and Caballo Reservoirs. During the period covered by the 2003 BiOp, New Mexico relinquished credit water several times and Reclamation's draft Biological Assessment includes language, primarily in Chapters 2 and 5, that summarizes the effects of the relinquishments completed since 2003. If the relinquishments had not occurred, Reclamation and the USACE would have had a more difficult time meeting the flow targets of the 2003 BiOp and may not have been able to do so under some circumstances.

The URGWOM model simulations demonstrate that the frequency and the amount of credit water available for relinquishment depends on the hydrologic sequence simulated. Using the 50-percent exceedence probability 10-year hydrologic sequence (Roach, J. D, 2009) model run, the state would be able to propose to relinquish credit water about 50% of the time and in significant amounts (Figure 2). However, given the history of relinquishments since signing the compact, that scenario likely overestimates the frequency and volume of future relinquishments. Relinquishments would provide water for storage to meet MRG demands when otherwise prohibited by the Compact.

The storage of the relinquishment water during the spring snowmelt runoff will reduce the volume of water entering the middle valley during the snowmelt runoff period and can reduce the peak flow in the middle valley if the storage results in the USACE releasing less than the safe channel release from Abiquiu Reservoir (1,800 cubic feet per second (cfs)). On the other hand, the 192,750 AF of relinquishment water stored during the snowmelt runoff of the past nine years has been released when natural flows are low thus helping to meet irrigation demands and ESA flow targets.



Therefore, the effects of the State's proposed actions in administering the Compact are, on the whole, positive as measured by the ability to make relinquishment water available in upstream storage for release to benefit municipal and irrigation needs and to meet flow targets when native water storage would otherwise not be available to do so.

4.2 Discretionary Actions to Administer Surface and Groundwater Resources in the Middle Rio Grande

Actions:

The SE proposes to continue to administer MRG surface water and groundwater resources to maintain the MRG hydrologic system balance by executing his statutory duties with respect to transfers of valid existing surface water rights and compliance with existing state water declarations, permits, licenses and the adjudications of the courts. Significantly, executing these statutory duties will ensure that impacts to the surface water flow of the MRG attributable to diversions by groundwater appropriators are offset to keep the river whole. The following offset mechanisms are employed for this purpose:

- Transfer of valid existing surface water rights, established prior to the March 17, 1907 Water Code, acquired by groundwater rights owners to comply with offset requirements. In the MRG, the transferrable portion of these water rights consists of 2.1 acre-feet per acre, out of an approximate total diversion amount of 7.5 acre-feet per acre associated with these surface water rights.

- Return flows to the river, pursuant to OSE approved return flow plans, to comply with offset requirements.

- State Engineer Letter Water Program for the release and/or storage by exchange of San Juan Chama (SJC) Project water.

The following list enumerates actions that the SE proposes to continue performing with respect to water rights administration in the MRG:

- Continue to evaluate applications submitted by water rights owners to transfer or otherwise modify valid water rights in accordance with the 2000 OSE MRGAA Guidelines for Review of Water Rights Applications.

- Continue to issue permits as required by New Mexico State Statutes, conditioned as necessary to ensure that there is no impairment to existing water rights, the exercise of which are not contrary to conservation or detrimental to the public welfare of the state, while ensuring that the MRG is kept whole through the offset mechanisms described above.

- Continue to administer compliance of existing water rights with declarations, permits, licenses, State water law, and the adjudications of the courts. Specifically, the SE proposes to continue administering existing water rights permits to ensure that the Rio Grande is kept whole through the offset mechanisms required by permit, licenses, and adjudications including those described above.

- For the 20,000 AF of additional transfers or other discretionary permits proposed and analyzed herein, we assume a similar distribution and effect on the river some thirty years after the 2013 MRG BiOp is finalized

Hydrologic Effects:

In the MRG, the three components of the offset program outlined above result in replacement of permitted groundwater pumping impacts to the river on a real-time basis whenever MRGCD is releasing from storage. The OSE evaluates groundwater pumping annually to ensure compliance with the permit and its conditions. The three components are summarized below:

Transfer of Senior Water Rights

The total volume of senior water rights transferred to date to offset the effects of permitted groundwater pumping on the river system is about 19,620 AF . This includes senior water rights transferred since the State Engineer's declaration of the Rio Grande Underground Water Basin on November 29, 1956 to offset the effects of permitted groundwater pumping on the river system or, in the instance of the BDD, needed for diversion and consumption. Five thousand AF of that number is held by the ABCWUA and 3,125 AF by the BDD, both of which have coverage under their existing BO's and are, therefore, not described further herein. The remainder is 11,495 AF (approximately 340 AF from the Cochiti Division; 1,770 AF from the Albuquerque Division; 6,585 AF from the Belen Division; and 2,800 AF from the Socorro Division). These 11,495 AF per year of senior consumptive use rights have been transferred from agricultural use in the MRGCD to municipal and industrial uses. About one-third of these transferred senior water rights are currently needed for offset requirements (OSE water rights files). The remaining portion of transferred senior rights is for offset of future impacts.

When the purpose of use is changed from irrigation to another use in the MRG, only the consumptive irrigation requirement (CIR) of the water right is transferred. The CIR portion of the water right in the MRG is 2.1 AF per acre or about one-third of the amount that would normally be diverted from the river (about 7.5 AF per acre) to irrigate those move-from lands. Therefore, for existing transfers that are being used for offset (not being leased back) when the natural flow is greater than MRGCD demand, MRGCD needs to divert less water to meet the demand. As a result, the river flow would increase by the amount of conveyance water that is left in the river as a result of the transfers.

Since 2003, most specifically due to irrigation improvements, MRGCD has reduced its annual river diversions by about 40 percent. As a result, MRGCD is using less natural river flow to meet its irrigation demand, and is leaving water in storage when the natural flows are sufficient to meet its demands. At times when MRGCD is releasing stored water to meet irrigation demand, less water needs to be released to meet demand, which means MRGCD can extend its delivery time period and, indirectly, help meet the Albuquerque gage flow target of the 2003 Biological Opinion.

In general, during spring runoff or when MRGCD is releasing stored water, transfer of a senior water right has a *de minimus* effect on river flow. During the winter months the river flow is continuous, however transfers may have a small impact on river flows due to continuing groundwater pumping at the move-to location. During summer months, transfers have an impact during periods of low river flows or during periods when MRGCD has no stored water to release. Using the OSE determined volume of senior water rights transferred from each MRGCD division since November 29, 1956, the impact of senior water rights transfers from the Belen and Socorro Divisions to the Albuquerque reach would result in a reduction of about 13 cfs of the flow near Albuquerque. This reduction of the flow is small in comparison to average annual flow at the Central gage, and is within the margin of error for most flow measurements. This reduction of the flow assumes that all the consumptive rights are currently needed for offset and ignores the benefits of the non-transferable portion of the right staying in the river system. During low flow time periods, MRGCD routinely diverts almost all of the water required for its Belen and Socorro Divisions at the Isleta Diversion Dam. Thus, transfers of senior surface-water rights from these divisions upstream into the Albuquerque division have no impact on the river below the Isleta Diversion Dam during those time periods. In the biological effects analysis, we assume that the 20,000 acre-feet of additional water rights transfers and permits for which ESA coverage is requested herein will have a similar distribution and effect on the river as calculated above for the water rights transferred to date. Because we have assumed that the groundwater pumping impacts the river immediately, this assumption should still be valid thirty years after the 2013 MRG BiOp is finalized.

In summary, the impact of water rights transfers(excluding the ABCWUA and BDD) on river flow varies in relation to the amount of flow in the river and whether the transfer is to an upstream or downstream point of diversion. In general, during periods of higher flow such as during winter months and the spring runoff, transfer of a senior water right for offset of historic and ongoing pumping impacts at either an upstream or downstream point of diversion has a *de minimus* effect on river flow. During lower natural flow periods when MRGCD is releasing water from storage, transfer of a senior water right for offset to either an upstream or downstream point of diversion most likely will have a small, positive, impact on the river due to retention of irrigation system conveyance flows resulting from the transfers remaining in reservoir storage. During low flow periods when MRGCD has no stored water to release, transfer of a senior water right for offset to either an upstream or downstream point of diversion will have a small, negative, impact on the river. Therefore, the overall hydrologic effects of the State action of permitting transfers of senior water rights is minimal as measured by the effects on the river flow.

The OSE routinely provides the MRGCD with geospatial data that identifies all those lands from which pre-1907 surface water rights have been severed and coordinates with the MRGCD to monitor the status of lands from which senior consumptive use rights have been transferred.

Return Flow Component

SE groundwater permits allow permitted users to use return flow to offset their river impact pursuant to an approved return flow plan. Offset credit for return flow can only be obtained by application and permit based on a return flow plan acceptable to the OSE (see baseline section). Return flow occurs simultaneously with diversions throughout the course of the year. Therefore, return flows provide a real time offset of the effect of groundwater pumping on the river. Currently about 67,000 AFY of water is returned directly into the river between the Otowi gage and Elephant Butte Dam. Of this quantity about 58,000 AFY consists of ABCWUA direct returns. Because the ABCWUA has its own existing biological opinion for all its water management activities, ABCWUA actions are not evaluated as part of the state actions and not included in the state’s hydrologic effect analysis. In certain instances, return flows exceed required offsets such that the river flow is augmented because groundwater pumping impacts are less than the return flows. The hydrologic effects of the State action approving return flow plans are in the whole neutral, as measured by the effects on the river and may even have some positive effects due to the augmentation.

The Letter Water Program

For each groundwater pumper that has SJC Project water in storage for use as an offset, the SE periodically provides Reclamation with letters requesting release or exchange of stored SJC Project water by certain dates to offset a portion of the permitted pumping impact. The impacts are quantified by the OSE as cumulative effects on Elephant Butte Reservoir (and therefore to New Mexico's deliveries under the Compact) and cumulative effects on the Rio Grande due to impacts in the MRG below the Otowi gage.

Impacts that occur during the irrigation season when MRGCD is releasing stored water to meet demand are considered effects on the MRG and are replenished by exchange of the SJC Project water in storage to MRGCD, which holds that water for release when needed to meet demand. As such, it provides a near real-time offset of the groundwater pumping effects on the river system except during times when MRGCD is not releasing water from storage. These conditions have occurred for portions of three irrigation seasons in the last ten years and not at all in the twenty preceding years. When it has occurred, it's been during the months of September and October. The maximum amount of SJC Project water that been exchanged to MRGCD (excluding by the ABCWUA) was about 350 AF in 2007. Assuming a total 350 AF reduction in flow during September and October would equate to a reduction of the flow of about 1.5 cfs during that period.

Impacts that occur during the months of November through March are considered effects on Elephant Butte Reservoir (and therefore to New Mexico's delivery under the Rio Grande Compact). The maximum amount needed for offset (again excluding the ABCWUA) was 870 AF in 2005. This SJC Project water is generally released to the Rio Grande in the winter for delivery to Elephant Butte Reservoir While there is some flexibility in when the water is delivered to Elephant Butte, it cannot be depleted in the middle valley.

In general, the amount of the letter water currently utilized in the Offset Program (excluding ABCWUA) has an insignificant effect on river flows as measured at Central gage. Letter water, including the SJC Project water that is stored by exchange in Nichols and McClure Reservoirs by the City of Santa Fe, has little or no effect on the river flow during spring runoff, when MRGCD is releasing stored water, or during winter months. During summer months, letter water can have a small impact at low river flows, especially when MRGCD has no stored water to release. Therefore, the hydrologic effects of the State letter water component of the MRG offset program are limited to certain periods and overall are minimal, as measured by the effects on the river flow.

Water operations associated with the Letter Water Program are also described by Reclamation in its draft Biological Assessment and are included in the URGWOM model simulations used in development of the draft Biological Assessment.

In summary, the hydrologic effects of the State's proposed actions in administering surface and groundwater resources in the MRG are on the whole minimal or neutral, as measured by the effects on the river.

4.3 Non-Discretionary State Actions to Administer Surface and Groundwater Resources in the Middle Rio Grande

Actions:

The SE will continue to administer MRG surface water and groundwater resources within the allowable limits in the following manner:

- The SE will continue to issue permits for small domestic, livestock and temporary uses as required under New Mexico Statute 72-12-1, in accordance with the OSE 2006 Rules and Regulations Governing the Use of Public Underground Waters for Household and Other Domestic Use.

- The SE will continue to limit the exercise of all pre-basin groundwater rights (rights established prior to State Engineer jurisdiction, which was 1956 for the Rio Grande corridor) so as not to exceed their historic legal maximum beneficial use amount, when such rights come under SE permit or license.

Hydrologic Effects:

The OSE is required by statute to grant permits for domestic wells. The current SE policy is to grant permits up to 1 acre-foot per year for watering livestock, irrigation of trees, lawn or garden, or for household or domestic use. The total estimated diversion amount of domestic and livestock uses is about 18,300 AFY (OSE Water Use Report, 2005) distributed as follows: 2,425 AFY in Santa Fe County; 2,880 AFY in Sandoval County; 6,415 AFY in Bernalillo County; 4,835 AFY in Valencia County; and 1,715 AFY in Socorro County. Assuming about 50 percent of total domestic well diversions return to the hydrologic system, the total impact on the river is a reduction of flow of about 9,150 AFY or about 12.6 cfs at the headwaters of Elephant Butte Reservoir. The expected impact at the Central gage is a reduction of flow of about 5,860 AFY or 8.0 cfs. This calculated amount is small and will not have any impact on the spring runoff; however, it may have minimal impact on the river during dry periods when MRGCD is not releasing water from storage. For the purposes of this effort, the OSE assumes it will issue a similar number of domestic well permits over the next 20 to 30 years (we have intentionally overestimated the number of domestic permits to be issued) and the effects of those wells will be distributed similar to the current distribution. The hydrologic effects of domestic well uses in the MRG are in the whole minimal, as measured by the effects on the river.

The SE limits the pre-basin groundwater pumpers (including municipal and industrial uses) to the historic legal maximum amount. Pre-basin water rights have not yet been determined through adjudication, but can be estimated based on pre-1956 water use simulated in the USGS groundwater model of the Albuquerque Basin (McAda and Barroll, 2002). Total pre-basin groundwater pumping in the MRG (exclusive of 18,000 AF for ABCWUA) is about 15,000 AF. About 50 percent of this pumping is returned directly to the river, so the net impact of pre-basin pumping (exclusive of that by ABCWUA) on the river is about 7,500 AFY or about 10.4 cfs. This amount is small and has been impacting the system for over 50 years prior to Reclamation's baseline information.

4.4 Discretionary State Actions to Administer Surface and Groundwater Resources in the Upper Rio Grande

Actions:

The SE proposes to continue to administer URG surface water and groundwater resources to maintain the status quo of the URG hydrologic system balance (1929 conditions) by executing his statutory duties with respect to transfers of valid existing surface water rights and compliance with valid existing state water declarations, permit, licenses and court adjudication. Executing these statutory duties will ensure that effects to the native flow of the Rio Grande at Otowi gage are kept at or below the 1929 conditions in the following manner:

- The SE proposes to continue to evaluate applications submitted by water rights owners to change valid water rights in accordance with SE policy and guidelines.

- The SE proposes to continue to issue permits as required by New Mexico State statutes, conditioned as necessary to ensure that there is no impairment to existing water rights, the application is not contrary to conservation or detrimental to the public welfare of the state, and that the Rio Grande is kept whole through the offset mechanisms described above (See Discretionary State Actions To Administer Surface and Groundwater Resources In the Middle Rio Grande).

- The SE proposes to continue to administer compliance of existing water rights with declarations, permits, licenses, State water law, and the adjudications of the courts. Specifically, the SE proposes to continue administering existing water rights permits and to conduct alternative administration to ensure that the Rio Grande is kept whole through the offset mechanisms required by permit, licenses, and adjudications including those described above (See Discretionary State Actions To Administer Surface and Groundwater Resources In the Middle Rio Grande), to conduct water rights administration, including alternative administration, as described in Section 2.3.

Hydrologic Effects:

In the URG the SE conjunctively manages surface water and groundwater to keep total human depletions at or below the 1929 conditions. All depletions occurring as a result of transfer at the move-to location must be offset by a decrease in depletion at the move-from location, return flow, or releases of SJC Project Water. In addition, the SE conducts alternative administration or water rights administration on the Rio Chama below Abiquiu Reservoir, when necessary, as required within the federal court adjudication. Therefore, the hydrologic effects of the State actions in the URG are in the whole neutral, as measured by the effects on the river at Otowi gage. The four components are summarized below:

Transfer of Senior Water Rights

When purpose of use is changed from irrigation to another use in the URG, only a portion of the water right is transferred. The transferrable portion is about one-third of the amount that would normally be diverted from the river to irrigate those move-from lands. Therefore, less surface water needs to be diverted to meet irrigation demand and the impact on river flow at the Otowi gage is neutral. Therefore, the hydrologic effects of the State's proposed actions in administering surface and groundwater resources in the URG are on the whole neutral, as measured by the effects on the river.

Return Flow Component

OSE groundwater permits allow permitted users to use return flow to offset their river impact pursuant to an approved return flow plan. Currently, about 1,000 AF of water is returned directly into the river between the state line with Colorado and Otowi gage. In certain instances, return flows exceed required offsets such that the river flow is augmented because groundwater pumping impacts are less than the return flows. The hydrologic effects of the State action approving return flow plans are in the whole neutral, as measured by the effects on the river.

The Letter Water Program

For each groundwater pumper utilizing SJC Project water in storage as offset, the OSE periodically provides Reclamation with letters requesting release or exchange of that storage by certain dates. This is done in order to keep total depletion above Otowi gage at or below 1929 conditions. In recent years letter water releases to offset URG stream depletion averaged about 300 AF per year. The hydrologic effects of the State action administering the letter water program are in the whole neutral, as measured by the effects on the river as measured at Otowi gage.

Water operations associated with the Letter Water Program are described by Reclamation in its draft Biological Assessment and are included in the URGWOM model simulations used in development of the draft Biological Assessment.

Alternative Administration

The SE proposes to continue administering existing water rights permits and to conduct alternative administration to ensure that the Rio Grande is kept whole through the offset mechanisms required by permit, licenses, and adjudications. Alternative Administration is based upon agreements by water right owning parties that resolve water disputes under conditions of shortage without the necessity for priority administration and curtailment of junior water rights; e.g., Rio Chama and Taos Valley. This activity serves to resolve conflicts especially during low flows and helps to balance water administration and management with available water volume.

4.5 Non-Discretionary State Actions to Administer Surface and Groundwater Resources in the Upper Rio Grande

Actions:

- The SE will continue to issue permits for small domestic, livestock and temporary uses as required under NMSA 1978, 72-12-1, in accordance the OSE 2006 Rules and

Regulations Governing the Use of Public Underground Waters for Household and Other Domestic Use.

- The SE will continue to limit the exercise of all pre-basin groundwater rights (rights established prior to State Engineer jurisdiction, which was 1956 for the Rio Grande corridor) so as not to exceed their historic legal maximum beneficial use amount, when such rights come under SE permit or license.

Hydrologic Effects:

The SE is required by statute to grant permits for domestic wells. The current State Engineer policy is to grant permits up to 1 acre-foot per year for watering livestock, irrigation of trees lawn or garden, or for household or domestic use. In the Nambe, Tesuque, Pojoaque Basin, requirements for domestic wells are more restrictive. The total estimated diversion amount of domestic use is about 4,400 AFY (OSE Water Use Report, 2005) distributed as follows: 1,480 AFY in Taos County; 2,320 in Rio Arriba County; and 600 AFY in Santa Fe County. Assuming about 50 percent of total domestic well diversions are returned to the hydrologic system, the impact on the river is about 2,200 AFY or about 3.0 cfs. The expected impact at Otowi gage is a reduction of flow of about 2,200 AFY or 3.0 cfs. This amount is insignificant and will not have any impact on the spring runoff at Central gage, however, it may have minimal impact on the river flow during dry periods and when MRGCD is not releasing water from storage. The SE is expected to issue a similar number of domestic well permits for the next 20 to 30 years (we have intentionally overestimated the number of domestic permits to be issued). The hydrologic effects of the domestic well uses are in the whole minimal, as measured by the effects on the river.

The SE limits the pre-basin groundwater pumpers (including municipal and industrial uses) to the historic legal maximum amount. We currently do not have an estimate of total pre-basin groundwater diversions in the URG. For the purpose of this analysis, based on historical water use estimates (Sorenson, 1982 Water Use By Categories in NM in 1980) with adjustments, we assume the impact of the pre-basin pumping is a reduction of the river flow at the Otowi gage of about 5 cfs. The hydrologic effects of the pre-basin pumpers are in the whole minimal, as measured by the effects on the river.

4.6 River Maintenance Actions

Actions:

The ISC proposes to continue to fund projects to control impacts and maintain river conveyance efficiency. The State proposes to continue to contribute funding to actions described in the Bureau of Reclamation Biological Assessment river maintenance activities section. The full description of the MRG river maintenance program, including State actions, is described in Reclamation’s draft Biological Assessment Part 2.

Hydrologic Effects:

See Reclamation’s Biological Assessment Part II.

4.7 Other Legal Existing Non-Federal Non-Pueblo Water Related Actions

The State proposes to include an additional 10 cfs of impact on the Rio Grande at Albuquerque in its proposed action to account for potential legal existing non-federal, non-Pueblo, water related activities that are not specifically described herein and/or the individual volumes estimated above for existing non-federal, non-Pueblo water related activities are low. This is a continuation of the State effort to seek broad coverage for existing legal users of water. The State recognizes that we may currently not have information about some uses (and thus would have under-estimated the effects of an individual category of actions) or may have inadvertently missed a legal existing action that is a sub-action of one of the above listing of categories.

***Hydrologic Effects**:*

This is a placeholder for an additional 10 cfs of impact on the river flow from existing legal non-federal, non-Pueblo uses analyzed as if the effect occurs in the Albuquerque reach.

5. Cumulative Effects

The State does not anticipate reasonably foreseeable additional future State (excluding federal) or private actions in the action area, aside from those actions described herein.

6. Consultation Coverage

1. **Action by Action analysis**

We request that the actions described in this BA supplement be included as part of the Proposed Action in Reclamation's formal Section 7 consultation. It is anticipated that these actions will be able to rely on the RIP as the means for ESA compliance, provided the RIP as addressed in the BO adequately minimizes the effects of the actions, the proponent of the action has signed the Cooperative Agreement (CA) with the Service if not already a signatory to the CA, and the RIP is maintaining sufficient progress toward recovery.

2. **Future Actions analyzed by Category**

It is requested that future actions within the seven categories of actions addressed in this BA supplement be included as part of the Proposed Action in Reclamation's formal Section 7 consultation. It is anticipated that specific future actions within these categories will be able to rely on the RIP as their means for ESA compliance, provided the RIP as addressed in the BO adequately minimizes the effects of the actions, the proponent of the action signs the CA with the Service if not already a signatory to the CA, and the RIP is maintaining sufficient progress toward recovery. Federal action agencies may choose to request and obtain confirmation from the Service of coverage for such individual actions upon submission of documentation establishing that the action is within a category covered by the BO and that the proponent of the action is a signatory to the CA.

7. Proposed Conservation Measures

The State proposes the activities identified in this Section to the State Supplement for inclusion as conservation measures in Reclamation's July 31, 2012 Joint Biological Assessment (July 31, 2012 BA) for water management and maintenance activities in the Rio Grande Basin (U.S. Bureau of Reclamation 2012). These conservation measures are intended to minimize or avoid effects to listed species or critical habitat that may occur through the actions proposed by the State. It is expected that Reclamation will include these conservation measures with those offered by other stakeholders (including Reclamation) in its July 31, 2012 BA to the Service for consideration by the Service in determining whether the overall proposed action is likely to jeopardize the continued existence of the listed species. The State will continue to utilize its authority to support objectives that alleviate jeopardy and to recover listed species in a manner not inconsistent with existing and future water uses, and consistent with State laws.

The following activities address and offset the effects of the actions proposed by the State for coverage in the current consultation. These conservation measures are responsive to two specific MRG flow regimes: (1) when there is a potential reduction in spring peak flow that may otherwise affect RGSM spawning and/or egg incubation and rearing of larvae, and (2) when there is a potential reduction in summer flow that could lead to reduced habitat diversity, river intermittency, or drying. Contingent on continuing authority, the availability of funding and/or water, and continuation or renewal of existing agreements, the State will endeavor to fulfill the following environmental commitments:

1. Work with the Rio Grande Compact Commission to secure approval for Army Corps of Engineers (ACOE) deviations from normal operations at its Flood Control Reservoirs to improve flow management for spawning;
2. Subject to availability, provide up to 60 acre-feet per deviation of senior consumptive use rights from the Strategic Water Reserve (N.M. Stat. § 72-14-3.3) to Reclamation and/or the ACOE for offsets of spawning-related depletions resulting from Cochiti Reservoir deviations for up to ten years unless able to extend;
3. Work cooperatively with other Program partners to maintain existing overbank habitat constructed by the State since 2006 in the Albuquerque and Isleta reaches for a period of at least 10 years from the date of construction, which will result in habitat availability at a greater range of flows in which spawning, egg incubation, and larval rearing can occur;
4. Continue to contribute depletion offsets for the State's existing habitat restoration projects within the Albuquerque and Isleta reaches;
5. Continue the habitat restoration depletion offset program for the ACOE MRG Floodway Projects in accordance with existing agreements between the ISC and ACOE; specifically, the Route 66 Project and Albuquerque Restoration Project;
6. Provide up to 2,000 acre-feet per event (not to exceed a total of 6,000 acre-feet) of currently unallocated Rio Grande Compact relinquishment credit for storage in El

Vado Reservoir under State Engineer Permit 1690 for later release at low flow rates when MRGCD is not otherwise releasing stored water. The low flow rate releases would be made to provide real time offsets.

In addition, the following activities address the highly variable nature of MRG hydrology, including prolonged drought, so as not to lose gains made for the species. Contingent on continuing authority, continuation or renewal of existing agreements, and the availability of funding and/or water, the State will endeavor to fulfill the following environmental enhancements:

1. Continuation of existing agreements for the management and operation of the Los Lunas Silvery Minnow Refugium; and
2. Lease senior consumptive use rights from the Strategic Water Reserve (N.M. Stat. § 72-14-3.3) to Reclamation and/or the ACOE for offsets of overbanking depletions resulting from ACOE Flood Control Reservoir deviations. ;

8. Species Effects

The following is an assessment of the effects of the State's actions on the federally listed species: Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow), Southwestern willow flycatcher (*Empidonax traillii extimus*; flycatcher), Pecos sunflower (*Helianthus paradoxus*, sunflower), and Interior least tern (*Sternula antillarum athalassos*, tern). A determination of the effect of each identified category of actions was made according to Section 7(c)(1) of ESA and the interpretations and implementing regulations provided in 50 CFR 402.12. In determining if a given action is likely to adversely affect a species, consideration was given to the potential effect of the action on life history functions (e.g., survival, reproduction, recruitment) at the population level and on the primary constituent elements of critical habitat. All determinations include direct and indirect effects. Three levels of effects were considered:

- Not likely to affect: there is no potential effect of the action on listed or proposed species, or on designated or proposed critical habitat;
- May affect, but not likely to adversely affect: there is a small potential effect of the action on listed or proposed species, or on designated or proposed critical habitat; this effect is not sufficient to adversely impact the species or it may be beneficial to the species; and
- Likely to adversely affect; there is a potential effect of the action on listed or proposed species, or on designated or proposed critical habitat such that the species is negatively impacted.

Rio Grande Silvery Minnow

<u>Summary of Effects on the Rio Grande Silvery Minnow</u>

In summary, the majority of the State's proposed actions may affect but are not likely to adversely affect the species and its critical habitat, and some actions are likely to directly or indirectly benefit the silvery minnow and its critical habitat (Table 1). Discretionary and non-discretionary actions related to administration of the Rio Grande Compact and surface water and groundwater resources generally help to provide water during low natural flow periods, to offset groundwater depletions, and to maintain flow during conveyance. These actions all help to provide more reliable river flows and help reduce the frequency, duration, and magnitude of drying events. Providing more continuous and reliable flow in the MRG benefits all life stages of the silvery minnow and its critical habitat in all seasons.

Table 1. Summary of effects of the State's actions on the Rio Grande silvery minnow.

Action Category	Summary of Effects	Summary of Determinations
1. Discretionary Actions Related to Administration of the Rio Grande Compact	These actions allow for storage of water during the spring snowmelt peak when it would otherwise not be allowed to meet water needs at other times of the year. This action reduces spring flows to some extent but helps to provide water at other times that benefits various life stages. During low flow periods, this reduces the frequency, duration, and length of river drying.	These actions may affect, but are not likely to adversely affect the Rio Grande silvery minnow and its critical habitat. Providing relinquishment water during low natural flow periods is likely to benefit the species.
2. Discretionary Actions To Administer Surface and Groundwater Resources In the Middle Rio Grande	These actions offset flow depletions from ground water pumping which will likely benefit the silvery minnow. In some instances, senior surface water rights transfers from south of the Albuquerque reach may result in a small amount of depletion in the Albuquerque reach that may affect habitat only in that reach during extremely low flows. The letter water program provides a near real-time offset of groundwater pumping, except during times when MRGCD is not releasing water from storage.	These actions may affect, but are not likely to adversely affect the Rio Grande silvery minnow and its critical habitat. Offsetting ground water depletions helps to maintain flow in the river, especially during low-flow periods.
3. Non-Discretionary State Actions To Administer Surface and Groundwater Resources In the Middle Rio Grande	These actions result in flow reductions in the MRG during low flow conditions. Such low flow periods happen only when MRGCD is not releasing water from storage.	These actions are likely to adversely affect the Rio Grande silvery minnow and its critical habitat because of small depletions at low flow conditions that occur only when MRGCD is not releasing water from storage.
4. Discretionary State Actions To Administer Surface and Groundwater Resources In the Upper Rio Grande	These actions have a minimal effect at the Otowi gage, which is upstream of critical habitat and occupied habitat of the silvery minnow.	These actions are not likely to affect the Rio Grande silvery minnow and its critical habitat because these result in minimal flow reductions at the Otowi gage that are too small to measure in occupied and critical habitat that is located further downstream.
5. Non-Discretionary State Actions To Administer Surface and Groundwater Resources in the Upper Rio Grande	These actions have a minimal effect at the Otowi gage, which is upstream of critical habitat and occupied habitat of the silvery minnow.	These actions are not likely to affect the Rio Grande silvery minnow and its critical habitat because these result in minimal flow reductions at the Otowi gage that are too small to measure in occupied and critical habitat that is located further downstream.

Effects on the Rio Grande Silvery Minnow by Action Category

1. Discretionary Actions Related to Administration of the Rio Grande Compact

The effects of the State's proposed discretionary actions in administering the Compact are as a whole positive as measured by the ability to make relinquishment water available in upstream storage for release to benefit irrigation needs in the middle valley, City of Santa Fe needs for storage in Nichols and McClure reservoirs, and to meet flow targets of the 2003 BiOp when native water storage would otherwise not be available to do so. Water stored and released during low natural flow periods provides higher flow in the MRG that benefits the silvery minnow by maintaining habitat for all life stages during summer (Table 2). Low flow periods are particularly critical to the species as the river may become intermittent or dry in some portions of the lower MRG leaving fish stranded in isolated and drying pools of water. Providing water during low flow events reduces the frequency, extent, and duration of drying events and increases survival of fish in river reaches that might otherwise become intermittent or dry. The silvery minnow is short-lived with a longevity of 2-4 years, and all ages of fish participate in spawning (including fish reaching one year of age), so maintaining river habitat annually, especially during dry periods sustains the reproductive stock of the population and enables self-sustainability.

Helping to maintain flow during low flow periods also helps to protect the primary constituent elements of critical habitat, including space for individual and population growth; food, water quantity and quality; cover or shelter; sites for breeding, reproduction, or rearing of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species. Continuous summer flow helps to maintain habitat, including water depth, temperature, and quality, as well as food production.

The storage of the relinquished water during the spring snowmelt runoff normally will have little impact on the peak flow of the MRG. The magnitude of reduction will depend on the release from Abiquiu Reservoir at the time storage occurs and the current snowmelt runoff flow reaching the Rio Grande from other parts of the basin. Under normal circumstances, the magnitude of flow reduction will be small and a snowmelt runoff peak will still occur in the MRG that stimulates the silvery minnow to spawn and provides suitable conditions for incubation of eggs and rearing of young. In years of low spring runoff, flow reduction may be measurable and may reduce spawning and nursery habitat. The effect of peak flow reduction will likely vary longitudinally as recent research has found that the flow to habitat relationship is different for the Albuquerque, Isleta, and San Acacia reaches. The reduction in peak flows is likely to adversely affect spawning and may only minimally affect conditions for incubation of eggs and rearing of young if the reduction occurs at a narrow flow range in which shallow-water habitats are affected.

In summary, the State's discretionary actions related to administration of the Rio Grande Compact can reduce spring peak flows but help to provide continuous summer flow that reduces the frequency, duration, and length of river drying. Overall, these actions may affect, but are not likely to adversely affect the Rio Grande silvery minnow and its critical

habitat. Providing relinquishment water during low natural flow periods is likely to benefit the species.

Table 2. Direct and indirect effects of discretionary actions related to administration of the Rio Grande Compact on life history and primary constituent elements (PCEs) of critical habitat for the Rio Grande silvery minnow.

2a. Life History					
Season	**Spawning**	**Eggs**	**Larval**	**Juvenile**	**Adult**
Spring (April-June)	• Reduction in peak flow may affect spawning and may only minimally affect conditions for incubation of eggs and rearing of young if the reduction occurs at a narrow flow range in which shallow-water habitats are affected; these actions are likely to adversely affect spawning, and egg and larval life stages of the silvery minnow.			• Reduction in peak flow is not expected to be of a magnitude that will affect habitat of juvenile and adult life stages; these actions may affect, but are not likely to adversely affect juvenile and adult life stages of the silvery minnow.	
Summer (June-September)	• There may be a small amount of spawning that takes place in summer; these actions are not likely to adversely affect spawning, and egg and larval life stages of the silvery minnow.			• Water stored and released during low natural flow periods provides continuous flow in the MRG that benefits the silvery minnow by maintaining habitat for all life stages; these actions are likely to benefit the silvery minnow.	
Fall (September-November)	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in fall and winter.				
Winter (December-March)					
2b. Critical Habitat Primary Constituent Elements					
Element	**Spawning**	**Eggs**	**Larval**	**Juvenile**	**Adult**
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats.	• Water stored and released during low natural flow periods helps to provide sufficient flowing water and maintaining a diversity of aquatic habitats; these actions will help provide continuous flows which will likely benefit the silvery minnow.				
Presence of a diversity of habitats for all life history stages	• Water stored and released during low natural flow periods provides continuous flow in the MRG that benefits the silvery minnow by maintaining habitat for all life stages; these actions are likely to help maintain in channel flow and habitat diversity which will likely benefit the silvery minnow.				
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	• Reduction in peak flow is not expected to affect a spawning trigger for silvery minnow; these actions may affect, but are not likely to adversely affect spawning of the silvery minnow.				
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow	• There may be a small amount of spawning that takes place in summer; these actions are not likely to affect spawning, and egg and larval life stages of the silvery minnow.			• Water stored and released during low natural flow periods provides continuous flow in the MRG that benefits the silvery minnow by maintaining habitat for all life stages; these actions are likely to benefit the silvery minnow.	
Constant winter	• Spawning, egg incubation, and larval rearing of			• Water stored and released during low	

Flow	silvery minnow normally do not take place in winter.	natural flow periods provides persistent habitat over winter, especially in deepened pools and around instream woody debris; these actions are likely to benefit the silvery minnow.
River reach length	• Water stored and released during low natural flow periods helps to maintain river reach length by reducing the frequency, duration, and length of river drying; these actions are likely to benefit the silvery minnow. • Reduced peak flow is not likely to affect river length, except possibly for a minor increase in sinuosity, which could increase habitat diversity; these actions are likely to benefit the silvery minnow.	
Habitat "Quality" in each reach and refugial habitats	• Water stored and released during low natural flow periods helps to maintain river flow and habitat that is likely to benefit the silvery minnow. • Reduced peak flow in low flow periods could reduce or increase habitat diversity and quality depending on magnitude of river flow; these actions may affect, but are not likely to adversely affect spawning and incubation of the silvery minnow.	
Substrates size	• The effect of reduced peak flow on sediment transport is expected to be minimal, and may affect, but is not likely to adversely affect the silvery minnow.	
Temp >1˚ - <30˚C. DO > 5 mg/L pH (6.6-9.0)	• Water stored and released during low natural flow periods helps to maintain river flow and circulation that benefits water quality; these actions are likely to benefit the silvery minnow. • The effect of reduced peak flow on water temperature, DO and pH is expected to be minimal, and may affect, but is not likely to adversely affect the silvery minnow.	
Other Contaminants	• Water stored and released during low natural flow periods helps to maintain river flow and should help with dilution of contaminants by maintaining river flow and circulation; these actions are likely to benefit the silvery minnow. • The effect of reduced peak flow on water contaminants is expected to be minimal, and may affect, but is not likely to adversely affect the silvery minnow.	

2. Discretionary Actions to Administer Surface and Groundwater Resources in the Middle Rio Grande

The three components of the offset program in the MRG include return flow, the letter water program, and transfer of senior water rights. These replace permitted groundwater pumping impacts to the river on a real-time basis whenever MRGCD is releasing water from storage. These components offset flow depletions and help to maintain balanced river flows that protect silvery minnow habitat year-around. These components are not likely to adversely affect the silvery minnow and may have a small benefit by reducing flow depletions (Table 3).

Of about 67,000 AF per year of water returned directly into the river between the Otowi gage and Elephant Butte Dam, only about 9,000 AF is included in the state's hydrologic effect analysis. The hydrologic effects of the State action approving return flow plans are as a whole neutral, as measured by the effects on the river and may even have positive impacts due to the flow augmentation. The letter water program provides a near real-time offset of the groundwater pumping effects on the river system, except during times when MRGCD is not releasing water from storage. These conditions have occurred about three times in the last ten years and not at all in the twenty preceding years. When they have occurred, it's been during the months of September and October. In general, the amount of the letter water has an insignificant effect on river flows as measured at the Central gage (1.5 cfs in September and October). Letter water has no effect on the river flow during spring runoff, or when MRGCD is releasing stored water or during winter months. During summer months, letter water has a small impact at low river flows or when MRGCD has no stored water to release. The letter water program is likely to have little effect on the silvery minnow and its critical habitat.

In general, during spring runoff or when MRGCD is releasing stored water, transfer of a senior water right has a *de minimus* effect on river flow. During the winter months the river flow is continuous, however, transfers may have a small impact on river flows due to continuing pumping at the move-to location. During summer months, transfers have an impact during periods of low river flows or during periods when MRGCD has no stored water to release. The impact of senior water rights transfers from the belen and Socorro Divisions to the Albuquerque reach would result in a reduction of about 13 cfs of the flow at the Central gage. This flow reduction is small in comparison to average annual flow at the Central gage, and is within the margin of error for flow measurement. In years of extremely low flow, this reduction could affect habitat and the silvery minnow in the Albuquerque reach. However, the amount of reduction is so small that it would not affect the Isleta and San Acacia reaches.

Letter water, including the SJC Project water that is stored by exchange in Nichols and McClure Reservoirs by the City of Santa Fe, has little or no effect on the river flow during spring runoff, or when MRGCD is releasing stored water or during winter months. This would have minimal impact on silvery minnow spawning and egg and larval habitat, as well as juvenile and adult life stages. During summer months, letter water can have a small impact at low river flows or when MRGCD has no stored water to release. This impact would also likely be minimal and could affect silvery minnow habitat primarily in those times when MRGCD is not releasing stored water. Therefore, the hydrologic effects of the State letter water component of the MRG offset program excluding ABCWUA are limited to certain periods and overall are minimal, as measured by the effects on the river flow. This form of letter water may affect, but is not likely to adversely affect the silvery minnow.

Depletions that occur during the irrigation season when MRGCD is releasing stored water to meet demand are considered effects on the MRG, and are replenished by exchange of the SJC Project water in storage to MRGCD, which holds that water for release when needed to meet demand. As such, it provides a quasi real-time offset of the groundwater pumping effects on the river system. Depletions that occur outside of the irrigation season are considered effects on Elephant Butte Reservoir. The required amount of SJC Project water is generally released to the Rio Grande in the winter for delivery to Elephant Butte Reservoir.

While there is some flexibility in when the water is delivered to Elephant Butte, it cannot be depleted in the middle valley and so there is no effect to the silvery minnow from this activity.

Offsetting depletions also helps to maintain the primary constituent elements of critical habitat, including space, food, habitat, and water quality. Continuous summer flow helps to maintain habitat, including water depth, temperature, and quality. Continuous flow also helps to maintain food production.

In summary, the State's discretionary actions to administer surface and groundwater resources in the Middle Rio Grande offset flow depletions from ground water pumping which will likely benefit the silvery minnow, although the senior water rights transfers may

result in a small amount of depletion in the Albuquerque reach that may affect habitat only in that reach during extremely low flows. The letter water program provides a near real-time offset of the groundwater pumping effects on the river system, except during times when MRGCD is not releasing water from storage. Overall, these actions may affect, but are not likely to adversely affect the Rio Grande silvery minnow and its critical habitat.

Table 3. Direct and indirect effects of discretionary actions to administer surface and groundwater resources in the middle Rio Grande on life history and PCEs of critical habitat for silvery minnow.

3a. Life History					
Season	Spawning	Eggs	Larval	Juvenile	Adult
Spring (April-June)	• This offset program replaces permitted groundwater pumping impacts to the river on a real-time basis that help to maintain river flow; these actions may affect, but are not likely to adversely affect the spawning, egg and larval stages of the silvery minnow.			• This program offsets effects of groundwater pumping but will have little effect on spring flows; these actions may affect, but are not likely to adversely affect the juvenile and adult life stages of the silvery minnow.	
Summer (June-September)	• There may be a small amount of spawning that takes place in summer; these actions may affect, but are not likely to adversely affect spawning, egg, and larval life stages of the silvery minnow. • The letter water component provides a near real-time offset of the groundwater pumping, except during times when MRGCD is not releasing water from storage; these actions are likely to adversely affect the silvery minnow when MRGCD is not releasing water (occurred 3 times in last 30 years only in September and October).			• This offset program will reduce the frequency and extent of river drying in summer, depending on annual hydrology; this may benefit the juvenile and adult stages of silvery minnow. • Senior water rights transfers may result in a small amount of depletion in the Albuquerque reach; these actions are likely to adversely affect juvenile and adult habitat during extremely low flows.	
Fall (September-November)	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in fall and winter.			• This offset program is likely to benefit the juvenile and adult stages of silvery minnow in fall and winter.	
Winter (December-March)					
3b. Critical Habitat Primary Constituent Elements					
Element	Spawning	Eggs	Larval	Juvenile	Adult
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats.	• This offset program replaces permitted groundwater pumping impacts to the river on a real-time basis that helps to maintain river flow and habitat diversity; this will likely to benefit the silvery minnow. • This letter water component will offset groundwater pumping except during times when MRGCD is not releasing water from storage; these actions are likely to adversely affect aquatic habitats.				
Presence of a diversity of habitats for all life history stages	• This offset program replaces permitted groundwater pumping impacts to the river on a real-time basis that helps to maintain river flow and habitat diversity for all life stages; this will likely to benefit the silvery minnow.				
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	• The offset program is not expected to affect a spawning trigger for silvery minnow; this action will not affect the silvery minnow.				
Flows in the summer (June)	• There may be a small amount of spawning that takes place in summer; this is not likely to affect			• Water stored and released during low natural flow periods provides continuous flow in the	

through fall (October) that do not increase prolonged periods of low or no flow	spawning, and egg and larval life stages of the silvery minnow.	MRG that benefits the silvery minnow by maintaining habitat for all life stages; these actions are likely to benefit the silvery minnow. • Senior water rights transfers may result in a small amount of depletion in the Albuquerque reach; these actions are likely to adversely affect juvenile and adult habitat during extremely low flows.
Constant winter Flow	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in winter.	• Offsetting groundwater depletions during low natural flow periods provides persistent habitat over winter, especially in deepened pools and around instream woody debris; these actions are likely to benefit the silvery minnow.
River reach length	• Offsetting groundwater depletions helps to maintain river reach length by reducing the frequency, duration, and length of river drying; these actions are likely to benefit the silvery minnow.	
Habitat "Quality" in each reach and refugial habitats	• Offsetting groundwater depletions helps to maintain river flow and habitat that is likely to benefit the silvery minnow.	
Substrates size	• The effect of groundwater depletion offsets on sediment transport is expected to be minimal, and may affect, but is not likely to adversely affect the silvery minnow.	
Temp >1˚ - <30˚C. DO > 5 mg/L pH (6.6-9.0)	• Offsetting groundwater depletions helps to maintain river flow and should help water quality by maintaining river flow and circulation; these actions are likely to benefit the silvery minnow.	
Other Contaminants	• Offsetting groundwater depletions helps to maintain river flow and should help with dilution of contaminants by maintaining river flow and circulation; these actions are likely to benefit the silvery minnow.	

3. <u>Non-Discretionary State Actions to Administer Surface and Groundwater Resources in the Middle Rio Grande</u>

In general, about 50 percent of total domestic well diversions return to the hydrologic system, therefore, the total impact on the river is a reduction of flow of about 9,150 AFY or about 12.6 cfs at the headwaters of Elephant Butte Reservoir. The expected impact at the Central gage is a reduction of flow of about 5,860 AFY or 8.0 cfs. This amount is insignificant and not measurable on the spring runoff. However, it may have minimal impact on the river during dry periods and on the silvery minnow when MRGCD is not releasing water from storage (Table 4).

The SE limits the pre-basin groundwater pumpers (including municipal and industrial uses) to the historic legal maximum amount. Total pre-basin groundwater pumping in the MRG (exclusive of 18,000 AF for ABCWUA) is about 15,000 AF. About 50 percent of this pumping is returned directly to the river, so the net impact of pre-basin pumping (exclusive of that by ABCWUA) on the river is about 7,500 AFY or about 10.4 cfs. This amount is insignificant and will not have any impact on the spring runoff; however, it may have minimal impact on the river during dry periods when MRGCD is not releasing water from storage. The hydrologic effects of the pre-basin pumpers in the MRG are in the whole minimal, as measured by the effects on the river.

In summary, the State's non-discretionary actions to administer surface and groundwater

resources in the Middle Rio Grande result in flow reductions that during low flow conditions are likely to adversely affect the Rio Grande silvery minnow and its critical habitat. This condition happens only when MRGCD is not releasing water from storage. These conditions have occurred about three times in the last ten years and not at all in the twenty preceding years. When they have occurred, it's been during the months of September and October.

Table 4. Direct and indirect effects of non-discretionary state actions to administer surface and groundwater resources in the middle Rio Grande on life history and PCEs of critical habitat for silvery minnow.

4a. Life History					
Season	Spawning	Eggs	Larval	Juvenile	Adult
Spring (April-June)	• Reductions in flow of about 12.6 cfs in lower MRG and 8.0 cfs at Central Bridge are insignificant in spring runoff and will not affect spawning or egg and larval life stages. • The net impact of pre-1956 pumping on the river is about 10.4 cfs which is insignificant in spring runoff and will not affect spawning or egg and larval life stages. • These actions may affect, but are not likely to adversely affect spawning, and egg and larval life stages of the silvery minnow.			• Reductions in flow of about 12.6 cfs in lower MRG and 8.0 cfs at Central Bridge are insignificant in spring runoff and will not affect juvenile and adult life stages. • The net impact of pre-1956 pumping on the river is about 10.4 cfs which is insignificant in spring runoff and will not affect juvenile and adult life stages. • These actions may affect, but are not likely to adversely affect juvenile and adult life stages of the silvery minnow.	
Summer (June-September)	• There may be a small amount of spawning that takes place in summer; these actions are not expected to affect spawning, egg, and larval life stages of the silvery minnow.			• Reductions in flow of about 12.6 cfs in lower MRG and 8.0 cfs at Central Bridge in summer are likely to adversely affect juvenile and adult life stages. • The net impact of pre-1956 pumping on the river is about 10.4 cfs in summer is likely to adversely affect juvenile and adult life stages. • These actions are likely to adversely affect juvenile and adult life stages of the silvery minnow in summer.	
Fall (September-November) Winter (December-March)	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in fall and winter.			• Reductions in flow of about 12.6 cfs in lower MRG and 8.0 cfs at Central Bridge in fall and winter may affect juvenile and adult life stages. • The net impact of pre-1956 pumping on the river is about 10.4 cfs in fall and winter may affect juvenile and adult life stages. • These actions are likely to adversely affect juvenile and adult life stages of the silvery minnow in fall and winter.	
4b. Critical Habitat Primary Constituent Elements					
Element	Spawning	Eggs	Larval	Juvenile	Adult
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic	• Reductions in flow of about 12.6 cfs in lower MRG and 8.0 cfs at Central Bridge in summer are likely to adversely affect diversity of aquatic habitats for all life stages. • The net impact of pre-1956 pumping on the river is about 10.4 cfs in summer is likely to adversely affect diversity of aquatic habitats for all life stages. • These actions are likely to adversely affect diversity of aquatic habitats for all life stages.				

habitats.		
Presence of a diversity of habitats for all life history stages	• Reductions in flow of about 12.6 cfs in lower MRG and 8.0 cfs at Central Bridge in summer is likely to adversely affect diversity of aquatic habitats for all life stages. • The net impact of pre-1956 pumping on the river is about 10.4 cfs in summer is likely to adversely affect diversity of aquatic habitats for all life stages. • These actions are likely to adversely affect diversity of aquatic habitats for all life stages.	
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	• The net impact of groundwater pumping on the river is insignificant in spring runoff and will not affect spawning or egg and larval life stages; these actions may affect, but are not likely to adversely affect spawning of the silvery minnow.	
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow	• There may be a small amount of spawning that takes place in summer; these actions are not likely to affect spawning, and egg and larval life stages of the silvery minnow.	• Reductions in flow from groundwater pumping may prolong periods of low or no flow by a small amount; these actions are likely to adversely affect the silvery minnow.
Constant winter Flow	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in winter.	• Reductions in flow of about 12.6 cfs in lower MRG and 8.0 cfs at Central Bridge in fall and winter may have a small reduction on flow in winter, but these actions are not likely to adversely affect this element of critical habitat.
River reach length	• Reductions in flows are not likely to affect river length, except possibly for a minor increase in sinuosity, which could increase habitat diversity; these actions are likely to benefit the silvery minnow.	
Habitat "Quality" in each reach and refugial habitats.	• Reductions in flows could reduce or increase habitat diversity and quality depending on magnitude of river flow; these actions may affect, but are not likely to adversely affect spawning and incubation of the silvery minnow.	
Substrates size	• The effect of flow reductions on sediment transport is expected to be minimal, and may affect, but is not likely to adversely affect the silvery minnow.	
Temp >1˚ - <30˚C.		
DO > 5 mg/L		
pH (6.6-9.0)		
Other Contaminants		

4. <u>Discretionary State Actions to Administer Surface and Groundwater Resources in the Upper Rio Grande</u>

In the URG the SE conjunctively manages surface water and groundwater to keep total depletion at or below the 1929 conditions. All depletions occurring as a result of transfer at the move-to location must be offset by a decrease in depletion at the move-from location, return flow, or releases of SJC Water. Therefore, the hydrologic effects of the State action approving transfers in the URG are in the whole neutral, as measured by the effects on the river at Otowi gage. The three components of the offset program in the MRG include the return flow component, the letter water program, and transfer of senior water rights. These components are not likely to adversely affect the silvery minnow and may have a small benefit by reducing flow depletions (Table 5).

The SE proposes to continue administering existing water rights permits and to conduct alternative administration to ensure that the Rio Grande is kept whole through the offset mechanisms required by permit, licenses, and adjudications. Alternative Administration is based upon agreements by water right owning parties that resolve water disputes under

conditions of shortage without the necessity for priority administration and curtailment of junior water rights; e.g., Rio Chama, and Taos Valley. This activity serves to resolve conflicts especially during low flows and helps to balance water administration and management with available water volume. This activity is not likely to affect the silvery minnow and, by averting water challenges during low flow periods, may benefit the silvery minnow.

In summary, the State's discretionary actions to administer surface and groundwater resources in the Upper Rio Grande are not likely to affect the Rio Grande silvery minnow and its critical habitat. These actions include activities upstream of the Otowi gage that will have only minimal effects to the silvery minnow in occupied habitat that is further downstream.

Table 5. Direct and indirect effects of discretionary actions to administer surface and groundwater resources in the upper Rio Grande on life history and PCEs of critical habitat for silvery minnow.

5a. Life History					
Season	Spawning	Eggs	Larval	Juvenile	Adult
Spring (April-June)	• This offset program replaces permitted groundwater pumping impacts to the river on a real-time basis, but these offsets will have little effect on spring flows; these actions may affect, but are not likely to adversely affect the spawning, egg and larval stages of the silvery minnow.			• This program offsets effects of groundwater pumping but will have little effect on spring flows; these actions may affect, but are not likely to adversely affect the juvenile and adult life stages of the silvery minnow.	
Summer (June-September)	• There may be a small amount of spawning that takes place in summer; these actions may affect, but are not likely to adversely affect spawning, egg, and larval life stages of the silvery minnow.			• This offset program will reduce the frequency and extent of river drying in summer, depending on annual hydrology; these actions reduce summer depletions that may benefit the juvenile and adult stages of silvery minnow.	
Fall (September-November)	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in fall and winter.			• This offset program is likely to benefit the juvenile and adult stages of silvery minnow in fall and winter.	
Winter (December-March)					

5b. Critical Habitat Primary Constituent Elements					
Element	Spawning	Eggs	Larval	Juvenile	Adult
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats.	• This offset program will reduce the frequency and extent of river drying in summer, depending on annual hydrology, and will help to maintain diversity of aquatic habitats; these actions reduce summer depletions and are likely to benefit all life stages of silvery minnow.				
Presence of a diversity of habitats for all life history stages	• This offset program will reduce the frequency and extent of river drying in summer, depending on annual hydrology, and will help to maintain diversity of aquatic habitats; these actions reduce summer depletions and are likely to benefit all life stages of silvery minnow.				
Sufficient flows from early spring (March) to early summer (June) to trigger	• This offset program replaces permitted groundwater pumping impacts to the river on a real-time basis, but these offsets will have little effect on spring flows; these actions may affect, but are not likely to adversely affect spawning of the silvery minnow.				

spawning		
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow	• There may be a small amount of spawning that takes place in summer; these actions are not likely to affect spawning, and egg and larval life stages of the silvery minnow.	• This offset program is likely to benefit the juvenile and adult stages of silvery minnow in summer and fall.
Constant winter Flow	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in winter.	• Offsetting groundwater depletions during low natural flow periods provides persistent habitat over winter, especially in deepened pools and around instream woody debris; these actions are likely to benefit the silvery minnow.
River reach length	• Offsetting groundwater depletions helps to maintain river reach length by reducing the frequency, duration, and length of river drying; these actions are likely to benefit the silvery minnow.	
Habitat "Quality" in each reach and refugial habitats	• Offsetting groundwater depletions helps to maintain river flow and habitat that is likely to benefit the silvery minnow.	
Substrates size	• The effect of groundwater depletion offsets on sediment transport is expected to be minimal, and may affect, but is not likely to adversely affect the silvery minnow.	
Temp >1˚ - <30˚C.	• Offsetting groundwater depletions helps to maintain river flow and should help water quality by maintaining river flow and circulation; these actions are likely to benefit the silvery minnow.	
DO > 5 mg/L		
pH (6.6-9.0)		
Other Contaminants	• Offsetting groundwater depletions helps to maintain river flow and should help with dilution of contaminants by maintaining river flow and circulation; these actions are likely to benefit the silvery minnow.	

5. <u>Non-Discretionary State Actions to Administer Surface and Groundwater Resources in the Upper Rio Grande.</u>

The maximum estimated impact of domestic and livestock wells at the Otowi gage is a reduction of flow of about 2,200 AFY or 3 cfs. This amount is insignificant and will not have any impact on the spring runoff at Central gage, however, it may have minimal impact on the river flow during dry periods and MRGCD is not releasing water from storage. The SE is expected to issue a similar number of domestic well permits for the next 20 to 30 years. The hydrologic effects of the domestic well uses are in the whole minimal, as measured by the effects on the river.

The SE limits the pre-basin groundwater pumpers (including municipal and industrial uses) to the historic legal maximum amount. The impact of the pre-basin pumping in the URG is a reduction of the river flow at the Otowi gage of about 3,600 AFY or about 5 cfs. This amount is small and will not have any impact on the spring runoff at Central gage; however, it may have minimal impact on the river flow during dry periods when MRGCD is not releasing water from storage (Table 6).

In summary, the State's non-discretionary actions to administer surface and groundwater resources in the Upper Rio Grande are not likely to affect the Rio Grande silvery minnow and its critical habitat. These actions include activities upstream of the Otowi gage that will have only minimal effects to the silvery minnow in occupied habitat and critical habitat

that are located further downstream.

Table 6. Direct and indirect effects of non-discretionary state actions to administer surface and groundwater resources in the middle Rio Grande on life history and PCEs of critical habitat for silvery minnow.

6a. Life History					
Season	Spawning	Eggs	Larval	Juvenile	Adult
Spring (April-June)	• Reductions in flow of about 3 cfs at the Otowi gage occur in the URG and are insignificant in spring runoff and will not affect spawning or egg and larval life stages. • The net impact of pre-1956 pumping on the river is about 5 cfs at the Otowi gage in the URG and is insignificant in spring runoff and will not affect spawning or egg and larval life stages. • These actions occur upstream of occupied and critical habitat and are not likely to affect spawning, and egg and larval life stages of the silvery minnow.			• Reductions in flow of about 3 cfs at the Otowi gage occur in the URG and are insignificant in spring runoff and will not affect juvenile and adult life stages. • The net impact of pre-1956 pumping on the river is about 5 cfs at the Otowi gage in the URG and is insignificant in spring runoff and will not affect juvenile and adult life stages. • These actions occur upstream of occupied and critical habitat and are not likely to affect juvenile and adult life stages of the silvery minnow.	
Summer (June-September)	• There may be a small amount of spawning that takes place in summer. • These actions are not expected to affect spawning, egg, and larval life stages of the silvery minnow.			• Reductions in flow of about 3 cfs at the Otowi gage occur in the URG and are insignificant to summer flows and will not affect juvenile and adult life stages. • The net impact of pre-1956 pumping on the river is about 5 cfs at the Otowi gage in the URG and is insignificant to summer flows and will not affect juvenile and adult life stages. • These actions occur upstream of occupied and critical habitat and are not likely to affect juvenile and adult life stages of the silvery minnow.	
Fall (September-November) Winter (December-March)	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in fall and winter.			• Reductions in flow of about 3 cfs at the Otowi gage occur in the URG in fall and winter and will not affect juvenile and adult life stages. • The net impact of pre-1956 pumping on the river is about 5 cfs at the Otowi gage in the URG and in fall and winter will not affect juvenile and adult life stages. • These actions occur upstream of occupied and critical habitat and are not likely to affect juvenile and adult life stages of the silvery minnow.	

6b. Critical Habitat Primary Constituent Elements					
Element	Spawning	Eggs	Larval	Juvenile	Adult
A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a	• Reductions in flow at the Otowi gage are well upstream of critical habitat for the silvery minnow; these actions are not likely to affect flows within critical habitat of the silvery minnow.				

diversity of aquatic habitats.		
Presence of a diversity of habitats for all life history stages	• Reductions in flow at the Otowi gage are well upstream of critical habitat for the silvery minnow; these actions are not likely to affect habitat diversity for the silvery minnow.	
Sufficient flows from early spring (March) to early summer (June) to trigger spawning	• Reductions in flow at the Otowi gage are well upstream of critical habitat for the silvery minnow; these actions are not likely to affect spawning of the silvery minnow.	
Flows in the summer (June) through fall (October) that do not increase prolonged periods of low or no flow	• There may be a small amount of spawning that takes place in summer; these actions are not likely to affect spawning, and egg and larval life stages of the silvery minnow.	• Reductions in flow at the Otowi gage are will upstream of critical habitat for the silvery minnow; these actions are not likely to affect summer flows in critical habitat.
Constant winter Flow	• Spawning, egg incubation, and larval rearing of silvery minnow normally do not take place in winter.	• Reductions in flow of about 3.0 cfs at the Otowi gage in fall and winter will not affect winter flows in occupied critical habitat.
River reach length	• Reductions in flows at the Otowi gage are not likely to affect occupied critical habitat.	
Habitat "Quality" in each reach and refugial habitats.		
Substrates size		
Temp >1˚ - <30˚C.		
DO > 5 mg/L		
pH (6.6-9.0)		
Other Contaminants		

6. Summary Effects of State Water Related Actions on the Rio Grande Silvery Minnow

Summary effects, in the context of a biological assessment, are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02).

- Municipal and industrial uses of water in the MRG are increasing and because no new water is available, entities seeking water must acquire it from other users and transfer it to the proposed new uses.
- Estimates of the total amount of land currently irrigated within the MRGCD are between 50,000 and 65,000 acres, and the claims to the water are likely much greater than the actual amount of wet water, particularly during drought. However, since only the consumptive use portion of the valid senior water right is allowed to be transferred, approximately two-thirds of the water currently needed to irrigate farms will remain in the system.
- The cumulative effects of the components of the OSE Offset Program to offset the depletive effect of groundwater pumping to date have been minimal and are expected to be so in the future. Because return flows currently offset the vast majority of

groundwater pumping impacts, the majority of offset is made contemporaneous with the impact of groundwater pumping on the river. If the OSE had not conjunctively managed water resources and surface water offsets were not required, there would be less water in the river system which would have a negative impact on the species.

- In summary, the effects of the actions proposed by the State on the Rio Grande silvery minnow are described in the analysis presented above. These effects equal about 32.9 cfs of depletions in the MRG, plus an estimated 10 cfs of additional depletion from other existing actions that may have been taking place for many years prior to the defined action and whose effects are likely to continue into the future. These depletions are the worst possible case scenario, based on generally conservative assumptions, as they are not likely to occur simultaneously or at the same location. The State also proposes to continue a number of permitting activities that would result, and have been analyzed herein, in an additional 30 cfs of effect on the river in 20 to 30 years time. These depletions may affect, but are not likely to adversely affect the silvery minnow when they occur at high and medium flow periods. However, these depletions are likely to adversely affect the silvery minnow if they occur under low flow conditions when MRGCD is not operating and may lead to river intermittency or drying. The 32.9 cfs depletion in the MRG is computed as the sum of: senior water rights transfers to date = 13 cfs; letter water program = 1.5 cfs; domestic wells and livestock use = 8 cfs; and pre-basin groundwater pumping = 10.4 cfs.

Southwestern Willow Flycatcher

<u>Summary of Effects on the Southwestern Willow Flycatcher</u>

In summary, the State's proposed actions are either likely to have negligible or slightly beneficial effects on the willow flycatcher and its critical habitat (Table 7). The State's actions are not likely to adversely affect the species and its critical habitat. Discretionary and non-discretionary actions related to administration of the Rio Grande Compact and surface water and groundwater resources generally help to provide water during low natural flow periods, to offset groundwater depletions, and to maintain flow during conveyance. These actions all help to provide more reliable river flows and help reduce the frequency, duration, and magnitude of drying events. These actions help to maintain water in the river that helps to sustain the overall river ecosystem and riparian areas used by the flycatchers for nesting, feeding, and stopover.

Table 7. Summary of effects of the State's actions on the southwestern willow flycatcher.

Action Category	Not Likely to Affect	Summary of Effects Determinations
1. Discretionary Actions Related to Administration of the Rio Grande Compact	These actions relinquish water from the spring peak to meet water needs at other times of the year. This reduces spring peak flows but help to provide continuous year-around that helps to maintain riparian habitat used by the willow flycatcher.	These actions may affect, but are not likely to adversely affect the southwestern willow flycatcher and its critical habitat. Providing relinquishment water during low natural flow periods is likely to benefit the species.
2. Discretionary	These actions offset flow depletions from ground	These actions may affect, but are not likely to

Actions To Administer Surface and Groundwater Resources In the Middle Rio Grande	water pumping which will likely benefit the willow flycatcher. The senior water rights transfers may result in a small amount of depletion in the Albuquerque reach that may affect habitat only in that reach during extremely low flows. The letter water program provides a near real-time offset of the groundwater pumping effects on the river system, except during times when MRGCD is not releasing water from storage.	adversely affect the southwestern willow flycatcher and its critical habitat. Offsetting ground water depletions helps to maintain flow in the river that helps to maintain riparian habitat.
3. Non-Discretionary State Actions To Administer Surface and Groundwater Resources In the Middle Rio Grande	These actions result in flow reductions in the MRG during low flow conditions. This happens only when MRGCD is not releasing water from storage.	These actions may affect, but are not likely to adversely affect the southwestern willow flycatcher and its critical habitat. Small depletions are not likely to affect the species or its riparian habitat.
4. Discretionary State Actions To Administer Surface and Groundwater Resources In the Upper Rio Grande	These actions have a minimal effect at the Otowi gage, which is upstream of critical habitat and occupied habitat of the willow flycatcher.	These actions are not likely to affect the southwestern willow flycatcher and its critical habitat because these result in minimal flow reductions at the Otowi gage that are too small to measure in occupied and critical habitat that is located further downstream.
5. Non-Discretionary State Actions To Administer Surface and Groundwater Resources in the Upper Rio Grande	These actions have a minimal effect at the Otowi gage, which is upstream of critical habitat and occupied habitat of the willow flycatcher.	These actions are not likely to affect the southwestern willow flycatcher and its critical habitat because these result in minimal flow reductions at the Otowi gage that are too small to measure in occupied and critical habitat that is located further downstream.

Effects on the Southwestern Willow Flycatcher by Action Category

1. Discretionary Actions Related to Administration of the Rio Grande Compact

The effects of the State's proposed discretionary actions in administering the Compact are as a whole, positive as measured by the ability of making relinquishment water available in upstream storage for release to benefit municipal and irrigation needs and to meet flow targets of the 2003 BiOp when native water storage would otherwise not be available to do so. Water stored and released during low natural flow periods provides a higher frequency of continuous flow in the MRG. The willow flycatcher uses some sites of the MRG for nesting and rearing its young in spring and early summer, and there is little effect to the species at other times of the year because there are either few birds in the area or the birds of all ages are mobile and move to necessary feeding and resting sites. The storage of the relinquished water during the spring snowmelt runoff normally has minimal impact on the peak flow of the MRG. This action may reduce wetted area in riparian habitats (depending on flow magnitude). These actions may affect, but are not likely to adversely affect the willow flycatcher (Table 8).

Table 8. Direct and indirect effects of discretionary actions related to administration of the Rio Grande compact on life history and PCEs of critical habitat for the willow flycatcher.

Life History	Migration (April-June & July-September)	Arrival to Territories/ Territory Establishment/Nest Building	Egg Laying/ Incubation/ Nestling/ Fledgling

		(May-July)	(June-August)
Breeding Season (April to September)	• The proposed action would have no effect on flycatcher stopover locations during migration due to the fact that flycatchers will use habitat that is less suitable during this time and farther away from water sources.	• The proposed action may indirectly affect flycatcher habitat on a negligible level. The State's actions could provide a more reliable continuous river flow, but the effect is expected to be negligible to the species	• Flycatchers during nesting are in their territories and less likely to abandon nests if conditions dry or decline in value. • Administration of the Compact may reduce peak flows that may, in turn, reduce wetted surface area in riparian habitat. These actions may affect, but are not likely to adversely affect the willow flycatcher.
Critical Habitat PCES			
Riparian Vegetation	• Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. The State's actions in administering the Rio Grande Compact are, on the whole, positive as measured by the ability of making relinquished water available and these actions are expected to benefit or have negligible effect on the critical habitat of the willow flycatcher.		
Insect Prey Populations	• A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the no action and the proposed action may affect, but is not likely to adversely affect the insect prey populations. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

2. Discretionary Actions to Administer Surface and Groundwater Resources in the Middle Rio Grande

The three components of the offset program in the MRG include return flow, the letter water program, and transfer of senior water rights. These replace permitted groundwater pumping impacts to the river on a real-time basis whenever MRGCD is releasing water from storage. These components offset flow depletions and help to maintain balanced river flows that help to maintain riparian habitat used by willow flycatchers. The actions related to surface water and groundwater offset flow depletions are not likely to adversely affect the willow flycatcher and its critical habitat, and the effect is likely to be negligible (Table 9).

Table 9. Direct and indirect effects of discretionary actions to administer surface and groundwater resources In the Middle Rio Grande on life history and PCEs of critical habitat for the willow flycatcher.

Life History	Migration (April-June & July-September)	Arrival to Territories/ Territory Establishment/Nest Building (May-July)	Egg Laying/ Incubation/ Nestling/ Fledgling (June-August)
Breeding Season (April to September)	• The proposed action would have no effect on flycatcher stopover locations during migration due to the fact that the overall hydrological effects of these actions are	• The overall hydrological effects of these actions are neutral and affects to the flycatcher and its habitat are negligible. These actions should not decrease the	• Flycatchers during nesting are in their territories and less likely to abandon nests if conditions dry or decline in value.

	neutral and that flycatchers will use habitat that is less suitable during this time and farther away from water sources.	potential for overbank flooding and overall water availability for vegetation, and it should not cause a decline in territory recruitment and canopy cover/plant health/seed establishment.	• The offset program is not likely to have a measureable effect on the willow flycatcher.
Critical Habitat PCES			
Riparian Vegetation	• Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. These actions are expected to have a negligible effect on the critical habitat of the willow flycatcher.		
Insect Prey Populations	• A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the no action and the proposed action may affect, but are not likely to adversely affect the insect prey populations. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

3. Non-Discretionary State Actions to Administer Surface and Groundwater Resources in the Middle Rio Grande

Assuming 50 percent of total domestic well diversions return to the hydrologic system, the total impact on the river is a reduction of flow of about 9,150 AFY or about 12.6 cfs at the headwaters of Elephant Butte Reservoir. The expected impact at the Central gage is a reduction of flow of about 5,860 AFY or 8.0 cfs. This amount is insignificant and not measurable on the spring runoff. However, it may have minimal impact on the river during dry periods when MRGCD is not releasing water from storage.

The SE limits the pre-basin groundwater pumpers (including municipal and industrial uses) to the historic legal maximum amount. Total pre-basin groundwater pumping in the MRG (exclusive of 18,000 AF for ABCWUA) is about 15,000 AF. About 50 percent of this pumping is returned directly to the river, so the net impact of pre-basin pumping (exclusive of that by ABCWUA) on the river is about 7,500 AFY or about 10.4 cfs. This amount is insignificant and will not have any impact on the spring runoff; however, it may have minimal impact on the river during dry periods when MRGCD is not releasing water from storage. The hydrologic effects of the pre-basin pumpers in the MRG are in the whole minimal, as measured by the effects on the river. These activities have some beneficial or neutral effect on the willow flycatcher. These actions are not likely affect to adversely affect the willow flycatcher or its critical habitat (Table 10).

Table 10. Direct and indirect effects of non-discretionary state actions to administer surface and groundwater resources In the Middle Rio Grande on life history and PCEs of critical habitat for the willow flycatcher.

Life History	Migration (April-June & July-September)	Arrival to Territories/ Territory Establishment/Nest Building (May-July)	Egg Laying/ Incubation/ Nestling/ Fledgling (June-August)

• Breeding Season (April to September)	• The proposed action would have no effect on flycatcher stopover locations during migration due to the fact that flycatchers will use habitat that is less suitable during this time and farther away from water sources.	• These actions are not expected to decrease the potential of overbank flooding or decrease the overall water available for vegetation, and no decline in territory recruitment and canopy cover/plant health/seed establishment is expected.	• Flycatchers during nesting are in their territories and less likely to abandon nests if conditions dry or decline in value. • These actions are not likely to have a measureable effect on the willow flycatcher.
Critical Habitat PCES			
Riparian Vegetation	• Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. The State's actions , but will likely have a negligible effect on critical habitat of the willow flycatcher.		
Insect Prey Populations	• A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the no action and the proposed action may affect, but is not likely to adversely affect the insect prey populations. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

4. Discretionary State Actions to Administer Surface and Groundwater Resources in the Upper Rio Grande

In the URG the SE conjunctively manages surface water and groundwater to keep total depletion at or below the 1929 conditions. All depletions occurring as a result of transfer at the move-to location must be offset by a decrease in depletion at the move-from location, return flow, or releases of SJC Water. Therefore, the hydrologic effects of the State action approving transfers in the URG are in the whole neutral, as measured by the effects on the river at the Otowi gage. The three components of the offset program in the MRG include the return flow component, the letter water program, and transfer of senior water rights. These components are not likely to adversely affect the willow flycatcher and may have a small benefit by reducing flow depletions (Table 11).

Table 11. Direct and indirect effects of discretionary actions to administer surface and groundwater resources In the Middle Rio Grande on life history and PCEs of critical habitat for the willow flycatcher.

Life History	Migration (April-June & July-September)	Arrival to Territories/ Territory Establishment/Nest Building (May-July)	Egg Laying/ Incubation/ Nestling/ Fledgling (June-August)
Breeding Season (April to September)	• The proposed action would have no effect on flycatcher stopover locations during migration due to the fact that the overall hydrological effects of these actions are small and occur at the Otowi gage which is further	• The overall hydrological effects of these actions are neutral and affects to the flycatcher and its habitat are negligible. These actions should not decrease the potential for overbank flooding and overall water	• Flycatchers during nesting are in their territories and less likely to abandon nests if conditions dry or decline in value. • These actions are not likely to have a

	downstream.	availability for vegetation, and it should not cause a decline in territory recruitment and canopy cover/plant health/seed establishment.	measureable effect on the willow flycatcher.
Critical Habitat PCES			
Riparian Vegetation	• Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. These actions have a minimal effect on flows at the Otowi gage and are expected to have a negligible effect on the critical habitat of the willow flycatcher that is located further downstream.		
Insect Prey Populations	• A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the no action and the proposed action may affect, but are not likely to adversely affect the insect prey populations. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

5. Non-Discretionary State Actions to Administer Surface and Groundwater Resources in the Upper Rio Grande

The expected impact at Otowi gage is a reduction of flow of about 2,200 AFY or 3 cfs. This amount is insignificant and will not have any impact on the flow at Central gage and on the willow flycatcher and its critical habitat. The SE is expected to issue a similar number of domestic well permits for the next 20 to 30 years. The hydrologic effects of the domestic well uses are in the whole minimal, as measured by the effects on the river.

The SE limits the pre-basin groundwater pumpers (including municipal and industrial uses) to the historic legal maximum amount. It is estimated that the impact of the URG pre-basin pumping on the Rio Grande is 5 cfs. This impact occurs at the Otowi gage and is not likely to affect the flycatcher whose critical habitat and occupied habitat is further downstream (Table 12).

Table 12. Direct and indirect effects of discretionary actions to administer surface and groundwater resources In the Upper Rio Grande on life history and PCEs of critical habitat for the willow flycatcher.

Life History	Migration (April-June & July-September)	Arrival to Territories/ Territory Establishment/Nest Building (May-July)	Egg Laying/ Incubation/ Nestling/ Fledgling (June-August)
Breeding Season (April to September)	• The proposed action would have no effect on flycatcher stopover locations during migration due to the fact that the overall hydrological effects of these actions are small and occur at the Otowi gage which is further downstream.	• The overall hydrological effects of these actions are neutral and affects to the flycatcher and its habitat are negligible. • These actions should not decrease the potential for overbank flooding and overall water availability for vegetation, and it should not cause a decline in territory	• Flycatchers during nesting are in their territories and less likely to abandon nests if conditions dry or decline in value. • These actions are not likely to have a measureable effect on the willow flycatcher.

		recruitment and canopy cover/plant health/seed establishment.	
Critical Habitat PCES			
Riparian Vegetation	• Riparian habitat in a dynamic successional environment to be used for nesting, foraging, migration, dispersal and shelter. Dense tree or shrub vegetation in close proximity to open water or marsh areas. These actions have a minimal effect on flows at the Otowi gage and are expected to have a negligible effect on the critical habitat of the willow flycatcher that is located further downstream.		
Insect Prey Populations	• A variety of insect prey populations found in close proximity to riparian flood plains or moist environments. The minimal difference between the no action and the proposed action may affect, but are not likely to adversely affect the insect prey populations. It is also important to note that a dry river does not impact insect populations when ponded water and adjacent drains are present.		

6. Summary Effects of State Water Related Actions on the Southwestern Willow Flycatcher

Summary effects, in the context of a biological assessment, are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02).

- Current demand for water in the MRG outstrips supply. Municipal and industrial uses of water are increasing and because no new water is available, entities seeking water must acquire it from existing uses and transfer it to the proposed new uses.

- Estimates of the total amount of land currently irrigated within the MRGCD are between 50,000 and 65,000 acres, and the claims to the water are likely much greater than the actual amount of wet water, particularly during drought. . However, since only the consumptive use portion of the senior water right is allowed to be transferred, approximately two-thirds of the water currently needed to irrigate farms will remain in the system.

- The effects of all water transfers to offset the depletive effect of groundwater pumping to date have been minimal and are expected to be so in the future. Because return flows currently offset the vast majority of groundwater pumping impacts, the majority of offset is made contemporaneous with the impact of groundwater pumping on the river. If surface water rights transfers were not required, offsets would not occur for historic pumping and there would be less water in the river system which would have a negative impact on the species.

- In summary, the effects of the actions proposed by the State on the southwestern willow flycatcher are described in the analysis presented above. These effects equal about 32.9 cfs of depletions in the MRG, plus an estimated 10 cfs of additional depletion from other existing actions that have been taking place for many years prior to the defined action and whose effects are likely to continue into the future. These depletions are the worst possible case scenario, based on generally conservative assumptions, as they are not likely to occur simultaneously or at the same location. The State also proposes to continue a number of permitting activities that would result, and have been analyzed herein, in an additional 30 cfs of effect on the river in 20 to 30 years time. These cumulative effects may affect, but are not likely to adversely affect the flycatcher. The 32.9 cfs depletion in the MRG is computed as the sum of: senior water rights transfers to date = 13 cfs; letter water program = 1.5 cfs; domestic wells and livestock use = 8 cfs; and pre-basin groundwater pumping = 10.4 cfs.

Pecos Sunflower

The main population of Pecos sunflower presently exists within the La Joya State Wildlife Area (SWA), a unit of the Ladd S. Gordon Waterfowl Complex, managed by the New Mexico Game and Fish Department. The La Joya SWA was excluded from critical habitat designation for the species because of the development of a habitat management plan that adequately protects the species. In 2010, the population was extended to a ditch (cleared of tamarisk and seeded with Pecos sunflowers) that delivers water between ponds within the La Joya SWA.

The Pecos sunflower in the MRG is limited to only the areas described above within the La Joya SWA. The State's actions have little effect on the area occupied by the Pecos sunflower and on the canals that transfer water from ponds within the La Joya SWA. The State's actions will likely have no effect or minimal effect on the Pecos sunflower.

Interior Least Tern

The Interior least tern (tern) has been observed as a 'vagrant' or 'highly unusual' species amongst the avian species detected at the Bosque del Apache NWR since 1940 (Service 1995). Historically, tern nesting has been confirmed on reservoirs in Texas and in the Pecos River, but not in the MRG. A range-wide survey completed in 2005 showed that the Rio Grande/Pecos river systems collectively made up 0.8% of the population (Lott 2006). Given the very low occurrence of the tern in the MRG and the lack of evidence for historical nesting in the MRG, the State's actions will have no effect the Interior least tern.

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