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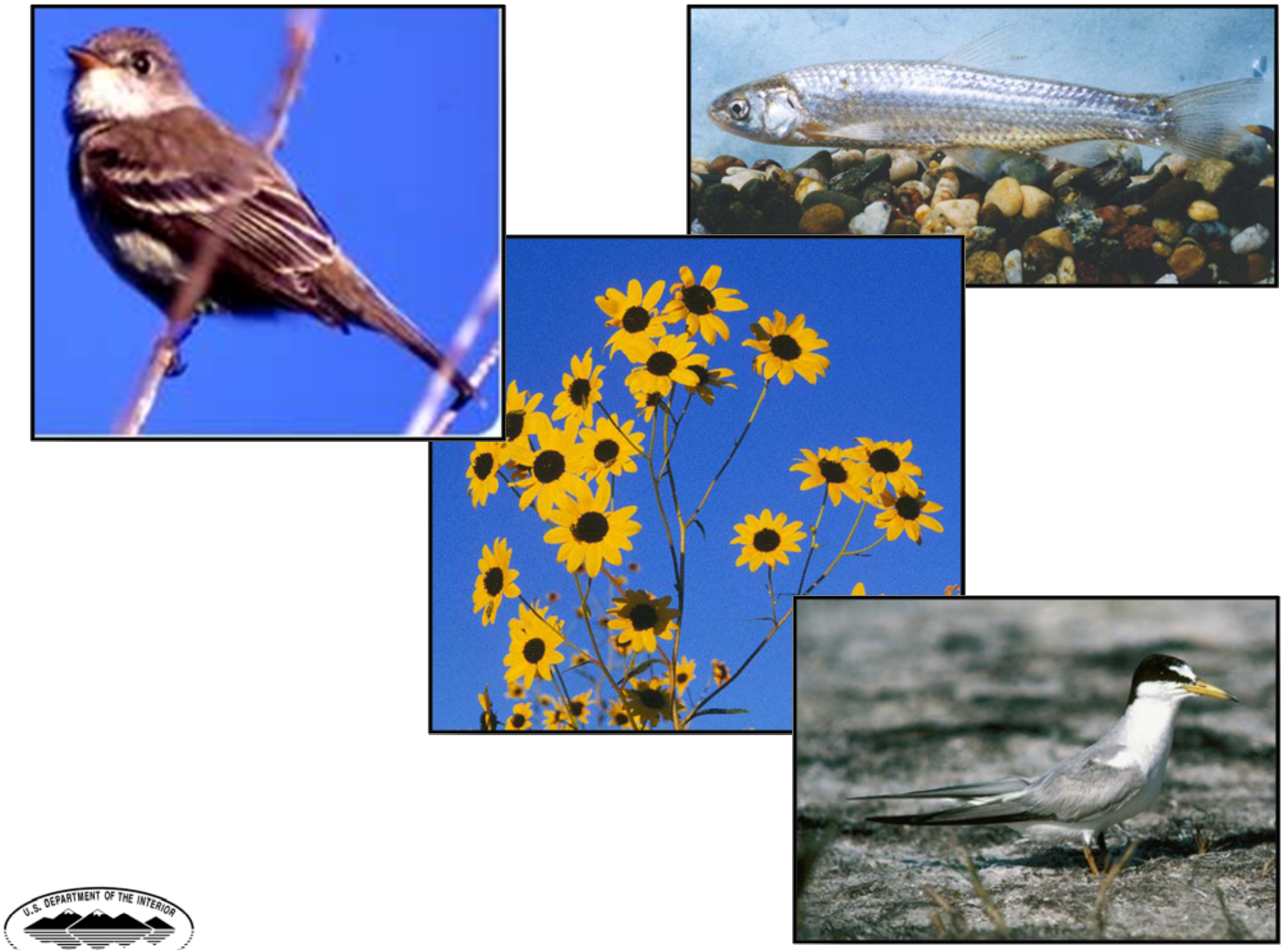
Managing Water in the West

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
Upper Colorado Region



U.S. Department of the Interior
Bureau of Reclamation

July 2012

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
Upper Colorado Region

Submitted to the U.S. Fish and Wildlife Service

Rio Grande Silvery Minnow

Pecos Sunflower

Southwestern Willow Flycatcher

Interior Least Tern

U.S. Department of the Interior
Bureau of Reclamation
Albuquerque Area Office
Albuquerque, New Mexico

July 2012

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

Contents

Attachments

Tables

Tables (continued)

Tables (continued)

Figures

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

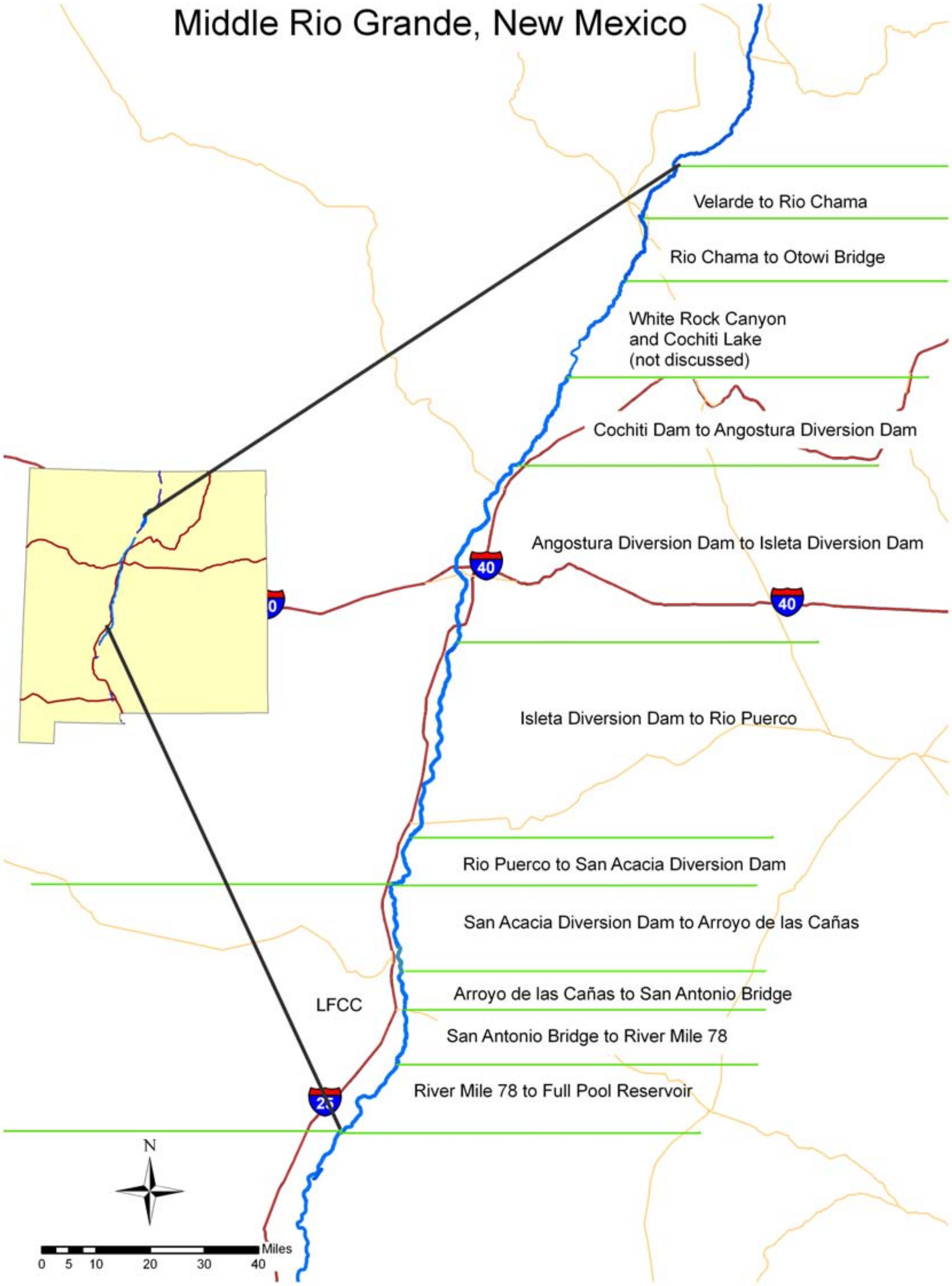


Figure 1. Geomorphic reach designation.

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). 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 top of slope on the western edge of the LFCC channel 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. 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 slope of LFCC channel 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.

- **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,

Table19. Historical River Maintenance Work: Velarde to Rio Chama Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
La Canova (2005)	1	**New Site** – Project undertaken to stop bank line erosion on west bank that threatened integrity of irrigation facility.	Longitudinal stone toe with bioengineering, riparian vegetation establishment	Bank line work, material placement	0.2	0.3	1.22	3 months (wet)	0.2 acre of bioengineered bank line (inherent part of design).	• Native vegetation has become established. • Design functioning as intended.
Lyden Outfall Structure (2007)	2	**New Site** – Project undertaken to address localized bank erosion at irrigation outfall (Reclamation constructed) that threatened to flank existing concrete structure.	Longitudinal stone toe with gabion basket revetment	Bank line work, material placement	0.2	2.5	0.03	1 month (wet)	None.	• Design functioning as intended.
Salazar Pit (2005)	3	**New Site** – Project undertaken to address gully formation in an arroyo where there had been a pre-existing Reclamation rock quarry. Project was not on the MRG.	Gabion basket weirs	N/A – work was done out of MRG corridor on dry land	2.8	0.5	N/A	7 months (dry)	None.	• Large rainfall event in 2006 caused damage to tops of constructed gabion weirs. • Some concern that original design did not provide adequate bank reinforcement in some areas.
Salazar Pit (2007)	4	**Adaptive Management** – Project undertaken to correct damage and address observed concerns to original design (2005) that were observed as a result of the 2006 monsoonal events.	Gabion basket weirs	N/A – work was done out of MRG corridor on dry land	2.8	0.5	N/A	6 weeks (dry)	None.	• Design functioning as intended after adaptive management.

Table 20. Historical River Maintenance Work: Rio Chama to Otowi Bridge Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
San Ildefonso (2007)	5	**New Site** – Project undertaken to address bank erosion due to lateral migration of a river bend that threatened integrity of a fishing pond.	Riparian vegetation establishment, diagonal vane, trench-filled bendway weirs	N/A – work was done out of the MRG active channel on dry land.	0.7	0.9	N/A	1 month (dry)	Planted tree poles (project mitigation).	• Localized scour in bend undercut bank vegetation during 2009 spring runoff.. • Bank erosion exposed three trench-filled bendway weirs, threatening to flank the northern ones. • Exposed portions of diagonal vane were directing flow into the bank. • Lost about quarter of planted poles from bank erosion.
San Ildefonso (2010)	6	**Adaptive Management** – Project undertaken to correct damage and address observed concerns to original design (2007) that were observed as a result of the 2009 spring runoff. This was an interim fix to provide time to plan and coordinate a longer term solution.	Trench-filled riprap, riprap windrow.	N/A – work was done out of the MRG active channel on dry land.	0.7	0.9	N/A	2 months (dry)		• Design functioning as intended after adaptive management. • Bank erosion continues but has not yet caused self-launching of the riprap windrow. • Secondary currents have created scallop areas between the weirs in the bank that have variable depth and velocity areas.

Table 21. Historical River Maintenance Work: Cochiti Dam to Angostura Diversion Dam Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
Santa Fe River Confluence (2004)	7	**New Site** – Project undertaken to address bank erosion south of the confluence with the Santa Fe River that threatened the integrity of a spoil berm protecting a drain facility.	Infrastructure setback, longitudinal bank lowering, riprap revetment, riparian vegetation establishment.	N/A – work was done out of the MRG active channel on dry land.	Used existing roads	3.0	N/A	5 weeks (dry)	Reconnection of flood plain to river (1.6 acres), and native species planting (1.6 acres) (both inherent part of design).	• Design functioning as intended. • Planted vegetation slow to establish.
Cochiti RM 228.9 (2007–2008)	8	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Island and bank clearing and destabilization, side channels, longitudinal bank lowering, bank line embayment (backwater area), longitudinal stone toe with bioengineering, riparian vegetation establishment.	River diversion, river reconnection, river crossings, river work, material placement.	0.4	1.0	1.9	7 months (wet)	Backwater area (3.0 acres), secondary channel network (3.5 acres), bioengineered bank line (0.1 acre), and natural reseeding at site (all inherent part of design).	• Longitudinal stone toe with bioengineering functioning as intended. • Native riparian vegetation in backwater area is coming in well naturally. • Side channel constructed through destabilized island has widened considerably and created riffles, runs, and an inset flood plain within the historical abandoned flood plain. • Planted vegetation slow to establish.
Cochiti RM 231.3 (2007–2008)	9	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Side channels, jetty removal, longitudinal stone toe with bioengineering, infrastructure setback (road), French drain, riparian vegetation establishment	River diversion, river reconnection, river work, material placement, material removal	2.8	0.5	2.3	7 months (wet)	0.6 acre of bioengineered bank line, and natural reseeding at site (both inherent part of design)	• Longitudinal stone toe with bioengineering functioning, but elevation to overtop stone toe is greater than design. • Planted vegetation doing exceptionally well. • French drain functioning as intended
San Felipe RM 213.4 (2010–2011)	10	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Longitudinal stone toe with bioengineering, riparian vegetation establishment	River diversion, working platform, material placement	0.9	9.0	2.4	9 months (wet)	Bioengineered bank (0.4 acre) – inherent part of design.	• Design functioning as intended • Planted vegetation slow to establish

Table 21. Historical River Maintenance Work: Cochiti Dam to Angostura Diversion Dam Reach (2001–2012 work) (continued)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
San Felipe RM 213.7 (2010–2011)	11	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting an irrigation facility.	Longitudinal stone toe with bioengineering, riparian vegetation establishment.	River diversion, working platform, material placement.	0.9	9.0	2.5	9 months (wet)	Bioengineered bank (0.5 acre), and willow trench (0.1 acre) — inherent part of design.	• Design functioning as intended • Bioengineering vegetation slow to establish. • Trench vegetation dong well.
San Felipe RM 212.0 (2011–2012)	12	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Island and bank clearing and destabilization, riprap revetment, longitudinal stone toe with bioengineering, riparian vegetation establishment.	River reconnection, river crossings, working platforms, bank line work, river work, material placement, material removal.	2.3	16.5	5.3	12 months (wet)	Bioengineered bank (0.8 acre); inherent part of design.	• Design functioning as intended. • Multiple flow paths observed where portion of midchannel bar was removed.
San Felipe Phase 1 Mitigation Sites (2010–2012)	13	**New Site** – Project required as mitigation for San Felipe Phase 1 project construction (RM 213.4, RM 213.7, RM 212.0, and RM 215.5)	Island and bank clearing and destabilization, bank line embayment (backwater area), side channels destabilization, riparian vegetation establishment.	River crossings, material placement.	2.3	18.0	0.7	1 month (wet), 3 months(dry)	Five high-flow backwater areas (2.9 acres), connection bar (0.7 acre), flow through channel (1.1 acres). All featured were part of project mitigation.	• Design functioning as intended; no high spring runoff flows since project completion; • Established side channel has ground water connection to river that allows channel to flow without direct upstream connection.
San Felipe RM 215.5 (2011–2012)	14	**New Site** – Project undertaken to address development of alternating thalweg pattern and channel narrowing from vegetation encroachment that has the potential to cause bank erosion threatening the integrity of a road and nearby houses in the village of San Felipe.	Island and bank clearing and destabilization.	River crossings, river work, material removal.	0.8	12.1	2.4	2 months (wet)	0.2 acres of willow trench; inherent part of design.	• Design being amended to only include bar removal. • Bar removal expected to be short term.

Table 22. Historical River Maintenance Work: Angostura Diversion Dam to Isleta Diversion Dam Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
Santa Ana Restoration Phase 1 (2000–2001)	15	**New Site** – Phase 1 of a project undertaken to address bank erosion and channel incision that threatened the integrity of a spoil berm protecting a drain facility.	Channel relocation using pilot channel, longitudinal dikes, jetty removal, longitudinal stone toe with bioengineering, gradient restoration facility, sediment augmentation.	River diversion, river reconnection, dewatering, river crossings, river work, material removal, material placement	2.0	5.5	62	16 months (wet)	0.6 acre of bioengineering bank line (inherent part of design).	• Gradient restoration facility and longitudinal stone toe with bioengineering functioning as designed • Potential for flanking of gradient restoration facilities (GRF) on west bank observed after the 2005 spring runoff. • Potential for flanking of GRF on east bank observed after the 2010 spring runoff. • Spoil pile from pilot channel was not removed by natural flows as per original designs. • Planted vegetation doing exceptionally well. • Potential for flanking of stone toe with bioengineering bank line protecting south bank of Jemez River at confluence with Rio Grande observed after the 2005 spring runoff.
Santa Ana Restoration Phase 2 (2002)	16	**New Site** – Phase 2 of a project undertaken to address bank erosion and channel incision that threatened the integrity of a spoil berm protecting a drain facility.	Bank line embayment (backwater area), longitudinal bank lowering, riparian vegetation establishment.	N/A – work was done out of the MRG active channel on dry land.	0.8	47.5	2.4	4 months (dry)	0.8 acre of backwater areas; 45 acres of flood plain reconnection (inherent part of design).	• Backwater areas had deposition at mouths and lacked drainage back to river. • Portions of the riparian vegetation were eroded from the 2005 spring runoff.
Santa Ana Restoration Phase 2 (2004–2005)	17	**Adaptive Management** – Project undertaken to correct damage and address observed concerns to backwater area drainage from Phase 2 and natural spoil pile removal.	Bank line embayment (backwater area), riparian revegetation, sediment augmentation.	N/A – work was done out of the MRG active channel on dry land.	2.0	5.5	10.5	4 months (dry)	Backwater areas planted with coyote willows (inherent part of design)	• Backwater areas were inundated during 2005 and subsequent spring runoff years. This brought in silt/clay material that deposited . • Deposition has occurred at mouth of backwater areas. • Backwater areas functioning as intended after adaptive management. • Planted vegetation doing exceptionally well in backwater areas. • Spoil pile management during 2005 spring runoff saw a portion of the sediment eroded, but significant amounts remained. Sediment appear to have deposited downstream and caused additional bank erosion.

Table 22. Historical River Maintenance Work: Angostura Diversion Dam to Isleta Diversion Dam Reach (2001–2012 work) (continued)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
Santa Ana Restoration Phase 3 (2007 and 2009)	18	**Adaptive Management** – Project undertaken to correct damage and address observed concerns to Phase 1 project that were observed as a result of the 2005 spring runoff and to remove the portion of the spoil pile that remained on Pueblo of Santa Ana land. Project also addressed bank erosion observed as a result of depositing sediment from 2005 spoil pile management. Also constructed a third backwater area.	Bank line embayment, backwater area, longitudinal bank lowering, trench-filled bendway weirs, riparian vegetation establishment.	River diversion, river reconnection, river crossings, material placement.	0.8	2.5	8.8	8 months (wet)	0.6 acre of backwater areas, 20 acres flood plain reconnection to river, and 0.4 acre of native species vegetation plantings (all are inherent part of design).	• Increased inundation of flood plain observed during the 2010 spring runoff as a result of the spoil pile removal. • Areas repaired functioning as designed. • Bank erosion area that was restored is functioning as designed. • Planted vegetation doing well. • Constructed backwater area doing well.
Santa Ana Restoration, GRF 1 Repair (2012)	19	**Adaptive Management** – Project undertaken to correct damage and address observed concerns to Phase 1 project that were observed as a result of the 2010 spring runoff	Longitudinal stone toe with bioengineering, riparian vegetation establishment.	Partial excavation of bank, bank line work, material placement.	1.2	1.3	6.2	2 months (wet)	Riparian planting on flood plain, and bioengineering planting –both are inherent part of design.	• Planted vegetation doing well
Las Huertas Creek (2002)	20	**New Site** – Project undertaken to address bank erosion on east bank of Rio Grande and south bank of Las Huertas Creek that threatened local landowner holdings. Project done as mitigation for landowner allowing access for Santa Ana projects.	Riprap revetment, riparian vegetation establishment.	Bank line work, material placement, material removal.	1.1	8	0.2	2 months (wet)	None.	• Design functioning as intended. • Planted vegetation doing well.
Bernalillo (2006–2007)	21	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Island and bank clearing and destabilization, side channels, longitudinal bank lowering, jetty removal, riparian vegetation establishment, trench-filled bendway weirs rootwads,	River diversion, river reconnection, river crossings, river work, material placement, material removal.	3.1	0.9	6.3	7 months (wet)	2 acres of secondary channel, 1.1 acres of vegetation planting, 3.8 acres of flood plain lowering and riparian habitat (All are inherent part of design).	• Bendway weir design functioning as intended. • Some of the bendway weirs have been exposed. • Secondary currents have created scallop areas between the exposed bendway weirs in the bank that have variable depth and velocity areas. • Side channels have filled in and function as high-flow channels. • Planted vegetation doing well. • Some native vegetation recruitment.

Table 22. Historical River Maintenance Work: Angostura Diversion Dam to Isleta Diversion Dam Reach (2001–2012 work) (continued)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
Sandia (2002)	22	**Interim Work** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility. This was an interim fix to provide time to plan and coordinate a longer term solution	Riprap windrow	N/A – work was done out of the MRG active channel on dry land.	0.8	1.6	N/A	2 months (dry)	None.	• Long-term project constructed before riprap windrow self-launched. • Riprap windrow removed as part of 2007–2008 Sandia project.
Sandia (2007–2008)	23	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Island and bank clearing and destabilization, bank line embayment (backwater area), side channels, longitudinal bank lowering, jetty removal, riparian vegetation establishment, trench-filled bendway weirs, rootwads,	River diversion, river reconnection, river crossings, river work, material placement, material removal.	0.8	1.6	9.1	14 months (wet)	0.65 acre - two backwater areas; 3.5 acres of secondary channels and bank lowering and vegetation planting areas (all are inherent part of design).	• Design discharge for crest height of weirs has increased due to incision. Bendway weirs still appear to be functioning as designed. • Some of the bendway weirs have been exposed. • Secondary currents have created scallop areas between the exposed bendway weirs in the bank that have variable depth and velocity areas. • Some of the exposed weirs have extensive scalloping that, if it continues, may have the potential to cause flanking. • Erosion at upstream and downstream ends that has the potential to flank rootwad bank protection. • Side channels have filled in and function as high-flow channels. • Backwater areas have filled in and require a higher discharge to inundate. • Planted vegetation doing well. • Native vegetation recruitment is high in backwater areas.

Table 23. Historical River Maintenance Work: Rio Puerco to San Acacia Diversion Dam Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
Drain Unit 7 (2005)	24	**Unanticipated Work** – Project undertaken to address bank erosion observed during the 2005 spring runoff that threatened the integrity of a spoil berm protecting an irrigation facility.	Riprap revetment.	Bank line work, material placement.	5.5	0.5	0.5	1 month (wet)	None.	• Placed riprap held bank line during 2005 spring runoff. • Additional bank erosion upstream of the 2005 bank erosion was observed during the 2007 spring runoff.
Drain Unit 7 (2007)	25	**Unanticipated Work** – Project undertaken to address bank erosion observed during the 2007 spring runoff that threatened the integrity of a spoil berm protecting an irrigation facility.	Riprap revetment.	Bank line work, material placement.	5.5	0.5	N/A	1 week (dry)	None.	• Placed riprap held bank line during 2007 spring runoff.
Drain Unit 7 (2009)	26	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting an irrigation facility.	Riprap revetment, riprap windrow, riparian vegetation establishment.	Working platform, material placement.	5.5	3.8	1.0	4 months (wet)	0.04 acre of trench planting and 0.1 acre of soil choked riprap planting (project mitigation).	• Design functioning as intended. • Vegetation cleared to allow project to proceed has returned and is doing well. • Vegetation on banks has done well in areas where maintenance is not an issue. • Planted vegetation has not been successful due to high water levels associated with checking up the water at the San Acacia Diversion Dam during irrigation season and from San Acacia Diversion Dam maintenance activities.

Table 24. Historical River Maintenance Work: San Acacia Diversion Dam to Arroyo de las Cañas Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
San Acacia RM 113/114 (2005–2007)	27	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting the LFCC.	Infrastructure setback jetty removal, riparian vegetation establishment, steel sheet pile grade control (on arroyo), sediment augmentation.	N/A – work was done out of the MRG active channel on dry land.	12.0	12.6	9 (in LFCC)	12 months (dry)	187 acres of widening of river corridor (inherent part of design); 27 acres of native species planting; and 4 acres of environmental feature establishment (the last two were project mitigation).	• Design functioning as intended. • Bank erosion has been allowed to proceed. • San Lorenzo Arroyo has re-connected to the Rio Grande, bringing in additional sediment. • Planted native vegetation is doing okay, still sparse groundcover. • Some exotic vegetation control is still needed, especially saltcedar.
San Acacia RM 111 (2006)	28	**Interim Work** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting the LFCC. This was an interim fix to provide time to plan and coordinate a longer term solution.	Riprap windrow.	N/A – work was done out of the MRG active channel on dry land.	2.8	1.5	N/A	7 weeks (dry)	None.	• Long term project constructed before riprap windrow self-launched. • Riprap windrow removed as part of 2007–2009 San Acacia RM 111 project.
San Acacia RM 111 (2007–2009)	29	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting the LFCC.	Infrastructure setback, riparian vegetation establishment.	N/A – work was done out of the MRG active channel on dry land.	7.9	7.2	6.4 (in LFCC)	12 months (dry)	59 acres of widening of river corridor (inherent part of design), and 1.8 acres of environmental feature establishment (project mitigation).	• Design functioning as intended. • Bank erosion has been allowed to proceed. • Planted native vegetation is doing okay, still sparse groundcover.
Arroyo de la Parida (2004)	30	**New Site** – Project undertaken to address bank erosion as a result of sediment from the Arroyo de la Parida pushing Rio Grande flows towards the west bank. The erosion threatened the integrity of sedimentation structure within the LFCC temporary outfall.	None.	Material removal (removal of sedimentation structure).	Used O&M roads	0.5	0.2 (in LFCC)	1 month (dry)	None.	• Erosion allowed to proceed with monitoring. • LFCC temporary outfall structure operational without sedimentation structure.

Table 25. Historical River Maintenance Work: San Antonio Bridge to River Mile 78 Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
BDA Channel widening (2003)	31	**New Site** – Project undertaken to provide mitigation (channel widening in a section of the MRG through BDANWR) for the 2000 Temporary Channel project.	Channel relocation using pilot cut, island and bank clearing and destabilization.	River diversion, river reconnection, river crossings.	1.4	67.5	20.7	8 months (wet)	Widened river corridor (inherent part of design).	• Design functioned as intended. • Channel widened from 150 feet to around 600 feet, majority during the 2005 spring runoff.
BDA Sediment Plug (2008)	32	**New Site** – Project undertaken to reconnect portions of the MRG separated by a sediment plug in order to facilitate delivery of water.	Pilot cut through sediment plug.	River reconnection, bank line work, river work.	0.6	13.3	7.3	6 weeks (wet)	None.	• Design functioned as intended: river widened pilot cut channel to presediment plug channel width. • Sediment continuity restored.
BDA Levee (2009–2010)	33	**Adaptive Management** – Project undertaken to strengthen existing levee (raising and widening) to provide ability to pass design capacity flows.	Levee strengthening.	N/A – work was done out of the MRG active channel on dry land.	18.0	1.0	N/A	15 months (dry)	None.	• Design is functioning as intended.
BDA Levee (2012)	34	**Adaptive Management** – Project undertaken to strengthen existing levee (widening) to provide ability to pass design capacity flows.. Widening stretch of BDA levee north of the BDANWR that wasn't widened in 2009–2010.	Levee strengthening.	N/A – work was done out of the MRG active channel on dry land.	4.0	1.0	N/A	2 months (dry)	None.	• Design is functioning as intended.

Table 26. Historical River Maintenance Work: River Mile 78 to Full Pool Elephant Butte Reservoir Level Reach (2001–2012 work)

Project Name	Site Number (See Figure 4)	Project Type and Purpose	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created	Observations
Tiffany Sediment Plug (2005)	35	**New Site** – Project undertaken to reconnect portions of the MRG separated by a sediment plug in order to facilitate delivery of water.	Pilot cut through sediment plug.	River reconnection.	0	7.3	N/A	9 weeks (dry)	None.	• Design functioned as intended: majority of river widened pilot cut channel to presediment plug channel width. • Some portions of river did not widen out and spoil berms from pilot channel were left in place.
Tiffany Levee (2005)	36	**Unanticipated Work** – Project undertaken to strengthen existing levee (raising and widening) to address concerns about levee seepage problems and levee cracks caused by 2005 spring runoff flows.	Levee strengthening.	N/A – work was done out of the MRG active channel on dry land.	4.0	1.0	N/A	2 months (dry)	None.	• Design is functioning as intended.
San Marcial Levee (2005)	37	**Unanticipated Work** – Project undertaken to repair levee breaches on access road between San Marcial Railroad Bridge and the San Marcial Levee and to strengthen existing levee (raising and widening) to address concerns about levee seepage problems and levee cracks caused by 2005 spring runoff flows	Levee strengthening.	N/A – work was done out of the MRG active channel on dry land.	2.0	1.0	N/A	1 months (wet)	None.	• Design is functioning as intended.
Fort Craig Bend (2011)	38	**Interim Work** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting the LFCC. This is an interim fix to provide time to plan and coordinate a longer term solution.	Riprap windrow, riparian vegetation establishment.	N/A – work was done out of the MRG active channel on dry land.	3.6	Used riprap stock pile as staging area	N/A	3 months (dry)	Vegetation planting (project mitigation).	• Riprap windrow has not self-launched yet. • Project mitigation is still in planning phase.

Table 27. Anticipated River Maintenance Work: Rio Chama to Otowi Bridge Reach (2012–2013 work)

Project Name	Description	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created
San Ildefonso (2013)	**Adaptive Management** – Project undertaken to correct damage and address observed concerns to original design (2007) that were observed as a result of the 2009 spring runoff. This is the longer term solution.	To be determined (TBD) – Methods within channel modification and bank protection/stabilization categories	TBD.	0.7	0.9	1.2 (estimated)	4 months (wet) (estimated)	To be determined (project mitigation and inherent part of design)

Table 28. Anticipated River Maintenance Work: Angostura Diversion Dam to Isleta Diversion Dam Reach (2012–2013 work)

Project Name	Description	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created
Santa Ana RM 205.8 (2013)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	TBD - Methods within channel modification and bank protection/stabilization categories.	TBD.	0.2 acre (estimated)	3.0 (estimated)	2.5 acres (estimated)	3 months (wet) (estimated)	TBD

Table 29. Anticipated River Maintenance Work: Cochiti Dam to Angostura Diversion Dam Reach (2012–2013 work)

Project Name	Description	River Maintenance Methods	Construction Techniques (Method Category BMPs)	Access Roads (Acres)	Project Impact Area in the Dry (Acres)	Project Impact in the Wet (Acres)	Project Duration	Habitat Features Created
Santo Domingo RM 225.1 (2012–2013)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Longitudinal bank lowering , trench filled riprap, riparian vegetation establishment.	River crossings (mob/demob).	3.1	0.5	N/A	2 months (dry) (estimated)	Increased area of inundation (inherent part of design).
Galisteo Creek (RM 224.6) (2012–2013)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Island and bank clearing and destabilization, jetty removal, longitudinal stone toe with bio-engineering, bendway weirs, riparian vegetation establishment.	River crossings (mob/demob), bank line work, river work, material placement, material removal.	0.4	1.0	3.2	4 months (wet) (estimated)	Bioengineered bank line, (inherent part of design).
Santo Domingo RM 223.9 (2012–2013)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	Channel reconstruction, island and bank clearing and destabilization, bank line embayment (backwater area), jetty removal, riprap revetment, longitudinal stone toe with bioengineering, riparian vegetation establishment.	River diversion, river reconnection, river crossings, bank line work, river work, material placement, material removal.	1.4	2.5	3.3	8 months (wet) (estimated)	Bioengineered bank line and 1.1 acres of backwater areas (inherent part of design).
San Felipe Phase 2: RM 214.4 (2013–2014)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	TBD – Methods within channel modification and bank protection/stabilization categories.	TBD.	1 (estimate per project)	8 (estimate per project)	7 (estimate per project)	24 months (wet) (estimated)	TBD.
San Felipe Phase 2: RM 210.3 (2013–2014)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	TBD – Methods within channel modification and bank protection/stabilization categories.	TBD.	1 (estimate per project)	8 (estimate per project)	7 (estimate per project)	24 months (wet) (estimated)	TBD.
San Felipe Phase 2: RM 210.0 (2013–2014)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	TBD – Methods within channel modification and bank protection/stabilization categories.	TBD.	1 (estimate per project)	8 (estimate per project)	7 (estimate per project)	24 months (wet) (estimated)	TBD.
San Felipe Phase 2: RM 210.1 (2013–2014)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	TBD – Methods within channel modification and bank protection/stabilization categories.	TBD.	1 (estimate per project)	8 (estimate per project)	7 (estimate per project)	24 months (wet) (estimated)	TBD..
San Felipe Phase 2: RM 211.3 (2013–2014)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	TBD – Methods within channel modification and bank protection/stabilization categorie.s	TBD.	1 (estimate per project)	8 (estimate per project)	7 (estimate per project)	24 months (wet) (estimated)	TBD
San Felipe Phase 2: RM 212.8 (2013–2014)	**New Site** – Project undertaken to address bank erosion that threatened the integrity of a spoil berm protecting a drain facility.	TBD – Methods within channel modification and bank protection/stabilization categories.	TBD.	1 (estimate per project)	8 (estimate per project)	7 (estimate per project)	24 months (wet) (estimated)	TBD.

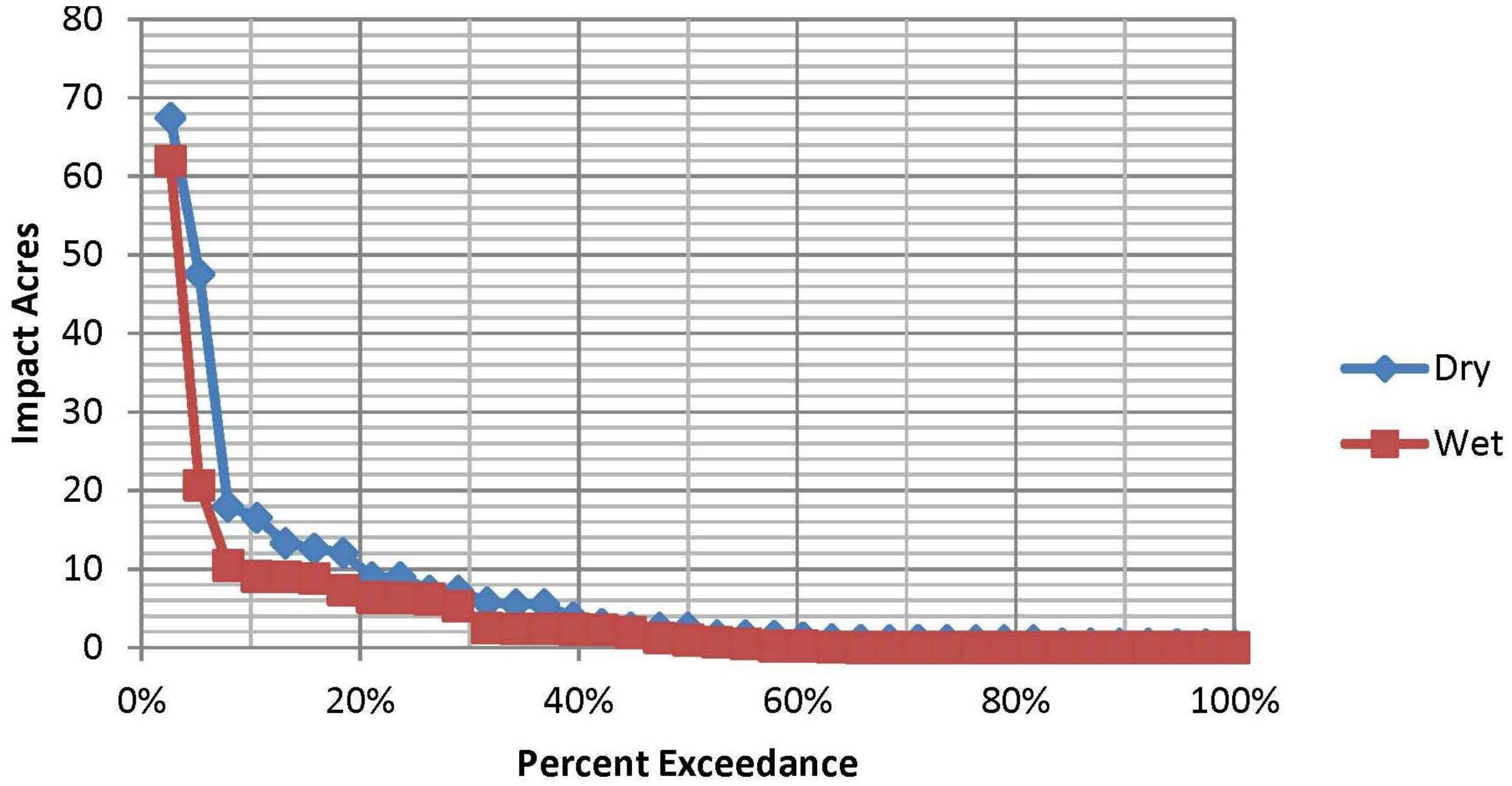


Figure 3. Percent exceedance curves for river maintenance project footprint impacts (2001–2012).

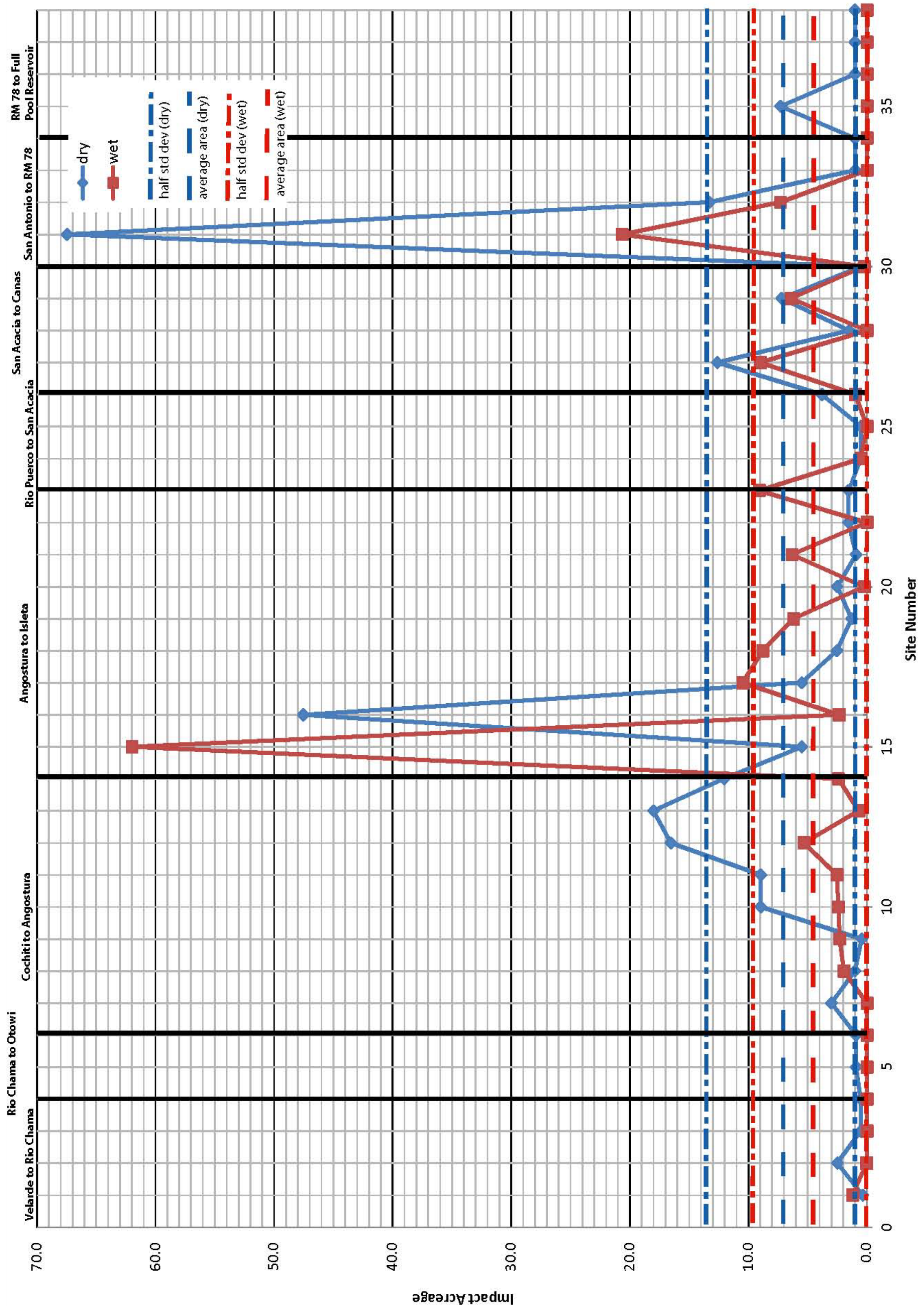


Figure 4. River maintenance project area by reach (2001–2012)

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:

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[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

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[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; maintaining 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, depending 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 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 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 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.	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. Preventing the formation of isolated pools decreases the likelihood 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.

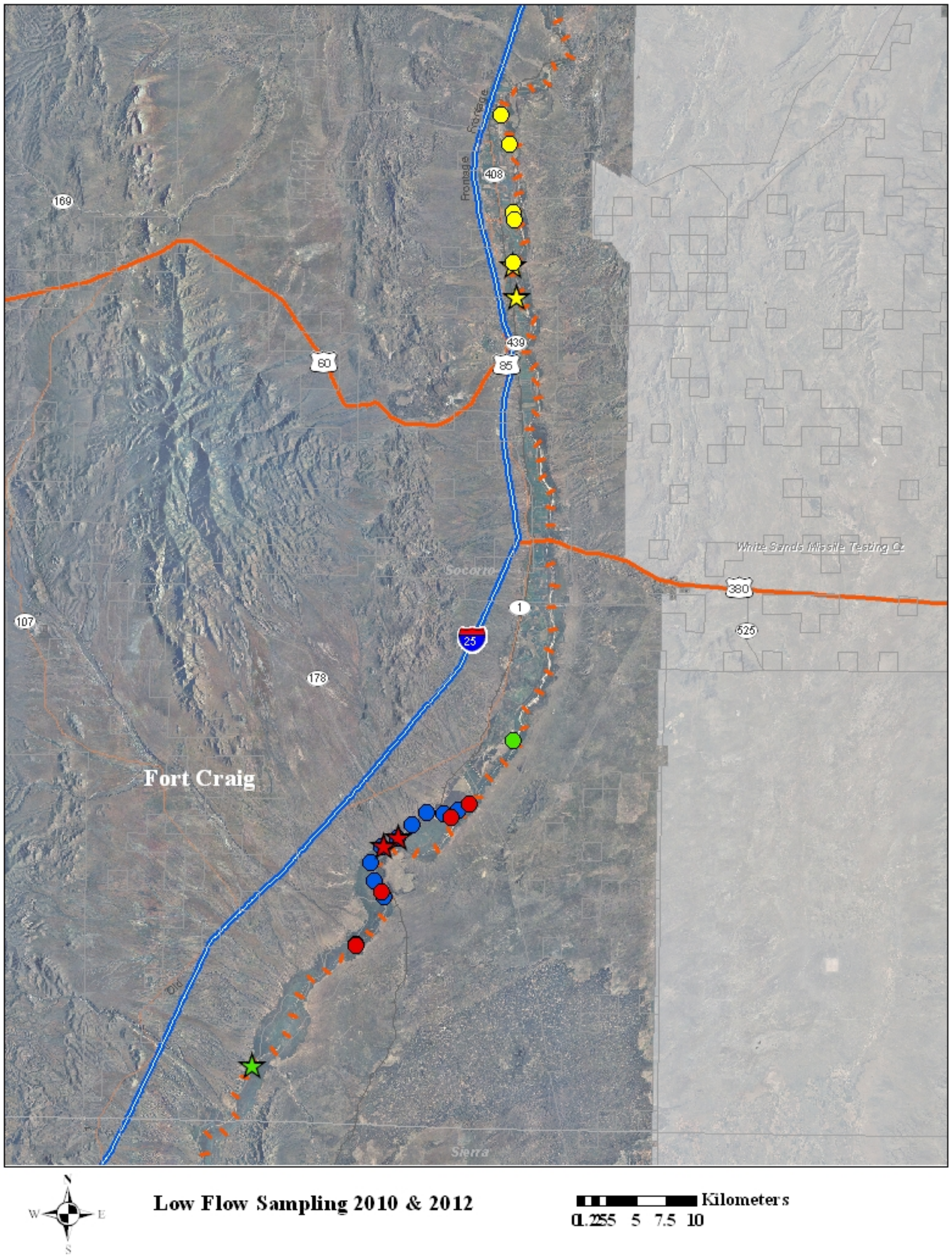

Figure 5. Presence/absence of silvery minnow at LFCC sites in 2010 and 2012. Stars indicate silvery minnow present at site. Green – February 2010, Yellow – March 2010, Red – September 2010, Blue – February 2012.

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

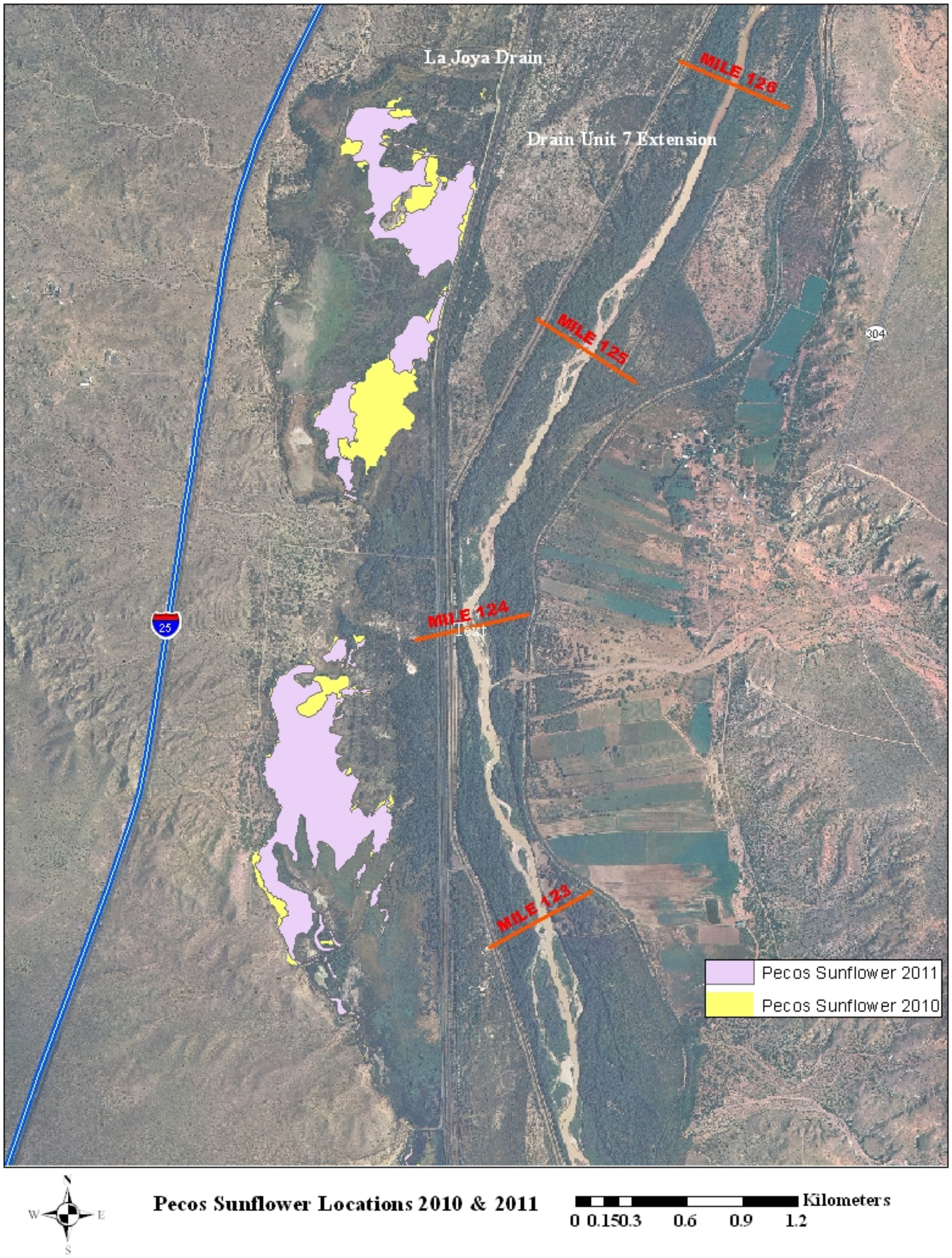

Figure 6. Extant of area occupied by Pecos sunflower on La Joya State Wildlife Management Area.

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.