APPENDIX A

Potential Actions for Reasonable and Prudent Alternatives, Reasonable and Prudent Measures, or Conservation Recommendations.

A. Introduction

Reclamation has identified a number of discretionary actions that assist with protection, conservation and/or recovery of the listed species. Reclamation has been conducting many of these activities over the past several years as part of its ESA, Section 7(a)(1), responsibilities. Included in these actions is Reclamation's acquisition and release of available supplemental water and pumping of water from the Low Flow Conveyance Channel (LFCC) to the river. Reclamation would consider continuing to participate, along with other partners, in implementing the following actions, subject to funding. The actions described in this Appendix could be used as elements of a reasonable and prudent alternative (RPA) to the proposed action, as reasonable and prudent measures to reduce any incidental take associated with the proposed action, or to promote conservation and recovery of listed species pursuant to Section 7(a)(1). Actions identified and selected for implementation would be accomplished during the time of this BA.

Any RPA to avoid jeopardy must be consistent with the intended purpose of the action, implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, and must be economically and technically feasible.

B. Supplemental Water Program

Reclamation has developed a program to lease water and work cooperatively with downstream water users to enhance Rio Grande flows. When Reclamation leases San Juan-Chama water from willing contractors, that water is subject to the limits of the Project's authorizing legislation, state law, and relevant compacts. Because of limitations on authorized uses of Project water imposed by these laws, e.g., San Juan-Chama Project water must be put to beneficial consumptive use within the State of New Mexico, Reclamation considers the cooperation of downstream users essential to the success of its supplemental water program. MRGCD cooperates in this conservation activity by using the water leased by Reclamation and, in return, bypassing an equal amount of native Rio Grande flow at downstream diversion facilities.

Leasing available supplemental water is contingent on the availability of water from willing sellers. Reclamation expects to be able to lease only up to 15,000 acre-feet of supplemental water in 2003. Because of court-ordered mediation for the *Minnow v. Keys* litigation in 2000, Reclamation has an outstanding commitment to repay the City of Albuquerque 15,000 acre-feet of water by the year 2014. Leased water could be used for repayment purposes after 2003 and to provide additional flows in the Middle Rio Grande to enhance aquatic habitat and benefit silvery minnow. Reclamation will continue to seek out and negotiate with willing sellers as sources of additional water for the future, although no minimum quantity of supplemental water can be guaranteed. Over the long term, and in cooperation with water users, the Federal agencies will consider implementing a water acquisition program that may involve elements of water use forbearance and water banking.

A critical component of the supplemental water program is the ongoing water operations inter-agency coordination process. A key to the success of water operations since 1996 has been the weekly, often daily, communications that developed between Reclamation, the Corps, the Service, MRGCD, the State of New Mexico, and other parties during the irrigation season. This process involves meetings, conference calls, and information exchange. This process is fully integrated with the Annual Operating Plan process described in the Description of Proposed Actions section.

C. Low Flow Conveyance Channel Pumping

As a result of court-ordered mediation in 2000, Reclamation has acquired and installed pumps along the LFCC with a total capacity sufficient to move a maintainable minimum combined flow of 75 to 100 cfs from the LFCC to the river at points below San Acacia Diversion Dam to Elephant Butte. During emergencies, it is possible that Reclamation could move up to an additional 50 cfs to the Rio Grande. The actual output of the LFCC pumps depends on the availability of water in the river and in the LFCC itself. Fifteen pumps are currently available to supplement flows in the mainstem of the river and fill depressions in river flow that are observed moving downstream during the irrigation season. Pumping is also used to manage river recession during dry periods. Permanent pumping facilities could also be installed, subject to available funding.

Potential pumping locations include Neil Cupp, north boundary of the Bosque del Apache National Wildlife Refuge, south boundary of the refuge, the Tiffany area, and Ft. Craig. Depending on how the river responds to pumping operations, some pumps could be moved at least once to maximize the benefits of increased flow on aquatic habitat.

Flows from the LFCC within the Elephant Butte Reservoir pool seep from the channel and create moist and wetted soil conditions conducive to breeding flycatcher from nest initiation in May through fledging in late August. Flows vary throughout the summer depending on the water usage, upstream diversions and recapture of agricultural drain water. However, pumping water from the LFCC to the river could significantly reduce the discharge of the LFCC in this expanding flycatcher breeding area. The flows within the LFCC and diversions through pumping could be monitored along with hydrologic components within selected sites of the reservoir pool with previously known nests. Through an adaptive management program coordinated with the Service, the pumping may be managed to provide adequate flows in the LFCC to maintain soil moisture through a period of nesting when a majority of nests have fledged.

D. Coordinate Facility Operations with Water Users

Reclamation will work with the MRGCD to develop an agreement addressing the reoperation of project facilities to support environmental and ESA-related needs.

Reclamation can manage the timing of releases from Heron Reservoir to offset depletions to the Rio Grande caused by storage of native water in Nambe Falls Reservoir to increase flow in the Rio Grande. Reclamation can also evaluate issuance of storage exceptions at El Vado Reservoir based not only on safety of dam and flood inflow considerations, but also on river flow in the Middle Valley. This consideration should address potential impacts of these storage exceptions on Middle Valley flows during periods of low flow.

E. Support for Fish Rescue Efforts

Should isolated pools be found that sustain significant numbers of silvery minnow, Reclamation and Corps will cooperate with the Service in rescue operations to relocate any stranded fish. Relocation of silvery minnow may also occur during periods of continuous flow if there is a need to augment upstream or captive populations.

Reclamation and the Corps will closely monitor low flow or river drying events as they occur. Reclamation and/or the Corps will notify the Service of potential low flow conditions with sufficient lead-time to ensure an adequate response time for rescue efforts. The Service has the lead for calling and coordinating a rescue event. Other Federal and non-federal parties will provide assistance with rescue efforts upon request of the Service. The primary method for coordinating with the Service during these critical periods will be the daily conference call.

F. Environmental Commitments

The following environmental commitments are from the June 2001 BA (Reclamation, 2001):

- Reclamation will carry out its actions to encourage seasonal overbank flooding and associated low velocity aquatic habitats in or near suitable willow flycatcher habitat within the bounds of the expected natural hydrograph.
- Reclamation will review the Southwestern Willow Flycatcher Recovery Plan and update the environmental commitments related to the willow flycatcher as appropriate.
- Reclamation will work with the MRGCD to: 1) facilitate fish passage at the three main diversion dams to allow upstream movement of the silvery minnow, 2) investigate the effects of fish, eggs and larvae passage over the structures, and 3) alleviate the entrainment of silvery minnow into the irrigation system. Reclamation is currently conducting a planning study that focuses on some of these issues at San Acacia Diversion Dam.
- Reclamation will pursue habitat restoration along the Middle Rio Grande, in coordination with other parties, which includes the restoration of the river channel to create and enhance aquatic habitat for the silvery minnow and native riparian habitat for the willow flycatcher and bald eagle. The principles of adaptive resource management will be incorporated into habitat restoration. Reclamation, as a component of the river maintenance program, will perform two river restoration projects annually.
- Increase the number and distribution of overbank flooding sites and sites with shallow, low velocity water conditions to enhance silvery minnow habitat, assist in regeneration of native vegetation, and provide for flooding in suitable habitat for the willow flycatcher during the breeding season. Monitoring will be conducted to quantify the extent of overbank flooding.
- Eliminate mowing of native riparian vegetation unless it contributes to habitat restoration or is required for safe conveyance of flood flows.
- In areas where impacts to mature cottonwoods cannot be avoided, Reclamation will replace the trees at a 10:1 ratio.
- Reclamation will continue to work with the MRGCD to improve gauging and real-time monitoring of water operations.

The following is an additional environmental commitment, separate from those offered in the June 2001 BA (Reclamation, 2001):

- Initiate efforts to define a suite of characteristics important for flycatcher habitat occupancy and nesting success. Conduct a preliminary examination and assessment of habitat parameters of occupied habitat within the delta of Elephant Butte Reservoir (near the LFCC) to determine features that characterize optimal habitat selected by flycatchers.

G. Additional Potential Corps Actions

Cochiti Dam and Lake Studies

The Corps of Engineers and the Pueblo de Cochiti propose, subject to the availability of funding, the conduct of an array of studies to characterize the interactions of reservoir operation with Tribal resources. The proposed studies, jointly developed by the Corps and the Pueblo, would provide a baseline against which the impacts of any future operational changes may be evaluated. The studies would include analyses of surface and subsurface hydrology; sediment dynamics; contaminants and hazardous risk; and ecological, cultural, and economic resources.

Jemez Canyon Dam and Reservoir Activities

The Corps of Engineers and the Pueblo of Santa Ana propose, subject to the availability of funding, an integrated plan of design, construction, and monitoring to significantly increase the sediment contribution of Jemez River to the Rio Grande. The proposed projects, developed jointly by the Corps and the Pueblo, include construction of a grade-stabilizing weir on the Jemez River upstream from the dam to protect aquatic, riparian, and wetland habitats from degradation; design and modeling of modifications to the dam's tower and outlet works to facilitate passage of accumulated sediment; and monitoring for potential impacts to the Pueblo of Santa Ana's natural, cultural, and economic resources.

H. Appendix A Water Operations Effects Estimation

Predicted hydrologic effects of the water operations presented in Appendix A are described to assist the Service in assessing their utility as potential RPA elements.

Constraints and Assumptions

- Normal MRGCD demand for diversion into MRGP facilities above San Acacia for the purposes of irrigation of Indian and non-Indian lands.
- MRGCD diverts 50 cfs into MRGP facilities at San Acacia Diversion Dam from March 1 through October 31.
- Return flow equal to 30% of MRGCD diversions made at Isleta Diversion Dam (but not less than 75 cfs) returns to the Rio Grande floodway at the Lower San Juan Drain. Lower San Juan Drain returns are greater as result of increased efficiency and cooperation from MRGCD.
- Return flows from San Acacia Diversion Dam are collected by the LFCC, and do not return to the Rio Grande Floodway.
- Constant inflow of 70 cfs from City of Albuquerque's wastewater treatment plant.
- 13,000 acre-feet of supplemental water available for endangered species release.
- No losses applied to supplemental water releases in reaches above Isleta Diversion Dam.
- Pumping stations located at Neil Cupp, North Boundary, South Boundary, and Fort Craig are available for endangered species operations.
- Article VII of Rio Grande Compact is in effect.

Contributions from precipitation downstream of Cochiti Dam are not included because no viable way could be identified to predict and then model the impact of storm inflows.

Methodology

The methodology in this analysis is essentially identical to what was applied to develop the hydrographs for the Normal Operations without Endangered Species Actions scenarios presented in the Analysis of Effects section. Hydrographs representative of Rio Grande flow at Cochiti, San Felipe, Central Avenue Bridge at Albuquerque, and Isleta were exported from the URGWOM RiverWare model containing the 2003 model run based on 1996 hydrology (dry scenario) and 1989 (average scenario).

For river reaches downstream of Isleta, approximate channel loss rates derived from historic URGWOM reach losses were applied to the URGWOM developed hydrograph for Isleta to approximate total Rio Grande flows at Bernardo, San Acacia, and San Marcial. Lag times were not applied to temporally shift the hydrograph between the various stations along the river.

A return flow based on 30% of Isleta Diversion Dam diversions, not less than 75 cfs, was applied upstream of San Acacia to account for MRGP Lower San Juan Drain irrigation return flows. Diversions at Isleta Diversion Dam were estimated based on values contained within the URGWOM model. A diversion of 50 cfs was assumed at San Acacia Diversion Dam, but return flows from San Acacia Diversion were discounted because they currently return to the LFCC rather than the Rio Grande floodway. It was assumed that 13,000 acre-feet of supplemental water was available for release to benefit endangered species. It was assumed that all existing pumping locations would be available for transferring water from the LFCC into the Rio Grande Floodway.

The hydrographs created using the described methodology were then used to evaluate and describe the potential occurrences of drying within the various river reaches based on historic observations of river drying episodes.

The hydrologic conditions described for Appendix A water operations approach the worst case for the described scenarios. Depending on the occurrence and magnitude of monsoonal storms, actual conditions could vary from those described.

Description of Appendix A Water Operations – Dry Hydrologic Scenario
By early May, flows south of San Acacia may no longer be sufficient to maintain a continuous wetted channel without the release of supplemental water and the use of LFCC pumping operations. Even with these actions, it is possible that intermittency could be experienced between San Acacia and San Marcial as early as late May (Figure A-1). Based on past observations, initial drying would likely occur near the center of Bosque del Apache National Wildlife Refuge, and drying could extend south as far as the south boundary of the Bosque del Apache NWR and north toward the north boundary of Bosque del Apache NWR within a few days. Historically, as much as 10 miles of river can become dry within the boundaries of Bosque del Apache for periods up to several days before complete rewetting occurs.

Similar intermittent and sporadic drying could occur between the Neil Cupp Pumping Station and the north boundary of Bosque del Apache, and between San Acacia and the Neil Cupp Pumping Station. Up to five miles has historically become intermittent between the Neil Cupp Pumping Station and the North Boundary Pumping Station for several days at a time. Intermittency between Neil Cupp and San Acacia is less likely to occur, although intermittency or complete drying could potentially extend for more than 10 miles north of the Neil Cupp Pumping Station for several days. During periods of intermittency, the LFCC pumping stations can effectively becomes isolated reaches of flow that can extend from less than a mile to several miles downstream.

It is likely that LFCC pumping operations could maintain a continuous wetted river channel from the south boundary of Bosque del Apache NWR to a point north of Elephant Butte Reservoir for the majority of the year, although sporadic and isolated incidences of stream intermittency would likely occur.

The described intermittent conditions south of San Acacia could occur between early May and late October (Figure A-1). Assuming no monsoonal moisture, more then 40 miles of river could be impacted through either complete drying or through sporadic and isolated stretches of intermittency. Rewetting of the river with continuous and sustained flows might not occur south of San Acacia until late October (Figure A-1).

During this same period, river intermittency as well as extensive reaches of completely dry riverbed could occur within a 30 to 40 mile stretch of the Rio Grande between Tome and the Lower San Juan Drain of the Middle Rio Grande Project. Assuming no monsoonal moisture, intermittency or extensive drying could occur within this area from mid-July through August, after the run-out of all supplemental minnow releases (Figure A-1). Intermittency could extend an additional nine miles north of Tome to Isleta during the months of July and August after the run-out of supplemental minnow water. The Rio Grande would likely remain continuous throughout the year within the 10-mile stretch between the Lower San Juan Drain and the San Acacia Diversion Dam.

During late July through mid-October, infrequent and short-term intermittency could occur within a stretch of river more than six miles long from north of Central Avenue in Albuquerque to the City's waste water treatment discharge point near Rio Bravo Boulevard (Figure A-1). It is likely that the remainder of the river to the north of Central Avenue would remain continuous throughout the year. The nine mile stretch of river from the waste water discharge point south to Isleta Diversion Dam would likely remain continuous throughout the year, with a minimum flow equivalent to the City's treated waste water discharge rate.

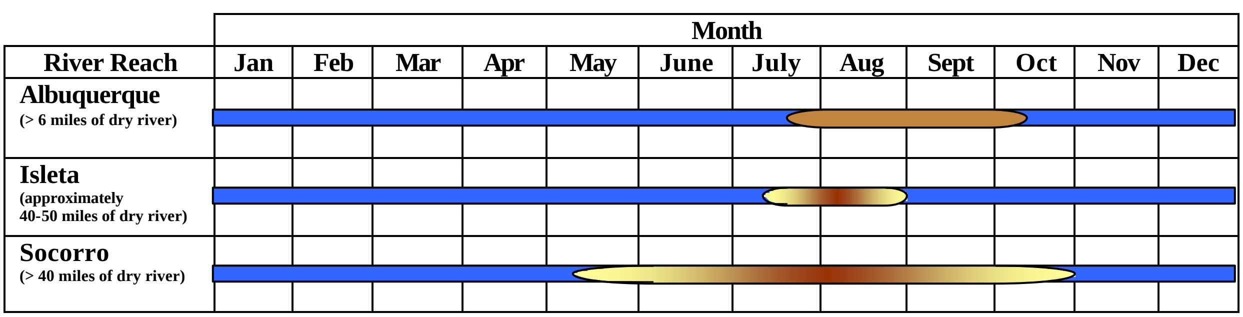

Figure A-1. Spatial and Temporal Representation of Anticipated Intermittent flow with "Appendix A Water Operations" under "Dry" Hydrologic Conditions.
The blue bar indicates continuous flow. Brown (dark) indicates intermittent flow; yellow (light) indicates recession or progression of flows; brown spots against a yellow background indicate sporadic and short-term periods of intermittency. The blending of colors (brown vs. yellow) indicates a time of transition as conditions change from perennial to intermittent, or the antithetical condition.

Description of Appendix A Water Operations – Average Hydrologic Scenario

By late May, flows south of San Acacia may no longer be sufficient to maintain a continuous wetted channel without the release of supplemental minnow water and the use of LFCC pumping operations. Even with these actions, it is possible that intermittency could be experienced between San Acacia and San Marcial as early as June (Figure A-2). Based on past observations, initial drying would likely occur near the center of Bosque del Apache National Wildlife Refuge, and drying could extend south as far as the south boundary of the Bosque del Apache NWR and north toward the north boundary of Bosque del Apache NWR within a few days. Historically, as much as 10 miles of river can become dry within the boundaries of Bosque del Apache for periods up to several days before complete rewetting occurs.

Similar intermittent and sporadic drying could occur between the Neil Cupp Pumping Station and the north boundary of Bosque del Apache, and between San Acacia and the Neil Cupp Pumping Station. Up to five miles has historically become intermittent between the Neil Cupp Pumping Station and the North Boundary Pumping Station for several days at a time. Intermittency between Neil Cupp and San Acacia is less likely to occur, although intermittency or complete drying could potentially extend for more than 10 miles north of the Neil Cupp Pumping Station for several days. During periods of intermittency, the LFCC pumping stations can effectively becomes isolated reaches of flow that can extend from less than a mile to several miles downstream.

It is likely that LFCC pumping operations could maintain a continuous wetted river channel from the south boundary of Bosque del Apache NWR to a point north of Elephant Butte Reservoir for the majority of the year, although sporadic and isolated incidences of short-term stream intermittency would likely occur.

The described intermittent conditions south of San Acacia could occur during late May through September. Assuming no monsoonal moisture, more then 40 miles of river could be impacted through sporadic and isolated episodes of intermittency. Rewetting of the river with continuous and sustained flows might not occur south of San Acacia until mid to late October (Figure A-2).

During this same period, river intermittency could occur within a 30 to 40 mile stretch of the Rio Grande between Tome and the Lower San Juan Drain of the Middle Rio Grande Project. Assuming no monsoonal moisture, intermittency could occur within this area from mid-July through August, after the run-out of all supplemental minnow releases (Figure A-2). Sporadic and isolated episodes of intermittency could occur between Isleta and Tome during the months of July and August after the run-out of supplemental minnow water. The Rio Grande would likely remain continuous throughout the year within the 10-mile stretch between the Lower San Juan Drain and the San Acacia Diversion Dam.

During the months of August through September, infrequent and short-term intermittency could occur within a stretch of river more than six miles long from north of Central Avenue in Albuquerque to the City's wastewater treatment discharge point near Rio Bravo Boulevard (Figure A-2). It is likely that the remainder of the river to the north of Central Avenue would remain continuous throughout the year. The nine mile stretch of River from the waste water discharge point south to Isleta Diversion Dam would likely remain continuous throughout the year, with a minimum flow equivalent to the City's treated waste water discharge rate.

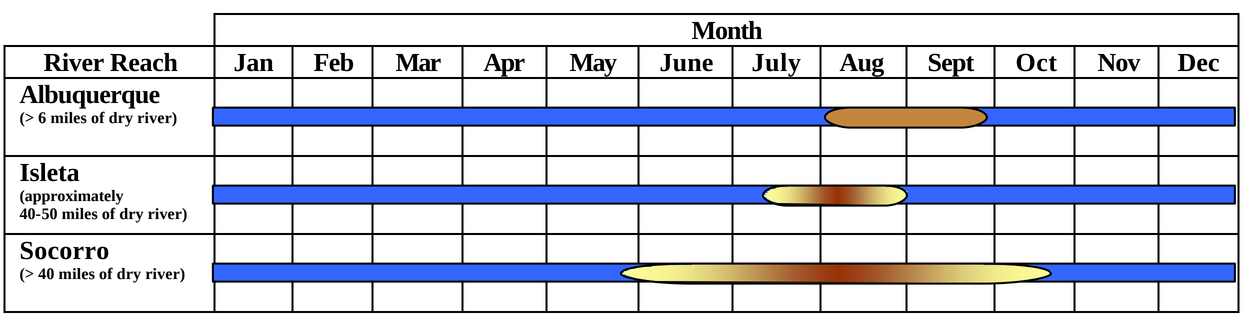

Figure A-2. Spatial and Temporal Representation of Anticipated Intermittent Flow with "Appendix A Water Operations" under "Average" Hydrologic Conditions.
The blue bar indicates continuous flow. Brown (dark) indicates intermittent flow; yellow (light) indicates recession or progression of flows; brown spots against a yellow background indicate sporadic and short-term periods of intermittency. The blending of colors (brown vs. yellow) indicates a time of transition as conditions change from perennial to intermittent, or the antithetical condition.

APPENDIX B

This appendix describes actions that, in addition to those listed in Appendix A, could be available as RPAs, RPMs, conservation measures, or terms and conditions if the Tenth Circuit Court of Appeals upholds the District Court's rulings regarding the scope of federal agency discretion related to Middle Rio Grande and San Juan-Chama Project water operations.

Current storage reservoirs have been depleted due to drought and increased release of stored water during the last several years because of drought and endangered species' needs. Reclamation's web site (http://albuq.uc.usbr.gov/info/wo) presents a chart estimating the current total amount of water in storage to provide guidance to the Service in developing its Biological Opinion and to meet the District Court's order that we consider possible water management contingencies for 2003. Reclamation will provide updates as requested.

In its September 23, 2002 order, the District Court directed the following:

> If necessary to meet flow requirements in 2003, either under the June 29, 2001 Biological Opinion or under a new Biological Opinion resulting from reinitiation of consultation, **the Bureau of Reclamation must reduce contract deliveries under the San Juan-Chama Project and/or the Middle Rio Grande Project, and/or must restrict diversions by the Middle Rio Grande Conservancy District under the Middle Rio Grande Project**, consistent with the Bureau of Reclamation's authority as determined in the Court's April 19, 2002 Memorandum Opinion and Order.

Therefore, the following actions are available consistent with the Bureau of Reclamation's authority as determined by the District Court. These actions will be available for implementation if the Tenth Circuit Court of Appeals upholds the District Court's rulings and if needed to meet ESA requirements. The actions are not described in a priority implementation order.

Middle Rio Grande Project-Related Actions

A. Restrict Direct Diversions of Natural Rio Grande Flows Through Middle Rio Grande Project Facilities for Non-Indian Water Users.

Diversions of natural Rio Grande flows made through the Middle Rio Grande Project for non-Indian water users could be restricted to target flows and flow conditions at various locations on the river if necessary in accordance with the final BO. The irrigation season begins on March 1 and extends to October 31 for non-Indian irrigators, although MRGCD has raised the issue of possibly starting the irrigation season earlier, if allowable under state and federal law.

B. Bypass Natural Rio Grande Water Instead of Storing it in El Vado Reservoir for Non-Pueblo Lands.

Under normal conditions, Reclamation captures natural Rio Grande water in El Vado Reservoir and stores it for Middle Rio Grande Project water users. Such storage occurs mainly during the spring runoff season. Consistent with the District Court's decisions, and if needed to meet target flow requirements or other ESA requirements, Reclamation could bypass the water instead of storing it for non-Pueblo lands.

At this time, however, Reclamation does not anticipate capturing any natural Rio Grande flows for non-Pueblo storage in El Vado Reservoir in 2003 because of restrictions imposed by the Rio Grande Compact. Storage to insure the rights of the six Middle Rio Grande Pueblos is not affected by this Compact requirement.

C. Release Water Stored in El Vado Reservoir for Non-Indian Middle Rio Grande Project Water Users

Release of native Rio Grande water stored for use by non-Indians within the MRGCD out of El Vado Reservoir normally occurs throughout the irrigation season when direct flow does not meet Project needs. This stored water would be released in a manner to help meet target flows. No such water is currently stored in El Vado, however, and we do not anticipate additional storage will be allowed in 2003 because of Compact restrictions.

San Juan–Chama Project – Related Actions

A. Reduce San Juan-Chama Project Contractors' 2003 Allocations and Release Water Directly for Target Flows.

Reclamation operates Heron Reservoir to meet contract obligations within the San Juan-Chama Project firm yield to its contractors and to deliver Cochiti Lake recreation pool evaporation replacement water. This water is delivered consistent with calls from contractors regarding timing and volume of releases. Shortages to yearly contractor allocations could occur to help meet target flows. Shortages would not be applied to the Cochiti Lake recreation pool evaporation replacement water, due to lack of discretion under PL 88-293.

B. Release Stored (Firm-Yield Pool) San Juan-Chama Project Water Directly for Target Flows

The Firm-Yield Pool is water carried over in Heron Reservoir to ensure that San Juan-Chama Project deliveries can be achieved in years with below-average inflow to Heron. Consistent with the District Court's ruling, this stored water could be released in a manner to help meet target flows, even if shortages to Project contractors result.

Six Middle Rio Grande Pueblos Water Deliveries Through the Middle Rio Grande Project

The District Court did not address the issue of whether Pueblo water deliveries would be affected by its interpretation of ESA requirements. If the six Middle Rio Grande Pueblos' water use is ultimately determined to be subject to curtailment to meet ESA flow requirements, the following actions would be considered, consistent with the Implementation Guidelines section of this Appendix.

A. Restrict Direct Diversions of Natural Rio Grande flows through Middle Rio Grande Project facilities for Pueblo Newly-reclaimed Lands.
B. Restrict Direct Diversions of Natural Rio Grande Flows through Middle Rio Grande Project Facilities for Prior and Paramount Lands for the Six Middle Rio Grande Pueblos.
C. Bypass Natural Rio Grande Flows Instead of Storing in El Vado Reservoir for Pueblo Newly-reclaimed Lands.
D. Bypass Natural Rio Grande Flows Instead of Storing in El Vado Reservoir for Pueblo Prior and Paramount Lands.
E. Release Water Stored in El Vado for Pueblo Newly-reclaimed Lands.
F. Release Water Stored in El Vado for Pueblo Prior and Paramount Lands.
G. Release Water Stored in El Vado for the six Middle Rio Grande Pueblos to the Pueblos, but restrict Middle Rio Grande Project Diversions of Natural Flows for the Pueblos.

Implementation Guidelines

Upon completion of a BO, Reclamation will also consider the following factors in determining how to implement the above actions, if necessary to meet BO requirements.

A. Application of actions across projects

- Appropriate balance between within-basin solutions and trans-basin solutions
- Prior Appropriation Doctrine
- Causal connection between actions and impacts.
- Sources of water that are unavailable

B. Implementation of actions within a project

1. Middle Rio Grande Project

- Priority of shortages.
- Prior Appropriation Doctrine.
- Six Middle Rio Grande Pueblos' water needs.

2. San Juan-Chama Project

- Application of contract shortage provisions.
- Pueblo and tribal water.
- Shortage of yearly contract allocations versus firm yield pool.

APPENDIX C

It is Reclamation's policy to analyze river maintenance sites by performing geomorphic analysis and investigations prior to implementation. One of the goals of these investigations is to identify the underlying geomorphic causes of problems such as excessive erosion, deposition, and excessive channel instability as suggested by Newson (1995) and determine the future river conditions using the qualitative methods developed by Schumm (1969) and other quantitative methods available. These methods relate changes in sediment and water discharge to changes in width, depth, velocity, channel slope, sinuosity, and width-depth ratio.

Studies of the entire Middle Rio Grande reach are in progress and appropriate sediment transport models (i.e., HEC-6T, G-STARS, FLO-2D, and others) are continually being developed. The intention of these studies and modeling efforts are to understand erosional and depositional sediment transport characteristics and the associated impacts on channel morphology to develop appropriate projects to meet all of the objectives. Some of the geomorphic studies include detailed analysis of historic, current, and estimates of future channel morphology based on trend analysis and modeling. Reclamation is also studying the effects of reduced sediment loads and peak flows on the channel substrate size and width. Reclamation's river maintenance program is evolving with regards to river engineering techniques and the spatial scope of analysis. Instead of focusing our efforts mainly on the symptoms of channel instabilities, e.g., bank erosion, we are increasingly analyzing and addressing the causative processes within the scope of our authority.

Presently the applicability of such techniques to large rivers such as the Rio Grande is not documented and tested. The hydraulic laboratory modeling is evaluating new maintenance techniques such as those proposed by Rosgen (1996) for their applicability to the Middle Rio Grande channel morphology and hydrology. The subsequent description of bio-engineering techniques, river training works, and sediment removal techniques were developed from experience gained on the Rio Grande over the last several years and review of recent publications on river engineering and geomorphic design. The authors reviewed are; Brizga and Finlayson (2000), Darby and Simon (1999), Thorne et al. (1997), Brookes (1988), Gordon et al. (1992), Hey (1994), Gore and Petts (1989), Costa et al. (1995), Wang et al. (1997), Rosgen (1996), and the Federal Interagency Steering Team (1998).

The following section lists and describes the specific river maintenance activities that could occur within the Middle Rio Grande Project. Activities are categorized by their primary objective. A combination of these activities will be used to successfully meet river maintenance objectives. Examples of how a combination of these techniques may be utilized in project designs is included under the "Hypothetical River maintenance Project/Projects" heading for each reach in the Analysis of Effects of Proposed Actions Section.

1. River Maintenance Techniques

River maintenance techniques include a variety of methods for influencing flow alignment, bank stabilization, and controlling and managing overbank flow. Each maintenance project may require subsequent maintenance due to changing river conditions and the Section 404 permit obligation to maintain permitted works. The following activities include traditional techniques as well as recent advances in the river engineering profession. Many of the techniques listed below fit into the category of river engineering termed bioengineering. Combinations of these activities will most likely be employed in maintenance designs.

Terrace and Overbank Lowering (Re-establish floodplain hydrologic connectivity) - This type of work activity would be to allow for the expansion of the active floodplain and to reconnect the river channel to the floodplain. Through an increase in the active floodway, velocities may be reduced at moderate to high discharges resulting in a reduction of bank erosion. Expansion of the active floodplain may also permit higher discharges to be released from upstream dams since there would be a decrease in the risk to threatened riverside facilities.

Channel Widening/Bank Destabilization - Widening the main river channel via vegetation clearing and bank destabilization to increase the flow area allowing for higher discharges to be released from upstream dams. Bank destabilization would be accomplished with jetty removal, clearing vegetation via root plowing, and bankline lowering.

Woody Debris Snags and Boulder Placements - Woody debris snags and boulders would be placed at locations within the river channel or along river banks to provide bank erosion protection by deflecting flows away from the bankline. Boulder placement would most likely occur in the upstream river channel reaches, e.g., Velarde and Espanola.

High Flow Side Channels - Provide an increase in flow area thereby increasing the ability to pass higher discharges. The activity would most likely involve pilot channel excavation, inner channel terracing, and bank material removal or de-stabilization.

Removal of Lateral Confinements - In areas where the river channel is constricted, the removal and/or relocation of confining terraces, levee, low flow channel, and jetties could be performed for floodplain expansion. If relocation of either a levee or low flow channel is pursued landowner permission would be necessary. Under the Middle Rio Grande project congressional authorization, Reclamation does not have authority to purchase or condemn lands.

Vegetation planting - Vegetation planting would be used in conjunction with other methods to provide erosion protection along the river channel as well as along structures such as levees/berms and deformable banklines. Potential methods include individual pole and willow whips, willow bundles/mats, or other planting methods.

Gradient Restoration Facilities (GRF'S) - Gradient restoration facilities are low head grade control structures with an apron designed to mimic naturally occurring riffles. These structures are utilized to halt channel degradation, reduce upstream velocities, trap finer sediments, and increase water surface elevations. Downstream sediment transport is not permanently reduced as sediment is only trapped by the GBF until an upstream equilibrium channel slope is attained. In addition, the amount of sediment deposited upstream of the GRF's is only a few percent of the Rio Grande's annual sediment load.

Increasing the Sand Load to Channel Reach - Mechanical introduction of sand into the river channel where the sediment transport capacity of the sand load is in excess of the available sediment supply and where the river is becoming gravel bedded. This activity will assist in raising the riverbed, changing the gravel substrate to sand, increasing the channel width, and decreasing the average depth. The activity may involve either moving river terrace sediment deposits with land-based equipment or even possibly hauling of sediment materials from upland areas for placement in the river channel. Under Reclamation's authority, we could not address the issues of passing more sediment through Cochiti or Jemez Canyon Dam.

Oxbow Re-establishment - Re-establishing a flow source to an Oxbow to increase the flow area and reduce the average velocity. Such activities may permit an increase in passable discharges.

Deformable Bankline(s) - A deformable bankline consists of a stone toe that is sized to be mobile at the five-year return interval flood event, and native vegetation plantings. The stone toe is required to temporarily stabilize the bank to allow planted vegetation to become established. Riprap, sized to erode in the 5 to 10 year frequency flood (relatively small rock) is placed beneath several layers of fabric-encapsulated soil. Willow and native tree species will be planted through the fabric-encapsulated soil. After the fabric degrades and the toe becomes mobile by subsequent events, the vegetation/soil interaction and natural fluvial processes will control the bank shape. Deformable bank lines can also be comprised of fabric encapsulated soils without a stone toe dependant on its location in the floodplain and stability criteria. Deformable bank lines will most often be established on newly created banks through activities such as channel re-alignment and terrace lowering.

Non-Native Vegetation Clearing and Floodplain Expansion - Mechanical clearing of exotic species vegetation adjacent to the river channel to expanding the floodplain and reducing vegetative consumption of water. This includes creating paths for river waters to occupy within the cleared area during peak spring runoff flows. Such activities will increase the flow area and the ability to increase discharges released from upstream dams.

Rock Weirs - Varying types of rock weir structures would be utilized for bed control and raising the river bed/water surface elevation. They are Vortex and "W" rock weirs and cross vanes. These structures are intended to alleviate excessive bank erosion and create grade stabilization. The apex of Vortex rock weirs is pointing upstream while the apexes of "W" rock weirs are pointing both upstream and downstream.

Channel Realignment/Channel Avulsions/Pilot Channel Work - Relocation of the river channel away from an existing riverside facility that is threatened by erosion and/or to bring the channel to an equilibrium slope and planform. Channel realignment may incorporate deformable banks to establish the new channel pattern and allow for natural fluvial process to shape the banks. Pilot channels are excavated to establish new river courses. Pilot channels may require stabilization with revetments or other works and will most likely be needed in areas where channel alignments are least defined and sediment plug formation is a problem. Pilot cuts encourage the river to move the sediment and reform the channel and allow for minimal disturbance as opposed to channel dredging.

Culvert and Low Water Crossings - Installation of culverts and low water crossings to provide water to disconnected areas of the floodplain and increase the flow area during higher discharges.

River Bar/Island Maintenance –This activity would involve maintenance of river bars or islands for the purpose of increasing flow area within the river channel and providing a more efficient channel for the delivery of water and sediment. Methods used to accomplish this activity may include vegetation clearing, lowering, and pilot channel construction. This activity can also be used in conjunction with other techniques to expand the active floodplain, dissipate stream energy, and reduce shear stress along vulnerable bankline.

Jetty/Snag Removal - Perform the removal of jetty jacks from areas where their function is no longer necessary as means to establish new banklines or where the jetties have been moved into main river channel as a result of erosional processes and may pose a hazard. Snags (vehicles, trash, etc.) may be removed from the river in rare occasions to prevent them from posing a serious public hazard. They may also be removed in instances where they are deflecting flows into a bankline causing significant bank erosion.

Rock Vanes - These weir structures are intended to deflect flows away from eroding bankline, and break up the secondary circulation cells which add to the stress in the near bank region.

Toe Revetment Plantings - These structures utilize a combination rock or riprap material and willow planting to protect an eroding bank. The rock or riprap material is placed at the toe of the bank to prevent erosion at the toe and the undercutting of a bank. The plantings are placed along the top of the bank or on terraces along the bank to prevent overland erosion to the bankline.

Native Material Bank Stabilization-rock and/or Log Spurs - These structures are intended to provide bank stabilization through various alternatives of root wad and boulder placement, J-Hook and Root wad Vanes, cross vanes, log revetments, and vegetation planting.

Groins/Bendway Weirs- Groins and Bendway Weirs are embankments or dikes projecting from the bank into the channel to regulate river flow alignments. Both may be perpendicular to the bank or angled either up or down stream in an “L” or “T” shape. These can be used in combination with bar reconstruction to move the channel away from a trouble spot along a safer alignment. Groins and Bendway Weirs could be used in all reaches except the Velarde Reach where the river is generally too narrow to make them practical. These are essentially the same structure as rock vanes but have larger top widths to enable heavy equipment to place the rock.

Training dikes- Training dikes are constructed more or less parallel to the channel to guide the flow. Most future training dikes would be built in conjunction with revetment works or channel re-alignment/pilot channel projects and would most likely be used in the Middle Reach and below where the riverbanks are low.

Freeboard dikes- Freeboard dikes are built to contain high flows with an adequate factor of safety to protect other works or facilities. Freeboard dikes are most often required in areas where there are no levees, or development or farmland is at the river’s edge.

Revetments- A revetment is a facing placed on a riverbank to resist and prevent further erosion. Many types of materials and systems are available for revetting banks. Economic consideration, feasibility of construction considerations and aesthetic factors govern the choice of a particular revetment system. All types of bank stabilization work require periodic maintenance. Rock riprap has generally been used in all reaches to revet banks; however, the use of native material for revetments is currently being explored.

Windrows- Windrows are used alone or in conjunction with revetments to limit future bank erosion. Riprap is piled in a windrow on top of the bank along a desired alignment. When the bank erodes back to the windrow, the rock is undermined and drops down the bank controlling erosion. After the rock begins to drop down the bank, additional rock is required to redress and shape the bank. Windrows could be used in all reaches to stabilize bank erosion.

Permeable jetties- Steel or wood Kellner jacks (jetty jacks) have been previously used to stabilize the Rio Grande. The effectiveness of permeable Jetties depends on an adequate supply of sediment being transported by the river and on site-specific hydraulic conditions. Currently no jetty jack installations are planned for the Middle Rio Grande Project, however this item is left in for the remote possibility of future installations.

Curve shaping- The realignment of river banks may be necessary in all reaches. Curve alignments are determined by right-of-way considerations and hydraulic parameters. This activity could be a component of previously mentioned river training works techniques or be used alone.

Stabilized soil, Manufactured revetment units, and Cellular confinement systems - The chemical 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 underwater. This technique would only be used in unusual circumstances. Several types of manufactured units are available for revetment construction. These units are typically made of concrete and are designed to be laid 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 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.

2. Sediment Removal

Removal of sediment from the river channel by mechanical means may be needed to maintain flow capacity. Disposal of spoil material is an important consideration when planning these operations.

> <u>Arroyo Plug Grading and Removal</u>- Sediment deposited in the river channel at the mouths of tributary arroyos sometimes must be removed by excavation. As a result of regulation by dams, main stem flow is often inadequate to remove arroyo plugs containing large gravel or cobble sized materials. Very large arroyo plugs can diminish channel capacity or deflect flows into banklines and/or riverside facilities. Reclamation would undertake arroyo plug grading or removal only in these instances.
>
> <u>Dredging/Sediment settling basins</u> - Dredging includes all underwater excavation of bottom material. Dredging may be done by machines scooping the bottom material up in buckets (bucket dredging) or by pumping a solid/water mixture and discharging the mixture through pipes (hydraulic dredging). Hydraulic dredging often requires the construction of settling ponds where the discharged solids are separated from the water. Construction of settling ponds usually requires building up embankments or dikes to contain the dredged material and overflow structures to decant the water. Size of settling ponds depends on the quantity of material being discharged and the type and size of the solids to be settled out. In open water areas, silt curtains may be used to diminish or limit turbidity effects caused by dredging. Dredging would be used to construct or maintain channels in areas where sediment is depositing and reducing the efficiency of water delivery such as at the delta of Elephant Butte.

3. Vegetation Management

The objectives of vegetation management are to maintain floodway capacity and reduce net depletions. Historically, vegetation management activity was concentrated in the Middle Reach and the upper portions of the Belen Reach where river bars were mown annually to prevent growth of woody vegetation. Under the current mowing program, Reclamation desires not to eliminate mowing but to further evaluate its effectiveness in meeting Reclamation's river maintenance goals as outlined in this document. Until further analysis and studies are performed, the mowing of native riparian vegetation on river bars is temporarily postponed. This program is currently being re-evaluated based on current geomorphic, hydrologic, and environmental conditions. Vegetation management will also likely be needed as the Elephant Butte Reservoir pool recedes, and salt cedar grows on the exposed delta.

> <u>Transect Brushing</u> – To accomplish successful river engineering, data collection of current river channel and floodplain conditions are necessary. Vegetation may be trimmed to create a clear line of sight along a transect as part of Reclamation's data collection program for river channel monitoring. Not only is the data used for studies and modeling for projects to assess the best course of action, but the data is also used to quantify project requirements, to determine quantities for permits, and assessing site conditions for construction purposes. The collection of hydrographic data from transects also provides information for better management of the Middle Rio Grande floodplain and river channel.
>
> <u>Mowing</u>- Vegetation may be cut with mowers. Mowing controls development of woody and perennial species while minimizing disturbance to grasses and forbs.
>
> <u>Root Plowing</u>- A root plow is a large blade that is pulled through the ground beneath the surface by a tractor to destroy underground rootstocks. Root plowing would ordinarily be used to eliminate exotic woody species such as salt cedar and Russian olive trees. Vegetative debris could be piled and left within the cleared area, stacked and burned within the cleared area, or removed to an offsite location.
>
> <u>Clearing of Understory Vegetation</u> - This activity would involve the removal of deadfall and/or exotic species vegetation beneath a native species vegetation canopy. This activity would reduce net depletions in the riverine corridor and increase the available flow area.

4. Levee Maintenance

Reclamation regularly maintains the levee system in the Socorro, Bosque del Apache, San Marcial and Elephant Butte Reaches. In other areas, Reclamation may perform levee maintenance on an intermittent, occasional or emergency basis at the request of MRGCD. Levee failure caused by bank erosion at less than flood flows is also a Reclamation responsibility. Levee maintenance includes raising levee heights, reinforcing by widening levee bases, filling and repairing washouts, stabilization with revetments or groins, drainage improvements, grading, shaping, and road graveling. Under the current levee maintenance program, impacts to endangered species and their habitat are avoided.

Another alternative for reaches below Cochiti Dam would be to relocate the levees, irrigation canals, and riverside drains in selected locations. This option would increase the available floodplain width, and will be explored at each site. Under the Middle Rio Grande Project Congressional authorization, Reclamation does not have authority to condemn and/or purchase land. Therefore, Reclamation would need landowner approval to pursue this river engineering technique. Reclamation is considering moving the levee, river channel and LFCC south of the San Marcial Railroad Bridge where Reclamation owns the land. This is part of a longer-term study currently underway to evaluate operational and structural modifications to the river and LFCC system. Separate Endangered Species Act and National Environmental Policy Act compliance will be developed for this work.

5. Access and Construction Requirements

Haul roads and operating areas - Access construction may require clearing, placement of fill, grading, installation of culvert pipes, and graveling.

Stockpiles - Sites for stockpiling material may require clearing, grading, and fencing. Material may be stockpiled for a particular construction project or may be stored for unspecified maintenance. Stockpiles may be in place temporarily or permanently.

Cofferdams/Inflatable water bladders - Cofferdams or inflatable water bladders are sometimes needed to divert water temporarily during construction operations.

Borrow areas for fill material - Fill material for bank shaping or embankment construction may be imported from borrow areas off site or excavated from adjacent bars or islands.

Spoil areas - Excess material excavated or dredged from the river channel is disposed in designated spoil areas.

Storage yards - Temporary storage of equipment, material and supplies is often needed at a job site and they need to be conveniently located. Storage areas may require clearing, grading, graveling, drainage, and fencing.

6. Reasonable Alternative Techniques for River maintenance

Traditional river maintenance techniques performed by Reclamation have evolved over time between the 1950's and current. Legislation such as NEPA, Clean Water Act, ESA, and river system needs have influenced the evolution into the exploration of new river maintenance techniques that go beyond the original goal of effective water and sediment transport. Promising new technology for river maintenance activities would be evaluated for effectiveness, cost, and environmental effects as the need arises. Those new and future methods found to be practical and appropriate may be used in future river management projects. These methods will be defined over time as they develop.

7. Reach Specific Activities

The following section describes and lists the specific river maintenance activities that could occur within a given reach. Refer to the previous section for a general description of each activity. All of the activities described for each reach in the following sections are the most likely to be pursued but every technique previously identified may possibly be used in each reach. Each reach has different river maintenance activities identified due to various anthropogenic, hydrologic, and geomorphic conditions and influences. A hypothetical river maintenance project is also described for each reach based on site-specific problems and goals. An example of a recently completed or ongoing project similar to the hypothetical project is presented to further quantify the proposed actions. Finally, a summary table qualitatively demonstrates the effect of specific river maintenance activities to the following geomorphic channel parameters: sinuosity, slope, channel width, channel depth, floodplain width, and width to depth ratio.

Velarde, New Mexico, to Rio Chama Confluence - (Velarde Reach)

The Velarde Reach is currently maintained for the safe and effective passage of flow discharges up to 5,000 cfs. The control of bank erosion is the most prevalent ongoing maintenance requirement. The most likely maintenance activities would be the following.

- Rock Weirs
- Deformable Bankline
- Vegetation planting
- Non-native Vegetation Clearing and Floodplain Expansion
- Terrace Lowering (Re-establish Floodplain Hydrologic Connectivity)
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Woody Debris Snags and Boulder Placement
- Rock Vanes
- Toe Revetment Planting
- Native Material Bank Stabilization - Rock and/or Log Spurs.
- Freeboard dikes
- Revetments and Windrows
- Curve Shaping
- Arroyo Plug Grading and Removal
- Transect Brushing

The preferred methodology for the control of bank erosion includes bioengineering techniques and floodplain interaction. On a limited basis due to lack of flood control regulation freeboard dikes may be necessary for the protection of property. Islands and bars may also be used as a convenient source of borrow material in conjunction with reconnecting the river with the floodplain.

Hypothetical River Maintenance Project /Projects

A hypothetical project for the Velarde Reach would be a stream bank protection project. Project goals would include: 1) Preventing damage to riverside facilities, 2) protection of water delivery and irrigation facilities, and 30 prevent excessive flooding of infrastructure. There is no levee system in this reach, unlike downstream within the city of Espanola. Discharges are unregulated and private property and agricultural land is subject to continuous flooding and erosion. Other components to this hypothetical project would be intensive native species plantings along any disturbed areas to prevent further bank erosion. In working with the landowners, other activities that may be pursued include River Bar/Island Maintenance and Oxbow reestablishment. Such activities would increase the wetted perimeter of the channel at higher flows and reduce the flooding potential.

An example of a recent project within this reach is the La Rinconada Dike Project. Reclamation analyzed the effects of constructing and enhancing two earthen freeboard dikes, respectively, in the Velarde Reach. As mentioned above, significant damages have occurred to agricultural lands between Velarde and the mouth of the Rio Chama as a result of flooding. The project included the construction of an approximately 3,700 feet long earthen dike along the eastern bank of the Rio Grande between the mouth of Truchas Arroyo and La Rinconada Diversion Dam. The dike has a top width of approximately 6 feet and an average height of 4 feet. The bottom width, or footprint, varies between 15-24 feet dependent on the height of the dike and level of protection necessary. Culverts were installed for cross drainage from agricultural lands to the river channel. An existing dike along the west side of the river was enhanced with additional fill material and an approximately 130 feet long tie back was constructed to connect the dike to higher ground. There was no change to the footprint of the existing, west side dike except for the tie back portion.

Rio Chama Confluence to Otowi - (Espanola Reach)

The channel capacity in the Espanola Reach increases to 7,850 cfs. Groins and root wad/boulder placement have been used at some sites to protect eroding riverbanks. Oxbow re-establishment has been performed in this reach through culvert installation, and small pilot channel and pond excavation. The most likely river maintenance activities would be the following.

- Rock Weirs
- Deformable Bankline
- Vegetation planting
- Non-native Vegetation Clearing and Floodplain Expansion
- Channel Realignment/Channel Avulsions/Pilot Channel
- Terrace Lowering (Re-establish Floodplain Hydrologic Connectivity)
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Channel Widening/Bank Destabilization
- Woody Debris Snags and Boulder Placement
- Rock Vanes
- Toe Revetment Planting
- Native Material Bank Stabilization -Rock and/or Log spurs
- Groins/Bendway Weirs
- Freeboard dikes
- Revetments and Windrows
- Curve Shaping
- Arroyo Plug Grading and Removal
- Transect Brushing

The river widens considerably below the Rio Chama confluence and it is at this location that bioengineering techniques may provide better methods to influence the river's future alignment while controlling excessive and damaging bank erosion. Islands and bars may also be used as convenient sources of borrow material in conjunction with reconnecting the river with the floodplain.

Hypothetical River Maintenance Project/Projects

A hypothetical project for the Espanola Reach would be a bioengineering stream bank protection project. Project goals would include: 1) Protection of water delivery and irrigation facilities and 2) Preventing damage to riverside facilities. A bioengineering stream bank protection project would likely use a combination of different activities including the installation of deformable bank lines and the placement of cottonwood root wads and boulders. The project would involve the installation of deformable bank lines allowing for temporary stabilization of the bankline until planted vegetation becomes established. The placement of native material revetments such as cottonwood root wads and boulders would be used along an eroding bank to deflect flows away from the bank. Other maintenance activities such as the placement of weir structures (Vortex, W, Rock Vanes) into or across the river channel could also be used to stabilize an eroding bankline. Willow/cottonwood plantings and terracing could also be performed along the bank lines for bank protection and to reconnect portions of the main channel to the historical floodplain, respectively.

An example of a recent stream bank protection project in the Espanola Reach is a pilot bioengineering bank stabilization project completed by Reclamation on the Santa Clara Pueblo in early 1997. The project consisted of installing combinations of root wads, boulders, and riprap in several treatments to determine which method provided the greatest bank stabilization. About 1,250 ft of stream bank was protected using these methods. All work was done with land-based equipment. Trees were placed into 3-4 feet wide by 20 feet long trenches with root balls exposed to the current. About

4,000 cubic yards of material was excavated for the trench work. Spoil material was spread on the top of the bank and seeded with native grasses. About 300 cubic yards of rock was placed between the root wads.

Initially only Russian olive root wads were used. However, the root masses were small and additional work was conducted to install larger cottonwood root balls, acquired from the Corps' Corrales Levee Project. The floodplain in this area is generally wide with numerous river bars and therefore, river bar/island maintenance activities such as clearing of exotic vegetation, bar lowering, and side channel work could occur on the opposite side of any bank stabilization activity. These activities would widen the river channel and allow the river to adjust to the presence of any newly introduced deflectors and provide high flow side channels to increase the flow area during high discharges. The re-establishment of ox-bows would also be an appropriate activity in this area.

Cochiti Dam to Hwy 44 Bridge, Bernalillo - (Cochiti Reach)

Maximum releases from Cochiti are expected to be in the 7,000-10,000 cfs range. However, recent releases have been less than this range because of floodway capacity constraints. To compound matters, the water released from Cochiti is clear, causing the riverbed to degrade (i.e. river bed lowering through sediment removal), the channel width to reduce, and the material to coarsen from a sand substrate to a gravel substrate. If the magnitude of peak flow releases out of Cochiti is increased during the spring runoff season, the river channel will have a tendency to migrate laterally due to the armoring of the river channel downstream of the dam. Problems associated with bank erosion could be particularly severe in this reach because the dam has diminished the sediment supply.

The most likely river maintenance activities would be the following:

- Woody Debris Snags and Boulder Placement
- High Flow Side Channels
- Increase Sand Load to Reach
- Grade Restoration Facilities
- Rock Weirs
- Deformable Bank lines
- Vegetation planting
- Non-native Vegetation Clearing and Floodplain Expansion
- Channel Realignment/Channel Avulsions/Pilot Channels
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Levee Maintenance
- Clearing of Under story Vegetation
- Removal of Lateral Confinements
- Channel Widening/Bank Destabilization
- Terrace Lowering (Re-establish Floodplain Hydrologic Connectivity
- Rock Vanes
- Toe Revetment Planting
- Native Material Bank Stabilization -Rock and/or Log spurs
- Groins/Bendway Weirs
- Training Dikes
- Revetments and Windrows
- Curve Shaping
- Arroyo Plug Grading and Removal
- Transect Brushing
- Mowing and Root Plowing

In many arroyos, the sediment deposits are sand sized materials. These deposits are readily washed away during high flows and provide a sediment supply for the river. Below Cochiti Dam, additional sediment supply is badly needed and arroyo sediments provide some sediment enrichment. Very large arroyo plugs, however, can diminish channel capacity or deflect flows excessively into riverside facilities and only in these instances would Reclamation undertake Arroyo plug removal or grading. Islands and bars may be cleared of vegetation, reshaped or destabilized increase the channel's width as part of reconnecting the river with the floodplain/and channel widening. Reclamation would perform levee maintenance in the Cochiti Reach on an intermittent basis at the request of MRGCD.

Hypothetical River Maintenance Project/Projects for the Cochiti Reach
A hypothetical project for the Cochiti Reach would be a gradient restoration, stream bank protection, and terrace-lowering project. Project goals would include 1) protecting levees and riverside facilities 2) reverse the trend of channel degradation 3) deceasing net depletions (i.e., evapotranspiration) and 4) increasing the flow area at higher discharges.

Stream bank protection and a gradient restoration project may use a combination of different activities including a bioengineering method of deformable bankline installation to protect a severely eroding bend. Installation of river training works such as rock vanes or bendway weirs may be necessary where a critical erosion problem exists. Installation of gradient restoration facilities which encourage localized sedimentation and grade stabilization would also help restore the function of the river channel in this reach offset by the current degradational trend. Channel realignment may also be a component of this project to relocate the river channel away from the threatened riverside facility. Newly created riverside terraces would be constructed at an elevation that would be inundated during the average spring runoff flow re-establishing floodplain\hydrologic connectivity and increasing the flow area during higher discharges.

The Santa Ana Bank Reconstruction and Stabilization Project is an example of an annual stream bank protection project that is identified after spring runoff and needs to be completed prior to the next runoff period. The project involved stabilizing a section of bank (levee) being eroded by high shearing flows of the Rio Grande. The angle of attack of high flows of the river on the Santa Ana Pueblo, just downstream from the confluence of the Jemez River, caused severe erosion and an adjacent levee was in imminent danger of failing during a future high flow event.

About 900 cubic yards of riprap (> 24" nominal) was used to stabilize the bank. All work was performed in the dry from the top of the existing bankline. Water quality impacts were minimal. This was a temporary stabilization project prior to the complete analysis and development of the long-term stabilization project described below.

An example of a long-term project in the Cochiti and Middle reaches is the Santa Ana Pueblo Rio Grande Project. Project objectives include protecting current irrigation and flood control facilities and widening the active floodplain. The Santa Ana Pueblo Rio Grande Project encompasses approximately 6,500 feet of the Rio Grande. The Project consists of three phases being constructed over a three to five year period. Phase 1 consisted of the installation of a gradient restoration facility (GRF), an accompanying fish passage apron, the excavation of a 25-foot pilot channel, installation of river dikes to block off the existing river channel, and excavation of trenches along the estimated bankline position to install bioengineering features. A cofferdam was established around the GRF construction. The bankline bioengineering consists of willows planted along the bankline and the toe protection of six-inch rock along the toe of the bank. The six-inch rock will be wrapped in biodegradable coir fabric. The coir fabric will keep the rock in place until vegetation is established on the bankline. The rock is sized such that it will move during a five-year flood event. The bankline will also have root balls and footer logs installed. The bioengineered bankline is to provide future bank protection.

The widening of the river may take longer than one year depending on the next spring runoff. Phase 2 began after the pilot channel has widened into the new river channel. This phase will consist of excavating and planting the remaining floodplain areas and the installation of bendway weirs. The bendway weir may be constructed in Phase 3 if the channel is continuing to adjust to the new alignment during Phase 2. Phase 3 will also consist of the installation of a second GRF and additional revegetation efforts along with under story vegetation clearing to offset net depletions.

The introduction of a streambank protection and gradient restoration project with these various components if carefully managed and planned would positively influence sinuosity, slope, width, depth, floodplain width, width to depth ratio, overbank wetted area, and main channel velocity from a river system stability standpoint (see summary table).

Hwy 44 Bridge, Bernalillo to Isleta Diversion Dam - (Middle Reach)
The average river width is about 600 ft. in this reach and has remained fairly constant since the installation of jetty jacks. However, the river channel is partially gravel bedded and has a slightly meandering planform in the upper section of the reach resulting in bank erosion. The maximum channel depth has been increasing and there is a disconnection between the river channel and the floodplain suggesting that the reach is incising. The most likely river maintenance activities would be the following:

- Woody Debris Snags and Boulder Placement
- High Flow Side Channels
- Increase Sand Load to Reach
- Terrace Lowering (Re-establish Floodplain Hydraulic Connectivity)
- Grade Restoration Facilities
- Rock Weirs
- Deformable Banklines
- Vegetation planting
- Non-native Vegetation Clearing and Floodplain Expansion
- Channel Realignment/Pilot Channels/Channel Avulsions
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Clearing of Understory Vegetation
- Removal of Lateral Confinements
- Channel Widening/Bank Destabilization
- Rock Vanes
- Toe Revetment Planting
- Native Material Bank Stabilization-Rock and/or Log spurs
- Groins/Bendway Weirs
- Training Dikes
- Revetments and Windrows
- Curve Shaping
- Arroyo Plug Grading and Removal
- Transect Brushing
- Levee Maintenance
- Mowing and/or Root Plowing

The degradation trend now manifesting throughout this reach may result in increased future bank erosion. Islands and bars may be cleared of vegetation, reshaped, or destabilized to increase the channel's width as part of reconnecting the river with the floodplain. Reclamation would perform levee maintenance in the Middle Reach on an intermittent basis at the request of MRGCD.

Hypothetical River Maintenance Project/Projects for the Middle Reach
In the Middle Reach, extensive bank stabilization works, e.g., jetty jacks, has led to the current stable bankline now consisting of the very dense Bosque vegetation and root material and minimizes the need for bank protection. The reach was extensively stabilized because it is the most heavily populated reach and contains many riverside facilities. The reach also contains many alternate river bars.

A hypothetical river maintenance project for the Middle Reach would be river bar/island maintenance. Project goals include: 1) protecting levees and riverside facilities, 2) reverse the trend of channel degradation, 3) deceasing net depletions (i.e., evapotranspiration), and 4) increasing the flow area at higher discharges.

Reclamation completed construction on the Albuquerque Overbank Project prior to the 1998 spring runoff. This activity is an example of a river bar/island maintenance project and was developed to help determine the effectiveness of clearing exotic vegetation on a river bar and lowering the bar to allow for overbank flooding during spring runoff. About 4 acres of the lower portion of a river bar near Albuquerque was cleared of vegetation. Stockpiled vegetation was later removed from the site. Portions of the exposed bar were lowered 2 feet by land-based equipment and terraced to mimic natural topographic variability. Nearly 8,000 cubic yards of material was excavated and spread out in newly forming depositional areas at the downstream end of the bar.

Significant bosque exists between the levees throughout this reach. A river bar/island maintenance project could potentially involve the removal of jetty jacks, clearing exotic vegetation, and lowering or destabilization of riverbanks. This work would be conducted during low flow conditions. These activities would serve to widen the river channel and increase the available overbank area thereby positively influence the sinuosity, slope, width, depth, floodplain width, width to depth ratio, overbank wetted area, and main channel velocity from a river system stability/habitat standpoint (see summary table).

Isleta Diversion Dam to Rio Puerco Confluence - (Belen Reach)
Conditions and river maintenance needs in the Belen Reach are very similar to the Middle Reach. The most likely river maintenance activities would be the following.

- Woody Debris Snags and Boulder Placement
- High Flow Side Channels
- Increase Sand Load to Reach
- Terrace Lowering (Reestablish Floodplain Hydraulic Connectivity)
- Grade Restoration Facilities
- Rock Weirs
- Deformable Banklines
- Vegetation planting
- Non-native Vegetation Clearing and Floodplain Expansion
- Channel Realignment/Channel Avulsions/Pilot Channels
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Clearing of Understory Vegetation
- Removal of Lateral Confinements
- Toe Revetment Planting
- Native Material Bank Stabilization-Rock and/or Log spurs
- Groins/Bendway Weirs
- Training Dikes
- Revetments and Windrows
- Curve Shaping
- Arroyo Plug Grading and Removal
- Transect Brushing
- Mowing and/or Root Plowing
- Levee Maintenance
- Rock Vanes
- Channel Widening/Bank Destabilization

Riverbanks in the Belen Reach have been stabilized by extensive jetty jack fields. However, the degradation trend now manifesting throughout this reach may result in increased future bank erosion. In a degrading channel environment, it is unlikely that extensive new jetty jack fields would be installed. Islands and bars may be cleared of vegetation, reshaped, or destabilized to increase the channel's width. Reclamation would perform levee maintenance in the Belen Reach on an intermittent basis at the request of MRGCD.

Hypothetical River Maintenance Project/Projects for the Belen Reach
As with the Middle Reach, the Belen Reach contains extensive bank stabilization works, e.g., jetty jacks which, has led to the current stable bankline now consisting of the very dense bosque vegetation and root material and minimizes the need for bank protection. The upper portion of this reach was extensively stabilized because it is heavily populated and contains many alternate bars and riverside facilities.

A hypothetical river maintenance project in the Belen Reach would be river bar/island maintenance. Project goals include: 1) protecting levees and riverside facilities, 2) reverse the trend of channel degradation, 3) deceasing net depletions (i.e., evapotranspiration), and 4) increasing the flow area at higher discharges. The specific activities associated with this project are the same as those discussed above for the Middle Reach. The Albuquerque Overbank Project also serves as a case study for this reach. Numerous saltcedar stands exist throughout the Belen, reach which would provide another hypothetical river maintenance project in the form of non-native vegetation clearing/floodplain expansion. These activities would serve to widen the river channel and decrease the net depletions.

Rio Puerco Confluence to San Acacia Diversion Dam - (Rio Puerco Reach)
The river channel and floodplain through the Rio Puerco Reach is generally wide and braided with extensive infestation of exotic species vegetation. The river is also now a partially gravel bed channel. The most likely maintenance activities would be the following.

- Woody Debris Snags and Boulder Placement
- High Flow Side Channels
- Increase Sand Load to Reach
- Terrace Lowering (Re-establish Floodplain Hydraulic Connectivity)
- Rock Weirs
- Deformable Bankline
- Vegetation planting
- Non-native Vegetation Clearing and Floodplain Expansion
- Channel Realignment/Channel Avulsions/Pilot Channels
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Channel Widening/Bank Destabilization
- Rock Vanes
- Removal of Lateral Confinements
- Grade Restoration Facilities
- Toe Revetment Planting
- Native Material Bank Stabilization-Rock and/or Log spurs
- Groins/Bendway Weirs
- Training Dikes
- Revetments and Windrows
- Curve Shaping
- Arroyo Plug Grading and Removal
- Transect Brushing
- Mowing and Root Plowing
- Clearing of Understory Vegetation
- Levee Maintenance

Some levee maintenance may be necessary below the confluence of the Rio Puerco because of changing geomorphic conditions and the location of various critical riverside facilities for both the State of New Mexico and MRGCD.

Hypothetical River Maintenance Project/Projects for the Rio Puerco Reach
The river through the Rio Puerco Reach is strongly influenced by the Rio Puerco and Rio Salado. These tributaries are a source of heavy sediment inflow during thunderstorm activity.

In the Rio Puerco and Socorro reaches, a hypothetical project would be channel rehabilitation. Project goals would include 1) protecting levees and riverside facilities 2) reverse the trend of channel degradation 3) deceasing net depletions (i.e., evapotranspiration), 4) increasing the flow area at higher discharges and 5) increasing the sand load to the reach. An example project would involve a combination of different activities including engineering techniques such as deformable banklines, installation of Gradient Restoration Facilities, terrace lowering to increase the sand load, and a method of rock vane/bendway weirs to protect severely eroding bends. Channel realignment may also be a component of this project to relocate the river channel away from the threatened riverside facility. Woody debris snag may be placed in the river channel to encourage sediment deposition and maintain channel width and planform. Other activities such as new floodplain creation by terrace lowering in areas where older age cottonwood stands may also be a component. Understory vegetation clearing may also be performed to decrease net depletions. As is the case in the Belen Reach, hypothetical river maintenance projects in the Rio Puerco Reach would include river bar/island maintenance and non-native vegetation clearing.

The introduction of a channel rehabilitation and stream bank protection project with the aforementioned components, through careful planning and management, would positively impact the sinuosity, slope, width, depth, floodplain width, width to depth ratio, overbank wetted area, and main channel velocity from a river system stability/habitat standpoint (see summary table).

San Acacia Diversion Dam to River Mile 78 (middle of BDANWR) - (Socorro Reach)

Channel degradation is occurring below San Acacia Diversion Dam through the Escondida/Socorro area due to changing upstream geomorphic factors that have diminished the sediment supply. The river channel is in a condition of instability characterized by vertical incision and lateral erosion. Vertical incision or bed lowering has resulted in a disconnection of the river channel from the floodplain. Lateral erosion is on effect of the change in planform of the river from a wide braided channel to a narrow single threaded, slightly sinuous channel. The channel bed between San Acacia Diversion and Escondida Bridge is mostly gravel with a sand veneer. It has been estimated that the sand veneer may be gone in approximately 3 to 5 years depending on the hydrologic conditions. The bank erosion is threatening the levee in areas downstream of San Acacia Diversion Dam. A levee system exists on the west side of the floodplain to protect the Low Flow Conveyance Channel and to control valley flooding. The most likely river maintenance activities would be the following.

- Woody Debris Snags and Boulder Placement
- High Flow Side Channels
- Increase Sand Load to Reach
- Terrace Lowering (Re-establish Floodplain Hydraulic Connectivity)
- Grade Restoration Facilities
- Rock Weirs
- Deformable Banklines
- Vegetation planting
- Clearing of Understory Vegetation
- Non-native Vegetation Clearing and Floodplain Expansion
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Rock Vanes
- Removal of Lateral Confinements
- Channel Widening/Bank Destabilization
- Toe Revetment Planting
- Levee Maintenance
- Native Material Bank Stabilization-Rock and/or Log spurs
- Groins/Bendway Weirs
- Training Dikes
- Channel Realignment/Avulsions/Pilot Channels/Pilot Cuts
- Revetments and Windrows
- Curve Shaping
- Arroyo Plug Grading and Removal
- Transect Brushing
- Mowing and/or Root Plowing

Activities associated with levee maintenance would be anticipated below San Acacia Diversion Dam because of changing geomorphic conditions and deterioration of the levee. Islands and bars may be cleared of vegetation, reshaped, or destabilized to increase the channel's width.

Hypothetical River Maintenance Project/Projects for the San Acacia Reach

A hypothetical river maintenance project in the San Acacia Reach would be similar to those described in the Belen and Rio Puerco reaches. Project goals would include 1) protecting levees and riverside facilities 2) reverse the trend of channel degradation 3) deceasing net depletions (i.e., evapotranspiration), 4) increasing the flow area at higher discharges and 5) increasing the sand load to the reach. An example project would involve a combination of different activities including engineering techniques such as deformable banklines, installation of Gradient Restoration Facilities, terrace lowering to increase the sand load, and a method of rock vane/bendway weirs to protect severely eroding bends. Channel realignment may also be a component of this project to relocate the river channel away from the threatened riverside facility. Woody debris snag may be placed in the river channel to encourage sediment deposition and maintain channel width and planform. Other activities such as new floodplain creation by terrace lowering in areas where older age cottonwood stands may also be a component. Understory vegetation clearing may also be performed to decrease net depletions. As is the case in the Belen Reach, hypothetical river maintenance projects would include river bar/island maintenance and non-native vegetation clearing.

The introduction of a channel rehabilitation and stream bank protection project with the aforementioned components, through careful planning and management, would positively impact the sinuosity, slope, width, depth, floodplain width, width to depth ratio, overbank wetted area, and main channel velocity from a river system stability/habitat standpoint (see summary table).

River Mile 78 (middle of BDANWR) to headwaters of Elephant Butte Reservoir - (San Marcial Reach)

The river channel throughout this reach is aggrading due to influences of the reservoir pool and a constricted floodplain established by the levee system. Due to its aggradational nature, the river channel (lying between the eastern mesa and the levee) in this reach is characterized as a perched channel being elevated above the western portions of the valley floor.

Temporary Channels, culvert and low water crossings, channel avulsions, non-native vegetation clearing, and floodplain expansion will be used to maintain the channel flow capacity and will be the most used river maintenance practices in this reach. The most likely river maintenance alternatives would be the following:

- Woody Debris Snags and Boulder Placement
- High Flow Side Channels
- Deformable Bankline
- Vegetation planting
- Clearing of Understory Vegetation
- Non-native Vegetation Clearing and Floodplain Expansion
- Channel Realignment/Channel Avulsions/Pilot Channels/Pilot Cuts
- Culvert and Low Water Crossing
- River Bar/Island Maintenance
- Oxbow Re-establishment
- Jetty/Snag Removal
- Rock Vanes
- Rock Weirs
- Removal of Lateral Confinements
- Channel Widening/Bank Destabilization
- Native Material Bank Stabilization-Rock and/or Log spurs
- Groins/Bendway Weirs
- Training Dikes
- Revetments and Windrows
- Permeable Jetties
- Curve Shaping
- Transect Brushing
- Mowing and Root Plowing
- Levee Maintenance
- Dredging/Sediment Settling Basins
- Toe Revetment Planting

Levee Maintenance, e.g., raising, widening, and repairing, is necessary to maintain a 8,500 cfs capacity with 2 ft. of freeboard and to maintain the levee's integrity by preventing seeps, slope, and foundation failure. Maintenance of a river channel to the reservoir pool will involve channel excavation and temporary berm construction. Pilot cut excavation, sediment plug removal, and riverside berm maintenance may be necessary to maintain channel flow capability up to 8,500 cfs and efficiently move sediment. Re-establishment of an outfall from the LFCC to the river is dependent on reservoir and river conditions. Native material, bioengineering, and other bank protection works may be utilized to protect the LFCC and existing levees. Excavation of sediment detention ponds in the reservoir delta may occur to capture and better distribute some of the in flowing sediment.

Levee maintenance on the levee at its current location is anticipated to continue another 5 to 8 years. During this time, Reclamation plans to move the river and the low flow channel to the west side of the valley below San Marcial. This future action is contingent upon completion of an Environmental Impact Statement, a favorable separate Biological Opinion from the Fish and Wildlife Service, and congressional appropriations. All activities associated with the river and low flow realignment will require separate ESA and NEPA compliance.

Hypothetical River Maintenance Project/Projects

The river channel in the San Marcial Reach is greatly influenced by the presence of saltcedar, an overabundant sediment supply, a minimal valley slope, past channelization activities, and changing reservoir levels. The San Marcial railroad bridge and embankment, the levee system, and Reclamation's LFCC are the primary riverside facilities that require protection. River channel capacity through this reach is a major bottleneck for the entire Middle Rio Grande below Cochiti Dam.

Two dominant river maintenance needs are sediment plug removal and maintaining a river channel to the reservoir pool. The purpose of sediment plug removal is to restore river channel capacity. The purpose of maintaining a river channel to the reservoir pool is to effectively transport water and sediment into the reservoir pool thereby decreasing aggradation upstream, preventing the loss of an active, flowing channel, and water delivery.

A hypothetical sediment plug removal project would involve a small pilot cut through a sediment plug thereby aiding natural fluvial processes in removing the overall plug. Removal of sediment plugs would increase channel capacity as well as allow for higher discharges throughout the entire Middle Rio Grande below Cochiti Dam. An example of a sediment plug removal project is the Tiffany Plug Removal Project. Reclamation excavated an approximately 4-mile long pilot cut through portions of a sediment plug between Bosque del Apache National Wildlife Refuge and San Marcial during 1996 and early 1997. A total of 10,000 cubic-yards of material was excavated from the pilot channel (dimensions: 10 feet top width, 5 feet bottom width, and 5 feet deep). Higher winter base flows and short-term increases in discharge prior to spring runoff removed a large portion of the sediment plug and high spring runoff flows moved the remainder of sediment downstream. Excavated material was placed along the pilot channel and was dispersed downstream with high flows. As a result, channel capacity through this critical reach of the Middle Rio Grande Valley was increased. Excavation work in the river channel was done primarily in the dry. Access to the site through the adjacent floodplain was limited to areas with predominantly saltcedar growth.

A hypothetical temporary channel to the reservoir pool would involve channel excavation through the exposed delta with the material placed on either side of the channel. An example of a temporary channel project is the Elephant Butte Temporary Channel Project. Reclamation constructed a temporary channel through the reservoir delta during early 1997 to efficiently deliver water and sediment into Elephant Butte Reservoir. A goal of this project was to relocate the active delta to a more strategic location to alleviate upstream channel aggradation and evenly distribute the sediment load across the headwaters region. The work involved construction of a temporary berm to direct flows and excavation of a new channel alignment to the reservoir pool. The temporary channel was about 1 mile long, averaged about 200 feet wide and 4-5 feet deep, and involved about 100,000 cubic yards of excavation. Approximately 20,000 cubic yards of fill material was used to construct the temporary berm, which was about 3,800 feet long. Two high flow side channels were constructed with center islands at the midway point of the temporary channel.

Reclamation's policy in maintaining a channel to the reservoir pool will be highly dependent on reservoir levels. For any established channel at reservoir contents between 1.9 and 2 million acre-feet, only the environmental features of the channel will be maintained on an annual basis. For reservoir content levels of below 1.9 million acre-feet, Reclamation will pursue performing maintenance to the established channel. For reservoir content levels below 1.6 million acre-feet, Reclamation will pursue establishing a new channel alignment at least once every five years. Establishing a new channel alignment would be accomplished to more evenly distribute sediment deposition across the delta.

The reasonable worst case scenario of a multi-year prolonged drought developed for the water operations analysis can also be used to develop a measure of potential Elephant Butte Reservoir content reduction and the associated extent of newly exposed channel for which river maintenance may be necessary. The content of the reservoir in the last year of this scenario dropped to about 1.1 million acre-feet. The reservoir pool would then be located several miles above the Narrows and about 6-8 miles downstream from the current location. It was also estimated that after five consecutive years of only 60% normal runoff, the reservoir would go from its present content approximately 1,990,000 acre-feet to 435,000 acre-feet. The hypothetical new reservoir pool location would be miles below the Narrows and within the lower sub-basin, about 15 to 20 miles downstream from the current location. Should each of the runoff volumes for the next five years be at or above normal, Elephant Butte Reservoir would remain at the current content of about 400,000 acre-ft.

Hot Springs Reach

The river channel in the Hot Springs Reach was channelized in 1985 and is relatively stable. Consequently, it is unlikely that any large-scale projects (i.e., beyond the scope of annual maintenance) would be required in this reach.

- Woody Debris Snags and Boulder Placement
- High Flow Side Channels
- Deformable Bankline
- Vegetation planting
- Clearing of Understory Vegetation
- Non-native Vegetation Clearing and Floodplain Expansion
- Jetty/Snag Removal
- Rock Vanes
- Rock Weirs
- Low Flow Stage Control Dikes
- Groins/Bendway Weirs
- Training Dikes
- Revetments and Windrows
- Permeable Jetties
- Curve Shaping
- Transect Brushing
- Mowing and Root Plowing
- Dredging/Sediment Settling Basins
- Toe Revetment Planting
- Arroyo Plug Grading and Removal

The most prominent aspect of annual maintenance in the Hot Springs Reach would be excavation of sediment in the river channel by arroyos. The four primary arroyos in the reach are Mescal Arroyo, Cuchillo Negro Arroyo, Arroyo Hondo, and Palomas Arroyo; the largest amounts of sediment accumulate at the mouths of Mescal and Cuchillo Negro arroyos. Some of the sediment travels a significant distance downstream from the arroyo mouths. Sediment excavation would occur during periods of non-release from Elephant Butte Reservoir. Flow in the river at this time consists of dam seepage and is less than 50 cfs. Excavation equipment would include a bulldozer, excavator, and/or scraper. Easements have been obtained for placement of spoil materials on property adjacent to Mescal and Cuchillo Negro arroyos; Arroyo Hondo and Palomas Arroyo are located on Reclamation lands with ample area for placement of spoil materials. All excavated material would be placed at sites away from the river channel, where there would be low probability of the material re-entering the channel during rainfall events. Existing access ramps to the river channel would be maintained. The average amount of excavated material would be about 40,000 cubic yards per year.

Since the channelization in 1985, Reclamation's policy has been to provide bank protection for infrastructure that existed prior to 1985. In accordance with this policy, riprap would be placed to control bank erosion at sites where pre-1985 structures were threatened. Additionally, dislodged riprap would be replaced at the two existing grade control structures in this reach. Total annual riprap placement would probably average approximately 850 cubic yards.

During periods of non-release from Elephant Butte Reservoir, a temporary low flow stage control dike would be built at a site within the city of Truth or Consequences. The dike would be removed immediately prior to the resumption of releases from the reservoir. A suitable site has been identified and has been in use since 1996. The dike would raise the water level in the channel and adjacent groundwater, which would increase flow rates at nearby hot springs. The 1985 channelization project lowered the bed of the channel, which resulted in a lower water table in the adjacent aquifer during periods of low flow in the river. Construction of the stage control dike would require approximately 600 cubic yards of riprap, most of which could be recovered when the dike was removed.

8. Geomorphology

In the following table, a positive symbol (+) denotes that the net effect to this geomorphic parameter would be an increase in magnitude. The negative symbol (-) indicates that the net effect to this geomorphic parameter would be a decrease in magnitude. Both symbols (+ or -) indicate that the activity has the potential of either increasing or decreasing the associated parameter's magnitude. For these cases, the river channel's response would be highly dependent on the specific usage of a given maintenance activity. The controlling factors are how the activity is used in combination with other activities and the exact location the activity is applied. The (N/A) symbol identifies activities that would not influence the specified geomorphic parameter.

Qualitative analysis of effects for specific river maintenance activities on geomorphic channel parameters by river reach. Reach specific deviations from the general channel response are shown parenthetically. The following river reach codes are used: V=Velarde, E=Espanola, C=Cochiti, M=Middle, B=Belen, RP=Rio Puerco, SO=Socorro, SM=San Marcial, HS=Hot Springs. (+) indicates an increase, (-) indicates a decrease, (N/A) indicates No Affect.

Maintenance Activity	**Applicable Reach**	***Sinuosity***	**Slope**	**Channel Width**	**Channel Depth**	**Floodplain Width**	**Width to Depth Ratio**	**Overbank Wetted Area**	**Velocity**
Gradient Restoration Facilities	C,M,B RP,SO,HS	N/A	-	.+.	-	.+.	.+.	.+.	-
Rock Weirs	V,E,C,M B,RP,SO	+	-	+ or -	+	N/A	+ or -	.+.	-
Deformable Bankline	V,E,C,M B,RP,SO SM	+ or -	N/A	+ or N/A	+ or N/A	+ or N/A	+ or N/A	+ or N/A	- or N/A
Vegetation Plantings	ALL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Non-native Vegetation Clearing and Floodplain Expansion	ALL	+ or -	+ or -	+ or N/A	- or N/A	+	.+.	.+.	- or N/A
Channel Avulsions	E,C,M,B RP,SO,SM	+	+ or -	+ or N/A	- or N/A	+	+	+ or N/A	- or N/A
Culvert and Low Water Crossings	SM	N/A	N/A	N/A	N/A	N/A	N/A	.+.	N/A
Re-establish Floodplain Connectivity	V,E,C,M B,RP,SO	+ or -	-	+ or N/A	- or N/A	.+.	+ or N/A	.+.	N/A
River Bar/Island Maintenance	V,E,C,M B,RP,SO SM	N/A	N/A	+ or N/A	N/A	+ or N/A	+ or N/A	+ or N/A	N/A
Oxbow Re-establishment	V,E,C,M B,RP,SO SM	N/A	N/A	N/A	N/A	.+.	N/A	.+.	N/A
Jetty/Snag Removal	ALL	+ or N/A	+ or N/A	+ or N/A	- or N/A	+ or N/A	+ or N/A	N/A	- or N/A
Channel Widening/Bank Destabilization	E,C,M,B RP,SO,SM	+ or N/A	+ or N/A	+	-	+ or N/A	+	+ or N/A	-
Strategic Bank Boulder/ Snag Placements	ALL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Terrace Lowering	V,E,C,M B,RP,SO SM	N/A	N/A	N/A	N/A	.+.	N/A	.+.	N/A
Rock Vanes	ALL	+ or -	+ or - (V=+)	+ or -	+ or -	+ or -	+ or -	+ or -	+ or -
High Flow Side Channel	C,M,BRP,SO,SM	N/A	N/A	+ or N/A	- or N/A	+ or N/A	+ or N/A	.+.	- or N/A
Removal of Lateral Confinements	C,M,B RP,SO,SM	+ or N/A	N/A	N/A	N/A	+ or N/A	N/A	+ or N/A	N/A
Increase Sand Load	C,M,B RP,SO,SM	-	.+.	.+.	-	.+.	-	.+.	-
Understory Vegetation Clearing	C,M,B RP,SO,SM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Toe Revetment Planting	ALL	+ or -	+ or -	+ or -	+ or -	+ or -	+ or -	N/A	+ or -
Native Material Revetment-Rock and/or Log Spurs	V,E,C,M B,RP,SO SM	+ or -	+ or -	+ or -	+ or -	+ or -	+ or -	N/A	+ or -
Groins/Bendway Weirs	E,C,M,B RP,SO,SM HS	+ or -	+ or -	+ or -	+ or -	+ or -	+ or -	N/A	+ or -
Training Dikes	C,M,B RP,SO SM,HS	N/A	N/A	N/A	N/A	- or N/A	N/A	-	N/A
Freeboard Dikes	V,E	N/A	N/A	N/A	N/A	-	N/A	-	N/A
Channel Realignment/Pilot Channels	C,M,B RP,SO,SM	+ or -	+ or -	+ or N/A	- or N/A	.+.	.+.	+ or N/A	- or N/A
Revetments and Windrows	ALL	N/A	N/A	- or N/A	+ or N/A	N/A	- or N/A	N/A	+ or N/A
Permeable Jetties	SM	+ or -	+ or -	- or N/A	+ or N/A	- or N/A	- or N/A	N/A	+ or N/A
Curve Shaping	ALL	N/A	N/A	-	+	- or N/A	-	N/A	+ or N/A
Low Flow Stage Control Dikes	HS	N/A	N/A	-	+	- or N/A	-	N/A	+ or N/A

Arroyo Plug Grading and Removal	V,E,C,M B,RP,SO HS	N/A	N/A	.+.	-	N/A	.+.	N/A	-
Dredging	SM,HS	+ or -	+ or -	+ or -	+ or -	+ or -	+ or -	N/A	+ or -
Sediment Settling Basins	SM,HS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Transect Brushing	ALL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mowing/Root Plowing	M,B,RP SO,SM	N/A	N/A	+ or N/A	- or N/A	+ or N/A	+ or N/A	+ or N/A	- or N/A
Levee Maintenance (existing levees)	C,M,BRP,SO,SM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

9. River Maintenance Schedule

The following schedule (Table 2) estimates future, proposed river maintenance activities by reach over the next three to five year period based on current river conditions. Key river maintenance and environmental issues are listed for each project. The order of projects, by reach, gives a rough approximation of relative priority. It must be emphasized that the schedule is tentative and project priorities are often adjusted based on changing river conditions, new problem areas, workload limitations, or political considerations. These projects are considered long term river maintenance activities as opposed to unforeseen annual or emergency projects. Thus, this schedule represents a subset of potential projects.

Table 2. Bureau of Reclamation river maintenance project scheduling timeline (Note: Bold action items denote critical points of involvement for Fish and Wildlife Service staff.)

River Reach	Project Name	Key Issues
1)Velarde, New Mexico to Rio Chama Confluence (Velarde Reach)	Lyden Ditch Bank Repairs	- uncontrolled river flows into an irrigation system
2) Rio Chama Confluence to Otowi (Espanola Reach)	Espanola Dikes Cross Drainage	- provide drainage for agricultural lands
	Phil Blood Pipe	- provide drainage for wetlands (wetland maintenance)
	San Ildelfonso Pond	- river bank erosion threatening tribal lake, river needs reclamation from gravel mining
	Santa Cruz	- river threatening bridge abutment, levee, sewer lift station
	Vigil Ditch Area Phase 7	- river threatening irrigation facilities and river reclamation from gravel mining
3) Cochiti Dam to Bernalillo-HWY 44 (Cochiti Reach)	Santa Ana Phases 2 and 3 (already consulted on)	- channel degradation and levee threatened via erosion
	San Felipe Phase 3	- bio-engineering for bank stability
	Cochiti Pueblo Phase 1, 2, 3	- channel degradation and levee threatened via river bank erosion
	Santo Domingo Phase 4	- channel degradation and levee threatened via erosion
4) Bernalillo-HWY 44 to Isleta Diversion Dam (Middle Reach)	Albuquerque Overbank Phase 2, 3	- floodplain expansion , clearing of understory vegetation
	Albuquerque Area Channel Widening Phase 1,2,3	- flow area expansion, clearing of understory vegetation.
	Hwy. 44 to Corrales Reach	- floodplain expansion , clearing of understory vegetation.
	Albuquerque Area	- floodplain expansion , clearing of understory vegetation.
	Bernalillo/Sandia Pueblo	- river threatening levee that protects irrigation facilities and the town of Bernalllillo
5) Isleta Diversion Dam to Rio Puerco Confluence (Belen Reach)	Isleta Reach	- floodplain expansion, , clearing of understory vegetation.

6) Rio Puerco Confluence to San Acacia Diversion Dam (Rio Puerco Reach)	Rio Puerco Reach La Joya Overbank Project Phase 2	- floodplain expansion, clearing of understory vegetation - floodplain expansion
7) San Acacia Diversion Dam to River Mile 78 (Socorro Reach)	San Acacia to Escondida Reach Socorro Channel Widening	- floodplain expansion, clearing of understory vegetation - floodplain expansion , clearing of understory vegetation
8) River Mile 78 to Headwaters of Elephant Butte Reservoir (San Marcial Reach)	Tiffany Mitigation & Channel Widening Tiffany Mitigation San Marcial Channel Avulsion BDANWR - San Marcial Levee BDANWR Overbank Project Ph. 2 San Marcial Berm Phases 2 & 3 Temporary Channel into Elephant Butte	- floodplain expansion - floodplain expansion - floodplain expansion - channel aggradation/sediment deposition(channel capacity) - floodplain expansion , - channel aggradation/sediment deposition(channel capacity) - channel aggradation/sediment deposition(channel capacity)

The following is an estimate of the total number of proposed and unforeseen river maintenance projects over the next five-year period, by reach, including long-term, annual and emergency work. Consideration was given to the number of projects constructed in recent years, current workload limitations, and the evolution of the river maintenance program.

Reach Name	Number of Projects
Velarde	3
Espanola	4
Cochiti	8
Middle	3
Belen	2
Rio Puerco	2
Socorro	7
San Marcial	19
Total	**40**

The above list represents a total river maintenance effort of about 8 projects per year.

10. Coordination Process

The timely coordination of river maintenance activities with the Service and other resource management agencies is essential to insure efficient project completion. While all river maintenance projects include intensive effort by Reclamation staff and numerous internal meetings, there are main points of coordination with the Service that are critical for effective ESA consultation. These include early project scoping, alternative development, and project design and description.

A series of meetings were held between Reclamation and the Service in 1995 to develop a scheduling process for critical river maintenance projects. The timeline presented in Table 2 represents time frames discussed during the 1995 meetings and subsequent refinements to reflect more current issues and processes.

As mentioned above, long-term projects allow for advanced planning and more time for hydrologic, geomorphic, and biological surveys. The general scheduling steps also apply to long-term projects but the time frame is often extended over several years. The same meetings and project reports would be developed for long-term projects.

Project scoping, analysis, and description and ESA compliance report guidelines follow. These report guidelines not only present the general content of each report but also a systematic approach to riverine problem solving. This is a general outline and will be customized for each project. It should be emphasized that informal consultation involving the Service will begin early and occur as often as needed for specific projects.

Scoping Report - In general this report introduces the goals and objectives of the project, summarizes the historic, current and future geomorphology of the reach, and addresses environmental concerns.

- Intro, purpose of paper
- project location
- description of current situation
- description of project need
- document and analyze historical and current channel geomorphology
- estimate future geomorphic trends
- characterization and summary of biological condition and trends with interpretation based on river morphologic condition, issues, or concerns
- endangered species
- general fish and wildlife

Alternative Analysis Report - In general, the Alternative Analysis paper summarizes the project and reach geomorphology, analyzes the alternatives and evaluates their feasibility, and defines the preferred alternative.

- Intro, purpose of paper
- project location
- description of current situation
- description of project need
- summary of geomorphology
- systematic engineering/geomorphic analysis of alternatives
- evaluate engineering/environmental/economic feasibility of alternatives and define preferred alternative

Project Description (Draft and Final) - In general this report summarizes the previous two reports and details the preferred alternative design.

- Intro, purpose of paper
- project location
- description of current situation
- description of project need
- summary of geomorphology
- summary of alternatives and why the preferred alternative was chosen
- summary of environmental issues/concerns and environmental features of the preferred alternative
- detail of the preferred alternative (distances, quantities, materials, alignment, etc.)
- project description drawings

ESA Compliance Report - In general, this report will 1) reference information from the above reports, 2) document the ESA coordination process followed for a specific project, and 3) confirm compliance with conditions/sideboards developed through this programmatic consultation. It is anticipated that the majority of river maintenance projects will fit within the sideboards developed in this document. Two additional reports are prepared after completion of the river maintenance project.

Construction Report - Summary of construction procedures and inspection reports

Project Evaluation Report (s) - In general this/these post construction reports evaluate the project effectiveness and impacts on upstream/downstream geomorphology.

- short term geomorphic response
- long term geomorphic response

The scheduling process for emergency projects is necessarily truncated but still must contain the same critical points of coordination with the Service, project scoping, alternative development, and project design. The development of ESA compliance documentation will take place during and after completion of the project. Reclamation would, as standard procedure, follow-up with adequate analysis once the immediate threat has become manageable. At this point, Reclamation would determine if additional long term planning needs to occur at the site.

The aforementioned coordination guidelines have been established for developing successful projects. These guidelines are not all-inclusive or meant to be project management “recipes.” They are intended to provide a framework around which meetings and reports can be developed, ultimately leading to a sound engineering design and ESA, section 7, compliance.