MIDDLE RIO GRANDE BOSQUE, NEW MEXICO
GENERAL INVESTIGATION STUDY

Final Feasibility Report

U.S. Army Corps of Engineers
Albuquerque District

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of Engineers ®

EXECUTIVE SUMMARY

Final Feasibility Study, Middle Rio Grande Bosque Ecosystem Restoration
General Investigation Study

The Middle Rio Grande Bosque Environmental Restoration (MRGBER) project seeks to restore riparian woodland habitat (known locally as the "bosque") to 916 acres of floodplain along a 26 mile stretch of the Rio Grande. This riparian corridor extends north across the city of Albuquerque, New Mexico, from its southern border to the northern limits of the city, and includes the community of Corrales and the Pueblo of Sandia.

The main goals of ecosystem restoration within this reach of the river are to:

- Protect and restore critical habitats for multiple species. These habitats have become degraded by urban development, as well as by flood control operations and the development of surface water supply facilities.

- Restore the river to a more natural flow condition; one in which floodplain wetlands and channels can absorb overbanking flows. This will better mimic natural flood regimes providing for improved recruitment of native floodplain vegetation.

- Reduce catastrophic fire risk within the bosque (and the threat to adjacent homes and businesses) through changes in vegetation composition and structure.

- Expand recreational opportunities while redirecting use away from sensitive riparian areas and flood control structures. The bosque constitutes an important urban/wildlands interface and is currently subjected to heavy, often unstructured, recreational use with negative impacts to flood control structures, vegetation, and wildlife. Improved recreational facilities would channel use away from sensitive areas while educating community members about their value.

This feasibility study evaluates alternative plans for ecosystem restoration within the study reach. The report details the current conditions and the likely future without-project conditions over the next 50 years. A series of restoration alternatives have been evaluated using National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), Other Social Effects (OSE), social justice, and other criteria. The Habitat Evaluation Procedure (HEP) process, developed by the U.S. Fish and Wildlife Service, was used to help quantify restoration benefits of the alternatives.

The recommended plan consists of:

- Construction of wet features in the floodplain, such as high-flow channels (side channels that connect to the main river only during peak flows), willow swales, and wetlands. These features will enhance the movement of overbanking flows through the floodplain, and will facilitate the movement of water from storm drain outfalls in ways that create new riparian habitat while reducing the risk of damage to flood control structures.

- Improvements to the complexity and diversity of the water/land interface for fish and invertebrate species. This will be accomplished through in-channel work, including bank destabilization.

- Restoration of native vegetation and habitat through augmentation, the reduction of exotic and invasive species, the restoration of native riparian gallery forests, and the removal of Kellner jetty jacks. Jetty jack removal will restore sediment mobility in the active channel, providing substrate favorable for the natural establishment of native vegetation.

- Changes to the vegetation canopy structure through reductions in understory density will reduce the incidence of catastrophic fire formation and spread. Understory thinning and jetty jack removal will also improve floodplain access by emergency vehicles and personnel to contain the spread of fires.

- Construction of recreation facilities, including new trails and signs, and the closure of trails in sensitive areas within the bosque.

The total project first costs for the recommended plan of $24 million and the fully-funded estimate of $24.8 million are within the $25 million authorized for federal spending. The project sponsor is the Middle Rio Grande Conservancy District (MRGCD).

The Corps' authority for undertaking this study is found in Public Law 228, Section 401 WRDA 1986, and HR 107-258. Construction authority comes from Section 3118 WRDA 2007 as amended by Section 114 Public Law 111-8, and construction appropriation is authorized by the 2009 Energy and Water Development Appropriations Act.

Section 3118 of WRDA 2007 directs the Secretary to select and carry out restoration projects in the Middle Rio Grande Basin from Cochiti Dam to the headwaters of Elephant Butte Reservoir in the State of New Mexico. Projects are defined as those that will produce, consistent with other Federal programs, projects, and activities, immediate and substantial ecosystem restoration and recreation benefits. In carrying out this program, the Secretary is to consult with, and consider the activities being carried out by, the Middle Rio Grande Endangered Species Act Collaborative Program and the Bosque Improvement Group of the Middle Rio Grande Bosque Initiative.

The recommended plan was coordinated with numerous sponsors and stakeholders, including the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) and the Middle Rio Grande Bosque Initiative. The Collaborative Program is a multi-agency organization that has funded a number of habitat restoration projects in the recommended plan area. The Corps, U.S. Bureau of Reclamation and the New Mexico Interstate Stream Commission have all constructed projects within the recommended plan area under the Program. These projects have been planned and constructed in coordination with each other and the development of the Middle Rio Grande Bosque Restoration Project. They have been planned so that they complement one another and do not overlap. The culmination of these projects would provide additional habitat for all species, and especially the Rio Grande silvery minnow and Southwestern Willow Flycatcher. There have been a limited number of Bosque Initiative projects in the recommended plan area due to lack of funding and the closure of that program. None of the Bosque Initiative completed projects overlap with the recommended plan.

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SECTION 1 - INTRODUCTION

1.1 Study Purpose

The U.S. Army Corps of Engineers, Albuquerque District (Corps), in cooperation with the Middle Rio Grande Conservancy District (MRGCD), as the local sponsor, and other stakeholders, has conducted the Middle Rio Grande Bosque, NM (MRGB) general investigation feasibility study. The study area lies within the Albuquerque reach of the Middle Rio Grande (MRG) and extends north to the Pueblo of Sandia and south to the Pueblo of Isleta. "Bosque" is a Spanish word that is used traditionally in the southwestern United States to refer to a wooded riparian area; the MRG refers to the portion of the river that passes through New Mexico and is typically defined as extending from Cochiti Dam, north of Albuquerque, downstream 160 miles to San Marcial, New Mexico, and Elephant Butte Dam. The MRG Bosque in New Mexico has been degraded due to a variety of causes. With local sponsorship, the Corps can participate through its congressional authorities to restore function and increase high value habitat through the Albuquerque reach. The goal of this collaborative effort is to formulate and evaluate a suite of alternatives in order to identify a cost effective plan, the Recommended Plan, which meets the objectives of the study and can be implemented to improve the Bosque ecosystem structure and function.

The Bosque of the MRG is an ideal location for restoration because of its unique quality and critical value as wildlife habitat and its importance on a local, regional, national, and international scale. Resource values within the Albuquerque reach of the MRG are significant because the Bosque:

- Remains the only corridor for terrestrial and avian species through the state's largest urbanized area.
- Functions as a critical link in a corridor connecting two designated Wild and Scenic River areas, eight national wildlife refuges, and several state parks and wildlife management areas.
- Embodies the largest remaining continuous cottonwood forest found in North America.
- Constitutes a critical travel corridor connecting Central and South America to North America along the Rio Grande Flyway. Over half of the 277 land birds found in the MRG are residents, and 54 bird species breed within this habitat (Yong and Finch 2002).
- Provides breeding and foraging habitat for two Federally listed animals, of which one fish is found only within this reach of river. The study area also provides habitat for eight additional species listed as state or Federal special status species.
- Serves as the subject of two multi-agency initiatives to maintain some hydrologic and geomorphic character through environmental water releases from Cochiti Dam and a sediment transportation project at Jemez Canyon Dam.

Habitat loss, fragmentation, and alteration have caused the loss of 12 fish species from the MRG, two of which are now extinct. The Federally listed Rio Grande silvery minnow occurs only in this reach of river. Habitat restoration within the MRG will provide additional habitat for imperiled species so that the species might increase in number. The project will also provide a more stable environment for population sustainability. These same benefits will extend to the overall wildlife community.

In addition to carrying out the authorities granted to the Corps for ecosystem restoration and specific legislation provided for initiation and support of this study, the project complies with the letter or intent of several Federal laws, executive orders, and treaties, with which the Corps must comply, concerning restoration and conservation efforts, which include:

- North American Waterfowl Management Plan. The project will increase the amount and quality of resting, breeding, and foraging habitat for waterfowl.

- Executive Order No. 11990 (Protection of Wetlands) and North American Wetlands Conservation Act of 1989. The MRG restoration project will conserve, create, or improve a significant portion of the 5,000-acre project area, which is largely considered wetland habitat under the Executive Order and Act. Permanent and seasonal wetlands will be created and temporary inundation of the floodplain will be restored to over 25 percent of the study area.

- Executive Order No. 11988 (Floodplain Management). Through restoration efforts, the project will improve, and in most cases restore, critical functions that provide for the health of the floodplain.

- Endangered Species Act of 1973, as amended. The project will provide essential hatching and rearing habitat for the endangered Rio Grande silvery minnow through extended areas of inundation of the floodplain during high flows. Additional low velocity or slack water habitats suited for the RGSM will be created within the river channel.

- Bald Eagle Protection Act of 194. The project would ensure existing and future roost sites for migratory eagles. The restoration would indirectly benefit the eagle from water quality and higher fish availability.

- Migratory Bird Treaty Act of 1918, Migratory Bird Conservation Act of 1929, and associated treaties. Habitat improvements and diversification will benefit migratory birds using the MRG as a travel corridor and breeding site. Habitat improvements will benefit neotropical migrants by providing essential feeding and resting habitats along the Rio Grande flyway.

The state of New Mexico has created the 4,300-acre Rio Grande Valley State Park that constitutes the study area. A local organization, the Bosque del Rio Grande Nature Preserve Society, was crucial in establishing the state park. The park was designated by the state and is operated by the City of Albuquerque under joint powers agreement. The Rio Grande Nature Center represents the visitor's center for the park whose mission is to preserve and protect the Rio Grande Bosque, to educate the public about Rio Grande ecosystems, and to foster positive human interactions with those systems. Trails from the nature center meander through various Bosque habitats and demonstrate the importance of this ecosystem to wildlife and the human environment. The City of Albuquerque Open Space Division has established parking lots, trails, and interpretive centers throughout the study area to provide residents and tourists the opportunity to experience this rare ecosystem. The City has sponsored with the Corps a smaller restoration project to create several wetlands sustained by water allocated by the City.

Local efforts to conserve or restore the MRG Bosque include that of the Bosque School, in which 5,000 students from 40 local schools participate in the Bosque Ecosystem Monitoring Program. The program performs field data collection monitoring key indicators of structural and functional change in the Middle Rio Grande riparian forest. The Bosque Youth Conservation Corps works on projects that protect, restore, and enhance Albuquerque's thriving Bosque environment along a two-mile stretch of the Rio Grande.

1.2 Study Authorization

The authority for this study was derived from a series of Congressional actions authorizing studies for projects on the Rio Grande, particularly in the MRG. These authorizations began with the flood control study authorization for the Rio Grande and its tributaries in New Mexico in Section 4 of the Flood Control Act of 1941of Public Law No. 228, 77th Congress, 1st Session, which stated:

> *The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control, to be made under the direction of the Chief of Engineers, in drainage areas of the United States and its territorial possessions, which include the following-named localities ....Rio Grande and tributaries, New Mexico.*

In keeping with that authority, the report of the chief of Engineers on "Rio Grande and Tributaries, New Mexico," dated April 5, 1948, was transmitted to the House of Representatives on June 10, 1949 and published in House Document Numbered 243, Eighty-first Congress, First Session. By resolution dated April 11, 1974, the House Public Works Committee requested that the Board of Engineers for Rivers and Harbors review that report of the Chief of Engineers with particular reference to providing a plan for development, utilization and conservation of water and related land resources of "the metropolitan region of the Rio Grande from Cochiti Lake to Elephant Butte Reservoir," with "Such studies to include appropriate consideration of the needs for protection against floods with particular emphasis on…general recreation facilities, enhancement and control of water quality, enhancement and conservation of fish and wildlife, and other measures for environmental enhancement…"

In 2001, the MRGCD requested initiation of a reconnaissance study by the Corps for ecosystem restoration in the MRG. Initial appropriations for that study were included in the Energy and Water Development Appropriations Act for fiscal year 2002, Public Law 107-66. The Conference Report, House of Representatives Report 107-258, stated:

The conferees have agreed to provide $350,000 for the Corps of Engineers to initiate and complete a reconnaissance study to evaluate environmental restoration, recreational, and related purposes for the Middle Rio Grande, Bosque, New Mexico. The conferees are aware of the unique nature of this study and encourage the Corps of Engineers to establish a regional inter-agency and inter-state steering committee to leverage lessons learned from the Rio Salado, Phoenix and Tempe Reaches, Arizona, and Tres Rio, Arizona environmental restoration projects as well as experience within the agency.

Subsequent additional appropriations for the Middle Rio Grande Bosque reconnaissance and feasibility studies were included in the Energy and Water Development Appropriations Acts for 2003,2004, 2005, 2006, and 2008, resulting in total cumulative appropriations of $1,786,000 for the Middle Rio Grande Bosque environmental restoration investigations.

In response to the study authorities and appropriations, a reconnaissance study was initiated in March 2002. The results and conclusions of the reconnaissance phase were presented in the Middle Rio Grande Bosque Restoration Section 905(b) Analysis, U.S. Army Corps of Engineers, Albuquerque District, June 2002. The recommendation of that report states that there is a Federal interest in proceeding to a feasibility phase of the MRGB General Investigation Study. A Feasibility Cost Sharing Agreement (FCSA) was signed between the MRGCD, as the non-Federal sponsor, and the Corps on 12 April 2004. The without-project condition Feasibility Scoping Meeting (FSM) was held 18 December 2006, and Corps Headquarters issued the FSM Policy Guidance Memorandum 21 December 2006, signifying completion of the existing conditions and future-without-project conditions milestones. The study was scheduled for completion in December 2008.

Section 3118 of the Water Resources Development Act of 2007, P.L. 110-114, "Middle Rio Grande Restoration, New Mexico", as amended by Section 114 of the Energy and Water Development and Related Agencies Appropriations Act, 2009, Division C of the Omnibus Appropriations Act, 2009, P.L. 111-8, authorizes Federal funding, without the standard cost share, of up to $25 million for MRG Bosque restoration, as follows:

(a) RESTORATION PROJECTS DEFINED.—In this section, the term "restoration project" means a project that will produce, consistent with other Federal programs, projects, and activities, immediate and substantial ecosystem restoration and recreation benefits.

(b) PROJECT SELECTION.—The Secretary shall select and shall carry out restoration projects in the Middle Rio Grande from Cochiti Dam to the headwaters of Elephant Butte Reservoir in the State of New Mexico in accordance with the plans recommended in the feasibility report for the Middle Rio Grande Bosque, New Mexico, scheduled for completion in December 2008.

(c) LOCAL PARTICIPATION.—In carrying out subsection (b), the Secretary shall consult with, and consider the activities being carried out by—

(1) the Middle Rio Grande Endangered Species Act Collaborative Program; and

(2) The Bosque Improvement Group of the Middle Rio Grande Bosque Initiative.

(d) COST SHARING.—Any requirement for non-Federal participation in a project carried out in the bosque of Bernalillo County, New Mexico, pursuant to this section shall be limited to the provision of lands, easements, rights-of-way, relocations, and dredged material disposal areas necessary for construction, operation and maintenance of the project.

(e) AUTHORIZATION OF APPROPRIATIONS.—There is authorized to be appropriated $25,000,000 to carry out this section.

1.3 Middle Rio Grande Bosque Study Area

The Rio Grande originates in southern Colorado and reaches 1,865 miles to the Gulf of Mexico, constituting the fourth largest river in the United States in terms of length and drainage area. The river bisects New Mexico in a north-to-south direction and delineates the 1,250-mile international boundary between Texas and Mexico (Figure 1.1). The river is designated a “Wild and Scenic River” to protect its outstanding resource values.

The Middle Rio Grande Bosque is a riparian area located in the middle reach of the Rio Grande, in the vicinity of the City of Albuquerque, New Mexico. The area is maintained as a part of the Middle Rio Grande Flood Control Acts of 1941 and 1950 and is within the facilities of the *Middle Rio Grande Floodway Project*, which resulted in the construction of additional levees and dams between Espanola and San Marcial, New Mexico (USACE 2002, 2003a, 2007, 2008a,b). The Bosque area within Albuquerque was designated as the Rio Grande Valley State Park (RGVSP) through the Park Act of 1983 and is cooperatively managed by the City of Albuquerque Open Space Division (AOSD) and the MRGCD (Figure 1.1). That is, the Bosque is offered protection as a state park, but without state operating funds, and is administered by the City and MRGCD through formal agreements.

> *Senate Bill 529 provides that it is the intent of the Rio Grande Valley State Park Act that the State Parks Division (SPD) of Energy, Minerals, and Natural Resources Department (EMNRD) not bear the operating costs for the Rio Grande Valley State Park except for the area within the Rio Grande Nature Center State Park. ... The Rio Grande Valley State Park is managed by the City of Albuquerque with a joint powers agreement with the MRGCD.*

The Bosque within Corrales is designated as the Corrales Bosque Preserve and is cooperatively managed by the Village of Corrales and the Corrales Bosque Commission through an agreement with the MRGCD. Pueblo of Sandia lands are also within the study area and those lands are managed by the Pueblo.

The Northern extent of the Corrales Bosque Preserve forms the north boundary of the study area, whereas the southern boundary is formed by the northern limits of the Pueblo of Isleta. The area is defined on the east and west by the Albuquerque Levee system, although the areas outside and adjacent to the levees within the original floodplain have also been considered in the study. The study area is approximately 26 miles in length along the river and roughly 5,300 acres in areal extent. The average width of the floodway area between the levees is 1,500 feet (Lagasse, 1981) and consists of the river channel and narrow strips of riparian habitat on each bank.

Because the MRGB study area is so large, and the relative effects of proposed designs are localized to some degree, the Corps divided the project area into five reaches (Figure 1.2). Reach designation allows for simplified hydrologic analysis of existing conditions and evaluation of proposed restoration plans. Bridges denote the upstream and downstream boundaries for each reach because bridge crossings tend to have the greatest influence on hydrology and, therefore, constitute a logical break point. The reach designations are amenable to consideration of stakeholder interests, vegetative community makeup, and geographic location.

1.4 Middle Rio Grande Bosque Ecosystem

River systems and their attendant wetland and riparian woodland communities provide significant resources for both humans and wildlife in the semi-arid western United States. In New Mexico, riparian habitats make up less than two percent of the state's land cover, yet nearly 50 percent of the vertebrate species are riparian obligates (NMDGF 2004). Although these riparian ecosystems are considered to be the most productive and biologically diverse ecosystems in the region, they are now believed to be the most threatened (Johnson and Jones 1977, Johnson *et al.* 1985, Knopf *et al.*1988, Ohmart *et al*. 1988, Johnson 1991, Minckley and Brown 1994). Substantial impacts from human activities, beginning approximately 250 years ago, have resulted in compounding rates of change in structure and vegetation dynamics to the point that the Bosque ecosystem is now on the verge of irreversible conversion (Crawford *et al.* 1996). Open water or wet soil habitat is scarce in arid regions, by definition, and increasing demands on water further threaten this resource.

The Rio Grande's riparian ecosystem continues to provide habitat for a wide variety of wildlife species, although in a much reduced and degraded state compared to its historic status. The Rio Grande remains a critical travel corridor for many species, especially migratory birds that include neotropical songbirds, waterfowl, raptors, and cranes. Wildlife diversity within the MRG riparian corridor is substantially higher than any upland habitats in the rest of the state (Figure 1.3). Both the degradation of the hydrologic and geomorphic character of the river and the decline in aquatic and riparian habitat value threaten this diversity. The persistence of species, however, provides the opportunity for these species to expand their occupied area or increase numbers once adjacent habitats are restored or existing habitats are improved. Water resource management activities (diversions, dams, levees, drains, channelization, jetty jacks) by Federal and other entities have significantly altered the nature of the hydrologic regime, ecological processes, water table, and sediment transport of the Rio Grande within New Mexico, contributing to the loss and attrition of the Bosque and subsequent loss of species diversity. Abiquiu, Jemez Canyon, Galisteo and Cochiti Dams, operated for flood and sediment control by the Corps, have contributed, in part, to the degradation of ecosystem functions and values.

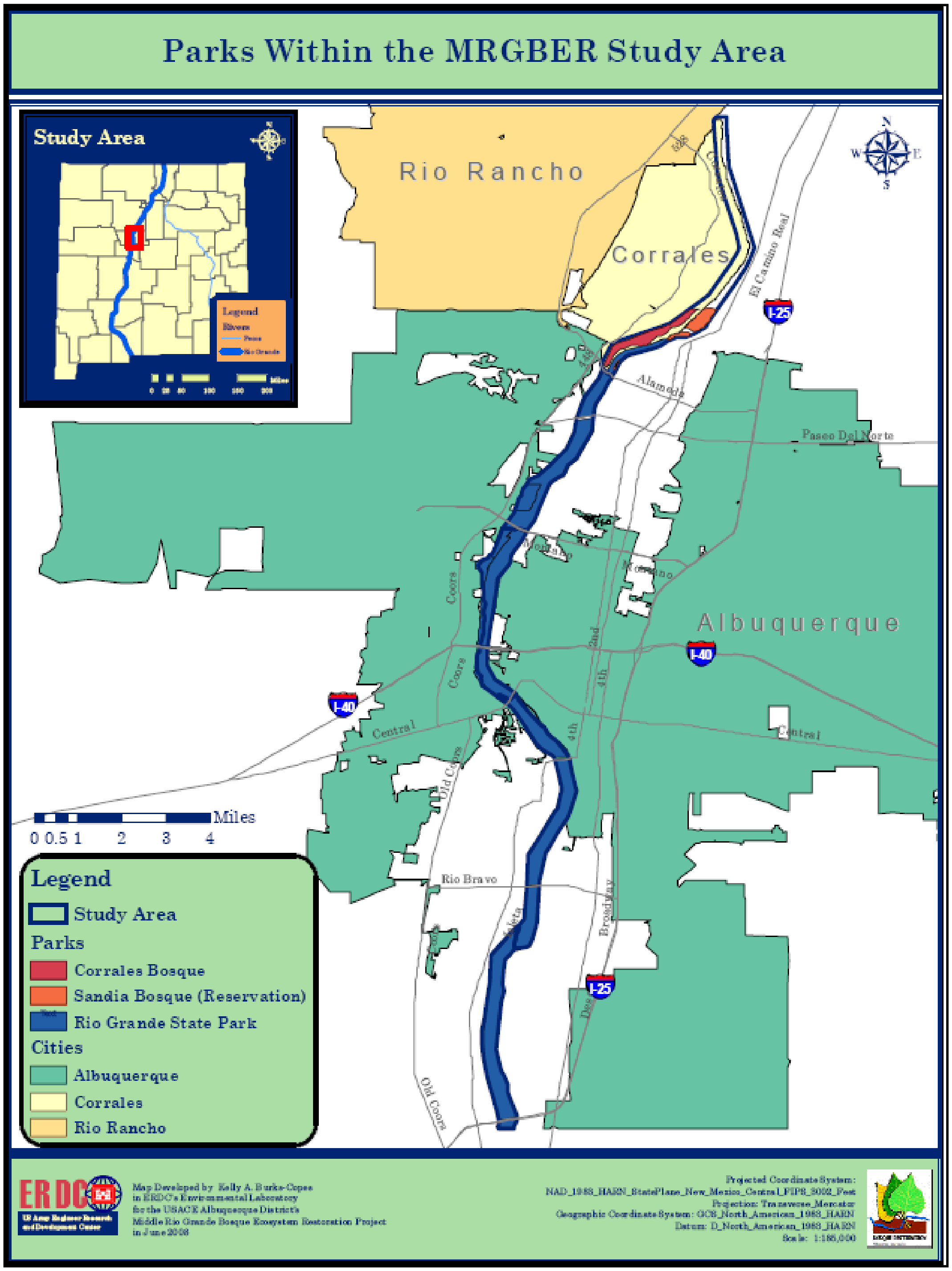


Figure 1.1. MRGB Location and Study Area.

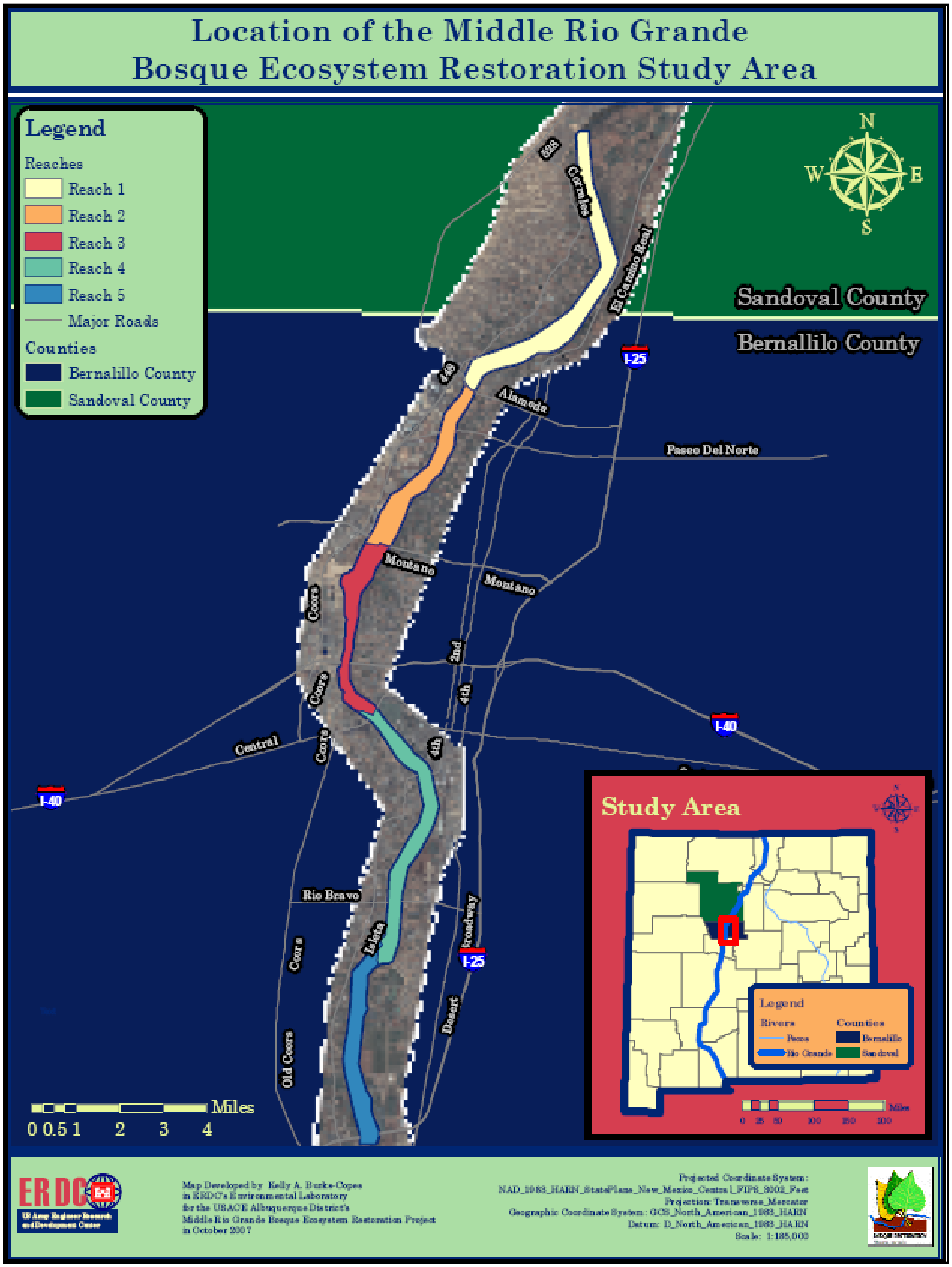


Figure 1.2. Reaches delineated for the Baseline Assessment.

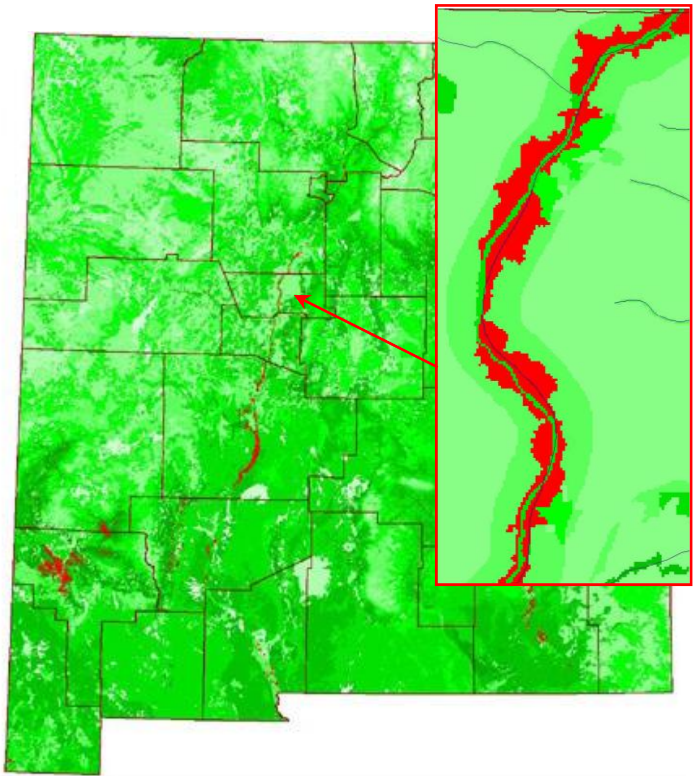


Figure 1.3. Species Diversity in New Mexico
- Inset is species diversity within the study area where red signifies the highest level of bio-diversity in total numbers of species.

1.5 Study Scope

This report provides an interim response to the study authority cited in Section 1.2, *Study Authorization*, and is intended to be a complete decision document that presents the results of the reconnaissance and feasibility phases of the MRGB General Investigation effort. This report presents the results and findings of the study, including those developed in the reconnaissance phase, so that readers can reach independent conclusions regarding the reasonableness of the report recommendations.

The scope of this feasibility study consists of:

- Identifying problems and needs associated with ecosystem degradation and related water and land resource problems and recreational needs within the approximately 26-mile-long study reach of the Rio Grande in Bernalillo County, New Mexico;

- Formulating and identifying alternative measures for ecosystem restoration, for increasing the amount or value of associated water and land resources, and for recreational needs, including National Environmental Restoration (NER), and

- Identifying a "Locally Preferred Plan" (LPP) if different from NER plan.

1.6 Scope Limitations

As with all planning-level work, much of the results of the hydrologic, hydraulic, design, economic, and environmental evaluations given in this report differ slightly from those presented in prior reports. The results presented in this report were subjected to a higher degree of refinement; however, the results are subject to further change with detailed design and cost estimation. The information presented in this report is based on Corps criteria for determining Federal interest in developing and implementing solutions to water resource problems, which differ from the criteria of other agencies for regulatory and other purposes. The information in this report does not supersede or in any way affect the results of other studies conducted for other purposes.

1.7 History of the Investigation

The Albuquerque District of the U.S. Army Corps of Engineers completed the first phase of the MRGB General Investigation (the reconnaissance phase) in June 2002. The report *Middle Rio Grande Bosque Restoration Section 905(b) Analysis*, U.S. Army Corps of Engineers, Albuquerque District, June 2002, presented the results and conclusions of the reconnaissance phase. The recommendation of that report was to proceed to the feasibility phase of the MRGB General Investigation. The Corps Headquarters certified the reconnaissance report on 23 July 2002, providing the Albuquerque District the authority to proceed into the feasibility phase. The Corps signed the FCSA with the MRGCD 12 April 2004. The without-project-condition Feasibility Scoping Meeting (FSM) was held 18 December 2006, and FSM Policy Guidance Memorandum was issued by the Corps Headquarters 21 December 2006, signifying completion of the existing- and future-without-project conditions milestone.

1.8 Prior Studies, Reports, and Existing Water Projects

Many studies have been conducted pertaining to water and related land resources within the study area and the region. These studies have examined themes including development trends, environmental resources, special status species, water supply, groundwater recharge, wastewater management, flooding and erosion, geology, cultural resources, history, and recreation. The following is not intended to be a comprehensive list of previous reports, but to provide a sample of the types of studies that have been completed in the study area and the region.

1.8.1 U.S. Army Corps of Engineers Reports

a. Middle Rio Grande Flow Frequency Study, U.S. Army Corps of Engineers Hydrologic Engineering Center, June 2006.

The purpose of this study was to develop a flow frequency curve for the Rio Grande at Albuquerque. Peak flows at Albuquerque are caused by snowmelt and rainfall upstream of reservoirs on the Rio Grande and major tributaries, as well as from intense rainfall on areas downstream of the reservoirs. Separate flow frequency curves were developed for ~~both~~ two runoff mechanisms, regulated flow from the reservoirs and runoff from local areas downstream of the reservoirs, and combined into one flow frequency curve at Albuquerque.

b. Final Rio Salado Oeste Feasibility Study, Salt River, Phoenix, Arizona, September 2006.
The Rio Salado Oeste Study conducted by the U.S. Army Corps of Engineers, Los Angeles District, and the City of Phoenix, with the cooperation of the Flood Control District of Maricopa County (FCDMC) identified a Federal interest in implementing a project along the Salt River from 19th to 83rd Avenues in Phoenix. The study identified feasible flood damage reduction and ecosystem restoration alternatives that are technically feasible, economically practicable, sound with respect to environmental considerations, and publicly acceptable.

c. Upper Rio Grande Basin Water Operations Review Environmental Impact Statement, June 2007.
The Upper Rio Grande Basin Water Operations Review (Review) and Environmental Impact Statement is a comprehensive system-wide review of the water operations activities that are conducted under the existing authorities of the Joint Lead Agencies, the Corps, the U.S. Bureau of Reclamation (Reclamation), and the New Mexico Interstate Stream Commission (NMISC) in the Rio Grande basin above Fort Quitman, Texas. These operations consist of the storage and release of water at reservoirs. The review will consider the means available to exercise existing water operations authorities of Reclamation, Corps, and NMISC with respect to Upper Rio Grande Water Operations to (1) meet agricultural, domestic, municipal, industrial, and environmental water needs, including water needs to conserve endangered and threatened species as required by law, consistent with the allocation of supplies and priority of water rights under state law; (2) meet downstream water delivery requirements mandated by the Rio Grande Compact and international treaty; (3) provide flood protection and sediment control; (4) assure safe dam operations; (5) support compliance with local, state, Federal, and tribal water quality regulations; (6) increase system efficiency; and (7) support compliance of the Reclamation and the Corps with the provisions of the National Environmental Policy Act (NEPA) for Upper Rio Grande Basin Water Operations and activities and support compliance of all signatories with the Endangered Species Act.

d. Environmental Assessment for the Bosque Wildfire Project, Bernalillo and Sandoval Counties, New Mexico, September 2004.
Work under the Bosque Wildfire Project has included the following within Bernalillo and Sandoval Counties: selective thinning of areas with high fuel loads and/or non-native plant species populations; removal of jetty jacks and removal of debris; improvement of emergency access in the form of drain crossings, levee road improvement, and construction of turn-arounds; and revegetation of burned and thinned areas.

e. Detailed Project Report and Environmental Assessment for Albuquerque Biological Park Wetland Restoration Project, Albuquerque, New Mexico, January 2004.
The project is located south of Central Avenue in Albuquerque, between Tingley Drive and the Rio Grande, within the Rio Grande Waterway, Bernalillo County, New Mexico, immediately adjacent to the levee of the Rio Grande Floodway. The ecosystem restoration project included approximately 15 acres of pond reconstruction, 9 acres of wetland

restoration, and 48 acres of riparian woodland (Bosque) restoration. The feasibility study considered this project during the planning process so that the projects would benefit rather than conflict with one another.

f. Detailed Project Report and Environmental Assessment, Ecosystem Restoration at Route 66 Habitat Restoration Project, September 2008.

This project is a Section 1135 Program Ecosystem Restoration project within the RGVSP between Interstate 40 and Bridge Boulevard. Construction began in January 2009 and was completed in April 2010. The feasibility study considered this project during the planning process so that the projects would benefit rather than conflict with one another.

g. Middle Rio Grande Bosque Restoration Supplemental Planning Document – July 2003.

This report was generated as the final documentation of the Middle Rio Grande Bosque Restoration 905(b) Reconnaissance Study. The information gathered from other projects and studies involving the Bosque has been collected, updated, and combined with field notes, additional graphics, and maps to develop the concepts and information presented in this document. The synthesized material has been used in this feasibility study as an aid in determining which restoration measures will be further analyzed.

h. Method & Cost Evaluation Report for the Middle Rio Grande Bosque Jetty Jack Removal Evaluation Study, January 2003.

This study was an initial evaluation of various methods of jetty jack removal within the Bosque. The intent of this study was to evaluate the efficiency and cost effectiveness of different removal methods with regard to jetty jack position, surroundings, and degree of sedimentary entrainment while attempting to minimize adverse environmental impacts.

i. Middle Rio Grande Bosque Reconnaissance Study, Section 905(b) Analysis, July 2002.

The purpose of the reconnaissance phase of this study, initiated in March 2002, was to determine if there was a Federal interest in participating in cost-shared feasibility studies to investigate ecosystem environmental restoration and low-impact recreation opportunities for the study area. The reconnaissance study determined that a Federal interest exists in continuing the study into the feasibility phase. The purpose of the Section 905(b) Analysis was to document the basis for this finding and establish the scope of the feasibility study.

j. Environmental Assessment and Finding of No Significant Impact for Middle Rio Grande Bosque Jetty Jack Removal Evaluation Study, July 2002.

The study evaluated various methods (manual, heavy equipment, *etc.*) for jetty jack removal with regard to position, surroundings, and degree of sedimentary entrainment while attempting to preserve the existing native vegetation to the greatest extent possible.

k. Rio Grande Floodway, Albuquerque Unit Evaluation Report, Albuquerque, New Mexico, October 2009.

This report documented the current conditions of the Albuquerque Levee system, which exists within the area of feasibility study. Information learned in this study has been considered during the planning process for this feasibility study.

l. Environmental Assessment and Finding of No Significant Impact for Rio Grande Habitat Restoration Project, Los Lunas, New Mexico, March 2002.

This project was initiated to fulfill the requirement of habitat restoration in the Belen reach of the Rio Grande as a result of a biological opinion of the U.S. Fish and Wildlife Service (USFWS). The project is intended to improve habitat conditions for the Rio Grande silvery minnow and the Southwestern Willow Flycatcher through widening of the active river channel and improving adjacent riparian woodland and wetland habitats. Jetty jacks were removed and the channel widened and excavated to create low-flow shallow-water habitat. In the riparian areas, wetlands were restored through excavation and replanting of herbaceous wetland vegetation, and attendant woodlands were restored through pole planting of cottonwoods and willows. Figure 1.4 shows the reach of the Rio Grande in Los Lunas where the channel was widened and excavated to restore shallow water habitat. The dashed line approximates the former channel bank. A high-flow channel and bank destabilization effort has taken place in an area impacted by wildfire. Lessons learned from construction and monitoring of this project and other Middle Rio Grande Endangered Species Act Collaborative Program (MRGESACP) projects were taken into consideration during the planning phase of this feasibility study.

Figure 1.4. Restoration at Los Lunas Reach of Rio Grande.

m. Detailed Project Report and Environmental Assessment for Riparian and Wetland Restoration, Pueblo of Santa Ana Reservation, New Mexico, February 2002 and June 2008.
The purpose of this Section 1135 Program feasibility study was to investigate and recommend cost-effective environmental quality improvements along the Rio Grande within the Pueblo of Santa Ana Reservation. Restoration of ecosystem functions and values was evaluated within riverine, riparian, and wetland communities. The recommended plan included grade restoration facilities (GRFs) and a downstream bed sill.

n. Rio Grande Nature Center Habitat Restoration Project Environmental Assessment, December 2006.
The proposed project is a MRGESACP project to provide habitat that would potentially benefit the Rio Grande silvery minnow (RGSM) and the Southwestern Willow Flycatcher. Project construction was completed in 2007 by reconnecting an historic remnant side channel that runs through the Rio Grande Nature Center State Park to the main stem of the river. Water flows in the side channel when the river is flowing 1500-2000 cubic feet per second (cfs) and greater. Off-channel embayments were constructed to provide nursery habitat for the RGSM. Lessons learned from construction and monitoring of this project and other MRGESACP projects were taken into consideration during the planning phase of this feasibility study.

o. Ecosystem Restoration Report and Environmental Assessment, Arkansas River Fisheries Habitat Restoration Project, Pueblo, Colorado, September 2001.
The purpose of this Section 206 Program feasibility study was to investigate and recommend cost-effective restoration measures for riverine processes along approximately 10 miles of the Arkansas River through the City of Pueblo in southeastern Colorado. The report evaluated the restoration of aquatic and riparian habitat, and the recommended plan included the following features: bank stabilization, habitat features, low-flow channel development, high-flow velocity breaks, channel realignment, shoreline enhancement, island development, floodplain reconnection, invasive vegetation control, and native vegetation plantings.

p. Tres Rios Del Norte, Arizona, Feasibility Report, Los Angeles District, January 2004.
The project involves restoration of riparian habitat along the Santa Cruz River in Tucson, Pima County, Arizona. The project provides flood risk management for the City of Tucson, the town of Marana, and a portion of Pima County. The project also increases recreational opportunities consistent with ecosystem restoration.

q. VaShly'ay Akimel Salt River Restoration Project, Maricopa County, Arizona, May 2004.
The project involves restoration of riparian habitat along the Salt River in Maricopa County and increases recreational opportunities consistent with ecosystem restoration. The VaShly'ay Akimel study area is located in the upper Sonoran Desert in the Salt River watershed. The study area includes portions of the Salt River Pima Maricopa Indian Community, the City of Mesa, and upland areas in the vicinity of the Salt River between the Pima Freeway (US 101) and Granite Reef Dam.

r. El Rio Antiguo, Rillito River, Feasibility Study, Pima County, Arizona, May 2004.
The project emphasizes opportunities to restore riparian habitat, addresses matters of surface and groundwater quality, explores aquifer recharge along the Rillito, restoration of natural riverbed conditions, fashion localized seasonal wetlands (known in the southwest by the Spanish noun *cienegas*) at opportune places in the river bottom, and creates venues appropriate for recreational and educational uses of the river. The feasibility study also addresses flood risk management on the Rillito River and several washes contributing to the river from the foothills of the Catalina Mountains.

s. Historical Documentation of Middle Rio Grande Flood Protection Projects (Corrales to San Marcial), 1997.
This report was prepared to meet the Corps requirement to comply with Section 106 of the National Historic Preservation Act of 1966 for a project to upgrade the existing levees. The report documents the MRGCD spoil-embankment levees that were constructed in the 1930's and the reconstructed levees designed to manage a flood of 42,000 cfs. The report also documents the construction of various flood risk management measures that exist in the floodway, in addition to the levees, and the impacts of these measures on the hydrologic system and the valley.

t. Middle Rio Grande Flood Protection Project, Bernalillo to Belen, New Mexico, Corrales Unit, Limited Reevaluation Report, August 1994.
The purpose of this Limited Reevaluation Report was to establish the Corrales Unit as a separable element of the MRG Flood Protection Project. The selected plan included the replacement of the existing spoil-bank levee by constructing an earthen levee on the west side of the Rio Grande, extending from the Corrales Main Canal Siphon downstream to the La Orilla outlet channel. The Corps completed the project in 1997.

u. Middle Rio Grande Biological Survey, U.S. Army Corps of Engineers, 1989.
This report prepared by Hink and Ohmart is the seminal biological survey for the middle reach of the Rio Grande. The report documents the type and status of vegetation and wildlife communities and provides recommendations for conservation, restoration, and further research. Updates have been made in 2002 and 2005.

v. Determination and Evaluation of Flood Protection Alternatives for the Middle Rio Grande Floodway, Bernalillo to Belen, New Mexico, 1977.
This study reviews existing hydrologic data, analyses, and conditions of the MRG floodway and drainage basin. The report also includes hydraulic studies, including cross sections and water surface profiles, to evaluate specific channels, bridges, levees based on potential damage flows. A standard flood estimate is projected based on climatological data and conditions of the basin and flood risk management structures.

1.8.2 Other Agency Reports

a. Middle Rio Grande Ecosystem Bosque Biological Management Plan - The First Decade: A Review & Update, Lisa Robert et al., June 2005.
This is an update to the *Middle Rio Grande Ecosystem: Bosque Biological Management Plan*. Included within this document are discussions concerning developments since the first plan, how the physical landscape has changed, and the additional knowledge gained about how the river functions. The updates include technical updates to the hydrology of the river, listing of endangered species, and ecosystem restoration.

b. Bosque Landscape Alteration Strategy, Objectives, Basic Requirements and Guidelines, Yasmeen Najmi, Sterling Grogan, and Cliff Crawford, June 2005.
This report presents a vision of the Bosque which would recreate a patchy mosaic of native riparian trees and open spaces characteristic of the wider historic floodplain. The knowledge base for this report was the culmination of two workshops organized by the Utton Transboundary Resources Center at the University of New Mexico School of Law. The workshops brought together scientists, managers, advocates, and citizens who are concerned about the Bosque.

c. Habitat Restoration Plan for the Middle Rio Grande, September 2004.
Prepared for the MRGESACP, this document provides a framework plan to implement and integrate actions needed to address both water and endangered species management issues in the MRG. This document was developed for the Habitat Restoration Workgroup in order to aid in the development of reach-specific habitat restoration plans.

*d. Biological Conference Opinions on the Effects of Actions Associated with the Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande, New Mexico, U.S. Fish and Wildlife Service, 200*3.
The biological opinion lists reasonable and prudent alternatives identified during interagency consultations to avoid the likelihood of jeopardizing the continued existence of listed species.

e. Effects of Fuels-Reduction and Exotic Plant Removal on Vertebrates, Vegetation and Water Resources in the Middle Grand Bosque: Final Environmental Assessment, US Fish and Wildlife Service, and MRGCD, 2001.
This report summarizes the effects of fuel reduction on the Bosque ecosystem. The report found no significant negative impact. This study was a precursor to a multi-pronged effort to reduce fuels in the MRG Bosque, which is currently being implemented by the MRGCD in several areas.

f. Middle Rio Grande Conservancy District Interim Progress Report for the Bosque Improvement Group, U.S. Fish and Wildlife Service and MRGCD, 2001.
This is an interim report by the MRGCD to report on activities pertaining to fuel reduction research (Valencia & Socorro Counties, NM), fuel reduction efforts (Belen, NM), wildfire

rehabilitation/restoration (Bosque, NM), and combined fuel reduction and trail improvements (Socorro, NM).

g. River Bars of the Middle Rio Grande: Progress Report Year II, Natural Heritage Program, Biology Department, University of New Mexico, Albuquerque, New Mexico, February 2000.
This report provides an overview of a multi-year study of the vegetation of river bars in the Albuquerque reach of the MRG in relation to environmental and biological factors. River bars are a critical element in floodplain and terrace development and possibly the most diverse and biologically active component of the Bosque ecosystem. Follow-up reports have included *Progress Report Year III* and *River Bars of the Middle Rio Grande: A Comparative Study of Plant and Arthropod Diversity*.

h. Albuquerque Open Space Facilities Plan – Albuquerque Open Space Division, 1999.
The purpose of this plan was to establish guidelines for development of the Major Public Open Space resources (Open Space) in the City of Albuquerque and Bernalillo County. The plan establishes policy for planning and management of Open Space, land use decision-making as it relates to or affects Open Space, and acquisition of additional Open Space. Each Open Space area has a management plan based on the landscape typology and neighborhood input.

i. San Antonio Oxbow Management Plan – Albuquerque Open Space Division, 1996.
This management plan documents existing conditions and describes management strategies for maintaining the oxbow marsh habitat on the west side of the Rio Grande near the confluence of the San Antonio Arroyo. The plan contains information about resident wildlife in the area. The plan recommends sediment management strategies to protect the wetland from impacts of recurrent siltation at the outlet of the San Antonio Arroyo. Implementation of measures proposed in this feasibility study would support implementation of the San Antonio Oxbow Management Plan.

j. Bosque Protection Master Plan Scoping Report – Middle Rio Grande Conservancy District, 1995.
This study's objective was to develop a management master plan for the Bosque in the middle reach of the Rio Grande that would guide municipalities and Pueblos in the development of local Bosque management plans as a part of their open space, land use, and resource planning efforts. The plan focused primarily on human impacts that are incompatible with protection of the Bosque ecosystems. Existing levels of disturbance and human-caused impacts are assessed and listed by type. The report concludes with recommendations for interim and permanent restrictions on access to the Bosque, as well as for a process to develop a planning procedure for the development of a comprehensive master plan for the MRG Bosque.

k. The Middle Rio Grande Ecosystem: Bosque Biological Management Plan, Cliff Crawford, Anne Culley, Rob Leutheuser, Mark Sifuentes, Larry White, James Wilber, October 1993.

In September 1991, Senator Domenici appointed the Rio Grande Bosque Conservation Committee, which presented him with a report in June of 1993. The report recommended that a biological management plan for the MRG be developed as "the first step towards restoring the Bosque's health". The report included historic and recent (1993) information regarding hydrological conditions, aquatic and terrestrial resources, and organisms, climate, river morphology, population trends, land use, and water management practices of the MRG. The plan reviews the history and evolution of the existing Bosque ecosystem, and portrays the basic ecosystem functions and services provided by the floodplain hydrologic regime, the cottonwood riparian woodland, and riparian wetlands. The report also describes changes in the hydrologic regime resulting from human interventions and the corresponding changes in aquatic, wetland, and forest habitat over time. The report concludes with 21 recommendations for future management of the river and its riparian corridor. These recommendations range from proposed ecological restoration goals, processes, and techniques to basic parameters for recreation, hunting, and other human use of the Bosque.

l. Bosque Action Plan – City of Albuquerque Open Space Division, 1993.

The Bosque Action Plan identifies the RGVSP as one of the few remaining intact riparian habitats in the southwest and one whose value has increased as a recreational amenity because of its location in the heart of Albuquerque. The purpose of the Bosque Action Plan was to identify specific environmental and recreational improvements for the RGVSP. The Bosque Action Plan establishes a framework specifying how to effectively manage the RGVSP as a public park without neglecting the ecological system function of the Bosque. The policy framework was developed using issues and concerns identified by the Citizen and Technical Planning Teams as well as comments received from the public and recommendations from the contemporaneous inventories and studies completed before or during the planning process. The Plan describes the park and management policies and lists specific actions and projects to be taken to implement these policies. Under the plan, the agency that became the AOSD was to implement the plan in coordination with the MRGCD, State Highway Department, Albuquerque Metropolitan Arroyo Flood Control Authority, the Corps, and Reclamation. Some but not all of the projects have been completed. Implementation of measures proposed in the MRGB study would support implementation of the Bosque Action Plan.

m. Bosque Fire Management Study – Albuquerque Open Space Division, 1992.

This study was undertaken for the AOSD to come up with management recommendations for reducing the fire hazard of the Bosque within the RGVSP. The report maps the Bosque by fuel type and identifies high fuel load areas. The report presents a series of recommendations to prioritize and manage fuels in the Bosque. Parts of this study are currently being implemented in areas identified for restoration by the AOSD. Fuel load reduction is a management goal of the AOSD in the Bosque.

n. Rio Grande Valley State Park Management Plan – State of New Mexico Department of Natural Resources and Albuquerque Open Space Division, 1983.

The management plan documents the agreements between the State of New Mexico and the City of Albuquerque regarding the city's management of RGVSP and legislative mandates for city responsibilities within the park. Implementation of measures proposed in MRGB study would support implementation of the RGVSP Management Plan.

o. Corrales Bosque Preserve Habitat Management Plan, Corrales Bosque Advisory Commission, April 2009.
The management plan provides recommendations for the Bosque in the Corrales reach of the Rio Grande, the Corrales Bosque Preserve, which is designated a nature preserve. Implementation of measures proposed in the MRGB study would support implementation of the Corrales Bosque Preserve Habitat Management Plan.

1.9 Corps Planning Process

The feasibility study for the MRGB project follows the Corps six-step planning process specified in Engineering Regulation (ER) 1105-2-100. The process is used to identify and respond to problems and opportunities associated with the Federal objective and specific state and local stakeholder concerns. The process also provides a rational framework for problem solving and sound decision making. The plan formulation process includes the following steps:

- The specific problems and opportunities to be addressed in the study are identified and the causes of the problems are discussed and documented. Planning goals are set, objectives are established, and constraints are identified.

- Existing and future without-project conditions are identified, analyzed, and forecasted. The existing condition resources, problems, and opportunities critical to plan formulation, impact assessment, and evaluation are characterized and documented.

- The study team formulates alternative plans that address the planning objectives. An initial set of alternatives is developed and evaluated at a preliminary level of detail.

- Alternative project plans are evaluated for effectiveness, efficiency, completeness, and acceptability. The impacts of alternative plans are evaluated using the system of accounts framework specified in the Corps Principles and Guidelines and the Planning Guidance Notebook.

- Alternative plans are compared. A cost effectiveness and incremental cost analysis is used to prioritize and rank ecosystem restoration alternatives. A public involvement program obtains public participation in the alternative identification and evaluation process.

- Selecting the recommended plan. The study team then selects plans that maximize benefits and minimize costs (consistent with the Federal objective).

A number of alternative plans have been developed by the Project Development Team (PDT) and compared with a reasonable estimation of the future without-project condition. The comparison provides a metric allowing for the ultimate identification of the recommended plan or National Ecosystem Restoration (NER) Plan. The NER Plan reasonably maximizes ecosystem restoration benefits compared to costs, considering the cost-effectiveness and incremental cost of implementing other restoration options. In addition to considering the system benefits and costs, the NER Plan would consider information that cannot be quantified, such as environmental significance and scarcity, socioeconomic impacts, and historic properties information.

The feasibility report is intended to serve as the basis for authorizing a specific project for construction, and as such, must include steps that guide the planning process to ensure the success of any selected plan. This report is organized to follow the planning process. Chapter 1 includes problems and opportunities. Chapters 2 and 3 contain the inventory and forecast of resource conditions. Chapter 4 describes the formulation, evaluations, and comparisons of alternative plans, and Chapter 5 describes the recommended plan in greater detail.

1.10 Problems and Opportunities

Public concerns were identified during the course of the reconnaissance study. Contributions from Federal, state, and local agencies were received through coordination and project meetings as well as quarterly agency coordination meetings. These meetings were attended by MRGCD, the AOSD, Reclamation, USFWS, the Middle Rio Grande Council of Governments, the Albuquerque Downtown Action Team, City of Albuquerque Planning Department, and others. On April 1, 2002, a meeting was held with stakeholders, including the above agencies and several non-governmental organizations and researchers, to poll concerns on issues in the MRG. In February of 2003, a public meeting was held to present restoration efforts beginning in the MRG and poll public concerns. The public and agency concerns that are related to the establishment of planning objectives and planning constraints are:

- Environmental degradation of the Bosque ecosystem;
- Loss of habitat for special status species;
- Existence of fire hazard;
- Limited recreational access and use of the Bosque;
- Persistence of non-native plant species;
- Personal security within the Bosque;
- Cultural awareness and environmental justice;
- Environmental education and outreach;
- Reduce current and minimize future operations and maintenance costs;
- Need for coordination of multi-agency effort and ongoing projects.
- Impact of neighboring land uses on the Bosque;
- Availability of water for multiple uses.

Water resources projects are planned and implemented to solve problems, meet challenges, and seize opportunities. In the planning setting, a problem can be thought of as an undesirable condition such as those expressed by the public above. An opportunity offers a chance for progress or improvement of the situation. The identification of problems and opportunities gives focus to the planning effort and aids in the development of planning objectives. Problems and opportunities can also be viewed as local and regional resource conditions that could be modified in response to expressed public concerns. This section identifies the problems and opportunities in the study area based on the assessment of existing and expected future without-project conditions.

On a regional scale, estimates of riparian habitat loss in the Southwest range from 40% to 90% (Dahl 1990), and desert riparian habitats are considered to be one of this region's most endangered ecosystems (Minckley and Brown 1994, Noss *et al*. 1995). Decline of natural riparian structure and function of the Bosque ecosystem was recognized in the 1980s as a major ecological change in the MRG (Hink and Ohmart 1984; Howe and Knopf 1991). In ecological terms, the cumulative effects of agriculture, urban development, and flood risk management measures initiated over the last seven decades have resulted in a disruption of the original hydrologic (hydraulic) regime along the Albuquerque reach of the MRG and the ultimate degradation of the Bosque ecosystem. This regime is crucial to sustaining and regenerating a variety of ecological components that make up the Bosque and the wildlife that it supports. Whereas it is not possible to return the MRG to its pre-flood risk management state, abundant opportunities exist to restore function and habitat value within the constraints of current water use restrictions and without imposing flood damages.

Along the approximately 26 miles of the Rio Grande within the Albuquerque reach of the MRG, several hydrologic and ecological problems have been identified along with corresponding opportunities:

- The past water management operations and flood risk management measures, including levees, jetty jacks, and upstream dams, have eliminated the historic broad, meandering channel and the flood regime that had resulted after periodic inundation of the Bosque. Even with these limitations, however, an opportunity exists to recreate limited overbank flow and areas of inundation within the levees by reconnecting existing high-flow side channels and excavating swales and expanding existing wet habitats.

- Confinement of the river channel and its subsequent deepening, coupled with the colonization of river banks by vegetation, has resulted in perched banks and stabilized islands. The low, sloping bank no longer exists to provide a wet-soil terrestrial or shallow, slow moving riverine environment at the water-land interface. The opportunity to devegetate and destabilize banks and islands will restore this habitat, facilitate overbank flows, and provide sediment for the natural geomorphic systems.

- The loss of wetlands, braided channels, and backwaters has reduced the extent and quality of aquatic habitat and the potential for aquifer recharge. An opportunity exists to restore and create new wetland habitat and backwaters, which would improve aquatic habitat and recharge potential, as well as provide storm water filtration.

- Confinement of the river channel by levees and jetty jacks and eventual degradation has deepened the channel and increased velocities through the study area. Although removal of the levees is not feasible, the opportunity exists to remove jetty jacks as well as reconnect side channels, recreate embayments, and provide additional areas of low river velocity within the levees.

- The lack of inundation, scouring and sediment deposition within the Bosque, as well as the lowering of the water table, has curtailed seedling recruitment of native tree species and increased the mortality rate of existing cottonwoods and willows. This has resulted in a skewed age structure in the remaining cottonwood stands and resulted in significant build-up of leaf litter and dead and down wood. An opportunity exists to reconnect the floodplain and river to restore the essential functions of forest renewal and nutrient cycling.

- Human uses in the Bosque have further degraded the Bosque through accidental fires and high-impact recreational uses. The opportunity exists to revegetate burn sites, limit vehicular access, and provide a formal recreational system that provides an experience that will promote community involvement and pride.

- The cumulative impact of the loss of inundation, confinement of the channel, the lower water table, cottonwood mortality, and urbanization has led to the replacement of the mosaic of native woodlands and wetlands in many parts of the study area by dense stands of non-native salt cedar, Russian olive, Siberian elm, tree of heaven, and white mulberry trees. An opportunity exists to remove non-native plants and revegetate with a variety of native plants, thereby improving and diversifying native habitat types.

- The altered vegetation structure of the Bosque has increased the potential for a catastrophic fire in the Bosque. The brushy growth form of non-native trees creates a hazardous fuel condition. The jetty jacks and heavy brush can also make access to fight fires difficult and potentially dangerous. An opportunity exists to remove some of the jetty jacks and much of the vegetation that has created the existing fire hazard.

- The change from a mosaic of native plant communities of various structures and ages to increasingly large stands of non-native forest has affected the overall value of aquatic and terrestrial wildlife habitat provided by the Bosque. An opportunity exists to rehabilitate the existing Bosque into a dynamic mosaic of native vegetation patches of various ages, structure types, and constituent species.

- The uncontrolled access, neglect, and degradation of the Bosque ecosystem have impaired interpretive, educational, and recreational uses of the Bosque. An opportunity exists to develop existing trails into an aesthetically pleasing and safe interpretive system that furthers the overall goal of restoration.

1.11 Planning Objectives and Constraints

Planning objectives and constraints provide a framework for the development of alternative plans. Planning objectives are statements of what a plan is attempting to achieve. Planning objectives communicate to others the intended purpose of the planning process. Constraints are limitations imposed on the scope of the study from physical, political, or social considerations. For instance, this restoration project hinges on the amount of water that flows through the study area and yet additional water cannot be provided because water is allocated per the Rio Grande Water Compact and MRGCD water delivery requirements. This study must focus on the efficient use of water as it flows through the study area without impacting the delivery requirements downstream. Project specific objectives and constraints are listed in Section 1.11.2.

1.11.1 Federal Planning Objectives

As planning objectives for this investigation, it is in the Federal interest to:

- Contribute to the National Ecosystem Restoration (NER) objective through restoration, with contributions measured by changes in the amounts and values of habitat. Numerous Federal laws and executive orders exist that have established the National policy for, and Federal interest in, the protection, restoration, conservation, and management of environmental resources. The focus of NER projects is "the restoration of ecosystems and ecological resources and not restoration of cultural and historic resources, aesthetic resource or clean up of hazardous and toxic wastes" (ER 1105-2-100, Appendix E). Ecosystem restoration projects implemented by the Corps might not be capable of addressing every undesirable condition associated with an ecosystem, but rather, should focus on restoration of "degraded significant ecosystem structure, function and dynamic processes to a less degraded, more natural condition" (ER 1105-2-100, Appendix E).

- Contribute to the National Economic Development (NED) consistent with protecting the nation's environment, pursuant to national environmental statures, applicable executive orders, and other Federal planning requirements. Contributions NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation.

- The Regional Economic Development (RED) account is intended to illustrate the effects that the proposed plans would have on regional economic activity, specifically, regional income and regional employment.

- The Environmental Quality (EQ) account is another means of evaluating the alternatives to assist in making a plan recommendation. This account is intended to display the long-term effects the alternative plans could have on significant environmental resources.

- Contributions to the Other Social Effects (OSE) account include long-term impacts to public facilities, health and safety, recreation, and community values.

1.11.2 Project Specific Planning Objectives and Constraints

The national objectives of NED and NER are general statements and not sufficiently specific for direct use in plan formulation. The water and related land resource problems and opportunities identified in this study are stated as specific planning objectives to provide focus for the formulation of alternatives. These planning objectives reflect the problems and opportunities and represent desired positive changes in the without-project conditions.

Ecosystem restoration projects require that the planning team develop objectives and constraints that apply to a systems approach and take into consideration "aquatic wetland and terrestrial complexes, as appropriate, in order to improve the potential for long-term survival as self-regulating, functioning systems" (ER 1105-2-100, Appendix E). Objectives and constraints must be specific to the ecosystem as well as realistic and attainable in order for the planning process to succeed.

Working from the problems and opportunities identified in Section 1.9, *Corps Planning Process,* key objectives of the feasibility study were developed and include:

- Improve habitat quality and increase the amount of native Bosque communities to a sustainable level. Sustainability of Bosque habitats refers to the habitats ability to perform key riparian functions that perpetuate those habitats. Using the Bosque Community Model, a habitat score of 0.50 to 0.59 is considered „moderately high functionality' (discussed in Appendix D). The objective of the restoration project is to achieve a moderately high functionality or higher habitat value over 30 percent or more of the area of consideration. This value will be achieved in 20 years or less after project implementation and be sustained for the remaining 30 years of the period of analysis.

- Reestablish fluvial processes in the Bosque to a more natural condition. Areas of scour or amounts of sediment mobilization through the Bosque would indicate improvements. The objective of the restoration would increase the amount of unvegetated point bars, islands, or banks within the study area by three percent.

- Restore hydraulic processes between the Bosque and the river characterized by a more natural overbank inundation pattern and higher riparian groundwater levels. A 25 percent or more increase in the area of inundation during flow events of 4,500 cfs is the objective of the MRG restoration project.

- Reduce the risk of catastrophic fires expressed in either number of fires or area affected. Most Bosque habitat types do not tolerate fire and will not regenerate effectively after wildfire. The objective of this restoration is to reduce the extent of catastrophic fires by 50 percent within the study area during the period of analysis.

- Protect, extend, and improve areas of potential habitat for listed species within the Bosque. For RGSM, overbank flooding provides areas for hatching and rearing; therefore, a 25 percent or more increase in area of inundation as described above would significantly increase minnow reproduction. The project objective is to provide an over-25-percent increase in high quality habitats suitable for migration and feeding by the SWFL.

- Provide interpretive features in recreational use areas within the study area. Interpretive sign will be provided at each access point leading to a restoration area.

- Integrate recreational features throughout the study area that are compatible with ecosystem integrity. Recreation access points and trails will be improved in 60 percent of the restoration areas. Alternative trail alignments or bridges will be provided to reconnect existing trails that are bisected by constructed water features.

Restoration efforts will be implemented over a five-year period beginning in 2011 and provide benefits through the 50-year period of analysis and beyond. Although positioning of each feature or measure area is dependent on the specific conditions present at a particular location, restoration measures could be dispersed throughout the study area. Interpretive and recreation features would be aligned with existing access points and trails. Constructed features that effect fluvial and hydraulic processes as well as fire risk and recreation could realize benefits immediately or within the first year after implementation. Restoration features that involve manipulation of existing habitat might realize some benefits immediately after implementation; however, features that include establishing plants could take five to 20 years to realize full benefits. In addition to these goals, the study ensures that any restoration implemented will be integrated with other established or ongoing restoration efforts in the Bosque.

Constraints must also be specific to guide the planning process. The following constraints represent restrictions that limit alternative development or need to be overcome:

- Water delivery policies and regulations will affect water availability for ecosystem restoration measures. Water-oriented legislation and policies include, but are not limited to, the following:

    - Rio Grande Compact
    - New Mexico State Engineer's Regulations
    - MRGCD Water Delivery Requirements

- Levees, dams, and existing channel conveyance and capacity necessary for existing water delivery and flood risk management cannot be compromised by environmental restoration and recreational measures developed for this project.

- Proposed restoration measures cannot impair the City of Albuquerque Public Works Department's ability to draw surface water from the Rio Grande for its potable and non-potable water projects.

- Water quality must remain at current levels as a result of restoration activities. Water quality will be addressed through the NEPA and Clean Water Act processes.

- Budget and capacity of local management agencies to maintain restoration features over the long term must be considered.

- Proposed features must not have a significant negative effect on endangered species or impair existing habitat for endangered species in the future.

The requirement to not compromise flood risk management infrastructure, the impracticality of acquiring water, and converting land use outside the levees ultimately limit the scope of the proposed project to restoration within the existing flood risk management levees along this reach of the Rio Grande. In several locations downstream of the study area, the risk exists of overtopping or failure of non-engineered (spoil-bank) levees at higher discharges. For this reason, operational water releases from Cochiti Reservoir are regulated to not exceed 6,500 cfs. A recent effort was made by the multi-agency MRGESACP to maximize the efficient use of water for competing purposes in the MRG and discussed in the *Upper Rio Grande Basin Water Operations Review Environmental Impact Statement* (USACE 2007). This effort succeeded in providing longer durations of higher flow events within operational parameters. This study examined ways to restore overbank inundation at discharge levels below 6,500 cfs.

Lastly, habitat restoration outside the levees would increase the area of available habitat and restore those parts of the floodplain to a more natural condition; however, these areas would remain disconnected from the river. Some regulating structure would be required to allow water through the exiting levee to the restoration site. Levees, drains, and associated trails or roads would also disrupt the continuity of habitat. Since ample opportunities exist for restoration within the levees that is contiguous with the riparian corridor and able to interact with the river flows, the team focused on these areas for restoration.

SECTION 2 - HISTORIC AND EXISTING CONDITIONS

2.1 Physiography, Geology, and Soils

The proposed project lies within the Middle Rio Grande valley, a wide floodplain of fertile bottomland (USDA 1977) that support vegetation as well as a variety of resident and migratory wildlife. The Middle Rio Grande valley is a productive agricultural area that contributes to the quality of life and economies of the urban areas of Albuquerque, Corrales, and Bernalillo, New Mexico, as well as several smaller communities. The general soil conditions in the floodplain are deep, nearly level, well-drained soils formed by alluvium deposition in the valley. Shallow water tables in the floodplain are typically four to five feet in depth and soil permeability is moderate (USDA 1977).

The Rio Grande follows a well-defined geologic feature called the Rio Grande Rift. The rift produced fault zone-bounded valleys (grabens), which consist of normal faulting on each flank with the central portion down dropped. The study area lies within the graben of the Albuquerque Basin and is characterized by gently sloping plains to the mesa (bluff) on the west and the more abrupt face of the Sandia and Manzano Mountains to the east. The Sandia and Manzano Mountains run parallel to the river and range in elevation from 10, 447 feet at Sandia Peak to 6,400 feet at the base of the foothills. From the foothills, the elevation drops nearly 1,400 feet over a distance of five to 10 miles to the Rio Grande. The valley contains several thousand feet of poorly consolidated sediment of the Santa Fe Group of middle Miocene to Pleistocene age.

2.2 Climate

The climate in the vicinity of the MRG is classified as semi-arid. The average maximum temperature measures 70ºF and the average minimum temperature is 44ºF. The average annual precipitation is 7.88 inches. Half of the annual precipitation falls during the period July to October and typically as brief summer rain storms. The snow season in the Albuquerque area generally extends from November to early in April, but snow seldom remains on the ground for more than one day. The average frost-free season in Albuquerque lasts 190 days, from mid-April to late in October. Relative humidity averages less than 50 percent and generally less than 20 percent on hot sunny afternoons. Winds blow most frequently from the north in winter and from the south along the river valley in summer. Yearly wind speed averages nearly nine miles per hour.

2.3 Historical Perspective

River systems are often described as existing in a state of dynamic equilibrium; however, the system is not static. The equilibrium actually results from a series of processes that are predicated on change. A river system is constantly adjusting, trying to achieve a new equilibrium between the discharge and the sediment load that the river transports (Bullard and Wells 1992). The river morphology of the MRG was once that of a wide, shallow, braided channel characterized by high sediment loads and frequent flood events (USACE 2003). The channel over the last several hundred years has moved across or flooded in its entirety what is now the 0.2%-chance flood zone as shown in Figure 2.1. Today, the Rio Grande in the Albuquerque area is no longer a braided channel nor is the river able to meander across the original floodplain.

Intensive grazing and logging in the watershed of the Rio Grande increased sediment supply to the stream, and by 1850 the rate of channel aggradation began to accelerate (Scurlock, 1998). By the early 1900s, concurrent with increased water diversions, aggradation of the river bed resulted in channel widening and formation of large mid-channel bars that were colonized by cottonwood (Scurlock, 1998). Increased sediment supply is suspected of causing a major shift in channel morphology and large-scale channel instability (*cf.* Schumm and Meyer 1979). Flooding increased in frequency and magnitude due to changes in watershed runoff characteristics (Scurlock 1998). Changes in channel alignment and rapid bank erosion occurred during flood stage because of the aggraded channel and lack of riparian vegetation, which rendered stream banks susceptible to accelerated rates of erosion (Scurlock 1998). Aggradation in the Albuquerque reach of the Rio Grande was at a maximum rate of about 2 feet per 50 years (0.6 meter per 50 years) prior to construction of dams in the drainage basin (Lagasse, 1981). A 1922 Reclamation Service map of the project area shows extensive sand bars and a paucity of riparian vegetation, much of which is noted as “brush”, with very little indication of cottonwood forest.

2.3.1 Historic Hydrology and Hydraulics

The MRG has been dramatically affected by changes in the hydrologic and hydraulic regime caused by the construction of flood risk management projects, and the change in seasonal discharges has impacted channel-forming processes. Discharge is the dominant variable that affects channel morphology, but sediment transport, channel bed and bank material, and other hydraulic factors are also important influences. Historically, the wide shallow channel was described as a sand-bed stream (Nordin and Beverage 1965) with a braided pattern (Lane and Borland 1953), likely resulting from sediment overload (Woodson 1961). The river followed a pattern of scouring and filling during floods and was in an aggrading regime (accumulating sediment). Flood hazards associated with the aggrading riverbed prompted the building of levees along the floodway. The Corps constructed the Albuquerque Levee projects in the mid 1950’s and the Corrales Levee project in 1996. However, the levee system confined the sediment and increased the rate of aggradation in the floodway. Additionally, channel stabilization works, which included jetty jacks installed during the 1950s and 1960s, contributed to elevating and stabilizing the overbank areas where the Bosque currently exists.

The Corps constructed Jemez Canyon Dam in 1953, Abiquiu Dam in 1963, Galisteo Dam in 1970, and Cochiti Dam and Lake in 1973. Figure 2.2 displays the flood risk management dams and reservoirs constructed in the Middle Rio Grande valley. Due to reservoir regulation, historic annual peak discharges through the study area have changed from peak flows of over 20,000 cfs prior to World War II to peak flows of less than 10,000 cfs after the construction of Cochiti Dam in 1973. Construction of the dams was expected to slow aggradation or reverse the trend and promote degradation in the MRG. The dams accomplished the flood risk management objectives for much of the river valley and reduced the sediment load in the MRG. However, dam construction has caused changes in the geomorphology of the Rio Grande through the Albuquerque reach and affected the conveyance capacity of the active river channel. The result of these changes has been a reduction in the frequency of overbank flows into the Rio Grande Bosque.

The Rio Grande is now confined as a result of the many water resource activities. The average width of the floodway area between the levees is 1,500 feet (457 meters; Lagasse 1981) compared to a historic floodplain width in the project area of approximately 13,120 feet (4,000 meters; Reclamation Service topographic map 1922). Figure 2.3 demonstrates how flood risk management projects, including levees, riverside drains, and jetty jacks, constructed since 1900 in the study area have reduced the Rio Grande's original floodplain. Figure 2.4 shows the channel alteration methods that confine the river and bosque.

Cochiti Dam began regulating flow on the Rio Grande in 1974. In the report *Middle Rio Grande Flow Frequency Study*, prepared by the U.S. Army Corps of Engineers Hydrologic Engineering Center and dated June 2006, the Corps computed and presented a comparative analysis of regulated flow versus unregulated flow at Albuquerque. The Corps used the U.S. Geological Survey (USGS) Rio Grande at Albuquerque stream gage (Gage ID 8330000) as the point of comparison. The Corps calculated the unregulated flow using a time-series analysis of daily average flows recorded at several USGS stream gages within the watershed to remove the effect of the dams and combine and route the resulting unregulated flows downstream to Albuquerque. Table 2.1 demonstrates the effects of regulation at Albuquerque for the post-Cochiti Dam period by comparing the recorded regulated daily average peak flows versus the computed unregulated daily average peak flows for the period 1975 through 2001. Floods generated by snowmelt and rainfall upstream of the reservoirs were included in this comparison.

Table 2.1 indicates that were it not for the regulation of upstream flows, the Rio Grande at the Albuquerque gage would have experienced spring flows of 10,000 cfs or greater a total of eight times between 1975 and 2001. This is consistent with the pre-Cochiti Dam flow record, which shows that from 1942 to 1973, spring flows reached or exceeded 10,000 cfs a total of seven times at the Albuquerque gage. However, the gage record shows that flows of 10,000 cfs or greater were never achieved at the Albuquerque gage during the post-Cochiti Dam period of 1974 to present. Flow releases from Cochiti Dam can be regulated to 7,000 cfs for flows generated by snowmelt and rainfall upstream of the reservoirs for any event up to, but not including, the 0.5%-chance frequency event. During the 0.5%-chance frequency event, the Corps predicts a spillway flow resulting in a total combined discharge of 10,000 cfs.

For comparative purposes, Figure 2.5 shows the 1987 hydrograph taken from the gage record at Albuquerque. The peak daily discharge measured 5,990 cfs. Figure 2.6 shows the 2005 spring runoff hydrograph measured at Albuquerque, with a peak daily flow of approximately 6,000 cfs, which was similar to the 1987 hydrograph. The 2005 event resulted in relatively limited overbank flow under existing conditions, and the same result would have been expected in 1987.

Table 2.1 reports that the 1987 computed unregulated daily peak flow at Albuquerque would have measured 10,881 cfs without the regulating effects of Cochiti Dam. An unregulated flow of 10,881 cfs would be comparable to the 1949 hydrograph (Figure 2.7) with a recorded peak daily flow of 10,556 cfs. These flows above 10,000 cfs would cause widespread overbank flows through the Rio Grande bosque under historic and existing conditions. These observations of recorded flows in the study reach support the assumption that watershed regulation has significantly reduced overbank flows throughout the study reach.

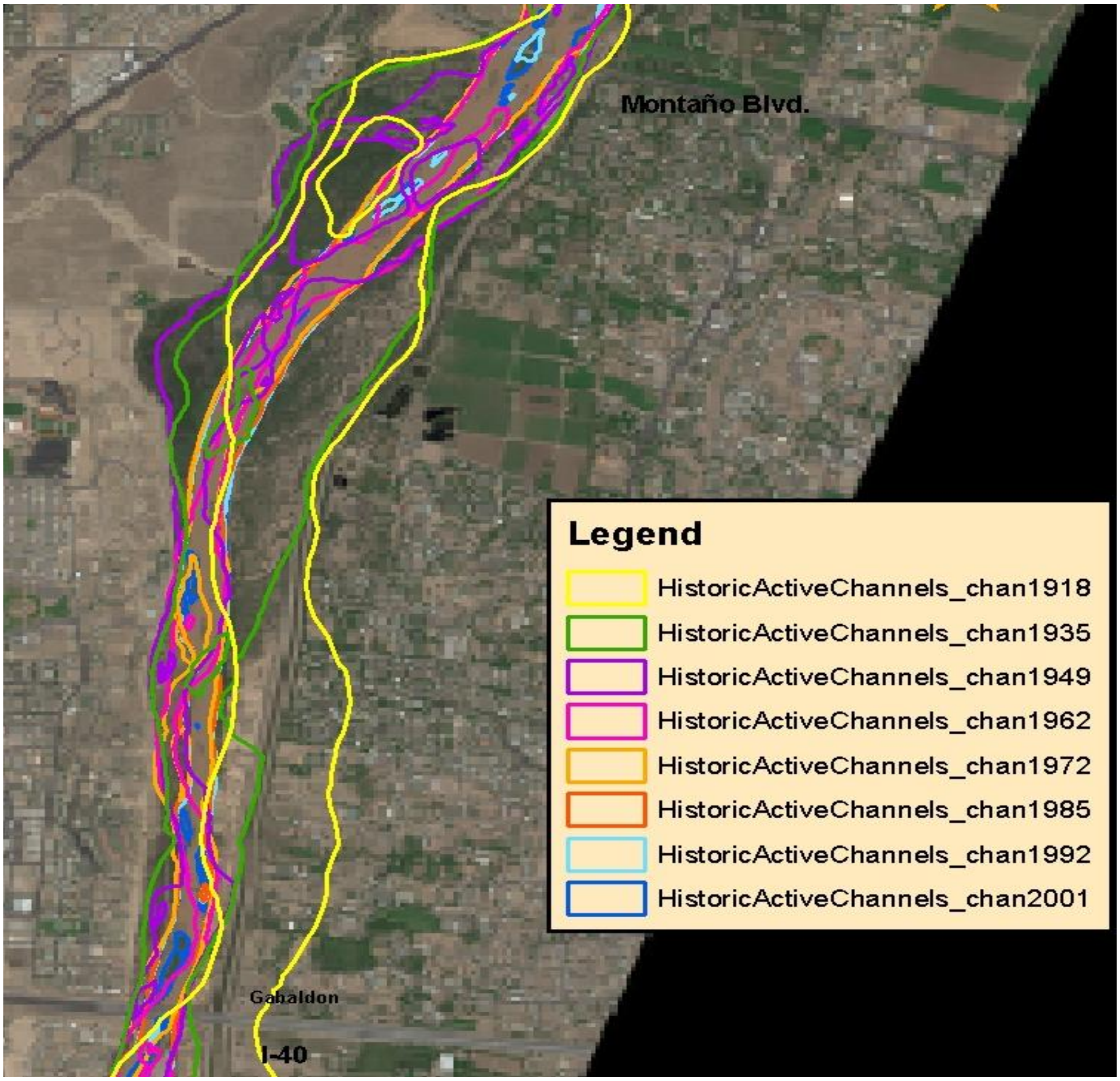


Figure 2.1. Historic Channels.

Figure 2.2. Reservoirs of the Middle Rio Grande.

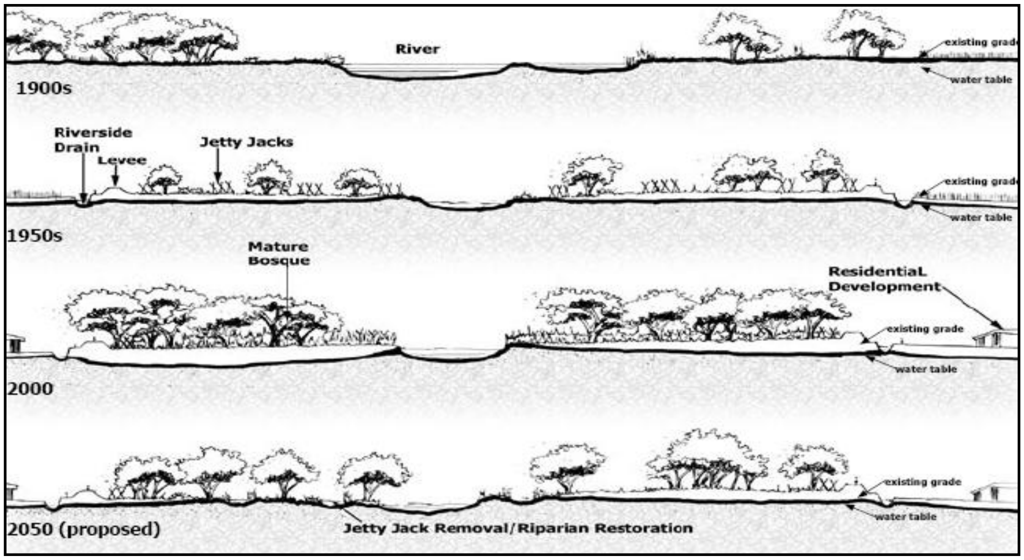


Figure 2.3. Flood Risk Management Projects have reduced the Rio Grande's Original Floodplain.

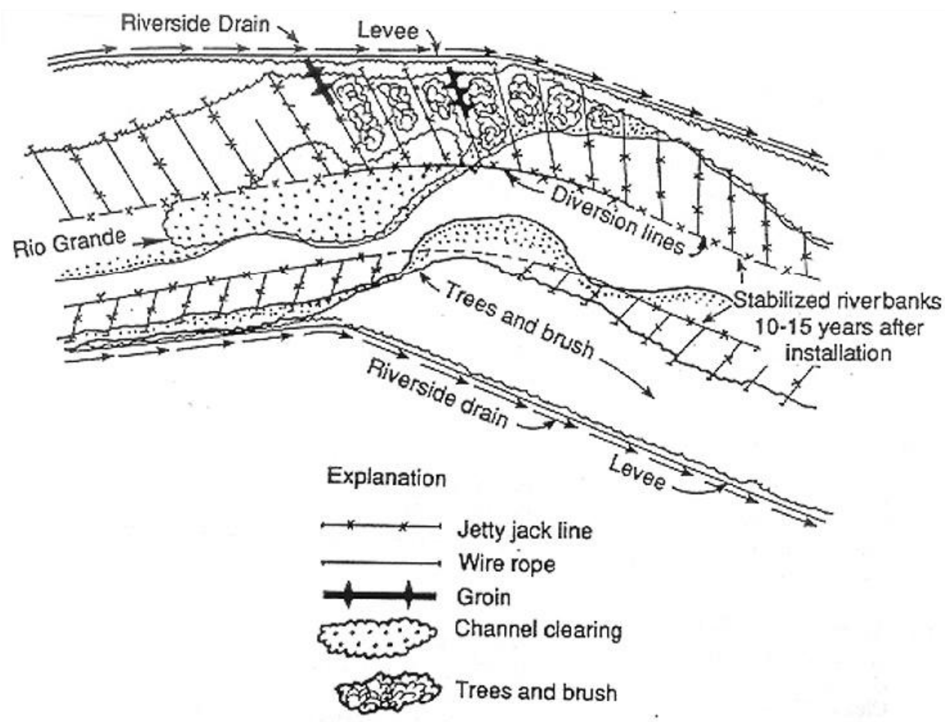


Figure 2.4. Alterations to the Rio Grande Channel and the Bosque.

Table 2.1 Comparison of Daily Average Peak Flows for the Gage at Albuquerque.

Year	Daily Average Peak Flow (in cfs)	Unregulated Daily Average Peak Flow (in cfs)
1975	5,800	8,848
1976	3,170	4,103
1978	4,320	5,528
1979	7,870	15,873
1980	7,130	11,023
1982	4,620	6,680
1983	6,970	11,965
1984	8,260	13,433
1985	8,650	16,503
1986	4,490	8,052
1987	5,990	10,881
1989	3,670	4,798
1992	5,360	7,916
1993	6,960	10,314
1994	5,230	10,070
1995	6,370	9,413
1997	5,430	8,171
1998	3,940	4,708
1999	4,520	6,018
2001	4,730	5,528

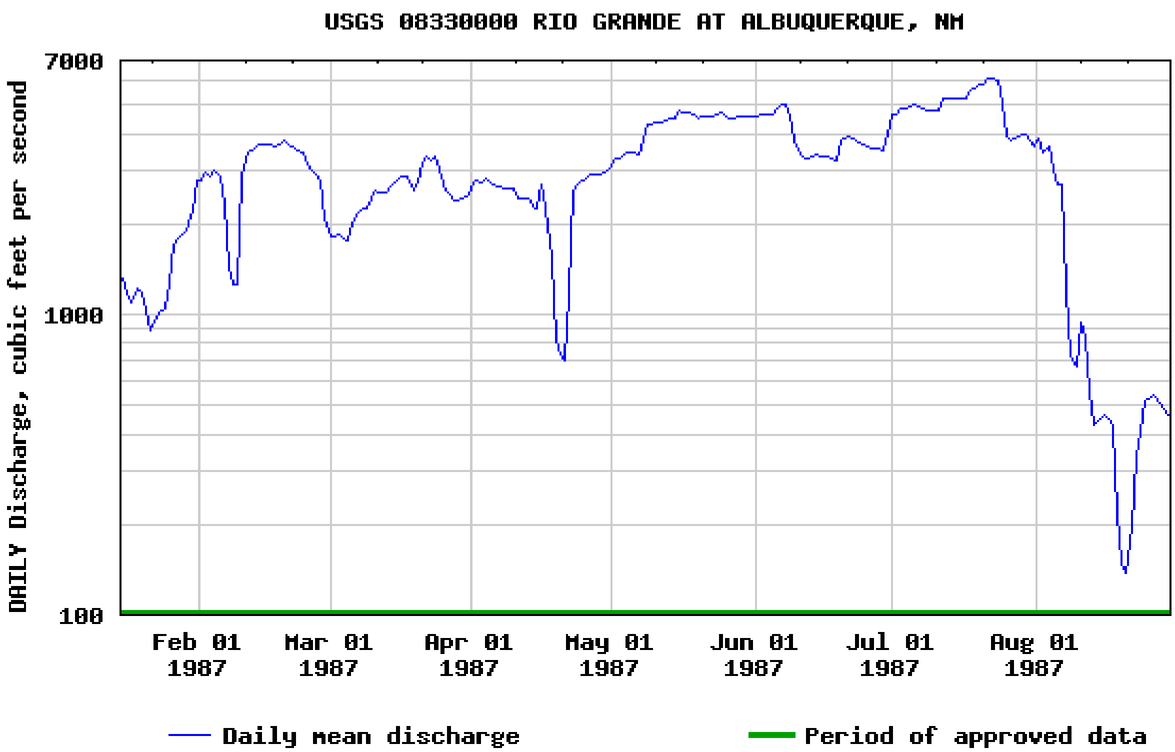


Figure 2.5. 1987 Hydrograph for USGS Gage at Albuquerque.

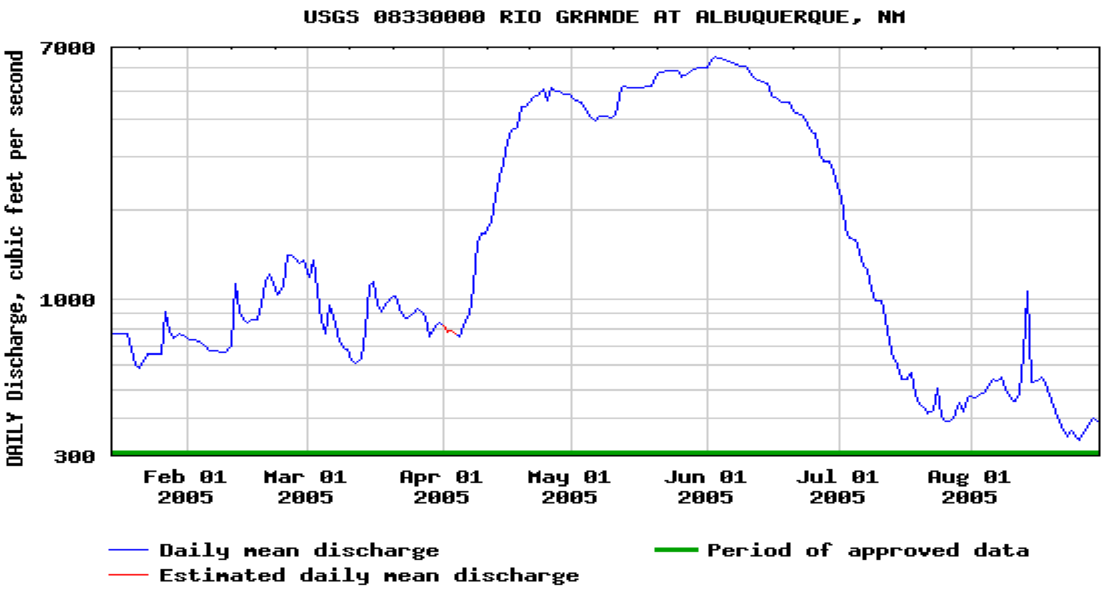


Figure 2.6. 2005 Hydrograph for USGS Gage at Albuquerque.

Figure 2.7. 1949 Hydrograph at Albuquerque.

2.3.2 Historic Vegetative Conditions

The following text summarizes the processes prior to major human impacts on the Middle Rio Grande:

> *.....(the river experienced) periods of stability that allowed riparian vegetation to become established on riverbanks (mostly on the inside of river bends) and islands alternating with periods of instability (e.g., extreme flooding) that provided, by erosion and deposition, new locations for riparian vegetation. A mosaic of cottonwood and willow community types, of varying age classes, size and extent, would be interspersed with more open areas of ponded water, grasslands, marches, and wet meadows. Areas where erosion forces were less active would produce older age class stands of native vegetation (Hanson 1997, Crawford et al. 1993, Leopold 1964).*

Large-scale, human-induced changes in riparian vegetation structure and ecological processes in the study area probably began in the 1500s (Crawford *et al.* 1996). Land clearing for irrigated agriculture and diversions from the river likely began to have an effect on the Bosque ecosystem at least as early as the late 1700s. Direct diversions from the river were indicated by the occurrence of wide, deep irrigation ditches (acequias) in the Albuquerque area in 1776 (Scurlock 1998). "Acequia" is a Spanish term that depicts the irrigation system used for agricultural purposes in New Mexico. The number of acequias and the area of floodplain under irrigated agriculture expanded with an increasing population from 1680 through 1817 (Scurlock 1998). Settlement of the Rio Grande continued as European immigrants moved into the area, with an estimated 130,000 people living along the river in the reach from Santa Fe to Belen by 1830. Population growth resulted in increased water diversions from the river, continued clearing of native vegetation (*cf.* Scurlock 1998: 202), and expanded areas of irrigated agriculture in the floodplain.

Diminished river flows from diversions was noted as early as 1807 (Scurlock 1998). By the 1820s, extensive irrigation had resulted in a very shallow water table, saturated soils, wetlands, and increasing alkalinity of floodplain soils (Scurlock 1998). Wetlands were historically common to the study area including a larger wetland complex called the "Esteros de Mejia". By the early 1920s, however, wetlands and alkali deposits in areas waterlogged by irrigation covered a substantial portion of the MRG (Van Cleave 1935, Scurlock 1998: 281). This condition was reversed with the construction of drainage ditches in 1925 and diversion and flood control dams beginning in 1930. Additionally, construction of levees along both banks established a defined floodway cut off from much of the historic floodplain and with it the cottonwood Bosque. The measures lowered the water table in the historic floodplain. The portion of the Esteros de Mejia in the study area had apparently been reduced to one small wetland on the east side of the Rio Grande north of Barelas Street. Some ponds associated with ditches located on the floodplain east of the river likely supported wetland vegetation. Also, an old channel named "Palmer Slough" on the east side of the river might have contained remnant wetland habitat. Large tracts of the floodplain in the project area classified as "alkali" in 1922 were zones of high alkalinity resulting from waterlogging and saturation of soils (Scurlock 1998). These areas were classified as wet meadows by Van Cleave (1935) and were dominated by sedge (*Carex* sp.), spikerush (*Eleocharis* sp.), bulrush (*Schoenoplectus [Juncus]* sp.), inland saltgrass (*Distichlis spicata*), and yerba mansa (*Anemopsis californica*). However, by the mid-1930s much of the wetland community in the floodplain had been eliminated by drainage and lowering of the water table (Van Cleave 1935).

Only remnants of the extensive stand of cottonwoods found in the Albuquerque area in the late 1600s known as the "Bosque Grande de San Francisco Xavier" remained in 1922 (Scurlock 1998). It appears that much of the trees in the Bosque had been cut down by 1846, when Lieutenant J. W. Abert noted, from his camp on the Rio Grande at Atrisco, that "no wood is to be obtained within less than 9 or 10 miles of Albuquerque" (Scurlock 1998). Streets, buildings, and farmland replaced much the Bosque outside the levees and, although some of the riparian forest regenerated within the levees, altered fluvial geomorphic processes increasingly hampered the sustainability of the Bosque. To compound the problem, two exotic phreatophytes, salt cedar (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*), were becoming increasingly common in the riparian plant communities of the Rio Grande in the mid-1930s (Van Cleave 1935). Siberian elm (*Ulmus pumila*) was introduced into the Albuquerque area in the 1920s (Scurlock 1998). These exotic trees compete with the native riparian vegetation.

In summary, man-induced changes in fluvial geomorphic processes that influence vegetation dynamics in the Bosque were initiated at least as early as the late 1700s. These processes were progressively altered from the natural condition through the 1800s and into the mid-1900s, when imbalances between sediment supply and discharge and removal of riparian vegetation apparently created very unstable dynamics in the riverine and riparian ecosystems. Channelization, levee construction, jetty jack installation, sediment retention in reservoirs, and flow regulation reversed the processes of aggradation and channel widening. These river management measures also created a fixed channel plan form and a narrower floodplain that was less frequently inundated or was disconnected entirely from the river. The result has been disruption or termination of major processes depicted in the dynamics of a naturally functioning Bosque ecosystem.

These substantial impacts from man resulted in compounding rates of change in structure and vegetation dynamics to the point that the Bosque ecosystem is now on the verge of irreversible conversion (Crawford *et al.* 1996). A similar pattern of loss of alluvial forests through channelization, flow regulation, and levee construction since the 17th century is well documented in Europe (Décamps *et al.* 1988). Decline of natural riparian structure and function of the Bosque ecosystem was recognized in the 1980s as a major ecological change in the MRG (Hink and Ohmart 1984, Howe and Knopf 1991).

2.4 Bosque Ecosystem

The mosaic or patchy distribution of habitats that once made up the Bosque has changed dramatically since the 17th Century (Pittenger 2003, Scurlock 1998). With changes in land use and settlement, the size and composition of various patches within the Bosque have also changed (Scurlock 1998). The existence in recent decades of a continuous cottonwood forest between the river and the levee appears to be unprecedented. That is, changes in land use had resulted in a Bosque dominated by a single habitat type made up of mature cottonwood trees with sparse understory and a grassy groundcover. Many Bosque researchers and commentators now believe that historically the Bosque was a dynamic mosaic of riparian wetlands, channels, woodlands, shrub thickets, and periodically wet meadows (Pittenger 2003, Crawford *et al.* 1998). Frequency of flooding, water table elevation, and the type of sediment substrate were and continue to be important determining factors of patch type and structure. The formerly dynamic river would destroy old growth forest and create wetlands, willow stands, channels, and areas recolonized by new cottonwood stands caused by river meandering across the unencumbered floodplain. Though the man-made flood risk management structures that now regulate the river and Bosque, are established, one of the goals of this study is to investigate alternatives to reconnect the river and the Bosque floodplain.

Another constraint is the presence of, and in many cases dominance by, non-native vegetation. Total eradication of all non-native vegetation within the Bosque is not a realistic goal. Therefore, this study will investigate integrating the non-native with native species to an acceptable level. An Integrated Vegetation Management (IVM) approach in collaboration with all stakeholders is a key component of the plan (Parker *et al*. 2005).

The hydrologic cycle in the MRG (delineated as Cochiti Lake to Elephant Butte Lake) is critical to the function of the Bosque cottonwood riparian communities and wetlands. The cycle represents high flows during spring snowmelt runoff and low flows during the fall and winter months. Additional high flows of short duration result from thunderstorms that occur in the late summer months. The high flows across the floodplain facilitate nutrient cycling, seed dispersal, and seed establishment. The inundation and high water-table recharges wetlands and provides for seasonal growth and nurturing of existing plant communities. Much of this inundation has been reduced by the disconnection between the river and floodplain due to installation of flood risk management structures. This „reconnection of function' can be obtained through restoration features such as the development of high-flow channels, backwater channels, and other features that connect the Bosque and the main river channel.

2.5 Jetty Jacks

Jetty jacks, specifically Kellner Jetty Jacks, initially facilitated the creation of a bank line for the low-flow channel by slowing the flow of water and allowing deposition of sediment. Vegetation colonized the newly deposited sediment, further stabilizing the new bank. Based on earlier studies and a preliminary determination by a special task force comprised of engineers from the Corps, MRGCD and Reclamation, non-essential jetty jacks are those that no longer provide bank stabilization, defined as armoring, for levees or bridge abutments. For the study area, that includes primarily all jetty jacks located where there is mature vegetation protecting a bank line, protecting bridge abutments, or found in areas where the bank is less than 100 feet in width. Many of the bank-line jacks would be difficult to remove because the jacks are deeply embedded in the riverbank.

The Corps evaluated various methods for mechanical removal of jetty jacks and assessed the subsequent environmental impacts (USACE 2003). Non-essential jetty jacks have been removed as part of Corps ecosystem restoration projects at Los Lunas and Santa Ana Pueblo. In addition, a Jetty Jack Removal pilot project removed jetty jacks in the study area at two locations on the east side of the river: immediately north of the Central Avenue bridge and south of the Bridge Boulevard bridge. Since that time and based on the pilot project results, jetty jacks have been removed by the Corps under the Bosque Wildfire Project. Other agencies and groups have removed jetty jacks in other locations as part of restoration projects after receiving approval from the Corps, MRGCD, and Reclamation.

2.6 Existing Conditions

The Corps used a two-dimensional hydraulic model to support the analysis of the Albuquerque reach of the Rio Grande. The Corps used the results from the existing conditions hydraulic model to compare the baseline conditions with the proposed restoration alternatives. The hydraulic model provides an assessment of overbank flows, storage, and hydraulic data to facilitate analysis of sediment-transport conditions and geomorphic processes along the reach. The detailed hydraulic modeling report and analysis results are included in Appendix A.

2.6.1 Existing Hydraulics

FLO-2D is a two-dimensional hydraulic model that estimates the routing of one or more hydrographs over a grid system representing the floodplain. Channel and floodplain flows are calculated using standard hydraulic parameters. FLO-2D can be applied to analyze split channel flows, sediment movement, mud and debris flows, and flows over alluvial fans. A detailed FLO-2D model can simulate rainfall and infiltration and flows with respect to levees, hydraulic structures, streets, buildings, and flow obstructions. FLO-2D provides an estimate for hydraulic parameters, including flow depth, velocity, and area of inundation. The model is an effective tool for predicting channel and overbank flow.

The Corps developed and calibrated a FLO-2D model specifically for the MRG as part of the interagency Upper Rio Grande Watershed Operations Review (URGWOPS). The Corps is one of the participating Federal agencies in the URGWOPS project. The URGWOPS FLO-2D model extends from Cochiti Dam downstream through the study area. The URGWOPS model proved ideal as the basis for a flow routing-model for the study area. The model uses the following data:

- A 500-foot-grid system using elevations from various sources. In the study area, the Corps derived the majority of the elevations from the 1999-2000 Bernalillo County Digital Mapping Project. The Corps converted the vertical datum from National Geodetic Vertical Datum 1929 (NGVD 29) to North American Vertical Datum 1988 (NAVD 88).

- Parameters related to the grid and channel system initially estimated based on engineering judgment. Channel roughness and infiltration parameters have since been calibrated.

- Channel sections surveyed over the past five years. Intermediate sections are interpolated from the surveyed sections.

- Levee elevation data obtained from surveys and digital terrain models (DTM).

The Corps calibrated the model using 1997, 1998, and 2001 recorded stream gage data and aerial photographs. Adjusted parameters include channel roughness and channel infiltration to improve hydrograph timing, hydrograph shape, and hydrograph volume. The calibration data did not represent a large flood event because significant flows have not occurred within the past 30 years.

2.6.2 Existing Hydrology

Table 2.2 lists the four hydrologic scenarios used to evaluate the baseline conditions.

Table 2.2 Summary of Hydrologic Scenarios.

Hydrologic Scenario	Description	Peak Discharge (cfs)
1	Active channel-full flow	6,000
2	Post-Cochiti Dam annual spring hydrograph	3,770
3	10,000 cfs post-Cochiti Dam hydrograph	10,000
4	1.0%-chance post-Cochiti Dam snowmelt hydrograph	7,750

2.6.2.1 The Active Channel-Full Flow (Scenario 1)

The Corps determined the active channel-full flow in the Albuquerque reach to be approximately 6,000 cfs. This scenario was modeled as a steady-state condition because the primary purpose is to evaluate the extent and location of overbank flooding that would occur under a sustained discharge of this magnitude. This discharge has a peak flow recurrence interval of approximately 2.3 years and a mean daily flow exceedance probability of 1.2 percent (*i.e*., the flow occurs, on average, four to five days per year).

2.6.2.2 A Representative Post-Cochiti Dam Annual Spring Hydrograph (Scenario 2)

The Corps developed a representative post-Cochiti Dam annual spring runoff hydrograph with a maximum mean daily flow of 3,770 cfs to evaluate the various riparian and wetland restoration alternatives. To develop the representative hydrograph, the Corps plotted the mean daily flow values for each of the 29 post-Cochiti Dam annual hydrographs. Because the individual hydrographs peak at different times each year, the Corps adjusted the timing of each of the annual hydrographs by centering the hydrographs so that the rising and falling limbs match as closely as possible to prevent over estimating the hydrograph volume, particularly on the rising and falling limbs. A 50-percent exceedance hydrograph was computed based on the translated hydrographs, and the hydrograph yielded a peak discharge of 3,770 cfs. A log-Pearson III frequency analysis of the annual peak flows performed for this evaluation indicates that the peak mean daily flow of 3,770 cfs corresponds to a recurrence interval of about 1.4 years and a mean daily flow exceedance probability of 8.1 percent (*i.e.,* the flow occurs 30 days per year, on average). Figure 2.8 displays the 50-percent exceedance hydrograph and compares the hydrograph with five natural hydrographs with similar peak discharges recorded in 1976, 1978, 1988, 1989, and 1998.

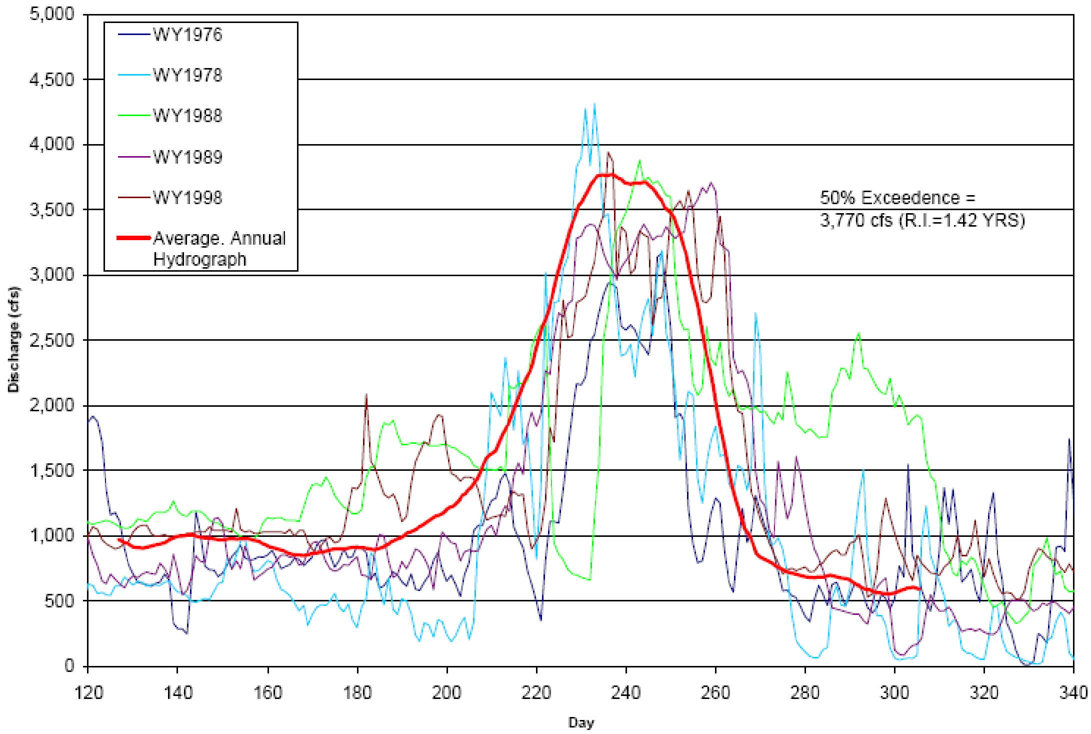


Figure 2.8. The representative 50-percent exceedance and five natural hydrographs.

The mean daily flow hydrographs that were developed for this analysis primarily represent snowmelt runoff from the upper part of the basin, which typically attenuates slowly due to the size of the drainage basin and the dampening effect of the upstream reservoirs. As a result, the mean daily and instantaneous maximum flows during the snowmelt season are not significantly different; therefore, the use of mean-daily flow values for this analysis is believed to be appropriate.

2.6.2.3 A 10,000 cfs Post-Cochiti Dam Flow Hydrograph (Scenario 3)

The Corps developed a 10,000 cfs hydrograph by scaling the ordinates of the 10-percent exceedance hydrograph, with a peak of 6,536 cfs, to provide a peak discharge of 10,000 cfs (Figure 2.9) and adjusting the hydrograph duration to achieve the target volume of 1,467,000 acre feet that was determined by extrapolating the best-fit curve in Figure 2.10 to 10,000 cfs.

In the development of the 50-percent exceedance hydrograph, the peak discharge was contained within the range of discharges and no scaling of the peak discharge was required. However, because the peak discharge of 10,000 cfs has not occurred during the post-Cochiti period, the 10-percent exceedance hydrograph was scaled, rather than the 50-percent hydrograph, because it provides a more realistic shape of the largest hydrographs.

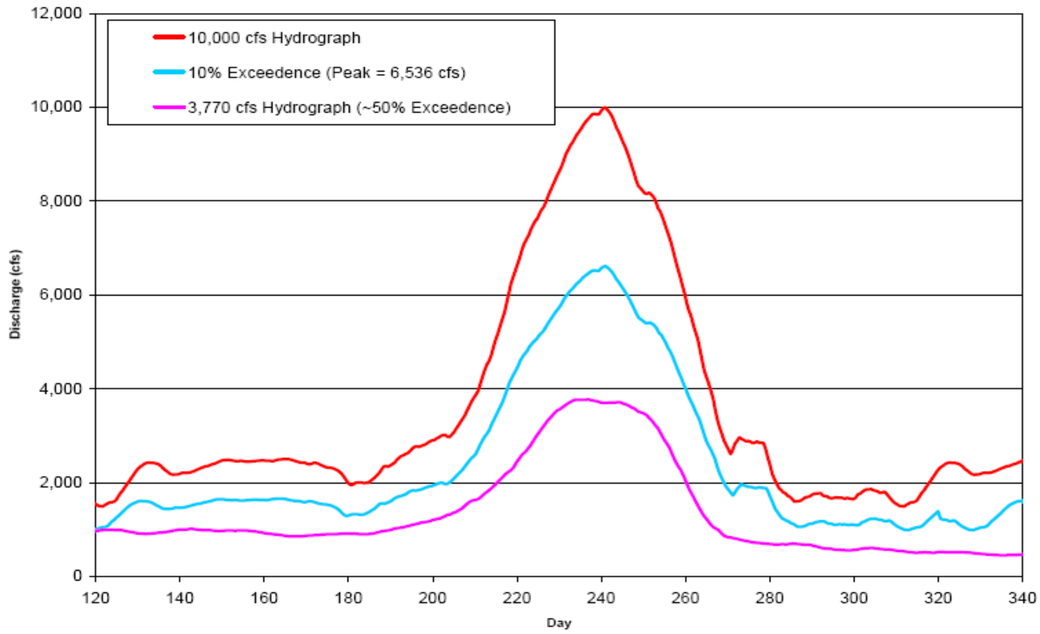


Figure 2.9. Comparison of the 10,000-cfs, 10- and 50-percent exceedance hydrographs.

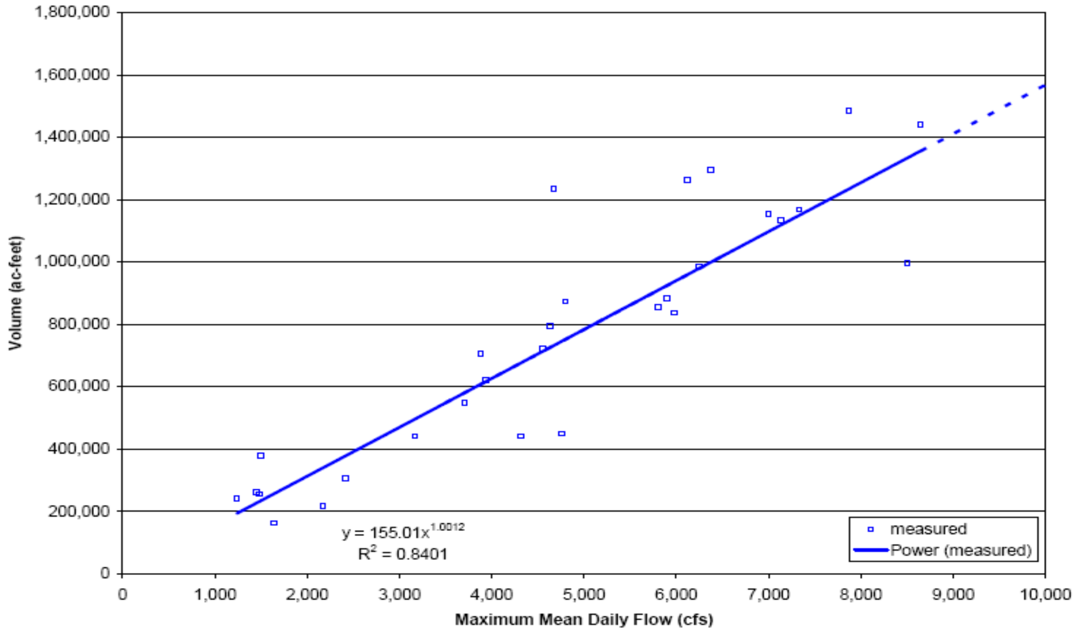


Figure 2.10. Comparison of mean daily flow values versus computed volumes.

2.6.2.4 The 1.0%-Chance Post-Cochiti Dam Snowmelt Flow Hydrograph (Scenario 4)

Analysis of the Rio Grande flood hydrology by the Hydrologic Engineering Center (HEC 2006) indicated that the 1.0%-chance snowmelt hydrograph (Scenario 4) has a peak discharge of approximately 7,750 cfs. The snowmelt hydrograph was developed by routing actual hydrographs from time-series analysis of unregulated flows through the upstream reservoirs using the HEC ResSim model, and then routing the resulting outflow hydrographs from Cochiti Dam downstream through the study reach using the FLO-2D model. The snowmelt hydrograph has a duration of approximately 17 weeks and is regulated by Cochiti Dam at a relatively constant flow of 7,000 cfs over the 17-week period. The hydrograph showing the effects of upstream regulation is shown in Figure 2.11.

A flow of 6,300 cfs was recorded in the study reach during the snowmelt runoff event in 2005. Comparison of the water surface elevation produced by a flow of 6,300 cfs predicted by the updated FLO-2D model with the water surface profile measured in the field during the 2005 event shows very good agreement. The Corps also evaluated the performance of the model over a broader range of flows and compared the results at four bridges where measured water surface elevations were available. Based on the results, the updated FLO-2D model appears to be reasonably well validated.

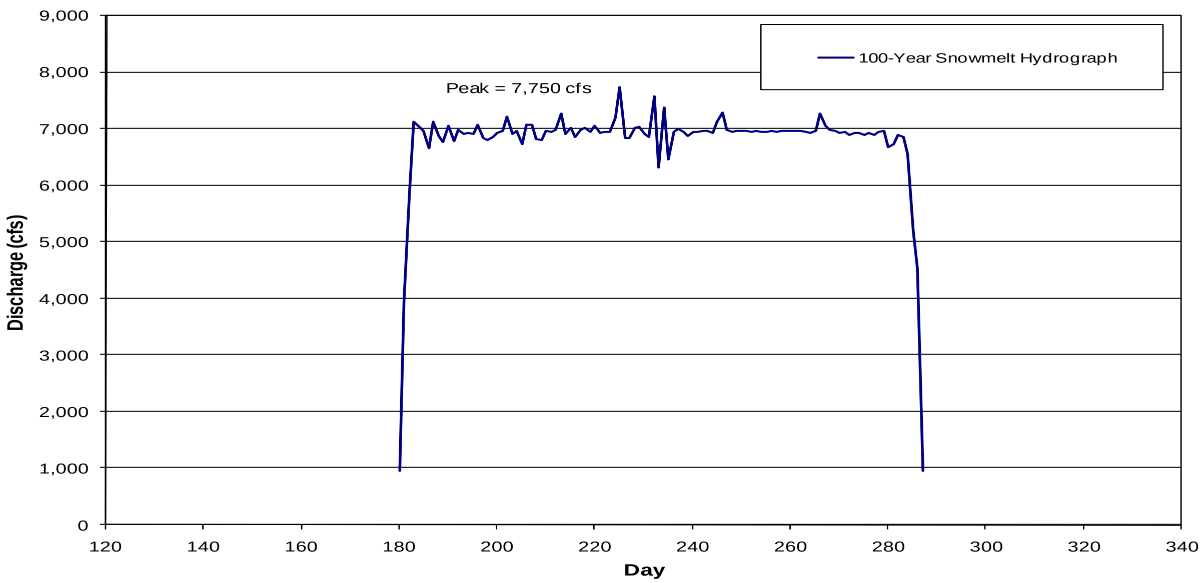


Figure 2.11. The Representative 1.0%-Chance Snowmelt Hydrograph.

2.6.2.5 Hydraulics - Model Results (250-foot FLO-2D Model)

The Corps ran the validated existing conditions FLO-2D model for the four hydrologic scenarios, and the results were used to compare the main channel water surface elevations with the top-of-bank elevations and to map and evaluate the extent, depth, and duration of overbank inundation along the reach. In the FLO-2D model, a representative elevation is assigned to each grid cell; therefore, the local depth or duration of inundation at any point within the cell might vary from the representative value predicted by the model due to variations in the ground elevations. To provide a more detailed depiction of the variation in depth than is shown with the 250-foot-grid spacing, a new water-surface DTM with 30-foot pixel resolution was developed based on maximum water surface elevations predicted by the FLO-2D model for each simulation. The local depth within each 30-foot pixel was then determined by overlaying the water-surface DTM onto the detailed ground-surface DTM.

Existing conditions results for the active channel-full flow hydrograph (Scenario 1) indicate that the water surface elevation is at or above the top-of-bank elevation at several locations along the project reach, including:

- East bank, approximately 4,000 feet upstream from the Central Avenue bridge (approximately midway between Central Avenue and the Interstate 40 Bridges)
- Extensively along the east and west banks from approximately 8,000 feet upstream from the Rio Bravo bridge to immediately downstream from the Rio Bravo bridge
- Extensively along the east and west banks from approximately 7,000 feet downstream from the South Diversion Channel to just downstream from the Interstate 25 bridge

The amount of overbank inundation for channel-full flow conditions was summarized for each reach based on the number of inundated grid elements computed in the FLO-2D simulation. Figure 1.3 shows the study reaches. Table 2.3 indicates that no overbank inundation occurs in Reaches 1 and 2. Approximately 9 acres, 280 acres, and 270 acres are inundated in Reaches 3, 4, and 5, respectively.

Table 2.3 Summary of area of inundation for existing conditions (acres).

Hydrology Scenario	Description	Reach					
		1	2	3	4	5	Total
1	Channel Full Conditions	0.0	0.0	8.6	279.8	269.7	558.1
2	Annual Spring Runoff	0.0	0.0	0.0	14.3	31.6	64.6
3	10,000 cfs Hydrograph	691.6	420.4	249.7	809.2	850.8	3,021.7
4	1.0%-Chance Peak Snowmelt	344.4	11.5	50.2	249.7	578.2	1,233.9

Reach 1 – Southern Boundary of the Pueblo of Sandia to Alameda Bridge
Reach 2 – Alameda Boulevard Bridge to Montano Boulevard Bridge
Reach 3 – Montano Boulevard Bridge to Central Avenue Bridge
Reach 4 - Central Avenue Bridge to the South Diversion Channel
Reach 5 – South Diversion Channel to Northern Boundary of Pueblo of Isleta

Existing Conditions, Hydrology Scenario 2 (Annual Spring Runoff Hydrograph): The maximum computed water-surface elevations during the average annual hydrograph (Hydrology Scenario 2) indicate that the top-of-bank elevation is exceeded at two locations along the project reach : (1) approximately 14 acres are inundated for less than one day along the east bank 1,500 feet downstream from Bridge Street, and (2) approximately 32 acres are inundated for less than one day at a channel contraction located approximately 8,000 feet downstream from the South Diversion Channel. Very little overbank inundation occurs under Hydrology Scenario 2 because the peak discharge of 3,770 cfs is substantially less than the channel capacity along the majority of the reach.

Existing Conditions, Hydrology Scenario 3 (10,000 cfs Post-Cochiti Dam Hydrograph): The maximum computed water surface elevations during the 10,000 cfs snowmelt hydrograph (Hydrology Scenario 3) indicates that overbank inundation occurs at similar locations to the channel-full condition, but with larger areas of inundation. Additional overbank inundation areas occur downstream from the Corrales Siphon. Significant inundation areas include the following:

- Extensive inundation along the east bank from Corrales Siphon to immediately downstream from the North Diversion Channel.

- East bank, approximately 4,000 feet upstream from the Central Avenue bridge (approximately midway between Central Avenue and Interstate 40 bridges) to midway between Central Avenue and Bridge Street bridges.

- Extensively along both banks from approximately 8,000 feet upstream from the Rio Bravo bridge to immediately downstream of the Rio Bravo bridge.

- Extensive inundation along both banks from the South Diversion Channel to the downstream end of the project area.

In Hydrology Scenario 3, approximately 3,021 of the 5,840 acres of available floodplain (about 51 percent) are inundated.

Existing Conditions, Hydrology Scenario 4 (1.0%-Chance Snowmelt Hydrograph): Based on the maximum computed water surface elevations produced by the 1.0%-chance snowmelt hydrograph (Hydrology Scenario 4), overbank inundation occurs at similar locations to the 10,000 cfs hydrograph, but with less total area of inundation (Table 2.3). In this scenario in which the peak discharge is approximately 7,750 cfs, approximately 1,230 of the 5,840 acres of available floodplain (about 21 percent) are inundated during the event. Appendix A presents the extent, maximum depth, and duration of inundation for this scenario. The majority of the overbank inundation occurs for approximately 14 to 16 days during the three-month hydrograph.

2.6.3 Sediment Continuity Analysis

The Corps performed a baseline sediment-continuity analysis to evaluate the potential for aggradation or degradation in response to both individual short-term hydrographs and longer-term flows (50-year period of analysis) with the present channel configuration and reservoir operations. In general, the analysis was conducted by estimating the bed-material transport capacity of the supply reach and each reach within the study area for each hydrology scenario and comparing the resulting capacity with the supply from the upstream river and tributaries within the reach. For this analysis, Hydrology Scenarios 2, 3, and 4 (mean annual runoff, 10,000 cfs post-Cochiti Dam, and 1.0%-chance snowmelt hydrographs, respectively) were used for the individual hydrographs, and the mean daily flow-duration curve from the Albuquerque gage for the post-Cochiti Dam period was used for the long-term analysis.

To facilitate the analysis, bed-material transport capacity rating curves were developed for each reach using hydraulic output from the 500-foot grid FLO-2D model, representative bed-material gradations and the Yang (Sand) sediment-transport equation (Yang 1973). In a previous study for the URGWOPS Environmental Impact Statement, MEI (2004) evaluated a range of possible transport equations that were developed for conditions similar to those in the project reach and determined that, among the available equations, this equation produced results that were the most consistent with the available measured data at the Rio Grande gages downstream from Cochiti Dam. The sediment-transport rating curves were then integrated over the individual hydrographs or the flow-duration curve to obtain a transport capacity volume for each hydrology scenario. In comparing the volumes, when the transport capacity of a particular reach exceeds the supply, the channel will respond by either degrading (*i.e.*, channel downcutting) or coarsening the bed material, and when the supply exceeds the capacity, the channel will respond by aggrading or fining its bed material. Significant amounts of downcutting or aggradation can also lead to lateral instability. The upstream supply reach used for this study extends from the upstream limit of the study reach to Arroyo de la Baranca (located approximately two miles downstream of Bernalillo), a distance of approximately 29,000 feet.

The representative bed-material gradations used in the analysis were taken from MEI (2004), with the gradation for URGWOPS Reach 12a (Bernalillo to Rio Rancho Wastewater Treatment Plant) representing the supply reach and URGWOPS Reach 12b (Rio Rancho to Isleta Diversion Dam) representing the primary study reach for this project (Figure 2.12). These gradations were developed using data collected by Reclamation and the USGS after 1990 and by MEI for various studies in 2002 and 2003. Observations by Reclamation indicate that fine material that is not characteristic of the typical bed material that controls the form of the channel tends to accumulate as a veneer over the primary bed material during the non-runoff season but is removed during the runoff season. To avoid biasing the results to this finer material, the data sets were restricted to samples that were collected between May 1 and August 31 because this is the period of highest flows when the fine material is not likely present.

Data collected in May 2001 (MEI 2004) were used to develop a representative bed material gradation for Reach 12a that is located in the supply reach between Bernalillo and Rio Rancho (Figure 2.13). The data set for the primary study reach consists of 17 bed-material samples collected by the USGS at the Albuquerque gage between 1990 and 1996 and 16 samples collected by Reclamation between 1998 and 2001.

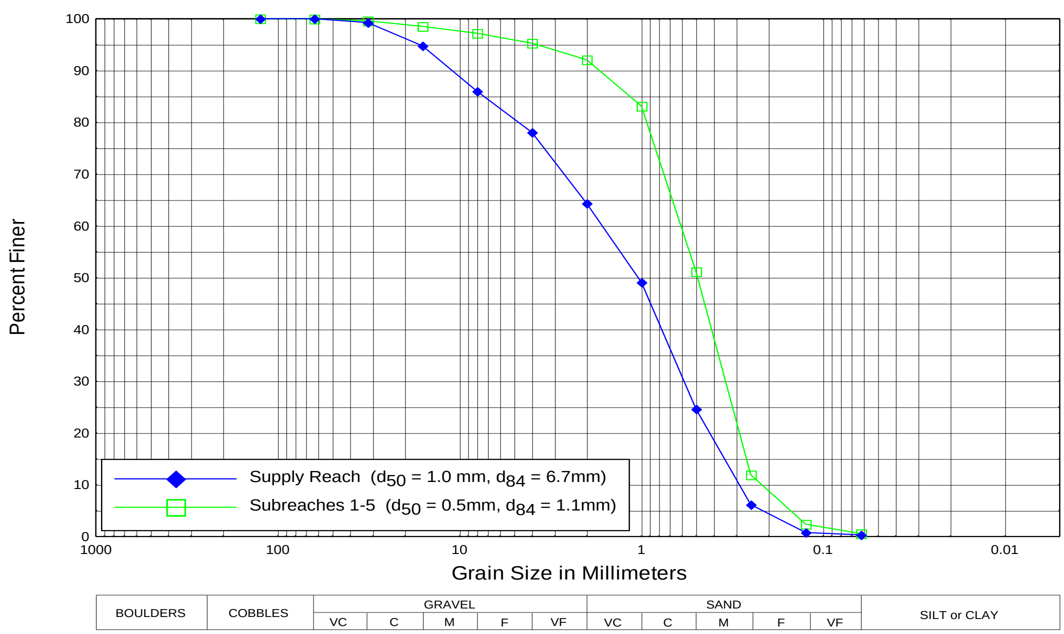


Figure 2.12. Representative bed-material gradation curve for the study reach.

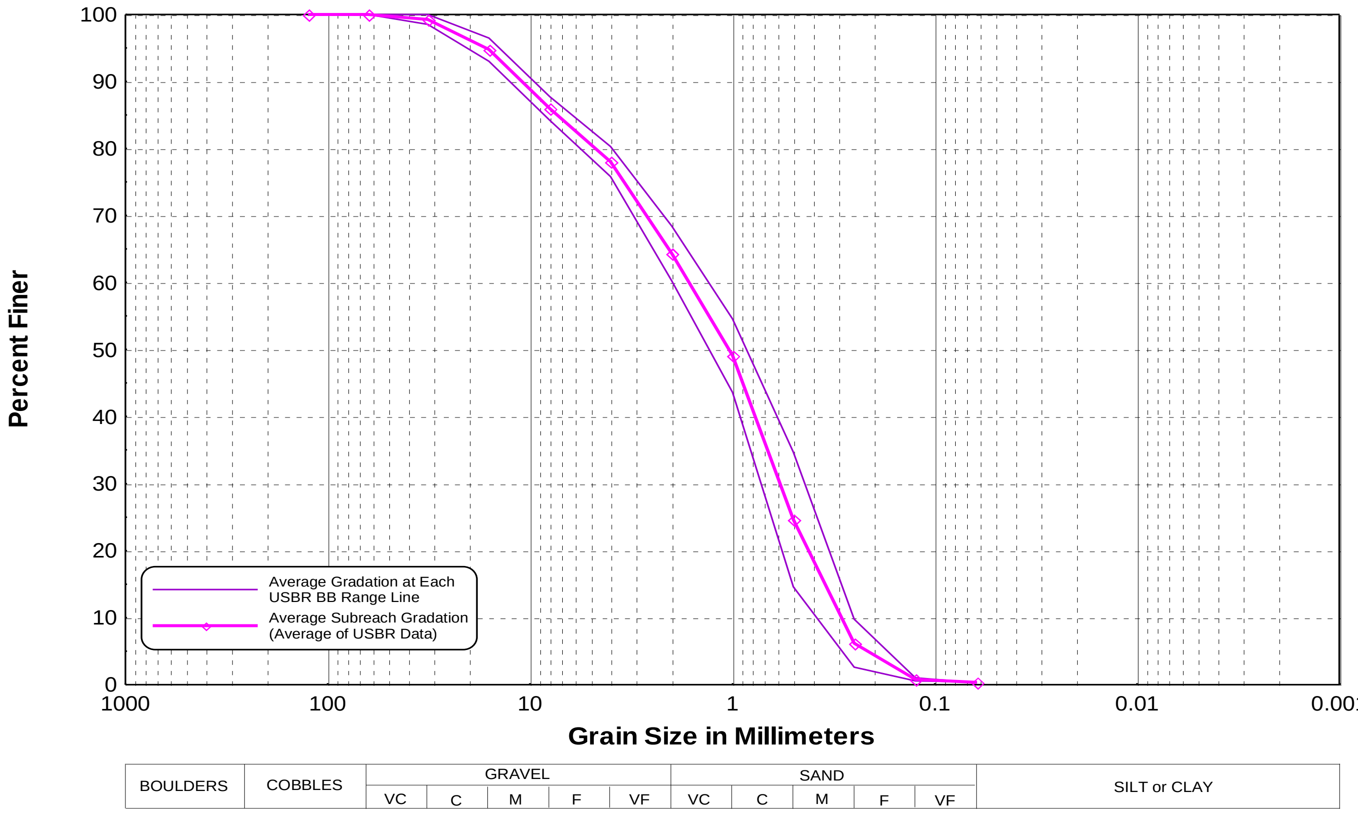


Figure 2.13. Representative bed-material gradation curve for the supply reach.

The supply reach gradation has a median size of about one millimeter (coarse sand), contains material up to about 128 millimeter (mm), and about 42 percent of the material is in the gravel- and cobble-size range (Figure 2.13). The gradation for the primary study reach has a median size of 0.5 mm (medium and coarse sand), contains material up to about 32 mm, and about 92 percent of the material is sand.

To validate the general approach for estimating the transport capacity rating curves, a bed-material rating curve was developed using hydraulic results from the FLO-2D model for the main channel at the Albuquerque gage and compared to measured values at the gage (Figure 2.14). The resulting rating curve is consistent with the measured data, indicating that the approach is appropriate. Rating curves based on the reach-averaged hydraulics for each of the reaches are shown in Figure 2.15.

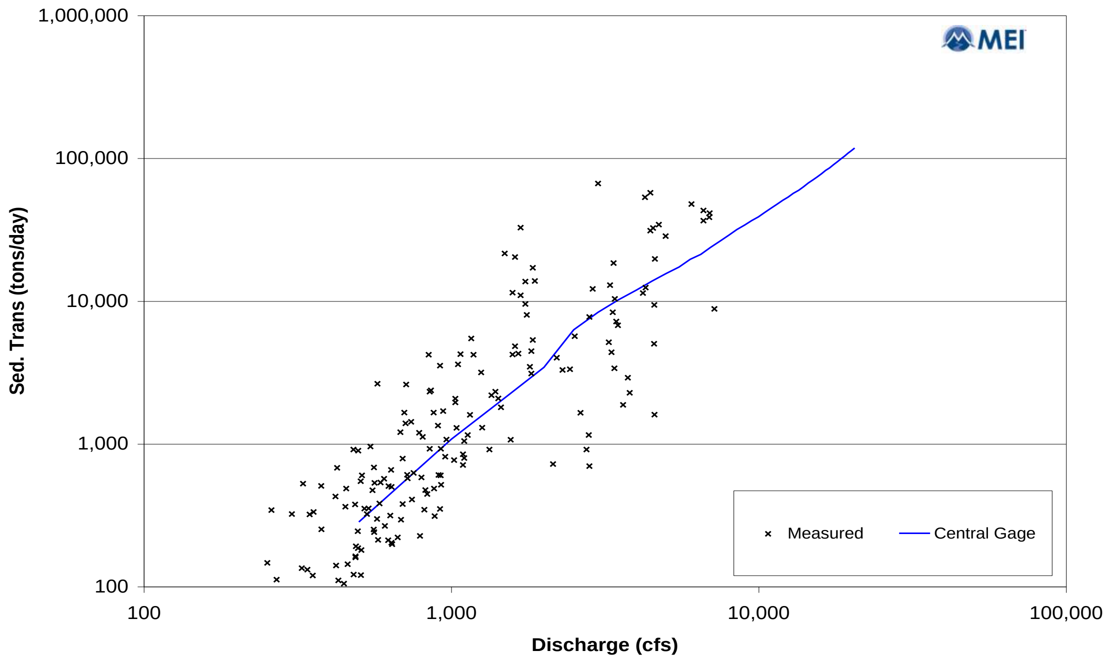


Figure 2.14. Bed-material rating curve at the Albuquerque gage.

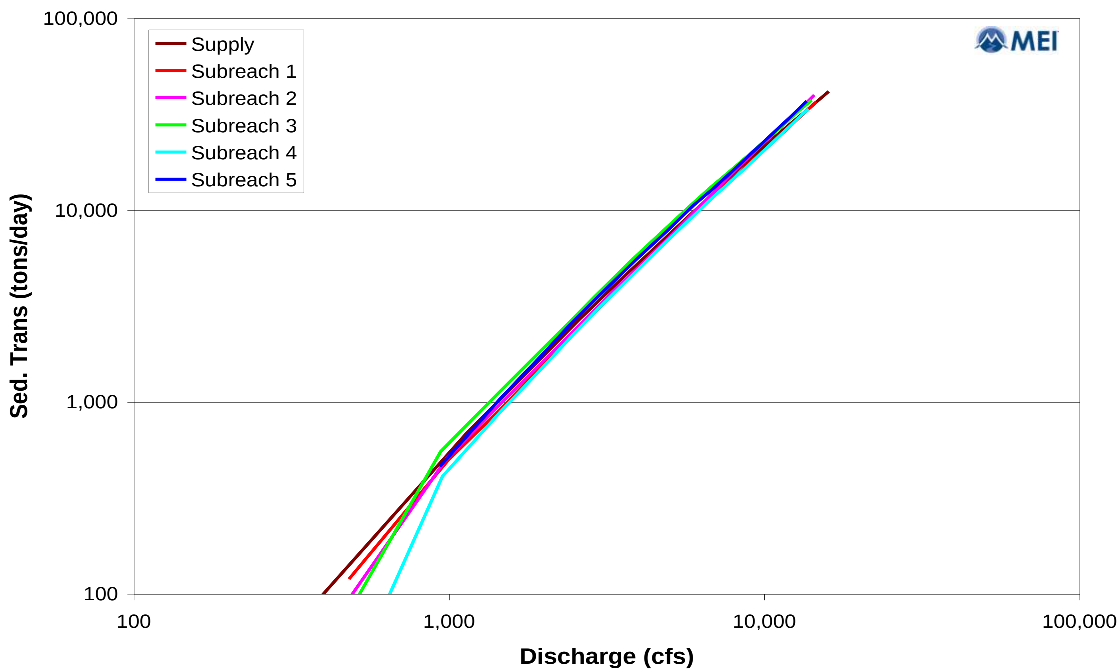


Figure 2.15. Bed-material rating curves for each of the reaches.

Three tributaries (Calabacillas Arroyo, North Diversion Channel, and South Diversion Channel) were identified along the study reach that have the capability to deliver significant quantities of sediment to the Rio Grande (Table 2.4). Sediment loads from the North Diversion

Channel (NDC) were obtained from previous studies (Copeland 1995, Mussetter and Harvey 1993). Due to the lack of available data for Calabacillas Arroyo and the South Diversion Channel (SDC), annual bed-material loads were estimated by assuming a unit bed-material supply of 0.1 acre feet per square mile, which is generally consistent with the range of unit yields from the tributaries for which information is available. Calabacillas Arroyo, the NDC, and the SDC are ephemeral channels that flow in response to rainfall events. Historically, significant floods from Calabacillas Arroyo have formed a large fan at the confluence with the Rio Grande that have fully or partially blocked the river at various times. Large magnitude events in the arroyo, such as the 1941 and 1988 floods, caused the Calabacillas Arroyo fan to prograde into the Rio Grande. Development of the watershed, channelization of Calabacillas Arroyo, and construction of Swinburne Dam (completed in 1991) has likely reduced the sediment load to the Rio Grande.

Integration of the transport capacity rating curves over the mean annual hydrograph results in a transported volume through the study reach of about 100 acre feet of sediment (Figure 2.16). The transported volume increases to about 450 acre feet and 630 acre feet for the 10,000 cfs and 1.0%-chance snowmelt hydrographs, respectively (Figures 2.17 and 2.18). Based on integration of the annual flow-duration curve, the long-term, average annual bed-material load through the study reach is about 240 acre feet (Figure 2.19). This value is higher than obtained for the mean annual hydrograph because the flow-duration curve includes flows that significantly exceed the mean annual flood peak.

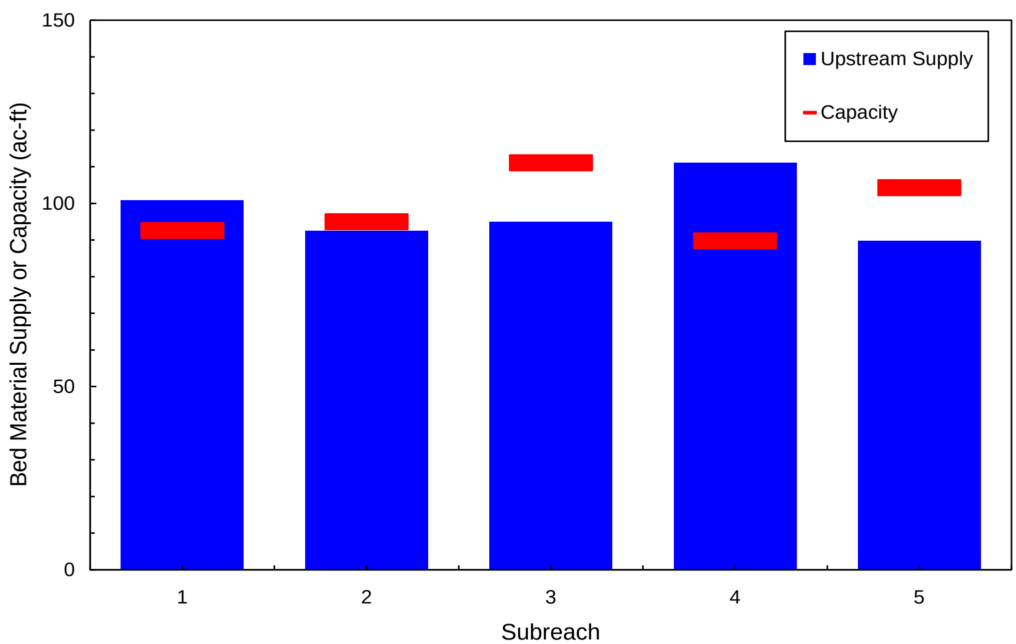


Figure 2.16. Comparison of average annual supply and bed-material transport capacity in the study reach.

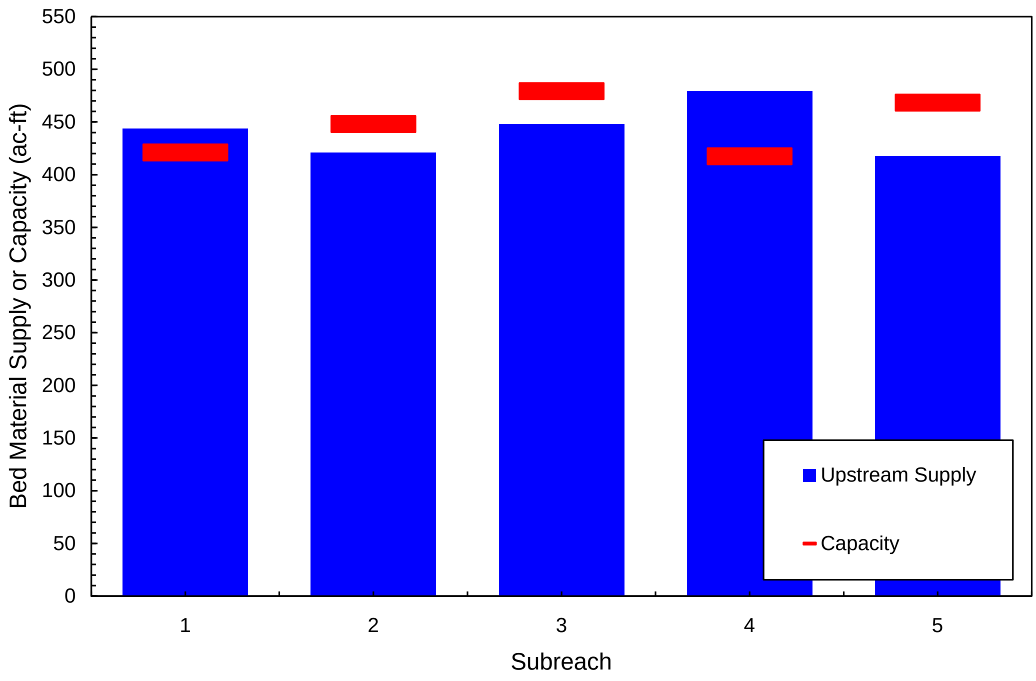


Figure 2.17. Comparison of supply and transport capacity for the 10,000-cfs hydrograph in the study reach.

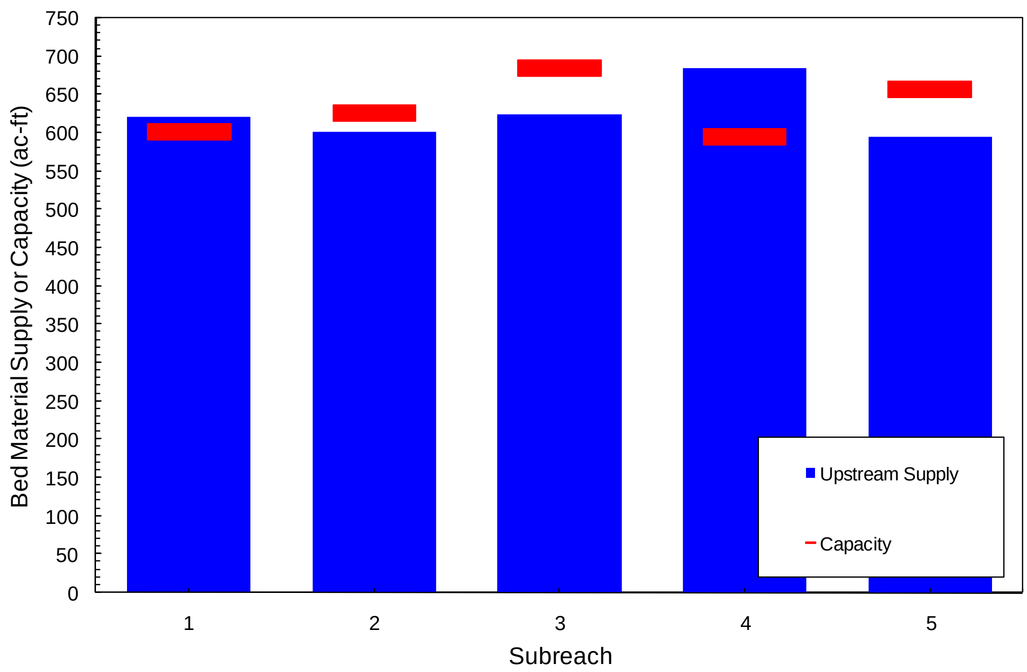


Figure 2.18. Comparison of supply and transport capacity for the 100-Year snowmelt hydrograph in the study reach.

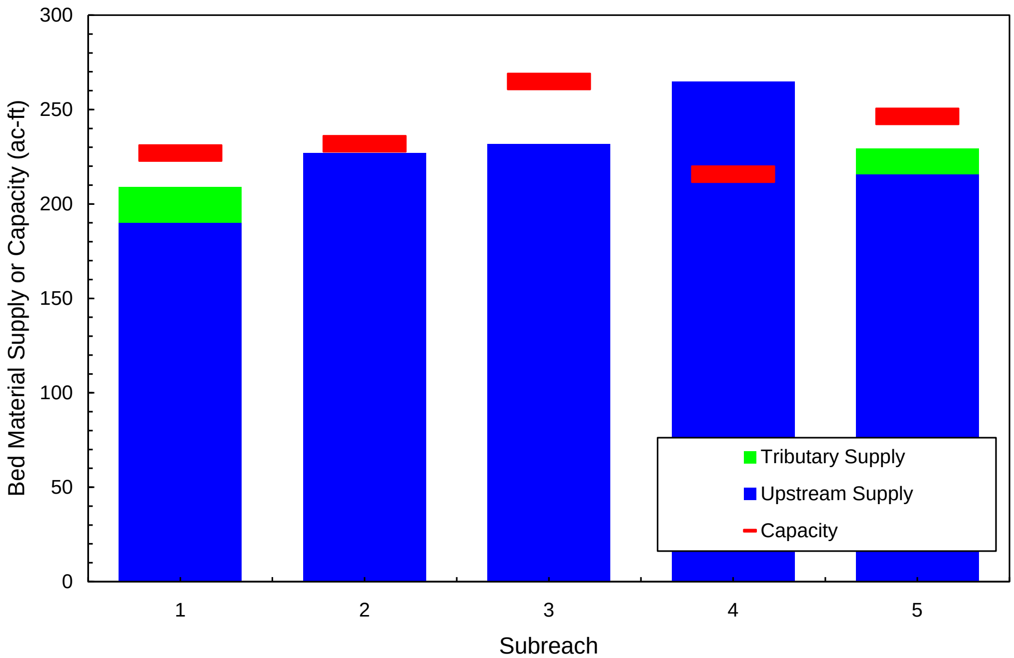


Figure 2.19. Comparison of supply and transport capacity for the flow-duration curve in the study reach.

Table 2.4 Summary of average annual bed-material contribution from each of the tributaries.

Tributary Name	Drainage Area (mi^2)	Average Annual Sediment Volume (ac-ft)	Unit Volume (ac/mi^2)	Source
Calabacillas Arroyo	100.8	10.1	0.10	Assumed 0.1 acre feet/mile^2
North Diversion Channel	102	8.3	0.08	Copeland (1995)
South Diversion Channel	133	13.3	0.10	Assumed 0.1 acre-feet/mile^2

(modified from MEI (2004)

The results shown in Figures 2.16 through 2.19 indicate that the bed-material transport capacity is relatively consistent from reach to reach, although a slight net degradational tendency occurs, in the absence of tributary sediment contribution, for the overall study reach for all three of the individual storm hydrographs that were analyzed. For the average annual hydrograph, the transport capacity at the downstream end of the reach is about 104 acre feet compared to the upstream supply of about 101 acre feet (Figure 2.16). For the 10,000-cfs hydrograph, the transport capacity at the downstream end is about 468 acre feet capacity versus 444 acre feet of supply (Figure 2.17), and for the 1.0%-chance snowmelt hydrograph, the downstream capacity is about 657 acre feet capacity at the downstream end versus 622 acre feet of supply (Figure 2.18). Tributary contribution were not considered for the mean annual, 10,000-cfs, and 1.0%-chance snowmelt hydrographs because storms in the tributaries will most likely occur during the monsoon season in late summer and early fall, whereas the large runoff hydrographs in the river typically occur during the spring snowmelt runoff period. On a long-term average annual basis, the transport capacity at the downstream end of the reach is about 246 acre feet compared to the supply of 209 acre feet (Figure 2.19).

In spite of the overall degradational tendency, Reach 4 tends to be aggradational for all of the hydrology scenarios. Over time, the upstream Reaches 1, 2, and 3 will probably respond to the deficit by coarsening of the bed material as these reaches approach a balance between the supply and capacity. The coarsening will decrease the supply to Reach 4, which will bring this reach into closer balance between the supply and capacity, reducing the aggradation potential.

The Corps estimated the approximate change in bed elevation (*i.e.*, aggradation/degradation potential) associated with these differences in volume by dividing the difference between the bed material supply and capacity of the reach by the surface area of the channel, based on the product of the reach length and channel top width (Table 2.5). In the evaluation of this information, the actual changes will not occur uniformly throughout the reach or across the channel at any given location, nor will they continue progressively for a long period of time because the bed material, channel geometry, and gradient will adjust to compensate for imbalances between the sediment supply and transport capacity. In spite of this limitation, the analysis provides a reasonable basis for comparing results from the sediment-continuity analysis.

Table 2.5 Summary of sub-reaches defined for the channel-stability analyses.

Reach	Reach Length (feet)	Main Channel Top Width (feet)[1]	Limits
1	10,760	710	Southern boundary of the Pueblo of Sandia to Alameda Bridge
2	22,190	650	Alameda Blvd. Bridge to Montano Blvd. Bridge
3	23,430	500	Montano Blvd. Bridge to Central Avenue Bridge
4	32,190	545	Central Avenue Bridge to the South Diversion Channel
5	25,640	550	South Diversion Channel to the northern boundary of the Pueblo of Isleta

[1]at the active channel-full flow of 6,000 cfs

Reaches 1 and 4 are net aggradational , Reach 2 is approximately in balance with the upstream supply, and Reaches 3 and 5 are net degradational in the absence of tributary contribution (Table 2.6). On a long-term, average annual basis, Reaches 1, 3, and 5 are net degradational (average of -0.11, -0.11, and -0.05 feet, respectively). Reach 2 is approximately in balance with the upstream supply (-0.01 feet, on average), and Reach 4 is net aggradational (average of about 0.13 feet) with tributary contribution.

Table 2.6 Summary Aggradation/Degradation Depths for Each Reach

Reach	Average (feet)		10,000 cfs (feet)		1.0%-chance Snowmelt (feet)		Long Term (feet)	
	Aggrade	Degrade	Aggrade	Degrade	Aggrade	Degrade	Aggrade	Degrade
1	0.04		0.13		0.12			0.11
2		0.01		0.07		0.07	0.01	
3		0.06		0.11		0.21		0.11
4	0.05		0.13		0.19		0.13	
5		0.04		0.15		0.18		0.05

This is the existing condition and does not represent a future trend. Based on the existing state of aggradation and degradation presented here, the MRG reach is in or near equilibrium, and restoration features designed to this condition would remain functional through the period of analysis. For more detailed future trends see the discussions in Section 3, *Future Without Project Condition*, and Section 4, *Plan Formulation and Evaluation Process*.

2.7 Ecological Setting and Resources

2.7.1 Current Vegetative Conditions (2005)

Investigators identified the loss of conditions necessary for regeneration of native riparian plants and increasing abundance of non-native species in river systems throughout the western U.S. beginning in the mid-1970s, with main-stem impoundments typically identified as the primary factor driving alteration of ecosystem structure and function (Fenner *et al.* 1985, Howe and Knopf 1991). Impoundments alter the hydrograph and reduce sediment supply in downstream reaches and cause channel incision and narrowing of the floodplain (Williams and Wolman 1984). Installation of jetty jacks, levee construction, sediment and vegetation removal, and irrigation diversions have exacerbated these effects in the study area (Crawford *et al*. 1993). Changes wrought by impoundments and channel modifications in the study area have created a riparian ecosystem organized by autogenic factors, including plant succession and invasion by non-native species, and novel allogenic factors such as fire. Conversely, the naturally functioning Bosque ecosystem was structured largely by fluvial geomorphic processes (cf. Déscamps *et al*. 1988).

A major change in vegetation dynamics in the Bosque ecosystem has been loss of meander cut-off, meander migration, and flood scour processes, which were a driving force in the dynamics of the naturally functioning system. These processes removed existing vegetation and created new sites for founding of plant communities. Sediment deposition in the project area is now restricted to several, largely ephemeral, mid-channel bars and transitory lateral bars proximal to the river. Meander cut-off and lateral meander migration no longer occur. Bare soil sites are now created primarily through mechanical disturbance or fire, typically in areas no longer subject to periodic inundation and with relatively dry soil-moisture regimes.

The frequency and duration of inundation, in addition to moisture requirements for establishment and persistence, also influences the structure of riparian vegetation (Wheeler and Kapp 1978, Kozlowski 1984). Riparian plant species vary in their tolerance to inundation and resulting anoxic conditions (Amlin and Rood 2001). Growth and regeneration of many riparian tree species declines with increasing hydroperiod, and permanent inundation results in eventual loss of tree cover in most riparian ecosystems (Hughes 1990). Seedlings are particularly sensitive to inundation and tolerance of plants generally increases with age (Jones *et al.* 1994).

Moisture gradients are a major determinant of the distribution of riparian plant species (Weaver 1960, Bush and Van Auken 1984, Tanner 1986). Soil texture affects moisture regime. Sands drain quickly, and anoxic conditions occur only with high water tables or extended inundation. Fine-particle soils, which are deposited in areas of low current velocity, have high water-holding capacity and slow drainage. Fine-grained soils might accumulate at arroyo mouths on the floodplain, behind natural levees, and in oxbows (Hughes 1990).

Soil-moisture levels and depth to groundwater on floodplain sites are influenced primarily by surface topography, the variation of which is created through fluvial geomorphic processes (Malanson 1993). The limits of riparian vegetation are controlled by depth to the water table (Hughes 1990). Moisture in upper soil layers is a primary influence on establishment of tree species while groundwater levels are important for their persistence (Dawson and Ehleringer 1991). Soil moisture has a major influence on seed germination and seedling survival of cottonwood (Moss 1938, Bradley and Smith 1986, Mahoney and Rood 1993) and willow (Taylor *et al.* 1999, Dixon 2003).

Salt cedar is now a prominent colonizer of exposed, bare-soil sites in the Bosque (Smith *et al,* 2002). While individual cottonwood seedlings have a greater competitive effect relative to salt cedar seedlings under ideal soil moisture conditions (Sher *et al.* 2000), the competitive effect is lost under conditions of water stress (Segelquist *et al.* 1993) or elevated salinity (Busch and Smith 1995). Salt cedar produces seed for several months beginning in late spring (Ware and Penfound 1949, Horton *et al*. 1960) and colonizes bare, moist-soil sites throughout the summer. Conversely, cottonwood produces seed for only a short time in the spring, and seed remains viable for approximately a month and a half under ideal conditions (Horton *et al.* 1960). The flowering and fruiting phenology of salt cedar allows seedlings to establish and dominate open sites wetted by runoff, rainfall, or river flows during the summer, precluding the possibility for cottonwood establishment on potentially suitable sites the following spring. Salt cedar also becomes established in the understory of mature cottonwood stands in the study area where sufficient light exists (Crawford *et al.* 1996).

Russian olive is established by seed in the understory of mature cottonwood stands and also colonizes openings along the river, often forming dense stands (Hink and Ohmart 1984, Sivinski *et al.* 1990). Russian olive is shade tolerant and can survive in areas where cottonwood canopy exists. Seeds germinate in moist-to-dry sites, and the plant sprouts readily from the root crown after damage to or removal of above-ground portions of the plant (Sivinski *et al.* 1990). Russian olive was present in the understory in 1981 (Hink and Ohmart 1984) and continues to increase in the Bosque in the study area (Sivinski *et al,* 1990).

Several other non-native tree species, in addition to salt cedar and Russian olive, are at least locally common, if not abundant, in the overstory. These species are Siberian elm, tree of heaven, and Russian mulberry (*Morus alba* var. *tatarica*). All three species are shade-tolerant and readily colonize disturbed sites (Crawford *et al.* 1996, Sivinski *et al.* 1990). Siberian elm was rare in the Bosque in 1981 and was found only at very low densities, ranging from less than 0.5 tree/acre to 3 trees/acre (Hink and Ohmart 1984). However, Siberian elm had become increasingly abundant by 1990 (Sivinski *et al.* 1990) and is now very common in the overstory. This species produces large seed crops and is ubiquitous in the project area as seedlings, saplings, and mature trees. It sprouts readily from the root crown. Siberian elm seed will germinate under normal rainfall conditions and does not require moist or saturated soils (Sivinski *et al.* 1990). Tree of heaven and Russian mulberry are more localized in their distribution in the project area than salt cedar, Russian olive, or Siberian elm. Both of these species typically colonize disturbed areas, such as along levees and in severely burned sites (Sivinski *et al*. 1990).

Fire was virtually unknown in naturally functioning, low-elevation riparian ecosystems of the Southwest (Busch and Smith 1993, Stuever 1997). However, fuel accumulations coupled with mainly human-caused ignitions have introduced fire as a major disturbance mechanism in the Bosque ecosystem (Stuever 1997). While cottonwood is highly susceptible to fire-induced mortality (Stuever 1997), salt cedar re-sprouts vigorously following fire (Busch and Smith 1993, Busch 1995). Cottonwood and willow (*Salix* spp.) are poorly adapted to fire and lack an efficient post-fire re-sprouting mechanism such as that found in salt cedar (Busch and Smith 1993).

Post-fire soils have significantly higher salinity than soils of unburned areas, which might suppress growth of cottonwood and willow seedlings and allow establishment of salt cedar seedlings (Busch and Smith 1993). Salt cedar has a higher salinity tolerance than willow and cottonwood and adjusts to high salinity sites through accumulation of salts and osmotic adjustment, whereas willow and cottonwood exclude ions at the root endodermis (Busch and Smith 1995). Salt cedar uses the absorbed ions to maintain turgor pressure at low water potential and also exudes salts through special glands, allowing it to tolerate higher salinities and water stress than cottonwood and willow (Busch and Smith 1995). Halophytes, such as salt cedar, might salinize soils when well supplied with moisture to reduce water uptake and transpiration (Busch and Smith 1995).

Two large fires occurred in the Bosque in Albuquerque in June 2003, burning a total of 253 acres. Since that time, the AOSD has initiated an extensive fuel-wood thinning project in order to prevent fires in the Albuquerque area. Unfortunately, two more fires occurred in 2004. One fire occurred between Rio Bravo and Interstate-25 on both sides of the river, burning approximately 63 acres, and the other fire occurred south of Bridge Boulevard on the east side of the river, burning approximately 18 acres. Prior to, and between, these recent fires, the City of Albuquerque has been thinning most areas within the RGVSP. To date, the majority of the Bosque acres in the RGVSP have been "treated" in some way to reduce fire hazards by the AOSD, Ciudad Soil and Water Conservation District (SWCD), the Corps (through the Bosque Wildfire Project) and other agencies and private organizations. This makes up the majority of the acreage within the study area; however, as stated above, some Bosque lands in the study area are within the Pueblo of Sandia and Corrales Bosque Preserve.

Areas treated within the RGVSP have been variably managed; some were lightly thinned while other areas were cleared of all non-native vegetation and dead material, depending on the level of fuel reduction required for the site. Clearing activities have greatly reduced the acreage of dense non-native woodlands, and mature cottonwood stands are largely devoid of understory vegetation. However, Russian olive and salt cedar have begun sprouting from the root crowns of cut trees in treated stands.

2.7.2 Fish and Wildlife

An estimated 407 species of vertebrates might occur in aquatic, semi-aquatic, or riparian habitat in Bernalillo and Sandoval Counties, based on a query of the Biota Information System of New Mexico (accessed March 2008). This estimate includes 24 species of fish, 11 amphibian taxa, 39 species of reptiles, 279 species of birds, and 54 mammalian taxa (Pittenger 2003). Birds are the most important group, based on number of taxa, comprising 69 percent of all vertebrate species in the estimate.

Herptile abundance and diversity was found to be greatest in habitats that lacked dense canopy cover and that were characterized by sandy soils and sparse ground cover (Hink and Ohmart 1984). Many of the species found in the Bosque were representative of drier upland habitats. Hink and Ohmart (1984) described a distinct assemblage of species associated with denser vegetation cover in mesic or hydric habitats. Common species included tiger salamander (*Ambystoma tigrinum*), western chorus frog (*Pseudocris triseriata*), bullfrog (*Rana catesbeiana*), northern leopard frog (*Rana pipiens*), Great Plains skink (*Eumeces obsoletus*), New Mexico garter snake (*Thamnophis sirtalis dorsalis*), western painted turtle (*Chrysemys picta bellii*), and spiny softshell turtle (*Trionyx spiniferus*). Recent studies done by Bateman *et al.* (2008) found that eastern fence lizards (*Sceloporus undulatus*) and New Mexico whiptails (*Cnemidophorus neomexicanus*) increased in relative abundance after non-native plants were removed. Another common species found in the 2008 study is Woodhouse’s toad (*Bufo woodhousii*). The study indicated that removing non-native plants in the understory perhaps allows more opportunities for heliothermic lizards to bask in areas where light penetrates the cottonwood canopy.

Small mammals were found to be more abundant in moister, densely vegetated habitats and those with dense coyote willow than at drier sites (Hink and Ohmart 1984). However, dominant species differed between various habitat types so that a variety of habitats increases the diversity of small mammals in the study area.

Hink and Ohmart (1984) recorded 277 species of birds in the Bosque ecosystem. Highest bird densities and species diversity were found in edge habitat vegetation with a cottonwood overstory and an understory of Russian olive or (Hink and Ohmart 1984). Studies done by Finch and Hawksworth (2006) indicate that bird densities of the mid-story nest guild show declining trends following treatment and removal of invasive plant species. Removal of some invasive plant species reduces the availability of nesting and foraging substrates for bird species that use the mid-story layer of habitat. Emergent marsh and other wetland habitats also had relatively high bird density and species richness. Thirty of the 46 species of breeding birds found in the Bosque used cottonwood forest habitat. No bird species showed a strong preference for Russian olive stands (Hink and Ohmart 1984). However, when Russian olive was present as a component of the understory in cottonwood stands, the species appeared to influence the quality of those stands for birds. Therefore, the higher bird densities appear to relate to the structure of the habitat rather than species of plant making up that component.

The MRG is a major migratory flyway for avian species (Yong and Finch 2002). Hundreds of species migrate through and nest within the study area. More recent bird sampling in the RGVSP found 62 species in winter and 90 during the breeding season (Stahlecker and Cox 1997). Of the 90 bird species found in summer in RGVSP, only 31 were found in the study area, and 15 of these species were considered to be nesting there (Stahlecker and Cox 1997). The greatest number of species and highest bird density in both winter and summer was found in emergent marsh habitat.

Red-tailed Hawk (*Buteo jamaicensis*) and Cooper's Hawk (*Accipiter cooperii*) were reported as common raptors along the river in winter (Stahlecker and Cox 1997). Cooper's Hawk and Great-horned Owl also occur as nesting birds in the study area (W. DeRagon, personal communication 2003). Twenty-eight stick nests were found in the study area in the spring of 2003. All of the stick nests were located in Rio Grande cottonwood; none was found in Siberian elm. Stick nests in the study area are used by Great-horned Owl, Cooper's Hawk, Red-tailed Hawk, and American Crow.

2.7.3 Special Status Species

Three agencies who have primary responsibility for the conservation of animal and plant species in New Mexico are the USFWS, under authority of the Endangered Species Act of 1973, as amended; the New Mexico Department of Game and Fish, under the authority of the Wildlife Conservation Act of 1974; and the New Mexico Energy, Mineral, and Natural Resources Department, under authority of the New Mexico Endangered Plant Species Act and Rule No. NMFRCD 91-1. Each agency maintains a list of animal and plant species that have been classified, or are candidates for classification, as endangered or threatened based on present status and potential threat to future survival and recruitment. Ten species that have the potential for classification occur in the study area. Five of these species are Federally listed and one is a candidate for listing under the Federal Endangered Species Act (ESA). The Rio Grande silvery minnow (*Hybognathus amarus)* (RGSM), Southwestern Willow Flycatcher (*Empidonax traillii extimus*) (SWFL), Black-footed ferret (*Mustela nigripes*), Mexican Spotted Owl (*Strix occidentalis lucida*), and Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*) are Federally listed. The Yellow-Billed Cuckoo (*Coccyzus americanus*) (YBCC) is listed as a candidate species. Table 2.7 contains the five Federally listed species and the one candidate for ESA listing. The river within the study area is also designated as Critical Habitat under the ESA for the RGSM. That is, the USFWS has determined that these habitats are critical to the continued existence and recovery of these species. Four state-listed species occur in the study area: Neotropic Cormorant (*Phalacrocorax brasilianus*, state threatened), Common Black-hawk (*Buteogallus anthracinus anthracinus*, state-threatened), Bell's Vireo

(*Vireo bellii*, state-threatened), and New Mexican meadow jumping mouse (*Zapus hudsonius luteus*, state-threatened).

The Bald eagle (*Haliaeetus leucocephalus*) is also known to be present in the study area and is protected under the Bald Eagle Protection Act of 1940. This bird species uses the study area as it migrates between the northern border and the Gila, lower Rio Grande, middle Pecos, and Canadian River valleys in New Mexico (Hubbard 1985a). Suitable foraging habitat is characterized by open expanses of water with abundant prey, such as waterfowl and fish, and large trees or snags for perch sites. Bald Eagles might occur in winter along the Rio Grande, particularly to the north and south of the study area (Stahlecker and Cox 1997: 17). No winter roosts are known in the study area, likely due to unsuitable conditions created by the existing level of human disturbance (Stahlecker and Cox 1997: 22).

Three of the Federally listed species, the RGSM, SWFL and YBCC, have been documented in the study area, and will be further discussed below.

Table 2.7 Special status species with the potential to occur in study area.

Common Name	Scientific Name	State or Federal	Date of Listing	Critical Habitat	Habitat Type	Presence in Project Area
Black-footed ferret	*Mustela nigripes*	Federal Endangered	1967	No	Plains Mesa	No
Mexican spotted owl	*Strix occidentalis lucida*	Federal threatened	1993	Yes, but NOT in project area	Subalpine coniferous forest	No
Rio Grande cutthroat trout	*Oncorhynchus clarki virginalis*	Federal Candidate	Review began in 1991	No	Aquatic	Not detected
Rio Grande silvery minnow	*Hybognathus amarus*	Federal	1994	Yes, in project area	Aquatic	Yes
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	Federal	1995	Yes, but NOT in project area	Dense riparian	As migrant only
Yellow-billed Cuckoo	*Coccyzus americanus*	Federal Candidate	Review began in 1991	No	Riparian	Yes, has been detected

2.7.3.1 Rio Grande Silvery Minnow

Rio Grande silvery minnow (*Hybognathus amarus*) (RGSM) historically occurred in the Rio Grande drainage in New Mexico and Texas (Lee *et al.* 1980, Propst 1999). The species was historically one of the most abundant and widespread fishes in the Rio Grande drainage (Bestgen and Platania 1991). In New Mexico, the historic range of the species included the Rio Chama from Abiquiu to the Rio Grande confluence, the main stem of the Rio Grande from Velarde downstream to the New Mexico-Texas state line, and the Pecos River downstream from Santa Rosa (Sublette *et al.* 1990). RGSM was extirpated from the Rio Grande downstream of the Pecos River by 1961 and from Pecos River by the mid-1970s. The species was also extirpated from the Rio Grande upstream from Cochiti Dam and downstream from Elephant Butte Reservoir. One of the greatest threats to its survival is poor water quality (Utton Transboundary Resources Center 2004). Currently, RGSM is present only in the Rio Grande between Cochiti Reservoir and the upper end of Elephant Butte Reservoir, which represents less than 10% of its historic distribution (Bestgen and Platania 1991, Propst 1999). Abundance of RGSM has declined markedly from 1994 to the present time and the population has become concentrated in the reach of the Rio Grande between San Acacia Diversion Dam and the headwaters of Elephant Butte Reservoir. Over the 2004 and 2005 monitoring season, a large population of RGSM was found in the Albuquerque reach of the MRG. Critical Habitat has been designated for the RGSM and is within the project area.

RGSM is a pelagic-broadcast spawner, producing non-adhesive, semi-buoyant eggs (Platania and Altenbach 1998). Spawning is initiated by elevated stream discharge and occurs primarily in the late spring and early summer when water temperatures range between 68^{o}F and 75^{o}F (Propst 1999). Females can produce three to 18 clutches of eggs, each clutch numbering from 200 to 300 eggs. Growth to maturation occurs in about two months. RGSM typically live only about one year, with less than 10% of the adult population surviving up to two years (Platania and Altenbach 1998, Propst 1999). Habitat used by adult RGSM is characterized by silty to sandy substrate, depths of eight inches to 2.6 feet, and slow to moderate current velocity ranging from zero feet/second to 0.98 feet/second (Dudley and Platania 1997). Habitats with slow current velocity and associated cover are used in winter. RGSM feed on algae and detritus (Propst 1999, USFWS 1999). Major threats to persistence of RGSM include diminution of river flows and dewatering by surface water diversions and dam regulation, modification of aquatic habitats that result in faster current velocities and narrower channels, and introduction of non-native fishes (USFWS 1999). Recovery of RGSM requires stabilizing the population in the MRG and reestablishing the species in suitable habitats within its historic range (USFWS 1999).

Dudley and Platania (1997) documented habitat preferences of RGSM. They found that individuals were most commonly collected in shallow water (less than 40 centimeters [cm]) with low-water velocities (less than 10 cm/second [cm/s]) and small substrate size, primarily silt and sand. Low-velocity habitats, such as backwaters and embayments, provide nursery areas for larvae (Dudley and Platania 1997, Massong *et al.* 2004), which grow rapidly in these areas. Restoration efforts that increase the availability of these habitat conditions would benefit RGSM. In addition to the quantity of preferred habitat, food availability might be influenced directly by river restoration activities. RGSM are herbivores that eat primarily diatoms, cyanobacteria, and green algae associated with sand or silt substrates in shallow areas of the river channel (Shirey 2004).

Recent research (Pease *et al* 2006; Porter and Massong 2004, 2006; U.S. Bureau of Reclamation 2007; SWCA 2007) indicates nursery habitat on inundated point bars, islands, and the floodplain provide essential conditions for spawning, with survival of RGSM eggs and larvae. Increased recruitment during average spring flow result in increased fall populations (US Army Corps of Engineers 2007), supporting the value of habitat restoration and hydrograph management for producing RGSM in the river. Currently, *Hybognathus amarus* is the only remaining endemic minnow with semi-buoyant eggs in the MRG. The pelagic spawning speckled chub (*Extrarius aestivalus*), Rio Grande shiner (*Notropis jemezanus*), phantom shiner (*Notropis orca*), and bluntnose shiner (*Notropis simus simus*) are either extinct or have been extirpated from the MRG (Bestgen and Platania 1991).

The remaining population of the silvery minnow is restricted to approximately five percent of its historic range. Every year since 1996, at least one drying event in the river has negatively affected the silvery minnow population. The population is unable to expand its distribution because poor habitat quality and Cochiti Dam prevent upstream movement and Elephant Butte Reservoir blocks downstream movement (USFWS 1999). Augmentation of silvery minnows with captive-reared fish will continue; however, continued monitoring and evaluation of these fish is necessary to obtain information regarding the survival and movement of individuals.

Several habitat restoration projects have been completed in the Albuquerque reach through the MRGESACP. These projects include two woody debris installation projects to encourage the development of pools and wintering habitat, and a river bar modification project south of the Interstate 40 Bridge designed to create side and backwater channels on an existing bar as well as modify the top surface of the bar to create habitat over a range of flows. Additionally, in 2005, the NMISC started a multi-year habitat restoration program that implements several island, bar, and bank-line modification techniques throughout the Albuquerque reach. Approximately 24 acres of habitat were restored in Phase I of the restoration program. In April 2008, the Corps completed the Rio Grande Nature Center Habitat Restoration Project reconnecting an ephemeral side channel to the river for silvery minnow habitat.

Various conservation efforts have also been undertaken in the past, and other efforts are currently being carried out in the MRG. Silvery minnow abundance has increased since 2003 population levels as a result of several years with average spring flows. The increased abundance of silvery minnow from 2004 to 2007 is a positive sign. Releases of captive-reared RGSM have been made at the Central Avenue bridge, which is within the study area.

2.7.3.2 Southwestern Willow Flycatcher

The Southwestern Willow Flycatcher (flycatcher) is found in the U.S. from May until September. It winters in southern Mexico, Central America, and northern South America (Unitt 1987). In New Mexico, the Southwestern Willow Flycatcher is distributed in nine drainages (Gila River, Rio Grande, Rio Chama, Coyote Creek, Nutria Creek, Rio Grande de Ranchos, Zuni River, Bluewater Creek, and San Francisco River). The flycatcher is an endangered species on the USFWS Endangered Species List, and Critical Habitat has been designated in the MRG, though not in the proposed project area. As of 1996, it was estimated that there were only about 400 Southwestern Willow Flycatchers in New Mexico, representing about 42% of the total population of the subspecies (Southwestern Willow Flycatcher Recovery Team, 2002). Southwestern Willow Flycatchers occur in riparian habitats along rivers, streams, or other wetlands, where dense growth of willows (*Salix* spp.), *Baccharis*, arrowweed (*Pluchea* sp.), salt cedar or other plants are present, often with a scattered overstory of cottonwood (Unitt 1987, Sogge *et al.* 1997, Finch and Stoleson 2000). These riparian communities provide nesting and foraging habitat. Throughout the range of Southwestern Willow Flycatcher, these riparian habitats tend to be rare, widely separated, small, and often linear locales, separated by vast expanses of arid lands. The Southwestern Willow Flycatcher is endangered by extensive loss and modification of suitable riparian habitat and other factors, including brood parasitism by the Brown-Headed Cowbird (*Molothrus ater,*Unitt 1987).

The Southwestern Willow Flycatcher is an obligate riparian species and nests in thickets associated with streams and other wetlands where dense growth of willow, Russian olive, salt cedar, or other shrubs is present. Nests are frequently associated with an overstory of scattered cottonwood. Southwestern Willow Flycatchers nest in thickets of trees and shrubs approximately six to 23 feet in height or taller, with a densely vegetated understory approximately 12 feet or more in height. Surface water or saturated soil is usually present beneath or next to occupied thickets (Muiznieks *et al*. 1994). At some nest sites, surface water might be present early in the breeding season with only damp soil present by late June or early July (Muiznieks *et al.* 1994). Habitats not selected for nesting include narrow (less than 30 feet wide) riparian strips, small willow patches, and stands with low stem density. Suitable habitat adjacent to high gradient streams does not appear to be used for nesting. Areas not utilized for nesting might still be used during migration. Breeding pairs have been found within the MRG from Elephant Butte Reservoir upstream to the vicinity of Española. Southwestern Willow Flycatchers begin arriving in New Mexico in early May. Breeding activity begins immediately, and young might fledge as soon as late June. Late nests and re-nesting attempts might not fledge young until late summer (Sogge *et al.* 1997).

Occupied and potential Southwestern Willow Flycatcher nesting habitat occurs within the MRG. Occupied and potential habitat is primarily composed of riparian shrubs and trees, chiefly Goodding's willow and peachleaf willow, Rio Grande cottonwood, coyote willow, and salt cedar. The nearest known breeding Southwestern Willow Flycatchers from the proposed project area occur along the Rio Grande at Isleta Pueblo. Potential habitat exists adjacent to the proposed project area. Designated Critical Habitat was determined for the SWFL in November 2005 but is not in the project area.

2.7.3.3 Yellow-Billed Cuckoo

The breeding range of this bird species extends from California and northern Utah eastward to southwestern Quebec and south to Mexico. Yellow-Billed Cuckoo has declined precipitously throughout its range in southern Canada, the United States, and northern Mexico. The number of breeding birds has declined by about 42 percent in the eastern United States (Elphick *et al*. 2001: 335). The Yellow-Billed Cuckoo's only remaining western "strongholds" are three small populations in California, scattered populations in Arizona (especially on the San Pedro River) and New Mexico (especially the Gila River), and an unknown number of birds in northern Mexico (Center for Biological Diversity 2000). The species winters in South America (DeGraaf *et al.* 1991).

Both Hink and Ohmart (1984) and Stahlecker and Cox (1997) reported Yellow-Billed Cuckoo as a nesting bird in the Bosque of the MRG, although none of these reports was from the study area. Habitat potentially suitable for nesting of Yellow-Billed Cuckoo is present in the study area.

2.8 Water Quality

Section 404 of the Clean Water Act (CWA) requires analysis under the EPA's 404 (b)(1) Guidelines if the Corps proposes to discharge fill material into a water or wetlands of the United States. Section 402(p) of the CWA regulates point source discharges of pollutants into waters of the United States and specifies that storm water discharges associated with construction activity be conducted under National Pollutant Discharge Elimination System (NPDES) guidance.

2.9 Air Quality and Noise

The study area is located in New Mexico's Air Quality Control Region No.152, which encompasses all of Bernalillo County and most of Sandoval and Valencia Counties. These three counties are "in attainment" (*i.e.,* do not exceed state and Federal Environmental Protection Agency air quality standards) for all criteria pollutants (NMED, 1997). Air quality in the project area is generally good. The closest Class I area is Bandelier National Monument, approximately 50 miles to the north of the project area. A Class I area is a wilderness area or a National Park. Air quality in the project area is generally good to excellent due to the lack of urban industrial development. Although high winds are common in and around the project area, blowing dust is generally not a problem except during extremely dry years. Airborne particulate and carbon monoxide concentrations from wood burning in the Rio Grande valley are occasionally high during winter months when temperature inversions and wood stove use are both more prevalent.

The Occupational Safety and Health Administration (OSHA) noise standard limits noise levels to 90 decibels A filter (dBA) averaged over an eight-hour day (29 Code of Federal Regulations [CFR] 1910.95), although hearing damage can begin at levels as low as 80 dBA over an eight-hour day. No worker may be exposed to noise in excess of 115 dBA without protection, which would reduce the exposure below 115 dBA (AFSCME, 2004).

Albuquerque's noise control ordinance was placed into effect in June 1975. The Environmental Health Department's Consumer Protection Division personnel are responsible for enforcing the ordinance. Noise control enforcement might involve many sources of excessive noise: radios, stereos, television, live bands, machinery, equipment fans, air conditioners, construction, vehicle repairs, motor vehicles, and general noise. The ordinance stipulates a property-line value in which the noise level emitted must not exceed 50 decibels (dB) or 10 decibels above the ambient level, whichever is greater (Mitzelfelt, 1996). For example, if you are playing a stereo, the sound level traveling from the stereo to the neighboring property lines cannot be more than 10 decibels higher than the general noise level existing before the stereo was turned on. Noise level meters are used to measure the sound level as it is crossing the property line. The meters are similar to radar meters the police use for speed detection; however, instead of detecting an object in motion, it detects air pressure (sound waves) in motion and produces a numbered level called decibels.

2.10 Cultural Resources

Considerable information is available from archaeological resources within the MRG. Archaeological sites in the valley span nearly the entire known 12,000-year period of human occupation in North America. Culture history for the MRG is described chronologically as including the Paleoindian (10,000 to 6,000 years BC), Archaic (6,000 years BC to AD 400), Puebloan (400 to 1600 AD), and Historic Periods (1600 AD to Recent). Paleoindian and Archaic sites are represented by lithic scatters with some diagnostic artifacts and a few habitation sites. In the proposed project area, the prehistoric Puebloan Period generally follows what is known as the Rio Grande Valley Sequence. The Puebloan Period is characterized by increasing population sizes, migrations of peoples, more sedentism and aggregation of peoples into larger villages, an increasing dependence on horticulture and agriculture, and a more intense and efficient use of the environment. Many smaller groups, however, remain nomadic. Small pithouse villages, larger above-ground roomblocks, and huge adobe pueblos with scattered fieldhouses become common. These permanent villages and base camps are primarily located near reliable water sources. This includes areas along the Rio Grande, on ridges, gravel terraces, or alluvial slopes adjacent to major arroyos, and occasionally in the vicinity of playas. Other sites, such as temporary camps, resource procurement stations, and many of the undated lithic sites, are found scattered throughout the region. As sedentism increases, so does the use of water management techniques and surface-water-flow control features, and local and long distance trade is important. The Protohistoric Period includes population movements as groups try to adjust to the encroachments of other Tribes as European exploration begins and Tribes try to relocate. Diseases new to the Americas spread across the landscape causing disruption to tribal lifeways. The Historic Period in the Southwest began with the 1540 Spanish *entrada*. Eventually, the Spanish colonized the Rio Grande Valley in the 1600s. Horticulture, agriculture, and ranching are intensified as European culture began to dominate and manage the area.

For an understanding of the Rio Grande Floodway in the Albuquerque area, the following historic text is adapted from Everhart (2004a, 2004b):

> *The Middle Rio Grande Conservancy District (MRGCD) was organized in 1925 under the State's 1923 Conservancy Act to deal with the severe flooding, waterlogged lands, and failing irrigation facilities (Ackerly et al. 1997:20-21; Scurlock 1998:281; Wozniak 1987:134; Biebel 1986:15-16). By 1928, a reclamation, flood control, and irrigation plan was developed (Burkholder 1928) and between 1930 and 1934 major portions of the plan, including flood control levees, riverside drainage canals, and irrigation ditches and diversions, were constructed by the MRGCD (Ackerly et al. 1997:21; Scurlock 1998:281; Wozniak 1987:134-138; Berry and Lewis 1997:12-15). The new facilities were to provide for the efficient delivery of irrigation water, prevent flood hazards and provide flood protection measures, regulate the Rio Grande channel and stream flows and provide drains to reclaim land that had become saturated and saline from high groundwater levels (Ackerly et al. 1997:20-21). The development and rehabilitation work conducted by the MRGCD had impacts to the whole MRG area (Ackerly et al. 1997:20-24; Biebel 1986:15-16). MRGCD construction incorporated "...about 70 independent community ditches in to a single*

[irrigation] system" (Ackerly et al. 1997:29; Burkholder [1928:25] and Linford [1956:292] in Wozniak 1987:130, 138). The extreme upstream portion and original headings of numerous historic acequias were cut off from the downstream portions of their ditch alignments by the construction of the flood control levees and riverside drains. During the Depression and continuing into the war years, funding the construction and maintenance of MRGCD's structures and equipment became a never-ending problem (Ackerly et al. 1997:20-24, 26, 57; Biebel 1986:15-16, 22-23; Welsh 1985:110-111, 166; Wozniak 1987:138-143).

The Flood Control Act of 1948 authorized several projects in New Mexico and called for a comprehensive plan for the Rio Grande (Crawford et al. 1993:26; Welsh 1985:115; Ackerly et al. 1997:57). At about the same time, a "…memorandum of agreement [was] signed between the Interior secretary and the Chief of Engineers on 25 July 1947" that "…delineated the areas of responsibility for the Corps and Reclamation in the Rio Grande basin" (Welsh 1985:115; Wozniak 1987:143).

By 1950, "The levees built with MRGCD money suffered from extensive erosion" (Welsh 1985:166). Starting in 1951, the Corps and Reclamation began a comprehensive Rio Grande Floodway project, authorized in 1950, that constructed and rehabilitated flood control levees and installed thousands of Kellner jetty-jacks to armor the river banks and maintain the Floodway (Crawford et al. 1993:26-27; Ackerly et al. 1997:57-58; Welsh 1985:166; Scurlock 1998:282, 328, 354). The major channel modification project to maintain channel capacity was completed by the Reclamation in 1959 and "The Corps of Engineers reconstructed the levee-riverside drains in the Albuquerque area in 1958" with most of the Corps and Reclamation work being completed between 1962 and 1964 (Ackerly et al. 1997:57-58; Scurlock 1998:282, 354; Crawford et al. 1993:43).

Numerous archaeological surveys have been conducted and histories written regarding the long human occupation of the Albuquerque area.

Until recently, very few cultural resources surveys had been conducted within the riparian/Bosque areas (*i.e*., within the Rio Grande's confined floodplain between the flood control levees). Restoration work, however, was pushed to the forefront subsequent to two Bosque wildfires that occurred in the summer of 2003. Recent archaeological work in the Bosque includes M. Marshall (2003), Everhart (2004a, 2004b), Estes (2005), Walt, Marshall and Musello (2005), Marshall and Walt (2006), as well as one report for flood control levee rehabilitation by Kneebone (1993) and an addendum by Kneebone and Everhart (1997). Other archaeological work in the area has primarily been associated with cultural resources compliance and management requirements, and for specific projects such as highway construction and maintenance and installation of utility lines such as Koczan (1991), Marshall (1991), and Schmader (1994, 1990). General histories on MRG flood risk management projects between Corrales and San Marcial have been prepared by Dodge and Santillanes

(2007) and Berry and Lewis (1997). Information regarding U.S. Army Corps of Engineers, Albuquerque District, history and projects can be found in Welsh (1997, 1985). The Ackerly *et al*. (1997) and Wozniak (1987) reports, prepared for Reclamation and the New Mexico Historic Preservation Division, provide significant overviews regarding the development of irrigation in the MRG, and both include a substantial list of references. Burkholder (1928) provides information regarding the initial plan for flood control, drainage, and irrigation work by the MRGCD. The above reports and references provide a significant amount of culture history information for the project area; therefore, a detailed culture history is not provided in this document.

Due to the nature of the Rio Grande, it has generally been thought that if archaeological sites occurred within the Rio Grande Floodway project area (within the flood control levees), they would have been either washed away or buried by river sediments (Sargeant 1987:36-37); however, that is not the case for more recent era properties. As of September 30, 2008, Corps surveys have recorded twenty-eight (28) archaeological sites within the Rio Grande Floodway project area. These sites are primarily remnants of historic earthen structures related to irrigation canals (acequias) and drainage ditches as well as some old, wooden bridge pilings, representing the alignments of historic bridges. Most of the acequia remnants are ditch segments that were abandoned as a result of the 1930s MRGCD construction of the levees.

One site, an abandoned segment of the historic Alburquerque Acequia Madre (LA143458), probably dates to the 1706 founding of the Villa de Alburquerque. Structural components of other historic acequias might also date to approximately the same period, and a few, such as the Atrisco and Ranchos de Atrisco acequia remnants (LA138859), might date to as early as the mid-1600s. No prehistoric archaeological sites are known to occur in the Rio Grande Floodway project area; however, at least one large prehistoric pueblo, of unknown location, might still exist in the area, potentially within the floodway. American Indian traditional cultural properties are known to occur within the Rio Grande Floodway project area.

For the Corps Bosque Wildfire Project and Ecosystem Restoration at Route 66, Albuquerque, New Mexico, Section 1135 Project, a total of approximately 2,228 acres covering 50 project areas within the Rio Grande Bosque have been surveyed for cultural resources (Marshall 2003; Everhart 2004a; Estes 2005; Walt, Marshall, and Musello 2005; Marshall and Walt 2006). For the MRGB project, archaeological survey will cover an additional 719 acres, covering 16 areas.

Section 106 of the National Historic Preservation Act [16 U.S.C. 470 et seq.] and its 36 CFR Part 800 implementing regulations require Federal agencies to consult with American Indian Tribes that have concerns in the project area, the public, the State Historic Preservation Officer, and if necessary, the Advisory Council on Historic Preservation. As the feasibility study progresses and a recommended plan is selected, intensive identification efforts such as Tribal consultation and archaeological survey will be conducted for the area of potential effect (APE). An intensive archaeological survey includes literature and data searches for information regarding previous archaeological survey work that has been conducted in the area and their results as well as a review of the State Register of Cultural Properties and National Register of Historic Places (NRHP) for any listed historic properties. The intensive pedestrian archaeological survey is conducted by walking transects spaced at intervals of no more than 15 meters apart. Dependent upon the number of years that have elapsed since previous survey work, some previously surveyed areas might be resurveyed. The purpose of the archaeological investigation is to identify and evaluate historic properties. If archaeological sites or other historic properties are identified during the identification process, they will be evaluated regarding their eligibility for nomination to the NRHP. Significance criteria for determining NRHP eligibility are listed in the National Park Service's National Register Bulletin No. 15 (NPS Revised 1991) entitled *How to Apply the National Register Criteria for Evaluation* and the more recent National Register Bulletin publication entitled *Guidelines For Evaluating And Registering Archeological Properties* (NPS 2000; http://www.nps.gov/history/nr/publications/bulletins/arch/) as follows:

Criterion A: Event(s) and Broad Patterns of Events
Criterion B: Important Persons
Criterion C: Design, Construction, and Work of a Master
Criterion D: Information Potential

Subsequent to completion of the archaeological investigation, the Corps will consult with interested parties including the State Historic Preservation Officer and American Indian Tribes regarding the survey results, eligibility, and potentially regarding mitigation of project impacts. Avoidance is preferred and dependent upon the significance of the historic property. The project might be redesigned to avoid the historic property. If historic properties are determined to be NRHP eligible and are to be adversely affected by the project, some form of mitigation, such as excavation, reporting, or public outreach would be developed in consultation with interested parties.

Pursuant to 36 CFR 800.13, should previously unknown artifacts or archaeological resources be encountered during construction, work would cease in the immediate vicinity of the resource. A determination of significance would be made, and a mitigation plan would be formulated in consultation with the State Historic Preservation Officer and American Indian Tribes that have cultural concerns in the area. The Corps construction contract plans and specifications have provisions to ensure that all known and unknown historic properties eligible for nomination to or listed on the National Register of Historic Places are protected

2.11 Socioeconomic Environment

Socioeconomic resources include population and economic activity, as reflected by personal income, employment distribution, and unemployment (USACE 2002, 2003a, 2007, 2008a,b). Bernalillo and Sandoval Counties serve as the Region of Influence in which most impacts can be expected to occur, and the state and region serve as regions of comparison. Specific information for recreation in the local area and Region of Influence are relevant and presented here. First, the population in Bernalillo County was estimated at 573,675 in 2002 (USACE 2002, 2003a, 2007, 2008a,b and references therein). Bernalillo County is approximately 1,166 square miles with 477 persons per square mile and is generally urban in character. Sandoval County is roughly 3,709 square miles with approximately 24.2 persons per square mile (Figure 2.20). The total population of Sandoval County in 2000 was 89,908 (USACE 2002, 2003a, 2007, 2008a,b and references therein), and it can be considered generally rural in character.

The Town of Bernalillo and the City of Rio Rancho had populations of 6,611 and 51,765, respectively, in 2000.

In 1999, Bernalillo County had a per capita personal income (PCPI) of $20,790. In 2000, Sandoval County had a PCPI of $22,247. The Sandoval County PCPI ranked 5th in the State of New Mexico, and was 101 percent of the State of New Mexico average, $21,931, and was 75% of the national average, $29,469. The average annual growth rate of PCPI over the past 10 years was 4.7 percent for Sandoval County. The average annual growth rate for the State of New Mexico was 3.9 percent and, for the nation, was 4.2 percent (U.S. Census Bureau 2001 a,b). In 2003, the median income of households in Albuquerque was $40,061. For more details on the economic status of the region, refer to Corps reports (USACE 2002, 2003a, 2007, 2008a,b).

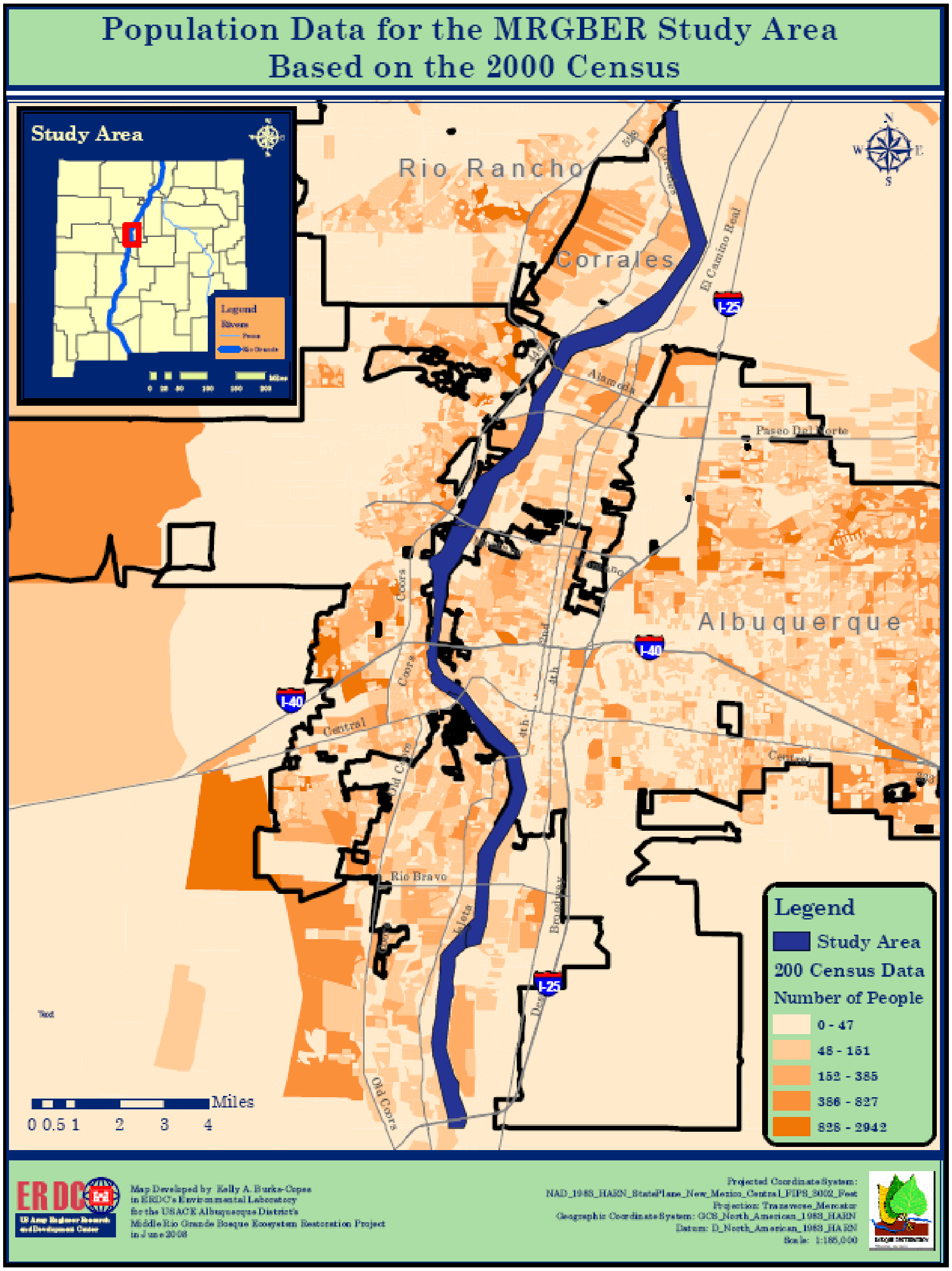


Figure 2.20. Population data for Bernalillo and Sandoval Counties (2000 Census).

2.12 Land Use

Land use in the Bosque is limited today to a floodway with passive recreation and educational uses. Historically, the Bosque has a rich legacy as a cultural landscape, which has been described in detail. Most of the historic uses, such as wood cutting and agriculture, have either been outlawed or displaced to adjacent areas.

As with many bottomlands on the margins of urban areas, the Bosque has also long functioned as an unauthorized public garbage dump or refuse disposal area. Early levee construction and armoring techniques employed the deposition of large amounts of construction debris. Along the river bank line, this has become part of the current bank line. This use of the Bosque continued until relatively recently, with construction debris from as late as the 1980s present in some areas along the levees. On the west side of the study area, just north of Central, spoils exist from ongoing ditch cleaning activities. In general, dumping has been one of the most frequently raised concerns of community members and stakeholders alike, and the AOSD has worked diligently to curb the dumping within the RGVSP limits.

Land use outside of the levees and adjacent to the Bosque has also changed a great deal over time. Currently, the primary uses are either residential or public in the form of the Albuquerque Biological Park (Zoo, Botanical Garden, and Aquarium) or one of a number of Bernalillo County and City of Albuquerque Parks. Historically, similarly situated floodplain in the MRG areas would have been a mosaic of wetlands, especially salt grass meadows, pasturelands, irrigated croplands and dumps. With the advent of major flood risk management measures, the active floodplain has been reduced to a tiny sliver; residential and other urban uses have claimed land that was formerly considered undevelopable right up to the riverside drain. The current mosaic of adjacent land uses tends to be patterned by the bridges and more recent commercial uses. Dumps and major industrial areas have become public parks and open spaces (*i.e.*, the Albuquerque Country Club Golf Course, Kit Carson Park, the Zoo, and the County Open Space that had been the Serna Trucking site). In the vicinity of the Central Avenue and Bridge Boulevard bridges, land uses tend to be commercial or high density residential with lower density residential in between. Isolated areas of irrigated farmland, small pastures, and other rural uses still exist.

2.13 Interpretive and Recreational Resources

In 1983, The Rio Grande Valley State Park Act was passed by the New Mexico State Legislature. Up to that point in time, the Bosque had been passively maintained as an unofficial open space by the MRGCD. Within the RGVSP, a paved trail along the east side of the river exists along the levee from Alameda Boulevard south to south of Rio Bravo Bouevard (approximately 18 miles). Trails within the Bosque exist on both sides of the river in the RGVSP and are a natural surface (in most cases dirt, although in some cases a formalized crusher-fine trail has been constructed). Various levels of recreation take place on the paved trail including jogging, bicycling, roller blading, and walking. On the natural surface trails jogging and walking take place but mountain biking and horseback riding are also favorite uses. No motorized vehicles, except for maintenance and emergency vehicles, are allowed per City of Albuquerque and Bernalillo County ordinances.

In the Corrales Bosque Preserve, a natural surface trail allows limited access (for those capable of navigating a natural surface trail to enjoy jogging, walking, horseback riding, and bicycling). No motorized vehicles are allowed, except for maintenance and emergency vehicles, per Village ordinance. Within the Sandia Pueblo, a formalized trail system does not exist but varying levels of recreation take place on the levee and inside the Bosque.

Another recreational activity that takes place in all locations is fishing. Sandia Pueblo has a formal fishing area called Sandia Lakes. In Corrales, fishing takes place along the drains. Within the RGVSP, various fishing locations exist. Tingley Ponds is the main fishing location, with two large fishing ponds and a children's fishing pond. Other areas remaining open to anglers include the Rio Bravo Picnic Area fishing pier, which is over the drain at the northeast corner of Rio Bravo and the river. Other fishing takes place on the drain at Paseo del Norte, Bridge Street on the east side of the river, and various other locations; however, these areas are not formalized.

The remainder of the study area is frequented by hikers, bicyclists, and equestrians along informal trails and roads. The current trail network is poorly configured; duplicate trail segments run throughout the study area. The use of informal trails in some places has caused deterioration of vegetation and disrupted wildlife habitat. The Corps developed the Middle Rio Grande Bosque Restoration Supplemental Master Plan in 2003, and the plan promotes the Bosque's primary land use as open space maintained for wildlife habitat and recreational uses. Project areas have been identified by the MRGCD to decrease the encroachment of invasive species, satisfy the recreational demand, promote educational use, and reduce hazardous fuel loads and risk of wildfire in the Bosque. However, many projects have remained incomplete due to the lack of funding sources for this scale of project.

2.14 Aesthetics

NEPA and Council on Environmental Quality (CEQ) regulations identify aesthetics as one of the elements that must be considered in determining the effects of a project. Aesthetics include the presence and appearance of landforms, water surfaces, vegetation, and human-created features relative to the surroundings and settings of the area. These features are primary characteristics of an area or project that determine visual character and the manner in which people view the setting. Aesthetics analysis considers the existing and future appearance, or perception of views, of the project site and areas surrounding the site, as well as viewer sensitivity. Aesthetics of the Bosque might be characterized as ranging from poor to high quality. In areas where fires have occurred and burn restoration (removal of burned and dead trees) has not been implemented, the aesthetics would be considered poor as the bare, burned ground and standing dead trees dominates the view.

In other areas, non-native vegetation has been thinned and dead material has been reduced. Some areas have been replanted with native vegetation (such as cottonwood, willow, New Mexico olive, etc.). Maintenance efforts are ongoing to keep non-native vegetation to a minimum, but resprouting from roots or stumps has occurred in all areas that have been treated. In these areas, the aesthetics would generally be characterized as medium to high (Corps-ERDC 2008). The view is dominated by cottonwoods, with clear views of the river, sometimes obstructed by jetty jacks. In areas where the Bosque is functioning as a healthy ecosystem, aesthetics would be considered medium to high. The area is dominated by cottonwoods and native understory vegetation, obstructing the view of the river.

2.15 Floodplains and Wetlands

Wetlands consist of marshes, wet meadows, and seasonal ponds that typically support hydrophytic plants such as cattails, sedges, and rushes. Wet meadows were the most extensive habitat type in the Middle Rio Grande valley prior to the construction of the MRGCD drains and ditches. Wetlands are an integral component of the Bosque ecosystem, not only increasing its diversity but also enhancing the value of surrounding plant communities for wildlife. Wetlands have experienced the greatest historical decline of any floodplain plant community. From 1918 to present, wetland-associated habitats have undergone a 93% reduction (Hink and Ohmart 1984, Scurlock 1998). Among the greatest needs of the riparian ecosystem are the preservation of existing wetlands and expansion or creation of additional wetlands (Crawford *et al*. 1993).

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water (Cowardin *et al*. 1979). Saturation with water determines the nature of soil development and, in turn, the types of plant and animals inhabiting these areas. Wetlands occurring within the riparian zone might be dominated by the same plant species common in the Bosque; however, wetlands exhibit wetter soils and support many additional plant and animal species.

Historically, the Rio Grande channel meandered throughout the floodplain, and abandoned channels often contained sufficient groundwater discharge to support marshes (cienegas), sloughs (esteros), and oxbow lakes (charcos; Scurlock 1998, Ackerly 1999). Currently, the extent of wetland plant communities within the Middle Rio Grande has been significantly reduced. The construction of drains in the 1930s significantly lower the groundwater elevation throughout the valley. Wetland areas throughout the floodplain have been directly displaced by agricultural and urban development. Irrigation and flood control operations have reduced the magnitude of discharges within the floodway, especially during the spring runoff period, and limit the extent of overbank flooding.

Jurisdictional wetlands (relative to the Clean Water Act) do occur in the study area. Most wetlands within the floodway have developed in areas with a high groundwater table. Those in shallow basins or relatively far from the river are likely seasonally or temporarily flooded; that is, inundated during the majority, or just a portion, of the growing season, respectively. Within the Rio Grande Floodway, most islands, point bars, and side channels are periodically inundated by river flows and support marsh, meadow, or shrub wetland communities.

Abandoned channels or depressions deep enough to intersect the regional groundwater table often support permanently or semi-permanently flooded ponds and marshes. The San Antonio Oxbow is an example of this type of abandoned channel within the study area, and the oxbow is one of the largest wetland complexes in the Middle Rio Grande valley. This wetland's water regime is influenced by shallow groundwater and surface water from the Rio Grande, San Antonio Arroyo, and the riverside drain.

Executive Order 11988 (Floodplain Management) provides Federal guidance for activities within the floodplains of inland and coastal waters. Preservation of the natural values of floodplains is of critical importance to the nation and the State of New Mexico. Federal agencies are required to "ensure that its planning programs and budget requests reflect consideration of flood hazards and floodplain management."

2.16 Hazardous, Toxic, and Radiological Waste

Inspections have found the presence of surficial solid waste which appears to have been deposited by wind and visitors to the Bosque. This waste is limited to paper, bottles, glass, cans, and other household trash items. In a few distinct locations, the presence of weathered asphaltic concrete pavements exists. No hazardous, petroleum, or special wastes have been noted in the Bosque area. No sign of releases of hazardous wastes, hazardous substances, or petroleum products such as distressed vegetation or soil staining have been observed; therefore, no soil sampling for chemical parameters in these areas has been conducted. No known Hazardous, Toxic, and Radiological Waste (HTRW) issues or concerns affect the lands or interests in the lands to be acquired or used for the proposed project. No signs of releases of hazardous wastes, hazardous substances, or petroleum products such as distressed vegetation or soil staining have been observed. No testing or sampling has occurred because no signs or evidence of environmental contamination have been discovered.

A mixture of recreational, residential, commercial, and industrial land uses are located adjacent to the Rio Grande. In a flooding situation, some commercial and industrial properties have a potential to pose an imminent threat to the river from the release of hazardous wastes, hazardous substances, or petroleum products. An Environmental Atlas for the Rio Grande corridor in this flooding situation has been provided in the HTRW Report (Appendix E).

Several locations that currently store hazardous materials, hazardous wastes, and petroleum products and where there have been significant releases of hazardous substances, hazardous wastes, and petroleum products in the past were identified within the 0.2%-chance event floodplain for the project. Because all the sites that were identified are located several miles from the proposed project sites, there would not be any apparent or expected impact from the project work on any of these identified release or storage sites. Likewise, the sites that do have released contaminants and petroleum products are located several miles from the proposed project sites and do not pose a hazard to the work site, workers constructing the proposed project features, or to the public which will be visiting these project sites after construction.

All work planned to construct the proposed features will be conducted in accordance with Federal, state, and local pollution control laws. Requirements will include the contractor's storage and use of fuels, herbicides, and other potential contaminants, and the implementation of the NPDES permit for stormwater pollution prevention from construction activities.

2.17 Environmental Justice

The planning and decision-making process for actions proposed by Federal agencies involves a study of other relevant environmental policies, including Executive Order (EO) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income*

Populations, which was issued by President Clinton on February 11, 1994. EO 12898 states that:

> *Each Federal agency shall conduct its programs, policies, and activities that substantially affect human health or the environment, in a manner that ensures that such programs, policies, and activities do not have the effect of excluding persons (including populations) from pa`rticipation in, denying persons (including populations) the benefits of, or subjecting persons (including populations) to discrimination under, such, programs, policies, and activities, because of their race, Color, or national origin.*

No groups of people, including racial, ethnic, or socioeconomic groups, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of Federal, state, tribal and local programs and policies. Also included with environmental justice are concerns pursuant to EO 13045, *Protection of Children from Environmental Health Risks and Safety Risks.* This EO directs Federal agencies to identify and assess environmental health and safety risks that might disproportionately affect children under the age of 18. These risks are defined as “risks to health or to safety that are attributable to products or substances that the child is likely to come into contact with or ingest.”

Environmental justice considerations addressed in this assessment involve both population demographics, including ethnic, racial, or national origin characteristics, and persons in poverty, including children under age 18. In order to determine whether environmental impacts affect minority or low-income populations, it is necessary to establish a basis of comparison, referred to as the “region of comparison.”

SECTION 3 - FUTURE CONDITIONS WITHOUT PROJECT

In order to evaluate the effectiveness of a proposed project, the proposed project must be compared to the most likely future conditions anticipated for the study area if no action is taken. This is known as the future without project (WOP) condition. By comparing the future WOP condition to the most likely future with project (WP) condition, the PDT can assess the difference or amount of improvements or enhancements that the project might have over the long term. In the case of a restoration project, improvements are expressed in the amount and value of habitats affected. That is, the project is beneficial if the resulting change from implementing the project over the future WOP increases the amount of habitat or improves the natural function or value to wildlife. The future WOP is universally regarded as a vital and important element of the evaluation and must adequately describe the future (USACE 2000). Significant variables, elements, trends, systems, and processes must be sufficiently described to support good decision-making. Forecasts must be based on appropriate methods, and professional standards must be applied to the use of those methods. Accuracy is an important element of the process. All future alternatives should be based on the assumption of rational behavior by future decision-makers. A good alternative must also pass the test of common sense.

For the purposes of this study, a 50-period of analysis is considered for determining the future WOP conditions. Comparisons between future WOP and future WP must be performed on standard length of time, and because changes over time might not follow a linear trajectory, it is necessary to develop a series of milestones or Target Years (TY) within the expected 50-year period of analysis. The TYs are used to compare the WP activities to the WOP projections. The Corps defined six TYs for the MRGB study that correspond to pertinent stages of restoration of the Bosque.

- TY = "**0**" refers to the baseline condition.
- TY = "**1**" refers to the last year of construction and planting activities.
- TY = "**6**" was chosen to capture 5 full years of vegetative growth.
- TY = "**21**" was selected to capture 15 full years of vegetative growth.
- TY = "**31**" was selected to capture 10 full years of vegetative growth.
- TY = "**51**" was selected to capture 20 full years of vegetative growth.

To develop project plans, it is necessary to predict both the short-term and long-term future WOP conditions of the environment (USACE 2000). Forecasting is undertaken to identify patterns in natural systems and human behavior and to discover relationships among variables and systems so that the timing, nature, and magnitude of change in the future conditions can be estimated. In the case of the MRGB, the project delivery team (E-team) provided the professional expertise and knowledge to develop a biological model of the Bosque and contribute to the model when forecasting change in the Bosque ecosystem over time. The E-team included professional ecologists and scientists within and outside of the Corps, several of which are experts in the ecology of the Rio Grande. The Corps used standardized hydrologic and hydraulic modeling to predict future conditions of the water flow and sediment transport. Reference sites were identified within and beyond the study area to verify predicted successional and degradational patterns in Bosque habitats. These tools, supported by scientific research and practical experience, were used to forecast the impacts and evaluate the effectiveness of proposed restoration plans, rate project performance, and determine many other important aspects of both WOP and WP conditions.

The following discussion presents the hydrologic and hydraulic modeling and describes qualitatively the probable future conditions within the study area if current trends continue through the 50-year period of analysis. Based on these results, Habitat Suitability Index (HSI) values for the hypothetical future habitats were projected. The results of the HSI be discussed in Section 5 as it pertains to the evaluation and comparison of project alternatives. These future conditions and effects are the basis for comparison with those of the Preliminary Proposed Alternative.

In the WOP condition, the Bosque in the study area would continue to decline, decreasing both in habitat value and as a resource for the greater Albuquerque community. The size and density of non-native vegetation patches, composed of Siberian elm, Russian olive, salt cedar, tree of heaven, and white mulberry, are likely to increase as they compete with the native cottonwoods, willows, and other native understory and mid-canopy plants. Native vegetation would not be planted to help increase their population. High-flow channels would not be constructed; therefore, a diversity of habitat created in these high-flow channels would not occur. Without plan implementation, a mosaic of different vegetation types as described would not occur. Non-native vegetation would continue to overtake the existing native vegetation and create thick patches of fuel for potential fire. Despite the best efforts of the AOSD and MRGCD, fires are likely to increase in number and magnitude. The future Bosque is likely to have a very different character than the current Bosque. The following sections describe the anticipated future conditions of specific facts of the resource.

A number of agencies are involved in restoration work along the Albuquerque reach of the MRG including the MRGCD, AOSD, Ciudad Soil and Water Conservation District, Reclamation, and the MRGESCP. Some of their work has taken place or is proposed to take place in the study area. Much of the work of MRGCD, AOSD and Ciudad Soil and Water Conservation District has been fuel reduction in the Bosque. Much of the work of Reclamation and the MRGESCP has been within the river to create habitat for the RGSM. This work is anticipated to continue on a small scale and in localized areas of the Bosque. High-flow channels, wetland creation, and habitat plantings would not occur or in an integrated fashion as with the MRGB project.

3.1 Climate

It is difficult to predict or quantify the effects of various possible climate change conditions. USGS Circular 1331, *Climate Change and Water Resources Management: A Federal Perspective*, dated 2009, makes several key points regarding climate change. The first point is that the best available scientific evidence based on observations from long-term monitoring networks indicates that climate change is occurring, although the effects differ regionally. The second point is that both research and monitoring are needed to fill knowledge gaps and advance our planning capabilities. Although neither will eliminate uncertainties, research and monitoring will provide significant improvements in to our understanding of the effects of climate change on water resources, including quantity and quality, and in evaluating associated uncertainties and risks required for more informed decision making.

While good evidence exists to support the occurrence of climate change, study of how the change might affect this region and the study area of the MRG has been limited. However, some references exist. A study was performed by Hurd and Coonrod in 2007 evaluating „Climate change and its implications for New Mexico's water resources and economic opportunities.' This study supports the current trend of a degrading Bosque ecosystem would continue. „Under severe climate change scenarios, runoff could be reduced by 30%' (Hurd and Coonrod, 2007). Therefore, the river and the Bosque are expected to remain disconnected. For the Future Without Project, measures to reconnect the Bosque and the river would not be developed and the floodway would remain disconnected. Because climate change is unpredictable with unknown direct effects, no evidence currently exists to suggest a change in the current trend toward a Bosque of declining quality.

The Rio Grande through this reach is used for conveyance of regulated flows for downstream irrigation and water deliveries to meet compact requirements. Reservoirs upstream of the project capture and store high flows from snowmelt and storm events and release this water per operational parameters. Project water features have been designed to operate at the water levels expected during an average water year. The average water year flows have been determined from historical data and are expected to continue into the future if water compact deliveries are to be met. Because the restoration features were not designed for (or dependent upon) extreme events, climate change would not be expected to affect them dramatically so long as water availability is sufficient to meet compact requirements.

3.2 Hydrology, Hydraulics, and Geomorphology

The Corps created a two-dimensional hydraulic model (FLO-2D) using the 250-foot grid to evaluate depth, extent, and duration of overbank inundation for the future without project condition. The analysis was conducted for initial channel conditions (Year 0) and for future channel conditions to evaluate the effects of aggradation or degradation on overbank inundation 5, 20, 30 and 50 years into the future. Results from this analysis will be used to provide baseline conditions for comparison with the restoration alternatives investigated.

3.2.1 Hydrology

As discussed in Section 2.4 and presented in Table 3.1, four hydrologic events (Hydrologic Scenarios) were modeled to evaluate baseline conditions and other project alternatives. Hydrologic Scenarios 1 and 2 are modeled for Year 0 and all future with-out project conditions, whereas Hydrologic Scenarios 3 and 4 were modeled for Year 0 only. Hydrologic Scenario 3, the 10,000 cfs post-Cochiti Dam hydrograph was modeled only for the purpose of determining the effect of a high-flow release through the study area under existing conditions.

Table 3.1 Summary of Hydrologic Scenarios.

Hydrologic Scenario	Description	Peak Discharge (cfs)
1	Active channel-full flow	6,000
2	Post-Cochiti Dam annual spring hydrograph	3,770
3	10,000 cfs post-Cochiti Dam hydrograph	10,000
4	1.0%-chance snowmelt post-Cochiti Dam hydrograph	7,750

3.2.2 Geomorphology

To reflect future channel conditions in the project reach, changes in the channel cross sections associated with aggradation and degradation 5, 20, 30, and 50 years after project implementation were estimated using a sediment transport model (HEC-6T) of the reach (MEI, 2007). The calibrated HEC-6T model was completed after the baseline conditions channel stability analysis (described in Section 2) was conducted. Compared to FLO-2D, and based on its much shorter computation times, the Corps considered HEC-6T the appropriate model to predict the amount of aggradation and degradation. The Corps used the amount of aggradation or degradation predicted by the HEC-6T model to adjust the cross-sectional geometry in the FLO-2D model to reflect future without project conditions for the 5-, 20-, 30-, and 50-year scenarios.

To facilitate the modeling, a 50-year mean daily flow record was developed based on flow records at the Rio Grande at Albuquerque gage for the post-Cochiti Dam period. Because the post-Cochiti Dam period of record includes only 30 years of record (Water Year 1974 to Water Year 2004), the Corps developed an additional 20 years of data by repeating the record for Water Year 1985 to Water Year 2004. The Corps selected this period to extend the record because the average mean daily flow was very similar to the longer-term, post-Cochiti Dam average mean daily flow (1,349 cfs for the period Water Year 1985 to Water Year 2004 versus 1,340 cfs for the entire 30-year period).

HEC-6T modeled the entire 50-year period, and cross-sectional geometry at 5, 20, 30, and 50 years was evaluated to determine aggradational/degradational changes throughout the reach. Because of the uncertainty related to how each specific cross section will change as the aggradation or degradation occurs, the model results were used to estimate a representative change in cross-sectional depth within each segment of the reach that exhibits consistent aggradation/degradation trends based on the detailed model results. Figures 3.1 and 3.2 show the predicted change in cross-sectional area from the model results and the assigned representative changes in channel depths for the 5- and 50-year conditions, respectively. The HEC-6T analysis indicates that both aggradational and degradational trends occur along the reach in Year 5. Over time, the aggradational areas shown in Year 5 change to stable or slightly degradational areas at Years 20 and 30, and a slight degradational trend exists along the entire project reach over the 50-year simulation. The manner in which the individual cross sections in the FLO-2D model were adjusted to represent the predicted changes in channel depths for each of the indicated time periods is illustrated in Figure 3.3.

The results presented above agree with the previous sediment-continuity analysis performed for the baseline conditions. Results from the sediment-continuity analysis indicate a slight net degradational tendency for the overall study reach for all of the individual storm hydrographs analyzed. Therefore, the Corps assumes that the occurrence of overbanking will continue to be infrequent for the future without project condition.

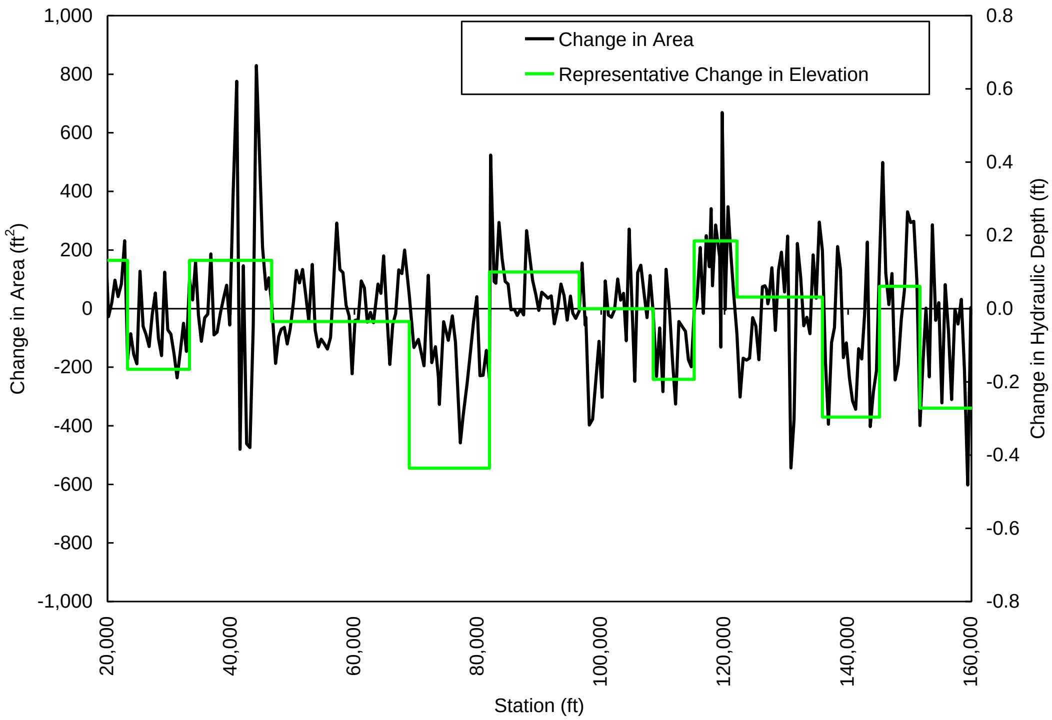


Figure 3.1. Predicted change in channel cross-sectional area at Year 5.

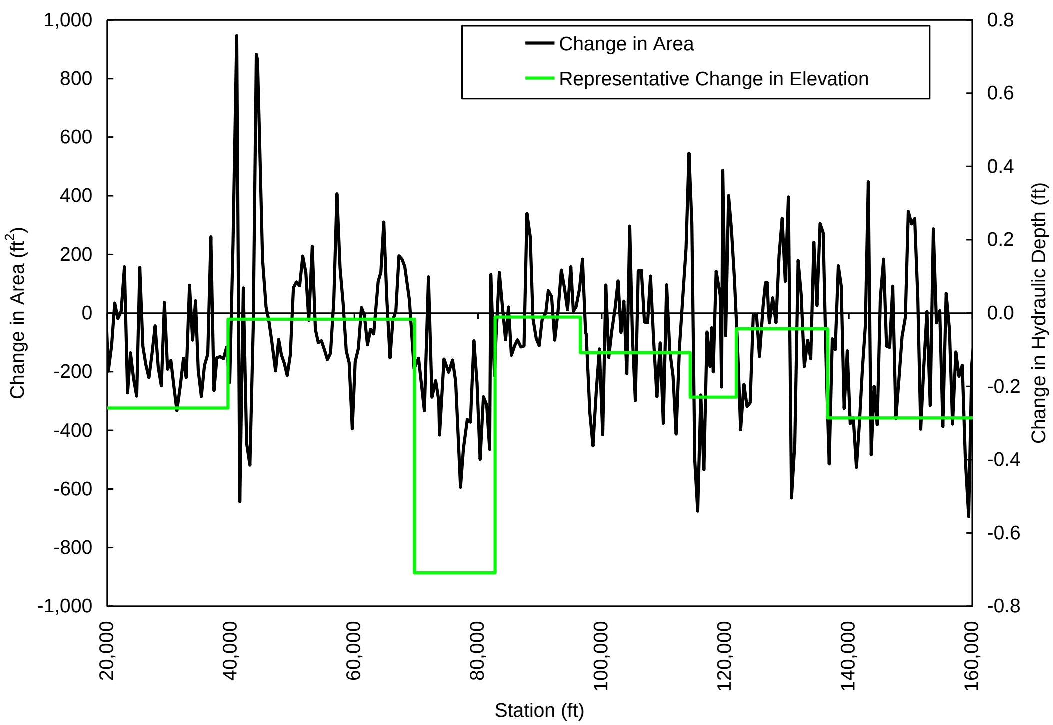


Figure 3.2. Predicted change in channel cross-sectional area at Year 50.

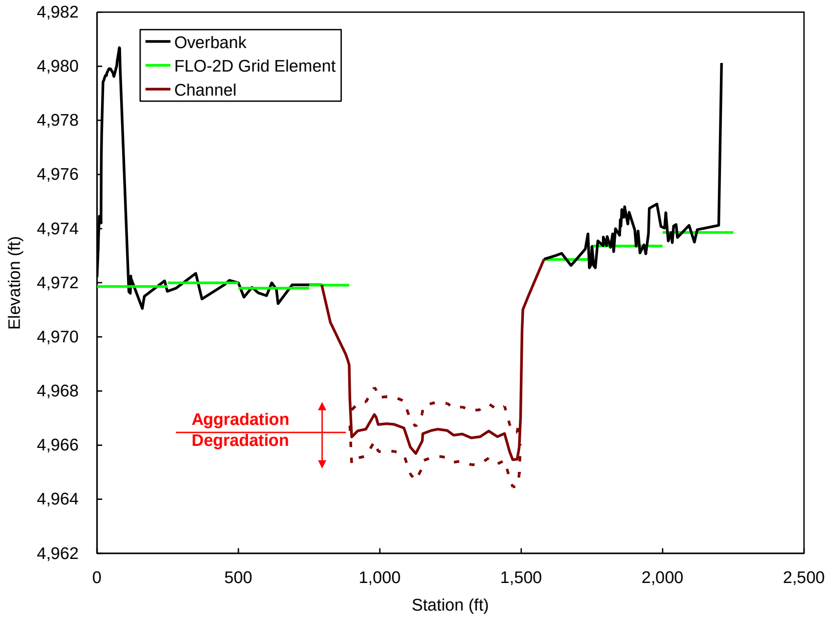


Figure 3.3. Channel cross-section for the 5-, 20-, 30-, and 50-year scenarios.

The amount of overbank inundation predicted by the FLO-2D model for each simulation under the future without project condition was estimated for each reach based on the number of inundated grid elements. Table 3.2 provides a summary of the areas of inundation for existing conditions and future without project conditions for Years 0, 5, 20, 30, and 50. The following sections summarize the results of these simulations.

Table 3.2 Area of inundation for Existing Conditions and Future Conditions Without Project (acres).

Hydrology Scenario	Description	Channel Condition (Year)	Reach 1	2	3	4	5	Total
	Channel Full Conditions	0 (Existing)	77.2	41.3	25.2	34.4	75.6	253.7
		5	78.0	41.1	23.9	34.0	74.0	251.0
		20	76.7	40.9	23.5	32.0	73.5	246.6
		30	76.7	40.7	23.3	32.0	74.6	247.3
1		50	75.9	40.7	23.7	30.0	73.6	243.9
	Annual Spring Runoff	0 (Existing)	45.2	23.1	7.7	4.0	7.9	87.9
		5	45.2	23.0	7.9	4.0	8.0	88.1
		20	43.6	22.1	8.3	6.7	5.7	86.4
		30	43.9	22.8	7.9	7.0	6.3	87.9
2		50	43.2	22.3	7.9	6.8	6.1	86.3
3	10,000 cfs Hydrograph	0 (Existing)	181.9	125.6	82.2	233.7	412.9	1036.3
4	100-Year Peak Snowmelt	0 (Existing)	84.4	59.9	14.6	133.4	364.9	657.2

3.2.2.1 Channel Full Conditions

The active channel-full flow in the Albuquerque reach is approximately 6,000 cfs. The channel-full flow simulations using a 6,000 cfs flow indicate that the area of overbank inundation would decrease slightly in Reaches 1 through 5 in future without project condition compared to existing conditions (Table 3.2). Approximately 75.9 acres, 40.7 acres, 23.7 acres, 30 acres, and 73.6 acres are inundated in Reaches 1 through 5, respectively, in Year 50 as compared to 77.2 acres, 41.3 acres, 25.2 acres, 34.4 acres, and 75.6 acres inundated in Reaches 1 through 5, respectively, for the Year 0 condition. The extent and maximum depth of inundation for the active channel-full flow scenario are shown in the Appendix A.

3.2.2.2 Post-Cochiti Dam Average Annual Flow Hydrograph

The average annual flow simulations indicate that the area of overbank inundation would increase slightly in Reaches 3 and 4 and decrease slightly in Reaches 1, 2, and 5 in the future without project condition compared to existing conditions (Table 3.2). Approximately 43.2 acres, 22.3 acres, 7.9 acres, 6.8 acres, and 6.1 acres are inundated in Reaches 1 through 5, respectively, in Year 50 as compared to 45.2 acres, 23.1 acres, 7.7 acres, 4.0 acres, and 7.9 acres inundated in Reaches 1 through 5, respectively, for the Year 0 condition. The extent, maximum depth, and duration of inundation for this scenario are shown in the Appendix A.

3.2.2.3 10,000 cfs Post-Cochiti Dam Hydrograph

The 10,000 cfs post-Cochiti Dam hydrograph was simulated for the Year 0 conditions only. This hydrology scenario was modeled for the purpose of determining the effect of a high-flow release through the project area under existing conditions. Approximately 181.9 acres, 125.6 acres, 82.2 acres, 233.7 acres, and 412.9 acres are inundated in Reaches 1 through 5, respectively, for the Year 0 condition (Table 3.2). The extent, maximum depth, and duration of inundation for this scenario are shown in the Appendix A.

3.2.2.4 1.0%-Chance Snowmelt Post-Cochiti Dam Hydrograph

The 1.0%-chance snowmelt hydrograph was simulated for the Year 0 condition only. Approximately 84.4 acres, 59.9 acres, 14.6 acres, 133.4 acres, and 364.9 acres are inundated in Reaches 1 through 5, respectively, for the Year 0 condition (Table 3.2). The extent, maximum depth, and duration of inundation for this scenario are shown in the Appendix A.

With the limiting factors of institutional and jurisdictional controls described in Section 2.2, the seasonal flow patterns and on-going channel maintenance activities are not likely to change in the future. The results presented above agree with the previous sediment-continuity analysis performed for the baseline conditions. Results from the sediment-continuity analysis indicate a slight net degradational tendency for the overall study reach for all of the individual storm hydrographs analyzed. Therefore, the Corps assumes that, in the absence of any restoration efforts, the occurrence of overbanking will continue to be infrequent for the future without project condition.

3.3 Water Quality

Under the future without project condition, there would be no potential improvement to water quality through the creation of wetlands (especially those that would use and increase water quality at storm-drain outfall structures). The potential wetland and willow swale habitats would assist with water quality that might have increased issues due to an increase in human population. Native plants could assist in removing nutrients that have a negative effect on water quality due to an increase in non-point-source pollution.

3.4 Air Quality and Noise

There would be no effect on air quality and noise under the future without project condition.

3.5 Ecological Resources

Continued isolation of riparian vegetation in the study area from fluvial geomorphic processes will eventually result in complete dominance of the plant communities by non-native plant species, including salt cedar, Russian olive, Siberian elm, white mulberry, and tree of heaven. Current vegetation management techniques such as understory clearing and planting of native species might temporarily reset patches of Bosque to more natural structural states, but gradual replacement by non-native species could continue to occur unless the function of the Bosque ecosystem and structure of the dynamic mosaic is restored. Eventual conversion of the Bosque to a non-native-plant-dominated ecosystem uninfluenced by hydrologic processes, with fire as the new main disturbance mechanism, would diminish habitat suitability and quality for many native animal species. Larger scale plantings, bank destabilization, or high-flow channel creation would not likely occur due to financial limitations. Some maintenance activities would likely continue by other agencies or private organizations. Some areas have been planted with native shrubs and trees through other projects. This native vegetation will continue to grow and provide some additional habitat for wildlife.

Inundation of the Bosque would remain infrequent and limited without modifications to high-flow channels and bank destabilization. Without the inundation, the key component of a functioning Bosque would remain absent limiting native plant recruitment, nutrient cycling, and recharge of the shallow aquifer. Existing wetlands would continue to diminish and remain isolated from other similar habitats as they are now.

3.5.1 Fish and Wildlife

With a trend towards larger dominance of non-native plant species, the abundance of some species would increase at the expense of overall diversity in the Bosque. Those species preferring the dense, low, and mid-story habitat structure would benefit while those preferring open mature cottonwood stands with open mid and understory would become less common. If native Bosque patches became smaller and distances between patches larger, some wildlife species might be lost to the area altogether. The overall trend would be for a less heterogeneous habitat favoring only a portion of the existing animal species. Likewise migratory species relying on varying age stands of cottonwood Bosque, wetlands, or open meadow would be forced to travel farther and possibly bypass the MRG near Albuquerque to find favorable habitat.

The lack of connectivity between the river and floodplain would also favor upland species that are fairly common in the region while the rarer floodplain species would remain scarce.

3.5.2 Special Status Species

The three special status species known to occur in the study area, and the potential future without project effects to them, is discussed below.

3.5.2.1 Rio Grande Silvery Minnow

Aquatic habitat in the study area is directly influenced by stream discharge volumes, patterns, and sediment supply. Bank erosivity, and thus direct sediment contribution from the study area and local channel dynamics, is unlikely to change without implementation of the proposed project. Other agency initiatives have created potential habitat for the RGSM. These are but a few projects within the 26-mile study area, creating some additional beneficial habitat for the minnow. However, under the future without project condition, existing aquatic habitat conditions would remain largely unchanged.

3.5.2.2 Southwestern Willow Flycatcher

Wetlands and native woody riparian vegetation would continue to decline in the study area with future without project condition, further diminishing habitat suitability for these species and contributing to their decline. Again, other agency initiatives (such as those under the MRGESCP) might propose projects to benefit the Southwestern Willow Flycatcher in this area, although none are known at this time.

3.5.2.3 Yellow-Billed Cuckoo

Without initiation of the proposed project, an increase in potential native riparian habitat to benefit the Yellow-Billed Cuckoo would not be implemented.

3.6 Floodplains and Wetlands

In the future without project condition, additional wetlands and reconnection within the floodplain would not occur. Loss of wetland habitat and connection between the river and Bosque would continue without the project.

3.7 Cultural Resources

Historic properties in the form of earthen structures related to irrigation canals (acequias) and drainage ditches as well as wooden bridge pilings are known to occur within the Rio Grande Floodway project area. These historic period structures are in a deflated condition but are still identifiable after being abandoned for approximately 70 years. The future without project condition would be a continuance of the existing situation, and these structures would be impacted by high river flows and natural weathering. The possibility of destructive flooding within the floodway channel could significantly affect and possibly destroy these structures; however, flooding has been very infrequent due to the existing flood risk management dams and modern water management practices. Therefore, the future without project alternative is considered to have a negligible effect to the existing condition of these historic properties.

Likewise, American Indian traditional cultural properties (TCPs) known to occur within the Rio Grande Floodway would not be affected.

3.8 Socioeconomic Environment and Environmental Justice

The existing conditions of neighborhoods adjacent to the Bosque are likely to remain comparable to the present situation in the Future without project condition. As such, the neighborhoods would not benefit from potential improvements in quality of life and possibilities for redevelopment stemming from restoration and additional recreation opportunities. The Bosque would be less likely to play a key role in redevelopment of the area and it would have an increasingly lower value as a tourist attraction. Some improvements might be made by local agencies if the proposed project were not implemented. Without the project, homeless encampments in the study area are likely to increase, increasing the potential for fire and illegal activities.

3.9 Land Use

Increased growth in the Albuquerque Metropolitan Area would be a further burden on the river and the lands along the Bosque. Most of the land in the study area is part of the RGVSP, and as a result, would remain otherwise undeveloped. Residential development south of Central Avenue, adjacent to the study area, and further development of the Albuquerque Biological Park facilities could increase the number of Bosque visitors. In a future without project setting, the lack of restoration and the design of a formal trail system to accommodate these additional visitors could result in even greater disturbance of the Bosque, further accelerating its decline. Based on the current regulatory regime, other problematic land uses such as dumping and wood harvesting should not be a widespread problem. Some of these problems might be addressed by local agencies if the proposed project were not implemented, but not at as large of a scale or as expeditiously.

3.10 Interpretive and Recreational Resources

Without the project, the educational and recreational activities currently enjoyed by the citizens of Albuquerque and visitors would remain roughly as they are. As the Bosque in the study area becomes increasingly hazardous and unsafe due to increased densities of non-native and dead and down vegetation, however, the quality and time for these activities would be increasingly diminished. The Bosque would have to remain closed for longer periods of time because of the fire hazard, and the experience would be further degraded. As noted above, the lack of a clearly defined interpretive trail system could lead to the proliferation of trails and off-trail uses, which would further disturb the Bosque and accelerate its decline. Again, some improvements by local agencies or other initiatives might improve this situation, but not to the level that the preliminary proposed project entails.

3.11 Hazardous, Toxic, and Radiological Waste

In the absence of the project, and given the current regulatory regime and policing of the Bosque, the current hazardous, toxic, and radiological waste is unlikely to change significantly. Illegal refuse dumping would likely continue in the less used and informal access areas. In some places, dumping also impedes law enforcement officers and firefighters in their efforts to secure public safety and extinguish fires in the Bosque.

3.12 Invasive Species

The majority of non-native species within the project area are plants. Though some non-native fish and other wildlife might exist, they are not of major concern.

3.12.1 Invasive Plants

A number of invasive tree species are proposed to be removed and/or reduced in number under the proposed action. These include salt cedar, Russian olive, Siberian elm, tree of heaven, and Russian mulberry. These species compete successfully with the native species and can convert riparian habitat to a drier, more upland habitat. Left unchecked, these species can successfully compete with all native vegetation and take over. This shift would eliminate the native riparian Bosque that the goals of this proposed project aim to protect and restore. In the future without project condition, invasive tree species would continue to spread throughout the Bosque. Some management of these species is performed by local agencies, but to a limited degree on an annual basis.

3.12.2 Noxious Weeds

Executive Order 13112 directs Federal agencies to prevent the introduction of invasive (exotic) species and provides for their control to minimize the economic, ecological, and human health impacts that invasive species cause.

In addition, the State of New Mexico, under administration of the United States Department of Agriculture, designates and lists certain weed species as being noxious (Nellessen 2000). "Noxious" in this context means plants not native to New Mexico that might have a negative impact on the economy or environment and are targeted for management or control. Class C listed weeds are common, widespread species that are fairly well established within the state. Management and suppression of Class C weeds is at the discretion of the lead agency. Class B weeds are considered common within certain regions of the state but are not widespread. Control objectives for Class B weeds are to prevent new infestations and, in areas where they are already abundant, to contain the infestation and prevent their further spread. Class A weeds have limited distributions within the state. Preventing new infestations and eliminating existing infestations is the priority for Class A weeds. In order to prevent this, all equipment would be cleaned with a high-pressure water jet before leaving an area and entering a new area.

Under the future without project condition, noxious weeds would continue to spread throughout the Bosque and would not be managed in the proposed project area.

3.13 Inventory and Forecasting Conditions

To develop plans for a community or region, it becomes necessary to predict both the short-term and long-term future conditions of the environment (USACE 2000). Forecasting is undertaken to identify patterns in natural systems and human behavior and to discover relationships among variables and systems so that the timing, nature, and magnitude of change in future conditions can be estimated. A judgment-based method, supported by the scientific and professional expertise of the evaluation team, is used to forecast the trends in habitat value for the study area if no project were to take place. The same method is used to evaluate the effectiveness of proposed restoration plans, rate project performance, and determine many other important aspects of both WOP and WP conditions.

3.14 Quantifying Wildlife Habitat

Most Federal agencies use annualization as a means to display benefits and costs, and ecosystem restoration analyses should provide data that can be directly compared to the traditional benefit:cost analysis. Since habitat value is difficult to express in monetary terms, the cost effectiveness of project features are measured in habitat units (HU). HUs are the product of the amount and value of the habitat. For instance, one acre of a particular habitat with a value that is determined to be 2.5 is equal to 2.5 HUs. HUs are annualized by summing HUs across all years in the period of analysis and dividing the total (cumulative HUs) by the number of years in the period of analysis. The results of this calculation are referred to as Average Annual Habitat Units (AAHUs) and can be expressed mathematically. Using AAHUs as a metric, the WOP and WP conditions can be compared over time based on the forecast conditions. In this way, it is possible to quantify a change in habitat by implementing the project and if that change is cost effective.

3.15 Generating a Target Mosaic

As noted above in Section 2, *Historic and Existing Conditions*, the nature of the Bosque and the mosaic of habitats or patches have changed dramatically since the 17th Century (Pittenger 2003, Scurlock 1998). With changes in land use and settlement, the size and composition of various patches within the Bosque have also changed (Scurlock 1998). The existence in recent decades of a continuous mature cottonwood forest between the river and the levee appears to be unprecedented. That is, changes in land use had resulted in a Bosque dominated by a single habitat type made up of mature cottonwood trees with sparse understory and a grassy groundcover. Many Bosque researchers and commentators now believe that historically the Bosque was a dynamic mosaic of riparian wetlands, channels, woodlands, shrub thickets, and periodically wet meadows (Pittenger 2003, Crawford *et al*. 1998). Frequency of flooding, water table elevation, and the type of sediment substrate were and continue to be important determining factors of patch type and structure. The formerly dynamic river would destroy old growth forest and create wetlands, willow stands, channels, and areas recolonized by new cottonwood stands through river meandering across the unencumbered floodplain. Frequency of flooding, water table elevation, and the type of sediment substrate were, and continue to be, important determining factors of patch type and structure.

Although all Bosque patch types contribute to the overall habitat value of the Bosque, key types of patches support a larger number of species and individuals, including wetlands and patches with thicker vegetation (Hink and Ohmart 1994, Pittenger 2003, Najmi *et al.* 2005). The latter would include Bosque forest or woodland areas with denser understories and shrub thickets. Hink and Ohmart's survey and subsequent research suggests that the edges of these patches, especially where they meet channels, open meadows or wetlands, are of particular importance for wildlife. Therefore, an overall mosaic that includes both "open" and "dense" patches as well as wet areas is the key to maximizing restoration opportunities.

Because of the importance of the mosaic to the goal of wildlife restoration, it was determined that a target mosaic consisting of various types of habitat including varying-aged cottonwood stands, shrub patches, grass meadow, and wet features (high-flow channels, backwater channels, willow swales) should be a basis for the planning process. The target mosaic needed to be based on accounts or descriptions of the Bosque prior to major flood risk management measures, yet no such accounts exist prior to the 20th Century. Information on the composition of the Bosque was recorded beginning in the early 20th Century. Starting in 1918, there are surveys of the vegetation types and communities along the MRG (Pittenger 2003). Aerial photographs were taken in 1935 and subsequently have been interpreted to generate vegetation cover maps. Beginning with the work done by Hink and Ohmart, vegetation in the MRG has been surveyed and classified by community type and structure on a decennial basis.

As in Section 2, the riparian ecosystem of the study area was much larger and functioned very differently than it does now. Periodic flood events maintained a dynamic Bosque with a mosaic of patches diverse in size, age, and species composition. With urbanization and the advent of flood risk management measures, however, flooding to the former extent is not possible in the study area (Pittenger 2003). The goal of the restoration project is to provide for a more natural condition to the study area that approximates the pre-flood risk management habitat mosaic.
In doing so, the PDT utilized information in the Bosque Landscape Alteration Strategy (2005), developed by the Middle Rio Grande Conservancy District (Yasmeen Najmi and Sterling Grogan) in partnership with Cliff Crawford, Professor Emeritus, University of New Mexico. Both Ms. Najmi and Dr. Crawford participated on the external PDT and helped develop the mosaic concept.

In order to evaluate the most current conditions and to project potential alternative vegetative mosaics, the PDT decided to use a newer modeling tool. The Habitat Evaluation Assessment Tool (HEAT) model combines the Habitat Evaluation Procedure (HEP) with some hydrological components in order to evaluate projects that would provide that „reconnection' between the Bosque and river. The modeling tool and how it was used is further described in Appendix C, Model Documentation Report.

3.16 Habitat Modeling

To evaluate the ecological benefits of proposed ecosystem restoration plans, the Corps and its stakeholders needed an assessment methodology that could capture the complex ecosystem process and patterns operating at both the local and landscape levels across multiple habitat types. Two methodologies were used to determine outputs of the restoration project. These methodologies used HEP to quantify outputs and based their habitat value on Habitat Suitability Index (HSI) and Spatial Heterogeneity Index (SHI), respectively. Each of these methodologies is discussed in detail in the Model Documentation Report (Appendix C). The Corps guidance on ecosystem restoration requires that benefits from the project meet the objectives listed in Engineer Regulation 1105-2-100, specifically, “The objective of ecosystem restoration is to restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition. Restored ecosystems should mimic, as closely as possible, conditions which would occur in the absence of human changes to the landscape and hydrology.” Because the HSI describes outputs in line with this guidance, the NER plan and, therefore, the recommended plan were selected using the HSI model only. For the purposes of this document, the discussion of benefits are restricted to the HSI outputs leading to the NER plan.

3.16.1 Using HEP to Assess the Habitat Potential (Suitability)

In 1980, the USFWS published quantifiable procedures to assess initiatives as they relate to change of fish and wildlife habitats (USFWS 1980a-c). These procedures, referred to collectively as Habitat Evaluation Procedures (HEP), use a habitat-based approach to assess ecosystems and provide a mechanism for quantifying changes in habitat quality and quantity over time under proposed alternative scenarios. HEP is an objective, quantifiable, reliable and well-documented process used nationwide to generate environmental outputs for all levels of proposed projects and monitoring operations in the natural resources arena. HEP provides an impartial look at environmental effects and delivers measurable products to the decision-maker for comparative analysis.

Habitat Suitability Indices are simple mathematical models that reflects a species's or community’s sensitivity to a change in a limiting factor (*i.e.,* variable) within the habitat type. Traditional HSI models reflect the basic requirements for a species existence such as food, shelter, water, and reproduction. These models provide a method of measuring habitat variables to determine the “suitability” of a habitat to support a population of that species. These measurements, or SI, are used in the HEP framework to quantify the outcomes of impact, mitigation, or restoration scenarios. These suitability relationships are depicted using scatter plots and bar charts (*i.e*., suitability curves). The SI value (Y-axis) ranges from 0.0 to 1.0, where an SI = 0.0 represents a variable that is extremely limiting, and an SI = 1.0 represents a variable in abundance (not limiting) for the species or community.

There is a limited number of species specific HSI that are appropriate for the Southwest United States and many do not account for arid land species or habitat types. Further, species specific HSI, even when multiple HSI are combined, tend to miss some components of a local ecosystem.

For these reasons, a community based HSI becomes a more useful tool in assessing habitat in this region. The community based HSI treats the habitat community, in this case the Bosque, as an organism, and the HSI include those functional components that the Bosque needs to persist.

HSI models have played an important role in the characterization of ecosystem conditions nationwide. They represent a logical and relatively straightforward process for assessing change to fish and wildlife habitat (Williams 1988, VanHorne and Wiens 1991, Brooks 1997, Brown *et al*. 2000, Kapustka 2005). The controlled and economical means of accounting for habitat conditions makes HEP a decision-support process that is superior to techniques that rely heavily upon professional judgment and superficial surveys (Williams 1988, Kapustka 2005). They have proven to be invaluable tools in the development and evaluation of restoration alternatives (Williams 1988, Brown *et al*. 2000, Store and Kangas 2001, Kapustka 2003, Store and Jokimaki 2003, Gillenwater *et al.* 2006, Schluter *et al*. 2006, Shifley *et al*. 2006), managing refuges and nature preserves (Brown *et al*. 2000, Ortigosa *et al*. 2000, Store and Kangas 2001, Felix *et al.* 2004, Ray and Burgman 2006, Van der Lee *et al.* 2006, and others), and mitigating the effects of human activities on wildlife species (Burgman *et al.* 2001, NRC 2001, Van Lonkhuyzen *et al*. 2004). Efforts are made during model development to ensure that the models are biologically valid and operationally robust. The functions included in models are often based on published and unpublished information that indicates that the functions are responsive to species density through effects on life requisites.

For the MRGB study, riparian habitat community assessment was necessary to quantify existing habitat value and forecast future values with and without the proposed project. However, few species specific models are published and available for application in arid southwest habitat types. Those that are applicable do not encompass the range of life requisites or indices that would provide for the goals of restoring Bosque habitats. The E-team chose to develop a new HSI model for the MRGB study. The strategy entailed five steps:

- Compile all available information that could be used to characterize the communities of concern.

- Convene an expert panel in a workshop setting to examine this material and generate a list of significant resources and common characteristics (land cover classes, topography, hydrology, physical processes, *etc*.) of the system that could be combined in a meaningful manner to "model" the communities. In the workshop(s), it was important to outline study goals and objectives and then identify the desired model endpoints (*e.g.*, results of the model). It was also critical for the participants to identify the limiting factors present in the proposed project area relative to the model endpoints and system requirements . The outcome of the workshop(s) was a series of mathematical formulas that were identified as functional components (*e.g*., Hydrology, Vegetative Structure, Diversity, Connectivity, Disturbance, *etc.*) for the Bosque (Riparian) Community Index Model which were comprised of variables that were:

  - Biologically, ecologically, socioeconomically, or functionally meaningful for the subject,
  - Easily measured or estimated,

  - Able to have scores assigned for past and future conditions,
  - Related to an action that could be taken or a change expected to occur,
  - Influenced by planning and management actions, and
  - Independent from other variables in each model.

- Develop both a field and a spatial data collection protocol and, in turn, use these strategies to collect all necessary data and apply these data to the model in both the "reference" setting and on the proposed project area.

- Present the model results to an E-team and revise/recalibrate the models based on their experiences, any additional and relevant regional data, and application directives.

- Submit the models to both internal ERDC-EL/Albuquerque District/E-team review and then request review from the initial expert panel that participated in the original workshop, as well as solicit review from independent regional experts who were not included in the model development and application process.

A series of ten workshops was held over the period of three years (2005-2008) to develop models, characterize baseline conditions of the study area, then formulate plans and assess alternatives for the ecosystem restoration study. Several Federal, state, and local agencies, as well as local and regional experts from the stakeholder organizations, and private consultants, participated in the model workshops. The Bosque Community HSI model was developed under this paradigm. A summary follows; however, the details of these metrics are presented in the Model Documentation Report (Appendix C).

For the Bosque (Riparian) Community Index Model three categories: (1) Hydrology, (2) Structure/Soils/Biotic Integrity, and (3) Spatial Integrity and Disturbance were identified as the key functional components necessary to model the ecosystem integrity of MRGB's Bosque community. Flow diagrams best illustrate the model's component relationships. Figure 3.4 shows two versions of the model; model use depends on the cover types being evaluated. Cover Types 1 through 5 (Forest and Shrubs) use the upper diagram, and Cover Type 6 (Marsh and Wet Prairies) uses the lower diagram.

Habitat Potential – Bosque (Riparian) Community Index Model

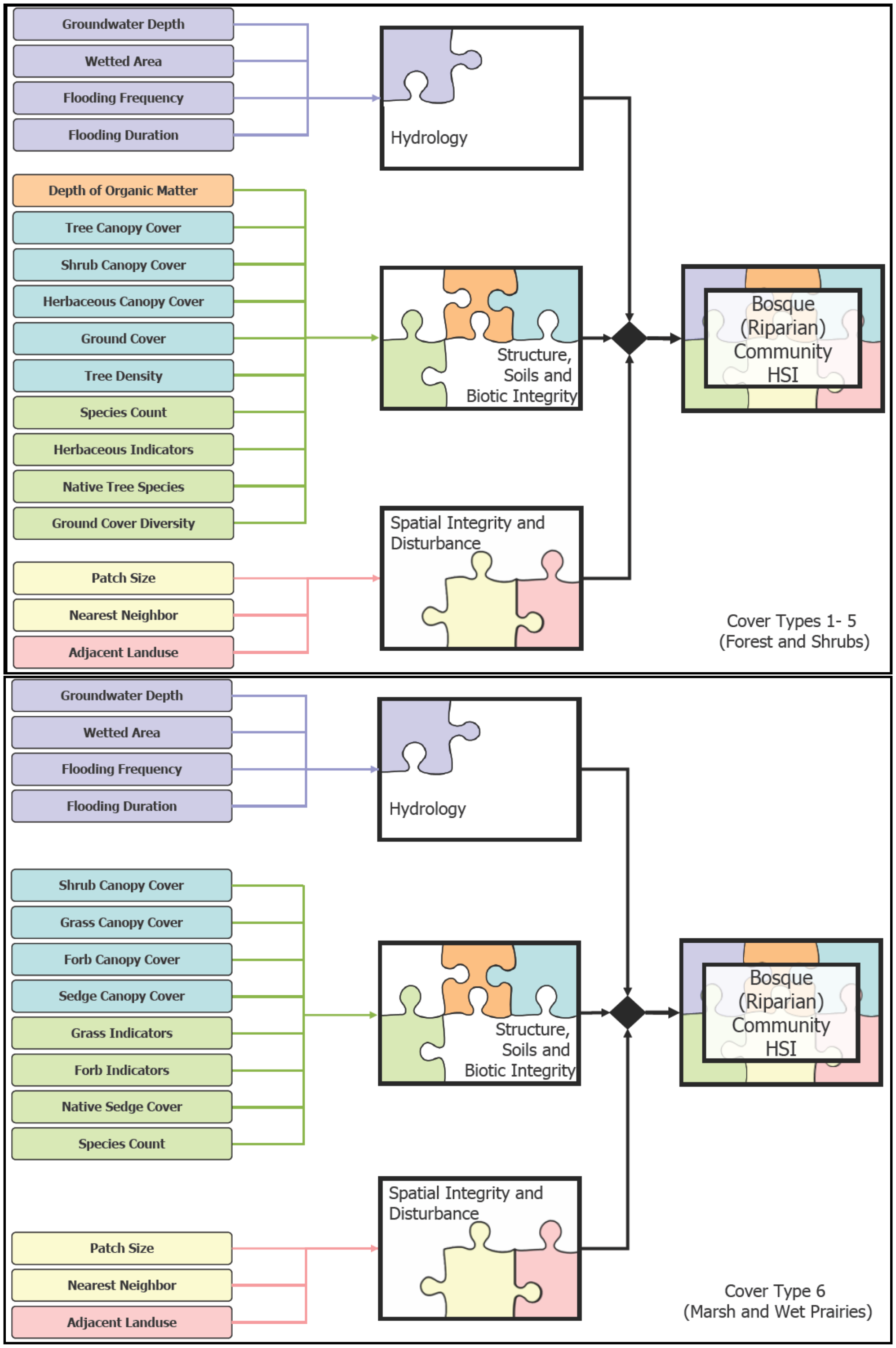


Figure 3.4. Combinations of model components to form the Bosque Community Index Model.

Figure 3.5. Bosque reference sites in the MRGB study area.

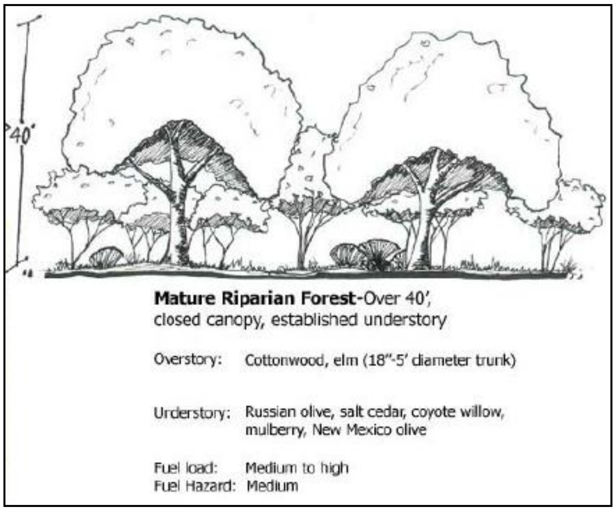
The E-team developed mathematical algorithms to relate the various components to the ecosystem processes occurring throughout the watershed in this community. To test these concepts, the E-team used a series of reference sites to provide relevant feedback and verification of the model's conceptual architecture. Figure 3.5 shows the Bosque reference sites used in the MRGB study area for calibration of the Bosque (Riparian) Community Index model.

The E-team used a systematic, scientifically-based, statistical protocol to calibrate the community index model. Modifications to the original algorithms were incorporated into the system as indicated, and the final formulas were made ready for the MRGB application. Further descriptions of the community-based index model and its development/verification can be found in the Model Documentation Report in Appendix C, which includes a general list and description of the model components and its associated variables.

3.16.2 Vegetative Communities of Concern

To obtain a value of the existing habitat in the study area and ultimately forecast the improvement in value resulting from any restoration measures, the Corps used an existing inventory of the habitats within the study area. The "Middle Rio Grande Biological Survey" completed by Hink and Ohmart in 1984, described the plant communities within the study area's riparian zone and provided detailed information on species composition and the structure of cover types. Hink and Ohmart (1984) developed six general plant vegetation categories based on several parameters including height and density of the vegetation and the make up of the mid and understory or lower layers. Figures 3.6 through 3.11 show the habitat structure types used in the analysis and the forecasting of the study area.

Type I: Mature Riparian Forests with tall trees ranging from 50 to 60 feet in height, closed canopies, and well established (relatively dense) understories composed of saplings and shrubs.



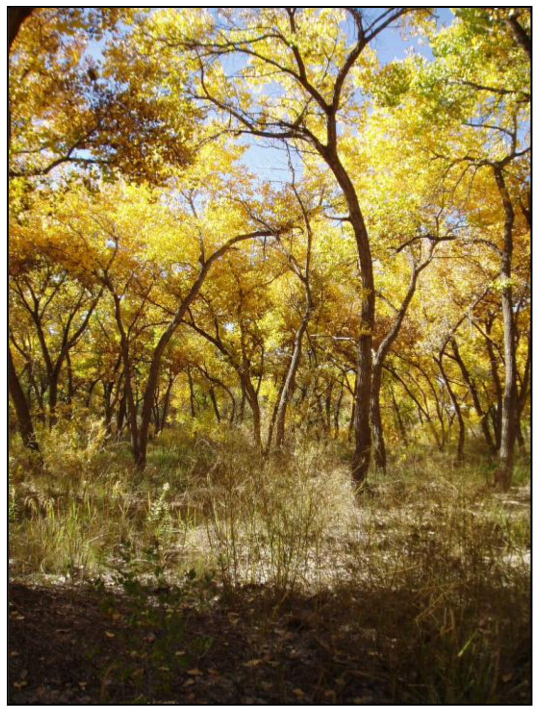


Figure 3.6. Classic examples of Type I vegetation in the study area.

Type II: Mature Riparian Forests with tall trees exceeding 40 feet in height and nearly closed canopies, but limited sapling and shrub understories.

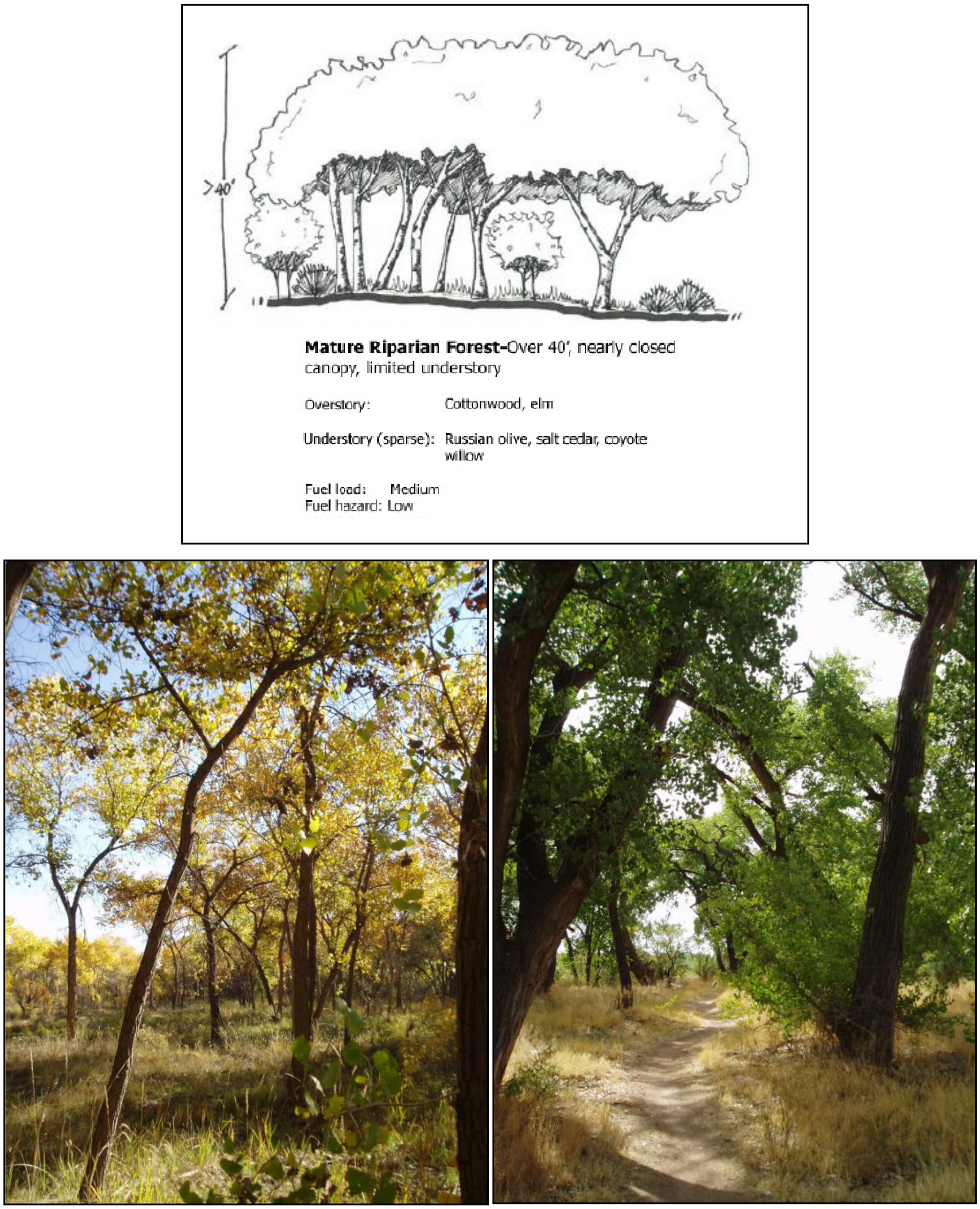


Figure 3.7. Classic examples of Type II vegetation in the study area.

Type III: Intermediate-aged Riparian Woodlands characterized by mid-sized trees less than 30 feet in height, but with closed canopies and dense understories.

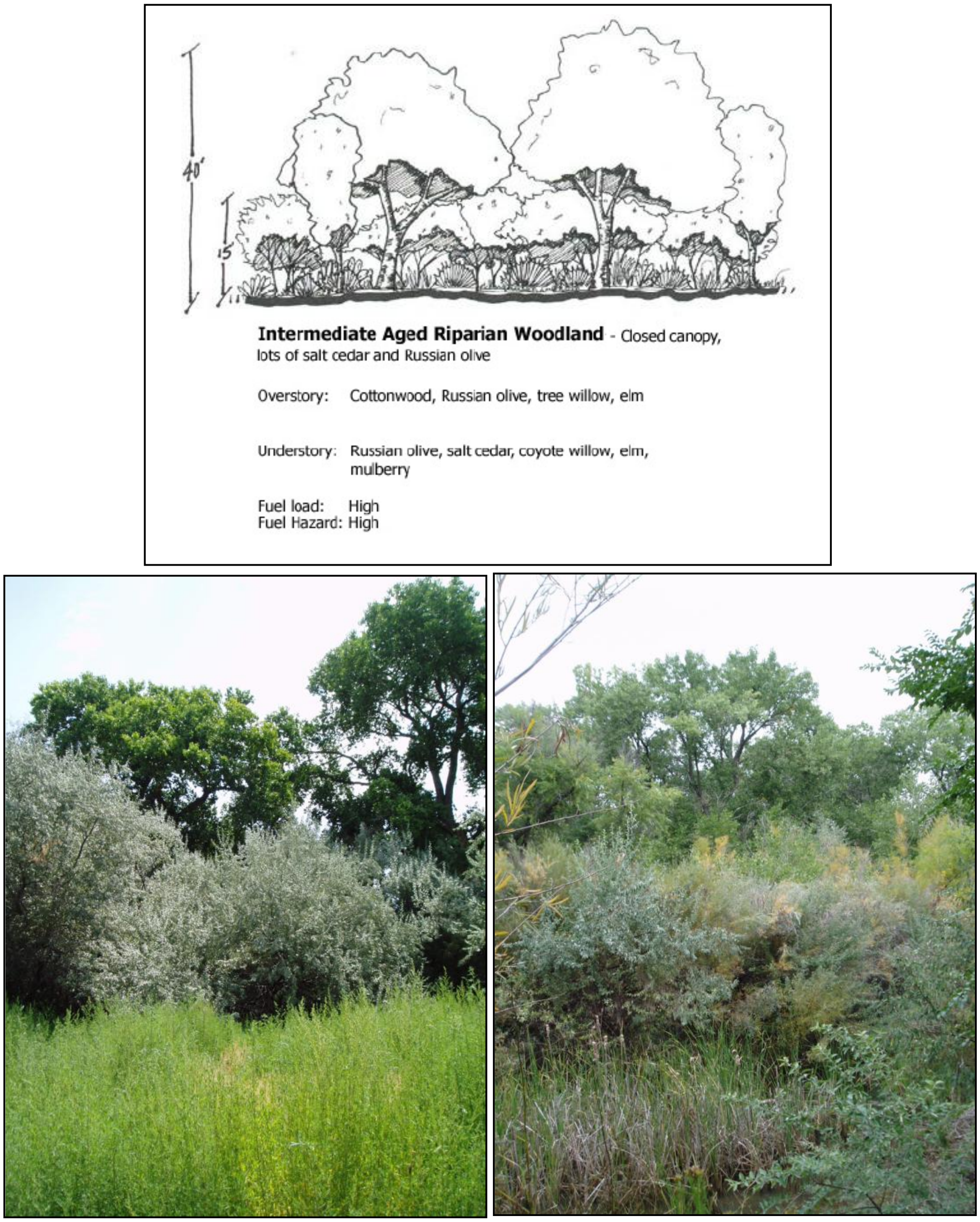


Figure 3.8. Classic examples of Type III vegetation in the study area.

Type IV: Intermediate-aged Riparian Woodland/Savannahs characterized by open stands of mid-sized trees with widely scattered shrubs and sparse herbaceous growth underneath.

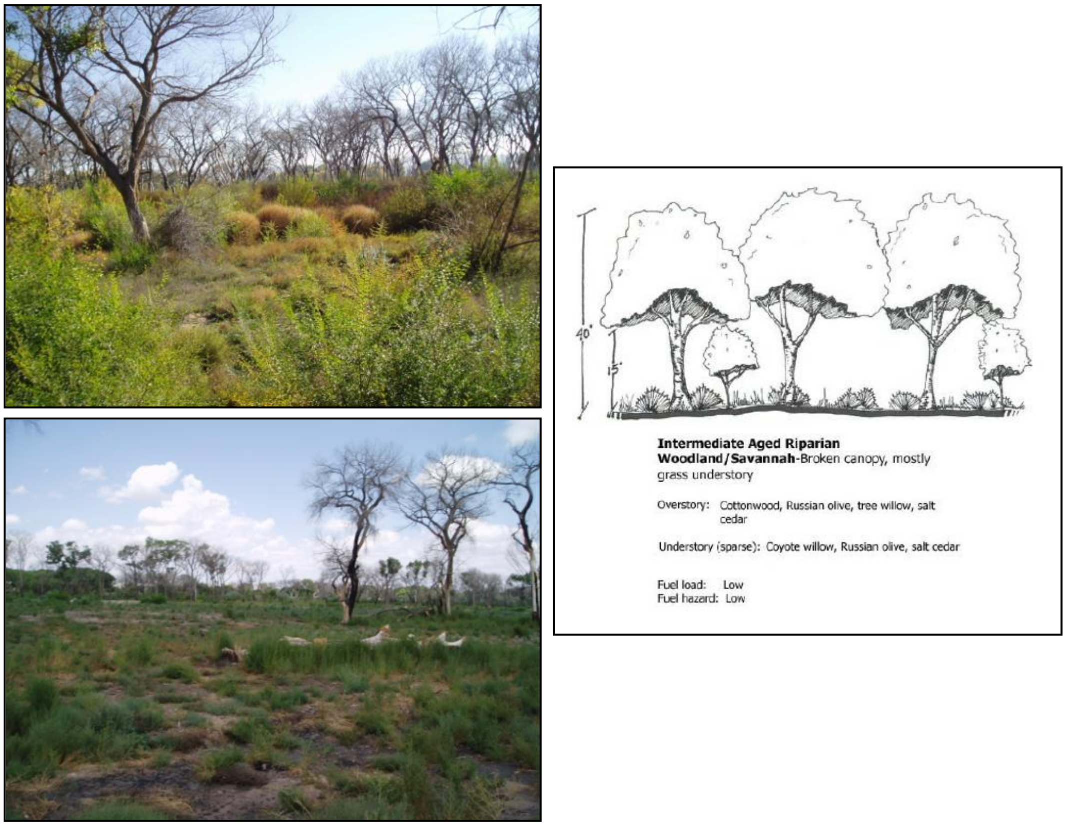


Figure 3.9. Classic examples of Type IV vegetation in the study area.

Type V: Riparian Shrubs characterized by dense vegetation (shrubs and saplings) up to 15 feet in height, but lacking tall tree species, and often having dense herbaceous growth underneath.

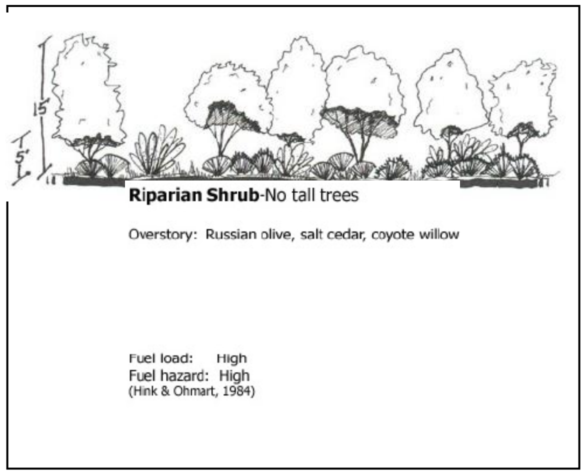


Figure 3.10. Classic examples of Type V vegetation in the study area.

Type VI: Dry Grass Meadows and Wet Marshes characterized by scattered plant growth composed of short shrubs (less than 5 feet in height), seedlings, and grasses. This category includes both dry meadows and the rare marshes found in the oxbow of the Rio Grande that are vegetated with cattail, bullrush, sedges, watercress and algae.

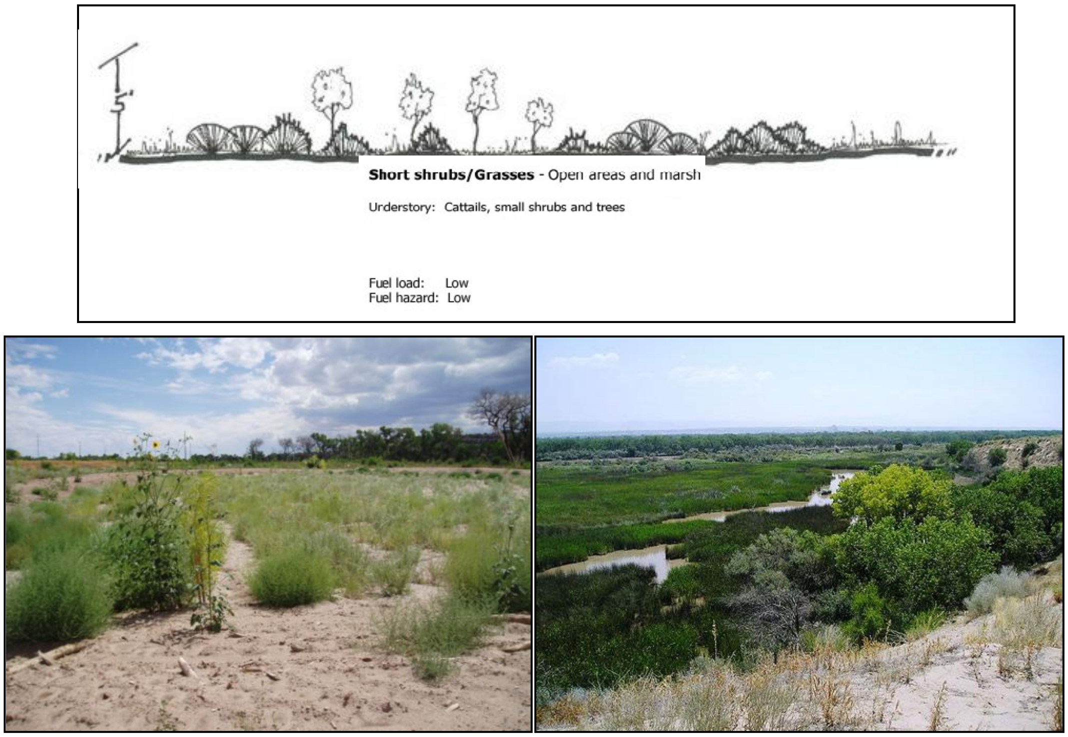


Figure 3.11. Classic examples of Type VI vegetation in the study area.

For purposes of the study, these six cover types (which were changed to 1-6) were subsequently divided into "Treated" (T), for areas where dead and down material was removed and/or selective thinning of non-native vegetation has occurred, and "Untreated" (U) categories, indicating the condition of "fire management" within their boundaries. Figure 3.12 shows an example of untreated forest with extensive fuel loads that are susceptible to fire. Therefore, in addition to the six vegetation types, four of the types were subdivided into T or U as appropriate and resulted in Types 2T, 2U, 4T, 4U, 6T, and 6U. A „wet' (W) descriptor was also added for Type 6 yielding a Type 6W category. Therefore, a total of ten categories exist. Table 3.3 lists the ten type categories as well as categories of open land, open water, islands, and utilities and calculates the number of each type within the five reaches and the total number in the proposed project area.

Figure 3.12. The District and stakeholders actively reduce fuel loads (left) to reduce the risk (right).

To quantify the community's habitat conditions, the HEP process requires that the study area be divided into manageable sections and quantified in terms of acres. This process, referred to as "cover typing," allows the user to define the differences between vegetative covers (*e.g.*, meadow, forest, marsh, *etc.*), hydrology, and soils characteristics and clearly delineate these distinctions on a map. The final classification system, based primarily upon dominant vegetation cover, captures "natural" settings as well as common land-use practices in a specific and orderly fashion that accommodates the Corps plan formulation process.

Table 3.3. Baseline acres assigned to the seven eco-reaches in MRGB study.

Code	Description	Reaches					Total Project Area
		1	2	3	4	5	
TYPE_1	H&O Class I not treated - MATURE RIPARIAN FOREST (Over 40' – closed canopy, established understory).	414	17	99	110	90	730
TYPE_2T	H&O Class II treated - MATURE RIPARIAN FOREST (Over 40' – nearly closed canopy, limited understory).	239	167	64	433	309	1,212
TYPE_2U	H&O Class II not treated - MATURE RIPARIAN FOREST (Over 40' – nearly closed canopy, limited understory).	27	22	41	11	68	169
TYPE_3	H&O Class III not treated - INTERMEDIATE AGED RIPARIAN WOODLAND (Closed canopy, lots of salt cedar and Russian olive).	65	42	51	56	7	221
TYPE_4T	H&O Class IV treated - INTERMEDIATE AGED RIPARIAN WOODLAND/SAVANNAH (Broken canopy, mostly grass understory).	93	83	85	50	0	311
TYPE_4U	H&O Class IV not treated - INTERMEDIATE AGED RIPARIAN WOODLAND/SAVANNAH (Broken canopy, mostly grass understory).	20	15	5	0	32	72
TYPE_5	H&O Class V shrublands not treated - RIPARIAN SHRUB (no tall trees).	135	206	82	58	98	579
TYPE_6T	H&O Class VI dry (grass) meadow treated - SHORT SHRUBS/GRASSES – Open areas.	6	7	64	2	0	79
TYPE_6U	H&O Class VI dry (grass) meadow not treated - SHORT SHRUBS/GRASSES – Open areas.	91	2	7	6	12	118
TYPE_6W	H&O Class VI wet meadow not treated - SHORT SHRUBS/GRASSES – Open areas and Marsh.	0	0	4	0	0	4
OPENLAND	Open Areas	51	49	36	57	38	231
OPENWATER	Open Water	392	290	229	363	262	1,536
ISLANDS	Islands	0	10	3	9	15	37
UTILITY	Utility Areas	14	8	0	0	0	22
	TOTALS:	1,547	918	770	1,155	931	5,321

3.16.3 Baseline Outputs - Indices and Units

HSIs captured the quality of the acreage within the reach for the Bosque (Riparian) Community Index Model. Units (*i.e.*, HUs) applied this quality to the governing area by multiplying the quality times the quantity (Quality x Quantity = Units) for HEP analyses. Table 3.4 provides the interpretation of the index scores and summarizes the results of the baseline ecosystem assessments for the study reaches.

Table 3.4 Interpretation of index scores resulting from HEP assessments.

Index Score	Interpretation
0.0	Not-suitable - the community does not perform to a measurable level and will not recover through natural processes
Above 0.0 to 0.19	Extremely low or very poor functionality (*i.e.*, habitat suitability and diversity) - the community functionality can be measured, but it cannot be recovered through natural processes
0.2 to 0 .29	Low or poor functionality
0.3 to 0.39	Fair to moderately low functionality
0.4 to 0 .49	Moderate functionality
0.5 to 0.59	Moderately high functionality
0.6 to .79	High or good functionality
0.8 to0.99	Very high or excellent functionality
1.0	Optimum functionality - the community performs functions at the highest level - the same level as reference standard settings

3.17 Bosque Community (HSI) Results

Habitat values throughout the project area were generally moderate with low and high scores occurring in localized patches. In most instances, the individual component indices (a.k.a. Life Requisite Suitability Indices or LRSIs) and composite HSIs scored in the mid-range of values (less than 0.5), indicating only a moderate level of functionality in the study area (Table 3.5). The highest functioning reach was Reach 1 (HSI equals 0.50). The E-team expected this result because the last vestiges of undisturbed Bosque are found in this area. Reaches 2 and 3 generated the lowest HSI scores (HSIs ranged from 0.40 to 0.41). Located in the heart of Albuquerque, these areas are highly urbanized and experience extreme levels of disturbance and invasive encroachment. In addition, Reaches 2 and 3 were targeted for moderate to heavy fire prevention, and as such, their understories incurred significant impacts. Figure 3.13 shows the baseline HSI results for the MRGB study based on the Bosque (Riparian) Community Index

Model. Figure 3.14 shows the baseline acre distributions for the MRGB study based on the model, and Figure 3.15 shows the baseline HU results for the study based on the model.

At baseline, 3,495 acres of Bosque habitat were associated with the model across the entire project area. Reaches 1 and 4 held the largest numbers of forested acres (1,090 and 726 acres, respectively). Reach 3 had the smallest Bosque holdings (502 acres). Overall, the study area generated 1,575 habitat units across all reaches. The baseline HUs within the reaches ranged from 225 units in Reach 2 to 541 units in Reach 1 (Table 3.5). In HEP, the maximum HSI score possible was 1.0. Given the total number of applicable Bosque acres at baseline (*i.e.*, 3,495 acres), the optimal conditions and outputs could be derived by multiplying the quantity and quality to generate the highest possible outcome (3,495 acres x 1.0 HSI = 3,495 units). By comparing the actual situation to this optimum, the E-team could determine at what level the ecosystem was functioning. In this case, the watershed was operating at approximately 45 percent of its potential habitat suitability (*i.e.*, total habitat outputs across all reaches divided by possible outputs). Using this same approach, the E-team considered the operational functionality of the five reaches. The individual performances ranged from 40 percent (Reach 2) to 50 percent in Reach 1. Clearly, opportunities exist for improvements; all the reaches were prime candidates for restoration/rehabilitation activities in terms of the community structure and functionality.

Table 3.5 Baseline tabular HSI results for the Bosque community.

Reach Name	HSI Model Component	Life Requisite Suitability Index (LRSI)	Habitat Suitability Index (HSI)	Applicable Acres	Baseline Habitat Units (HUs)
Reach 1	BIOTA	0.41	0.50	1,090	541
	LANDSCAPE	0.76			
	WATER	0.32			
Reach 2	BIOTA	0.39	0.40	561	225
	LANDSCAPE	0.54			
	WATER	0.28			
Reach 3	BIOTA	0.38	0.41	502	206
	LANDSCAPE	0.59			
	WATER	0.26			
Reach 4	BIOTA	0.41	0.42	726	307
	LANDSCAPE	0.53			
	WATER	0.33			
Reach 5	BIOTA	0.37	0.48	616	296
	LANDSCAPE	0.75			
	WATER	0.33			

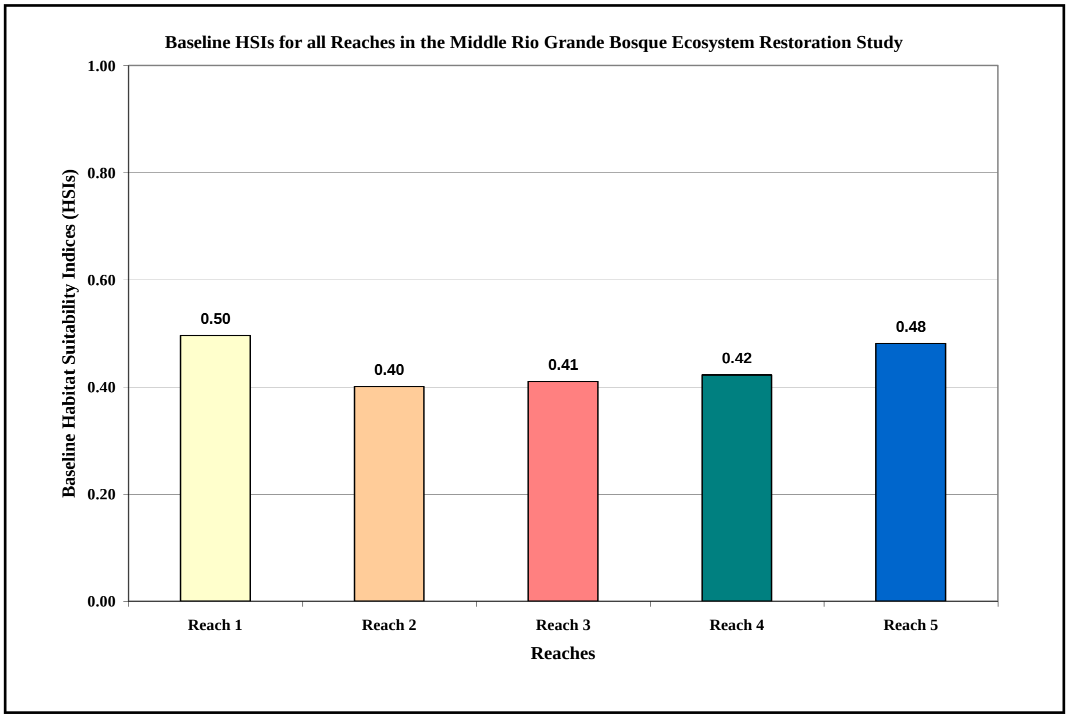


Figure 3.13. Baseline HSI results for the MRGB study.

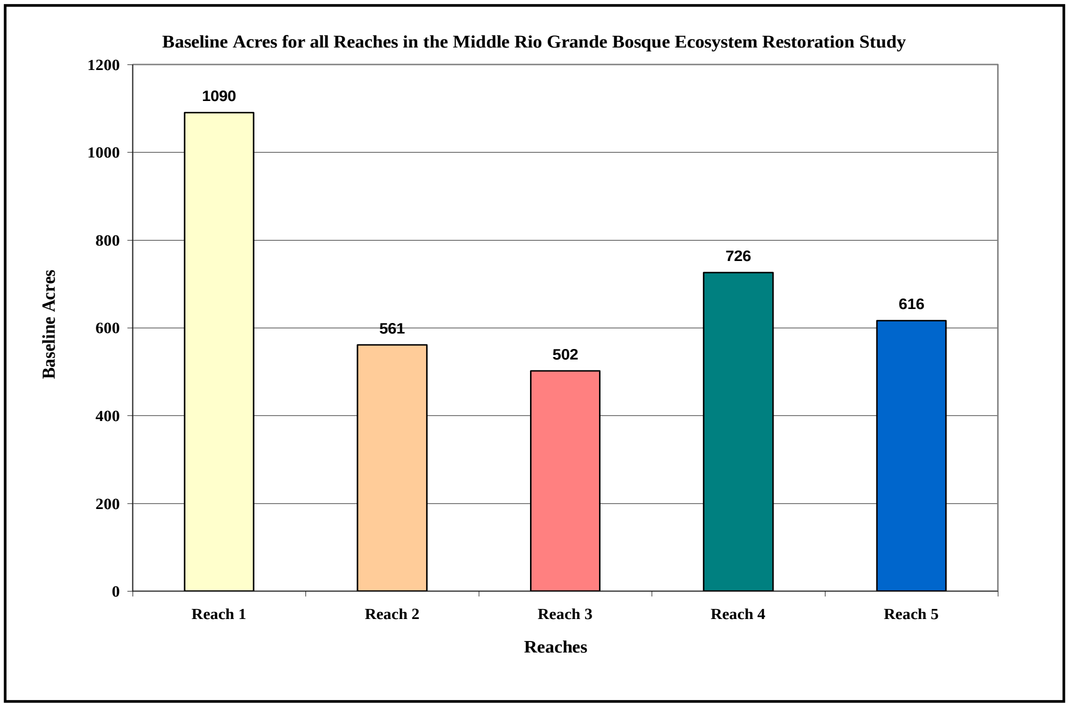


Figure 3.14. Baseline acre distributions for the MRGB study.

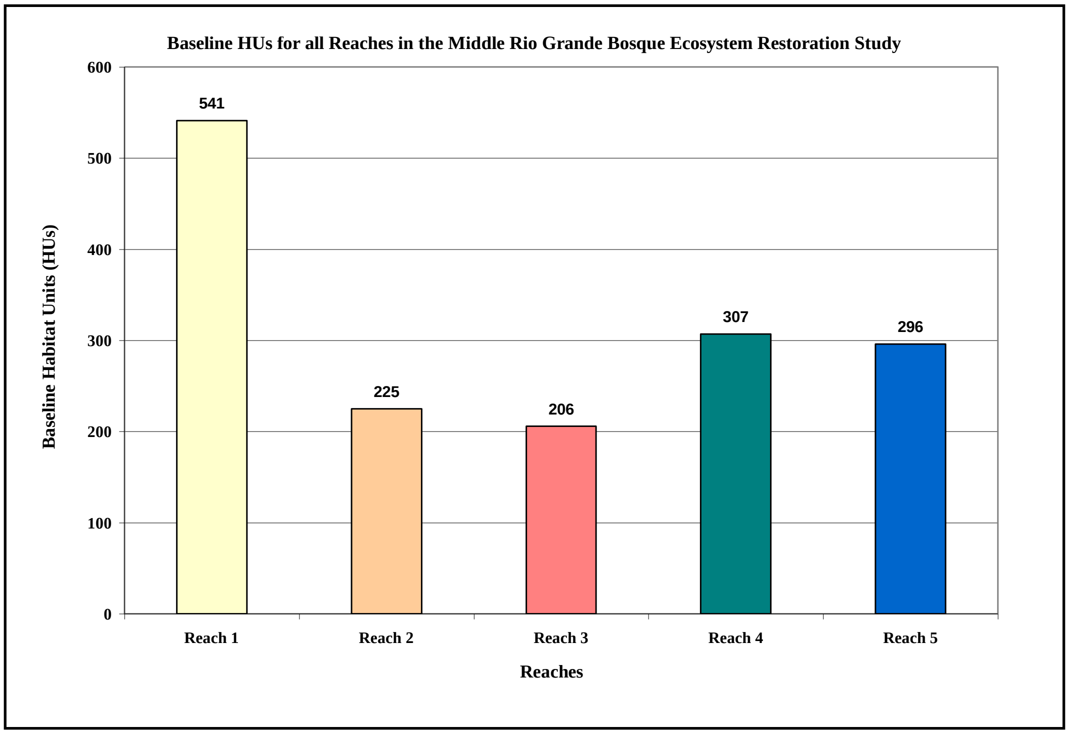


Figure 3.15. Baseline HU results for the MRGB study.

3.17.1 Future Without Project Condition Analysis Results

The general consensus of the E-team is that the future without project conditions of the study area (and the surrounding community) were certain to reflect some losses in ecosystem function (*i.e.*, quality) and presence (*i.e.*, quantity) when faced with the pressures of continued hydrologic alterations (*i.e.*, continued disconnection from the hydrologic pulse perpetuating the cyclical life cycle of the Bosque's cottonwood community), increased population growth (and urban sprawl), increased risks of catastrophic fires, and escalated invasive species encroachment. In essence, the future Bosque was assumed to have a very different character than the current system; the gallery forest was likely to disappear and be replaced with a more shrub-like-savanna character. The E-team addressed these issues in several workshops over the course of the study, and developed trends to capture both the changes in quantity and quality to generate a future without project condition for the study. Numerous assumptions were used to support the projected values, and the assumptions are presented below.

3.17.2 Predicted Future Without Project Condition Acreage Trends (Quantity)

For the E-team, the key to quantifying the future without project conditions for the Bosque was to capture the direct linkages between the hydrology and the vegetative community itself. The first step was to recognize that previous water projects on the Middle Rio Grande had significantly altered the functioning of the system and produced an incised river channel with perched overbanks disconnected from the potential flooding regime that perpetuated the cottonwood forests ability to recruit and persist (USACE 2002, 2003a, 2007, 2008a,b and references therein). The E-team acknowledged that this disconnect was likely to continue in the future without project condition.

The E-team made that assumption that the Bosque's riparian vegetation would remain isolated in the study area and would eventually succeed to a non-native shrub-like Bosque condition dominated by such species as salt cedar, Russian olive, Siberian elm, white mulberry, and tree of heaven. The team further assumed that ongoing vegetation management techniques such as understory clearing and planting of native species would temporarily "reset" patches of Bosque to more natural structural states, but that gradual replacement by non-native species was inevitable. Eventual conversion of the entire Bosque to a non-native ecosystem uninfluenced by hydrologic processes, with fire as the new main disturbance mechanism, would diminish the overall productivity of the system and result in a total loss of the Bosque's current character. A somewhat intricate rule-based cycle was hypothesized by the E-team in which mature cover types would die back, and shrublands and savannas would become more pervasive. In an effort to capture these significant vegetative changes in the MRGB study area, the E-team created spreadsheets to capture acreages changes per cover type on a TY basis. The overall trends are presented in Table 3.6.

Table 3.6 Changes in habitat types for the WOP condition.

	Target Year					
	2005	**2016**	**2021**	**2036**	**2046**	**2066**
Code	**TY0**	**TY1**	**TY6**	**TY21**	**TY31**	**TY51**
TYPE_1	730	642	602	482	402	241
TYPE_2T	1,212	1,048	974	750	601	303
TYPE_2U	169	158	153	138	128	108
TYPE_3	221	189	175	131	102	44
TYPE_4T	311	266	246	185	144	63
TYPE_4U	72	156	194	308	384	537
TYPE_5	579	712	773	954	1,075	1,318
TYPE_6T	79	79	79	79	79	79
TYPE_6U	118	241	297	464	575	799
TYPE_6W	4	4	4	4	4	4
OPENLAND	231	231	231	231	231	231
OPENWATER	1,536	1,536	1,536	1,536	1,536	1,536
ISLANDS	37	37	37	37	37	37
UTILITY	22	22	22	22	22	22
	5,321	**5,321**	**5,321**	**5,321**	**5,321**	**5,321**

At baseline, 5,321 acres were associated with the Bosque models. By 2066 (TY51), 70% of the gallery forest (Types 1, 2U/T, 3, and 4T with 1,884 acres) had converted to early successional habitat types (Types 4U, 5, and 6U). Figure 3.16 shows the successional trend hypothesized by the E-team to correspond with the disconnect between the hydrology and the Bosque under the future without project condition.

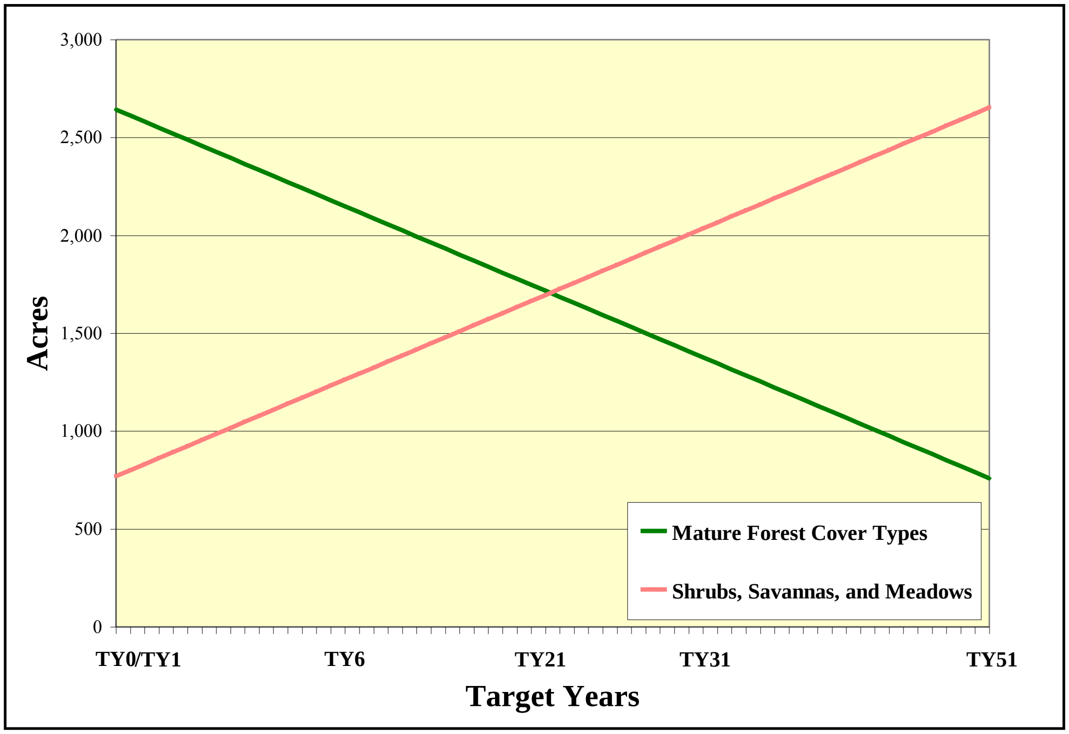


Figure 3.16. Successional trend under the future without project condition.

An existing narrow band of riparian habitat disconnected from the river would continue to exist (Types 1, 2U/T, 3 and 4T with 759 acres remaining), but would decline over time to a significant extent. The loss of terrestrial and wetland communities that serve as habitat for a myriad of wildlife species is significant.

3.17.3 Predicted Without Project Habitat Value Trends (Quality)

Under the current forecasted future without-project condition, indices will drop well below the recoverable limit. The final HSI scores ranged from 0.34 to 0.38. These results indicate that the desirable habitat communities will either cease to exist entirely or remain as fragmented pockets that have lost a great deal of functionality. By 2066 (TY 51), the baseline indices fell well below acceptable standards. Most of the reach scores were well below the 0.5 index midpoint (fair to moderate functionality), which suggests wildlife diversity would fall significantly, and vegetative communities would decline well beyond the level from which they could recover on their own. When reviewed across time, and against one another, these changes are readily apparent. Based on the findings, the final results for the study indicate a relative decline in functionality (and integrity) over the 50-year life of the project. Table 3.7 shows the predicted losses in habitat value for the future without project condition.

Table 3.7 Predicted losses in habitat value for the WOP condition.

Reach	Final WOP HSI	Net Change in HSIs (TY51-TY0)	Baseline HUs	TY 51 HUs	Net Change in HUs (TY51-TY0)	Percent Loss of HUs	AAHUs
Reach 1	0.35	-0.14	541	386	-155	29%	426
Reach 2	0.38	-0.02	225	214	-11	5%	218
Reach 3	0.35	-0.06	206	175	-30	15%	187
Reach 4	0.38	-0.04	307	278	-28	9%	287
Reach 5	0.34	-0.14	296	210	-86	29%	235
Total			1575	1263	-310	19%	1353

Table 3.7 Predicted losses in habitat value for the WOP condition.

3.17.4 WOP Outputs (Quality x Quantity)

When the loss of quality described above was combined with the resultant loss in wetland acreage across the study area, the projected future conditions was relatively low. By 2066 (TY51), 20 percent of the Bosque community's functionality is lost (Table 3.7). Reaches 1 and 5 are likely to incur the highest losses (29% each). Reaches 2, 3, and 4 will incur some loss, but these reaches are already relatively non-productive. Figure 3.17 shows the Bosque Community HSI over the projected 50-year period, and Figure 3.18 shows the Bosque Community Hus over the same period.

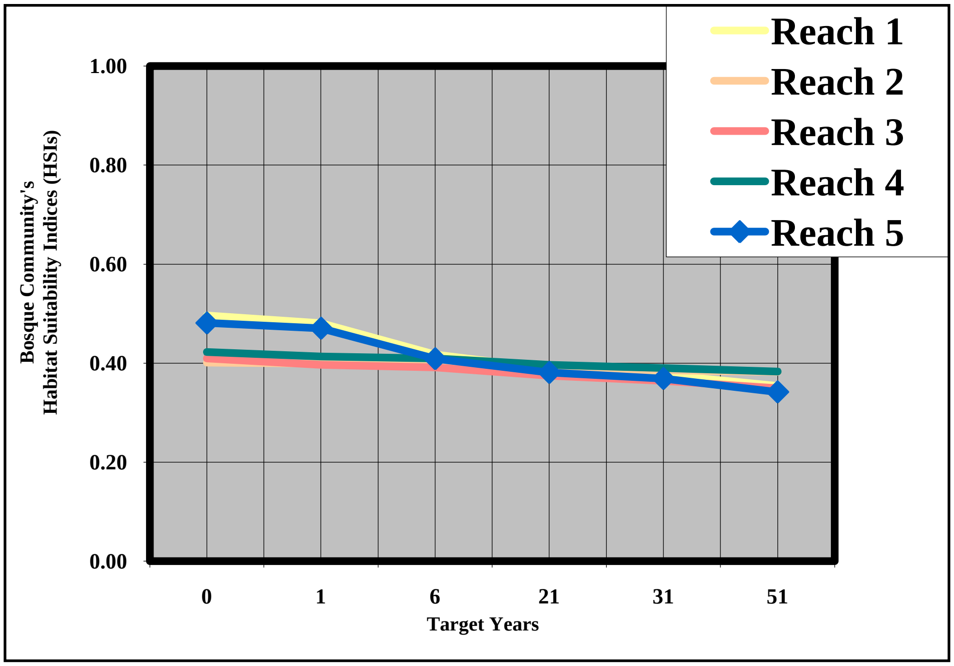


Figure 3.17. Bosque Community's Habitat Suitability Indices.

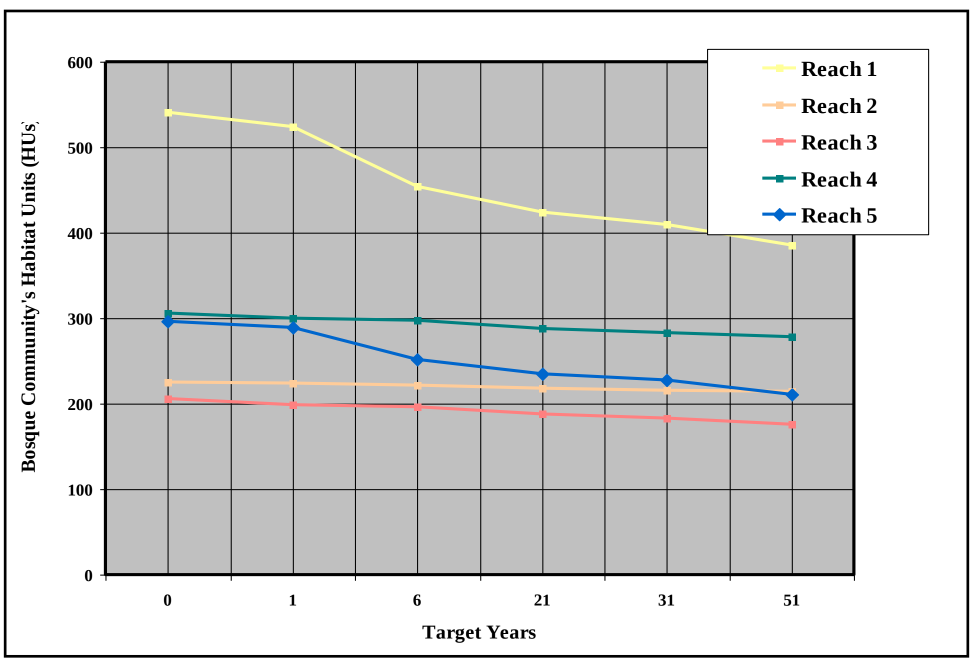


Figure 3.18. Bosque Community's Habitat Units.

SECTION 4 – PLAN FORMULATION AND EVALUATION PROCESS

The planning process for this study has been driven by the overall objective of developing an ecosystem restoration plan that most reasonably maximizes net ecosystem restoration benefits by producing the maximum quantity of habitat or the most improvement in habitat value for the cost. The first phase of this process was to establish the magnitude and extent of the problems. The next phase is to develop and evaluate an array of alternative solutions to meet the existing and long-range future needs of the area.

4.1 Alternative Development Rationale

Alternatives are formulated to address a comprehensive Federal project for ecosystem restoration in order to:

- Ensure that a wide variety of possible solutions were considered that incorporate public and stakeholder concerns, the highest cost benefit output feasible, and the least negative impact on the human environment;
- Provide decision-makers, both Federal and local, with information that might be used to help determine the balance between construction costs and social issues and concerns;
- Comply with NEPA and other environmental laws and regulations;
- Restore a diversity of riparian and associated floodplain habitats to a more natural state;
- Provide an acceptable means of capturing storm water using existing outfall structures to benefit restored ecosystems and habitat areas;
- Maintain or enhance existing conveyance of peak discharges and ensure that project implementation would not increase flood flows or worsen flooding conditions downstream in existing developed areas;
- Produce NER benefits while positively contributing to the NED Account, the Regional Economic Development Account and the Other Social Effects Account;
- Provide a framework for responding to future urban development in the floodplain consistent with Executive Order 11988; and
- Blend existing and proposed improvements where possible to take advantage of local improvements and to be consistent with future master planning of the local community.

The team also implemented planning strategies according to the Corps Campaign Plan. Strategic and policy documents such as the National Security Strategy, the National Defense Strategy, the National Military Strategy, the Army Campaign Plan, the Army Strategy for the Environment, Corps program areas strategic plans, and Corps priorities provide the strategic framework for the Corps to implement its global mission set. These missions include water resources management nationwide, engineering research and development, design, construction management, and other engineering and real estate services worldwide for the Army and Air Force, the Defense and State Departments, the Federal Emergency Management Agency, and many other international, national, state, and local partners and stakeholders.

Corps Campaign Plan goals and objectives are derived, in part, from the Commander's Intent, the Army Campaign Plan, and the Office of Management and Budget. The four goals and associated objectives build on prior strategic planning efforts. The successful achievement of the goals and objectives contained in this Campaign Plan are dependent on actions implemented by the entire Corps team. The MRGB project falls within the water resources management mission and provides for the following objectives outlined in the Corps Campaign Plan:

- **Deliver integrated, sustainable, water resources solutions.**
  The Bosque Restoration Project would provide a holistic, landscape-scale solution that compliments existing or ongoing restoration projects being implemented by other entities. The measures proposed have been formulated with a primary goal of restoring essential function to the Bosque and, therefore, are sustainable within project constraints.

- **Implement collaborative approaches to effectively solve water resource problems.**
  Subject matter experts and interested parties from three Federal and three state agencies, as well as two Tribes, universities, and non-governmental organizations and the public participated in the identification of problems and opportunities as well as the formulation of project alternatives for the Bosque restoration. The restoration project builds on previous efforts to map out problems and solutions in the Middle Rio Grande.

- **Deliver reliable infrastructure using a risk-informed asset management strategy.**
  Identification of uncertainties early in the study provided a framework on which restoration features and measures were formulated to minimize risk. These features and measures would provide benefits despite fluctuations in water deliveries, normal climatic events, and future anthropogenic factors.

- **Develop and apply innovative approaches to delivering quality infrastructure.**
  Several methods of habitat improvements have been used by the Corps and other agencies within the Middle Rio Grande. The Bosque restoration project combines and builds on these methods to form a more holistic approach to restoring essential ecosystem function that provides for wildlife.

The MRGB feasibility study process involves successive iterations of alternative solutions to the defined ecosystem degradation problems. These solutions are based upon the study objectives and constraints and address problems and opportunities that have been previously defined. The project objectives are reiterated here:

- Improve habitat quality and increase the amount of native Bosque communities (expressed in Average Annual Habitat Units) to a sustainable level.
- Reestablish fluvial processes in the Bosque to a more natural condition. Areas of scour or amounts of sediment mobilization through the Bosque would indicate improvements.
- Restore hydraulic processes between the Bosque and the river characterized by a more natural overbank inundation pattern and higher riparian groundwater levels.
- Reduce the risk of catastrophic fires expressed in either number of fires or area affected.
- Protect, extend, and improve areas of potential habitat for listed species within the Bosque.
- Provide interpretive features in recreational use areas within the study area.
- Integrate recreational features throughout the study area that are compatible with ecosystem integrity.

Restoration efforts will be implemented over a five-year period and provide benefits through the period of analysis of 50 years and beyond. Although positioning of each feature or measure area is dependent on the specific conditions present at a particular location, restoration measures could be dispersed throughout the study area. Interpretive and recreation features would be aligned with existing access points and trails. Constructed features that effect fluvial and hydraulic processes as well as fire risk and recreation could realize benefits immediately or within the first year after implementation. Restoration features that involve manipulation of existing habitat might realize some benefits immediately after implementation; however, features that include establishing plants could take five to 20 years to realize full benefits.

As part of Federal guidelines for water resources projects, the general feasibility criteria that are required to be met are as follows:

- *Completeness* – Does the plan include all necessary parts and actions to produce the desired results?
- *Effectiveness* – Does the alternative substantially meet the objectives? How does it measure up to the constraints?
- *Efficiency* – Does the plan maximize net NER benefits? (NER benefits must exceed the economic costs)
- *Acceptability* – Is the plan acceptable and compatible with laws and policies?

The general approach to accomplish these criteria is to formulate restoration alternatives that restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition. The restored Bosque ecosystem would mimic historic, natural conditions that exhibited overbank flooding, gently sloping banks with backwater areas, and off-channel wetlands and facilitated water infiltration, provided for native plant regeneration and nutrient cycling in the Bosque, and reconnected the river channel to the floodplain. Existing vegetation communities would be enhanced with supplemental plantings, invasive species control, and creation of wetland habitats. Near shore and riparian aquatic habitats would be restored. With the restoration, habitat structure would be improved and would promote an increase in the number and diversity of wildlife species in the area. This approach to restoration focuses on restoration of Bosque community functions and processes via the rehabilitation of hydrologic and morphological processes and vegetation structure. This redirects future trends to a more natural, sustainable system that will uphold or increase in habitat value.

The planning framework requires the systematic preparation and evaluation of alternative ways of addressing concerns, problems, and opportunities. The criteria and broad planning objectives previously identified form the basis for subsequent plan formulation, screening, and ultimately plan selection. During the formulation process, other projects that have been or are being constructed by the Corps and/or other agencies were considered; therefore, measures were not considered in these locations. Figure 4.1 displays projects, wells, and research and monitoring sites previously constructed and installed in Reach 3. Planning for this project also focused on benefiting project features from various projects where possible.

4.2 Formulation of Restoration Features, Measures, and Alternative Plans

The study team implemented a proactive strategy to formulate ecosystem restoration plans specifically tailored to focus on restorative initiatives at a landscape level on a system-wide basis. The PDT identified a set of alternative restoration plans that addressed the planning goals and objectives of the study. Each alternative plan is made up of smaller components called features and measures. Restoration features, the smallest components of the alternative plans, were developed to provide a specific element or restorative function, such as creating a high-flow side channel or planting native riparian trees. An initial screening eliminated unsuitable features that exceeded the constraints of the project or were deemed impractical. Features were then combined based on position in the landscape, dependencies, and combinability to form restoration measures. Measures are a combination of several compatible features at a specific location that achieves functional and sustainable restoration at that site. At any given location, more than one measure might be possible, but they must be mutually exclusive. For instance, a measure that includes creation of a wetland could not be implemented at the same place as a measure that includes planting a new stand of cottonwood trees. Alternative plans were formulated from various combinations of management measures, added together, eliminated as necessary, rescaled, and otherwise modified so that the resultant suite of formulated alternative plans addressed the planning goals and objectives enumerated earlier. Finally, the PDT evaluated the plans for cost effectiveness, completeness, and acceptability.

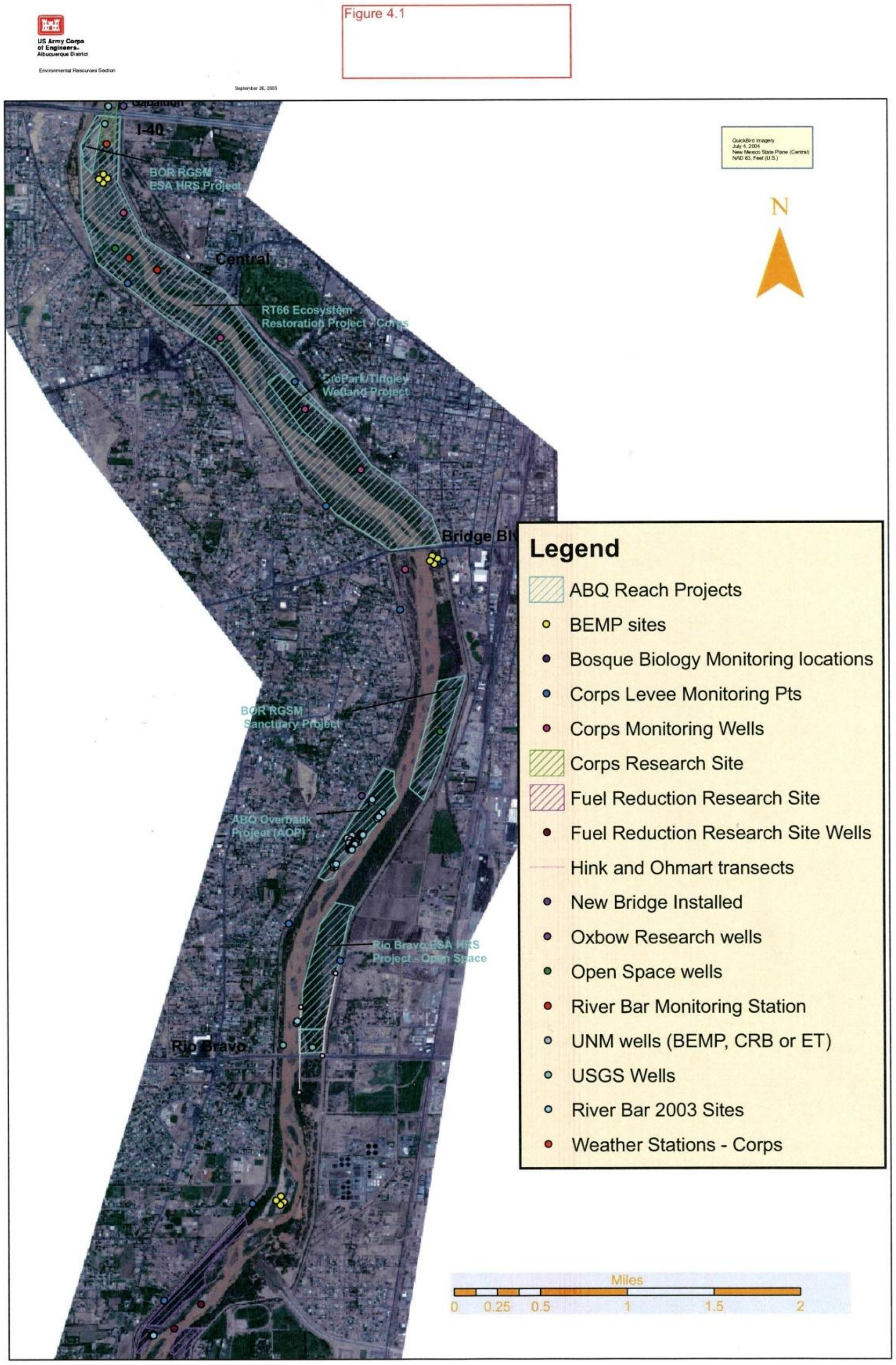


Figure 4.1. Map of Other Projects in Reach 3.

4.2.1 Initial Screening of Restoration Features

Several features were evaluated early by the E-team and removed from further consideration for being impractical or violating the constraints established early in the formulation process. These features include:

- Install grade reduction features or weirs in the river channel to raise the water elevation to flood overbank areas. This feature was discounted because weirs would interrupt the sediment movement through the system and might reduce the capacity of the floodway.

- Manipulate water releases from upstream dams that flood overbank areas and create scour. Under the Upper Rio Grande Compact and as a condition of the biological opinion for water operations in the MRG, releases have been maximized to benefit the silvery minnow without compromising flood protection downstream.

- Creation of wetlands using reclaimed or groundwater. Similar projects, including the Albuquerque Biological Park Wetland Restoration, have successfully used groundwater or reclaimed water for this purpose. Although it is possible to create and maintain high value habitat this way, irrigation water and even reclaimed water falls under allocation requirements of the water compact. Pumping of water from deep aquifers requires a higher level of maintenance and operation to keep the water flowing.

- Artificially maintain habitat with irrigation. Similar to use of artificial means to maintain wetlands, perpetual irrigation to maintain riparian plant communities is requires reallocation of water and a higher degree of maintenance to irrigation infrastructure as well as the commitment of resources to operate it.

A key component to sustainability of restoration of the Bosque plant communities is to allow water to flow out of the channel and into the overbank riparian areas. As described in Section 2, perched bank and channelization of the river has eliminated overbank flows even with the maximum operational releases from upstream dams. The first two features mentioned above attempt to raise the water surface until it spills out of the channel into the overbank areas. Water restrictions and floodway capacity constraints make this extremely difficult. Therefore, it follows that manipulation of the perched bank is needed to allow water to flow into overbank areas. Features that perform this function were carried forward in the formulation process.

4.2.2 Final Set of Features

Other features developed during formulation were validated by comparing them to the list of Problems, Opportunities, and Objectives presented in Section 1. Table 4.1 presents a matrix of these criteria and the features that would entirely or partially address the problems and meet each objective. Because no single feature will meet all of the objectives simultaneously, the features do not meet the criteria of being effective unless combined with other features.

Table 4.1 Crosswalk of planning concerns, problems, opportunities, objectives and management measures.

Problem	Opportunity	Planning Objective	Restoration Feature
Lack of scour, sediment deposition and lack of inundation of the Bosque has curtailed seedling recruitment of native tree species. This has resulted in a skewed age structure in the remaining cottonwood stands, and resulted in significant build-up of leaf litter and dead and down wood.	Recreate overbank flow to restore the essential functions of forest renewal and nutrient cycling.	• Reestablish fluvial processes in the Bosque to a more natural condition. • Restore hydraulic Processes between the Bosque and the river to a more natural condition. • Protect, extend and enhance areas of potential habitat for listed species within the Bosque.	High-flow side channels, Bank Destabilization
Due to confinement and deepening of the river channel, the low, sloping bank and shallow near bank habitat no longer exists to provide a wet soil environment and shallow slackwater at the water-land interface.	Provide sloping riverbank habitat.	• Reestablish fluvial processes in the Bosque to a more natural condition. • Protect, extend and enhance areas of potential habitat for listed species within the Bosque.	Bank Destabilization
Coordinate with other agencies and Projects in the study area.	Promote communication and cooperation among stakeholders while integrating various project goals.	• Integrate project implementation and monitoring with other, ongoing restoration and research efforts in the Bosque.	Organize stakeholder meetings and lines of communication, solicit stakeholder input and provide updated project status during study.
Lowering of the water table has curtailed seedling recruitment of native tree species and increased the mortality rate of existing cottonwoods and willows.	Establish new growth forest where root zones reach the shallow water table.	• Improve habitat quality and increase the amount of native Bosque communities • Restore hydraulic Processes between the Bosque and the river to a more natural condition.	Excavate swales Bank Destabilization High-Flow Channels.

Problem	Opportunity	Planning Objective	Restoration Feature
Loss of wetlands, braided channels and backwaters.	Restore and create new wetland habitat and backwaters	• Improve habitat quality and increase the amount of native Bosque communities Reestablish fluvial processes in the Bosque to a more natural condition. • Restore hydraulic Processes between the Bosque and the river to a more natural condition. • Protect, extend and enhance areas of potential habitat for listed species within the Bosque.	High-flow side channels, Wetland Creation
The cumulative impact of the loss of inundation, confinement of the channel, the lower water table, cottonwood mortality and urbanization has led to the replacement of the mosaic of native woodlands and wetlands in many parts of the study area by dense stands of non-native salt cedar, Russian olive, Siberian elm, tree of heaven and white mulberry trees.	Remove non-native species and revegetate with various native plant communities.	• Improve habitat quality and increase the amount of native Bosque communities	Remove Non-Native Plants Reestablish
The altered vegetation structure of the Bosque has increased the potential for a catastrophic fire in the Bosque. The brushy growth form of non-native trees creates a hazardous fuel condition. The Brush and jetty jacks can also make fighting a fire difficult and potentially dangerous.	Remove hazardous fuels and obstacles to emergency access.	• Reduce the risk of catastrophic fires in the Bosque.	Remove jetty jacks and live and dead vegetation considered hazardous. Replace with non-hazardous plants to create fire breaks such as open habitat types.

Problem	Opportunity	Planning Objective	Management Measure
The change from a mosaic of native plant communities of various structures and ages to increasingly large stands of non-native forest has affected the overall value of aquatic and terrestrial wildlife habitat provided by the Bosque.	Rehabilitate the existing Bosque into a dynamic mosaic of native vegetation patches of various ages, structure types and constituent species.	• Improve habitat quality and increase the amount of native Bosque communities	Establish select native plants where appropriate to provide interpretive components to existing habitat and remove non-native stands and revegetate to provide uncommon interpretive or new age class of native vegetation.
Perception of unfair distribution of open space resources.	Ensure Fair Distribution of Resources	• Provide educational or interpretive features. • Integrate recreational features that are compatible with ecosystem integrity.	Connect existing and create new trails throughout project area. Create periodic access points in areas lacking them currently.
Lack of awareness of Bosque values and connection to cultural uses.	Make use of highly visible and accessible natural area as an educational resource to instill pride and ownership of the restoration.	• Provide educational or interpretive features. • Integrate recreational features that are compatible with ecosystem integrity. • Provide educational or interpretive features. • Integrate recreational features that are compatible with ecosystem integrity.	Connect existing and create new trails throughout project area, provide interpretive amenities and provide ADA compliant facilities. Install interpretive/educational signage, wildlife viewing blinds. Engage public participation during study and implementation.

Problem	Opportunity	Planning Objective	Management Measure
Presence of informal trails, trash, accidental fires and high-impact recreational uses.	Rehabilitate disturbed areas and establish uncommon habitat types.	• Improve habitat quality and increase the amount of native Bosque communities. • Reduce the risk of catastrophic fires in the Bosque. • Provide educational or interpretive features. • Integrate recreational features that are compatible with ecosystem integrity.	Establish formal trail system. Promote education within the community about Bosque values.

Following the screening process, the E-team identified a refined set of features that could be used to restore large areas of the Bosque. Table 4.2 presents features considered in the study. These features were divided into three broad categories: water features, vegetative, and physical removal.

Table 4.2 Proposed features and activities considered for ecosystem restoration.

Category	Features / Activities	Details
Water Features	Wetland Restoration	Absent a meandering channel in which abandoned flow paths and oxbows left off-channel depressions that formed wetlands. Wetlands would be established or restored at appropriate locations to create a diverse and high value habitat. Storm water outfalls were numerous throughout the Bosque in the Albuquerque area and would be modified to function as wetlands, increasing diversity of habitat and providing some water quality treatment. There was an existing oxbow wetland that would also be restored to function more naturally. Restoration of wetland habitat was critical to ensuring that the dynamic mosaic of the Bosque ecosystem's structure and function was perpetuated.
	Bank Destabilization	To offset channelization , banks of the Rio Grande would be shaved to create a less incised channel and shelves, or destabilized to create sediment sources. Such areas would increase the diversity of both fringe riparian and aquatic habitat.
	High-Flow Channels	Excavation of smaller, high-flow channels to convey waters through the Bosque during typical spring flows would occur. This would mimic the historic hydrograph and recreate connections between the Bosque and the Rio Grande.
	Willow Swales	A number of areas had also been identified for installation of moist soil willow swales that would serve a dual purpose of reestablishing connectivity between the Bosque and the river, as well as providing shrub, mid-canopy habitat - an integral piece of the Bosque ecosystem mosaic.
Vegetative	Bosque Forest (Mosaic) Restoration	A primary element of the restoration would be the planting and reestablishment of Bosque communities. Areas would be cleared of exotic species and replanted with native species of the cottonwood forest, willow thicket, and open grasslands/savannahs. Especially important would be the reestablishment of the mid-canopy vegetation to ensure that the dynamic mosaic of the Bosque ecosystem was restored.

Category	Features / Activities	Details
Vegetative	Exotic Species Removal	A key element in the restoration of the Bosque is the removal of exotic plant species. Salt cedar, Siberian elm, tree of heaven and Russian olive were foreign exotic species that invaded parts of the Bosque, forcing out key native species of willow and cottonwood. In addition, removal of exotics would potentially allow the water table to return to higher levels in this area of the Rio Grande Bosque. Removal of exotics would enhance the potential to reestablish native species over the long term. Exotic removal was considered a precondition for the restoration of natural processes in the Bosque. Removal of exotics would also help decrease fuel loads because they comprise most of the understory in denser areas of the Bosque.
	Fuel Load Reduction	Another key element to enhancing the health of the Bosque would be fuel load reduction. Fuel load reduction entailed removing dead and down wood and excess leaf litter within the cottonwood gallery forest. When the flood disturbance regime was still functional, much of this material would have been removed by periodic flooding. Much of this material represented a fire hazard, and in many instances encroached on recreation systems and limited the surveillance necessary for security within the Bosque. Fuel load removal would advance a number of objectives of the study.
Physical Removal	Jetty Jack Removal	Another important measure proposed in alternative development was the removal of jetty jacks. Jetty jacks were originally used to stabilize banks and control floods within the Middle Rio Grande floodplain. Jetty jacks would be removed wherever possible and left only where they were critical to levee stabilization.

4.3 Detailed Description of Proposed Features

4.3.1 Jetty Jack Removal

The removal of non-essential jetty jacks would be necessary to allow the removal of non-native vegetation and the creation of additional restorative features (*i.e.*, high-flow channels). Removal of non-essential jetty jacks would also provide access for fire or emergency crews, enhance the aesthetic qualities of the Bosque, and increase safety to potential visitors.

Within the study area, all jetty jacks were assessed by the Corps, Reclamation, and the MRGCD. Both non-essential jetty jacks and jetty jacks that continue to provide necessary stabilization functions were identified and mapped. The three agencies agreed to the strategy of identifying non-essential jetty jacks (Figure 4.2), and the agencies agreed that jetty jacks within these areas can be removed by any of these agencies and/or other local stakeholders as part of restoration projects after receiving approval from the Corps, MRGCD, and Reclamation. Any proposed alternatives that include areas where jetty jacks cannot be removed without additional protection would be evaluated to determine what type of protection would be needed in order to remove the jetty jacks as part of the study.

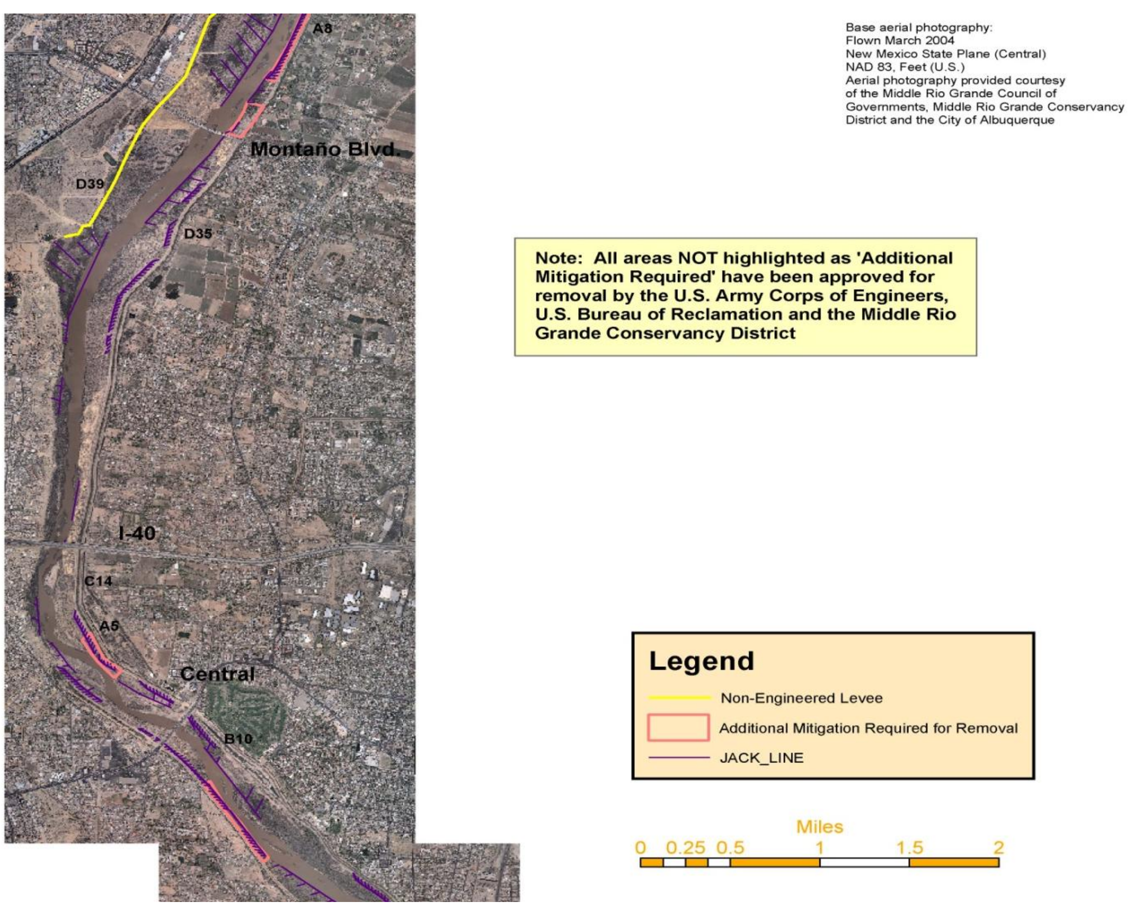


Figure 4.2. Map showing location of non-essential Jetty Jacks.

4.3.2 Exotic Species Removal and Fuel Load Reduction

Non-native plant removal would facilitate restoration efforts by removing the chief competition to native trees, shrubs, forbs, and grasses. Non-native plant removal would also reduce the fire hazard, enhance aesthetic and recreational aspects of the Bosque, and improve security. In many areas, continued maintenance and repeated treatment for stump sprouting and removal of juvenile volunteer non-natives would be necessary. This is provided for under the operations and maintenance portion of the project. Both the removal of jetty jacks (where needed) and the thinning of non-native vegetation and the reduction of fuel loads would have to occur prior to initiating the remaining features discussed below.

4.3.3 Water Features

Establishment of healthy stands of cottonwoods and other native species requires water, preferably in the form of flooding for brief periods of time, until the roots are mature enough to reach essential fluids and nutrients. The purpose of the water-related features described in this section is to attempt to mimic natural periods of inundation in specific areas under certain conditions. This would create a hospitable environment for propagation of native vegetation and produce wetted areas that would increase the diversity of habitat types.

A number of water features were considered and will be discussed. The features include wetland restoration/construction, bank destabilization, construction of high-flow channels, and construction of willow swales. To maintain water delivery requirements and not induce losses of water to evaporation or infiltration, the Interstate Stream Commission requires water related measures (wetland, high-flow channel) to be implemented within 300 feet of the existing channel.

4.3.3.1 Wetland Restoration/Construction

Wetlands consist of marshes, wet meadows, and seasonal ponds that typically support hydrophytic plants such as cattails, sedges, and rushes. Wet meadows were the most extensive habitat type in Middle Rio Grande valley prior to the construction of the MRGCD drains and ditches. From 1918 to present, wetland-associated habitats have undergone a 93% reduction (Hink and Ohmart 1984, Scurlock 1998). Wetlands are an integral component of the Bosque ecosystem, not only increasing diversity but also enhancing the value of surrounding plant communities for wildlife. Wetlands have experienced the greatest historical decline of any floodplain plant community. Among the greatest needs of the riparian ecosystem are the preservation of existing wetlands and expansion or creation of additional wetlands (Crawford *et al.* 1993). Wetland restoration/construction features in the form of open water wetlands, outfall wetlands and marsh wetlands were considered in all reaches of the study area.

An open water wetland could be something similar to that constructed at the Albuquerque Biological Park Wetland (Figure 4.3). Wetlands of this type provide open water habitat for migrating and local waterfowl and aquatic habitat for numerous species.

Figure 4.3. Albuquerque Biological Park Wetlands prior to wetland plant establishment.

Outfall wetlands could be constructed and enhanced in areas where stormwater outfalls exist but currently do not create or use the potential to create habitat. An example of an existing outfall wetland is the Osage/LaMedia storm drain outfall at the northwest corner of Central Avenue and the river (Figure 4.4). Simple modifications to existing outfalls could provide several benefits. The conceptual idea is to connect the outfall through the Bosque and to the river, providing wetland and/or moist soil habitat. Each area can be designed based depending on the outfall size.

Figure 4.4. Osage/La Media Storm Drain Outfall.

The concept is to divert the low flows from the outfall into a reconstructed channel. The majority of the pollutants and trash from these systems is generally contained in the „first flush,' that is, the storm water associated with the first 0.25 inches of runoff. The conceptual design includes a sediment pond to collect the bulk of the sediment and pollutants exiting the system during these low flows and a series of shelves within the channel to help address the issues discussed above. The channel would be planted with wetland plants to promote biological activity. Screening devices, either directly on the outlet of the pipes, or a „dam' within the sedimentation pond, could be designed to remove the trash and help deposit the sediment. The configuration presented in Figure 4.4 allows for energy dissipation associated with higher flows. Extremely large flows would quickly run through the channel habitat system. Some erosion protection could be included on a site-specific basis if needed for the existing flow paths. These measures would serve to replicate some of the benefits of historical wetlands by removing the contaminants through both biological and hydraulic means (settling) and providing diverse habitat. The channel would function as backwater habitat. When flows are low, the shelf' adjacent to the river would contain water. As flows increase, water would move from the river back into the channel and create wet habitat.

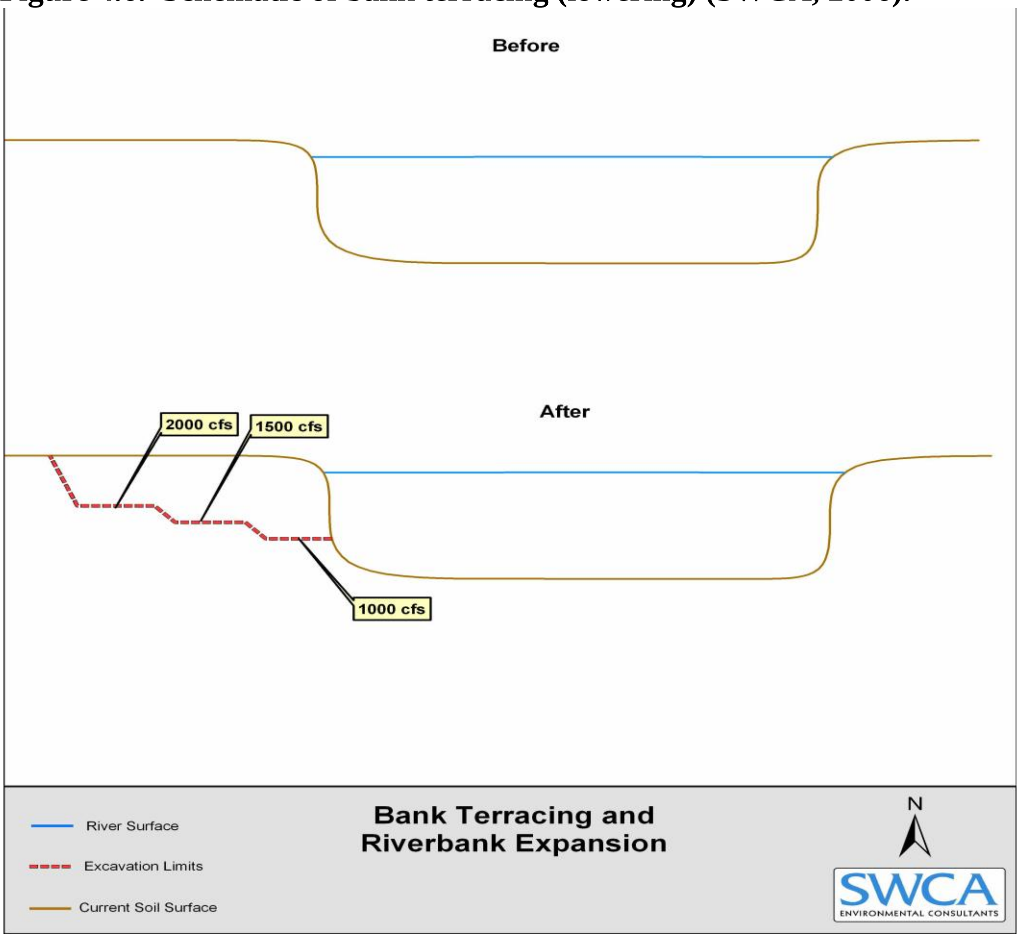
A marsh wetland (or wet meadow) would have fluctuating water levels and various vegetative species. These areas can be created by lowering the ground level and/or letting surface water from a wetland area flow into a riparian area. Marshy or moist soil habitat is created, similar to that of the wet meadow at the Albuquerque Biological Park Wetland (Figure 4.5).

Figure 4.5. Albuquerque Biological Park Wetlands Wet Meadow, May 2007.

4.3.3.2 Bank Destabilization

Bank destabilization or bank lowering involves the removal of vegetation and excavation of soils adjacent to the main channel to enhance the potential for overbank flooding (Tetra Tech 2004). This technique, demonstrated in Figure 4.6, has been used in various locations of the Middle Rio Grande, primarily for creation of potential habitat for the Rio Grande silvery minnow by the MRGESCP. The E-team analyzed various locations for bank destabilization potential.

Figure 4.6. Schematic of bank terracing (lowering) (SWCA, 2006).



4.3.3.3 High-Flow Channels

Under historic flood flow regimes, high-flow channels once represented an integral part of the river form and function. Evidence of former channels is present in many locations within the study area. The objective of this measure is to re-establish the connections between the river and the Bosque by creating a situation in which side channels would become inundated at flows between 2,500 cfs to 3,500 cfs. Actions necessary for this feature typically include dredging the sediment from the upstream and downstream portions of the remnant high-flow channels in order to re-establish the Bosque-river connection, clearing out debris and non-native plants, and revegetating with native plants to increase the habitat quality within the Bosque. High-flow channels would deliver much-needed water to Bosque vegetation and increase potential water-based habitats for animals. The Rio Grande Nature Center Habitat Restoration Project is an example of a recent high-flow channel feature (Figure 4.7).

Figure 4.7. Photo of the south end of the Rio Grande Nature Center high-flow channel exiting to the river.

Figure 4.8 is a schematic and provides a conceptual cross-section design of a typical high-flow channel. The figure also provides some generic information about the revegetation plan for these measures. Appropriate sediment removal regimes, crossings necessary for fire fighting access, and restricted access issues would need to be determined during design development.

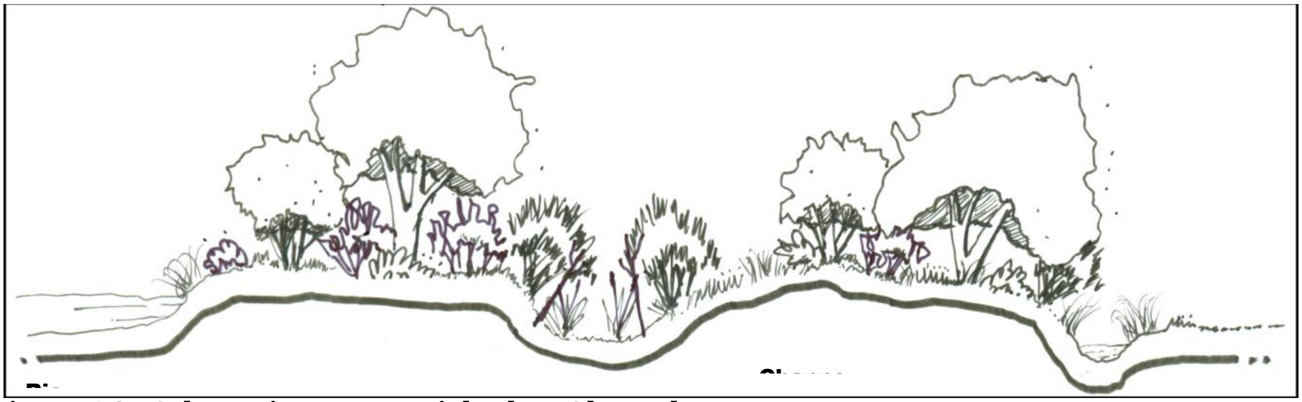


Figure 4.8. Schematic concept High Flow Channel

4.3.4 Swales

The willow swale feature entails optimizing the depressions created by removal of non-native vegetation, dumped debris, and jetty jacks to provide micro-environments to contain native plants that can thrive due to the decreased distance to the water table and moist soils. In certain areas of the Bosque, the depth-to-water table is minimal, and even slight excavations expose water. Willow swales also help create vegetative habitat where establishment of native plants or seed would be challenging due to soil type. Sample plots have illustrated that standing water can occur when the non-native phreatophytes are removed. These excavated areas could be planted with riparian shrub, wetland, or mesophytic plants. Depending upon the location, there could be a series of willow swales that become progressively drier with increasing distance from the river or water table. Once established, native plants could thrive in these depressions. The established swales at the Zoo Burn area, Interstate 40, and the Brown Burn are examples of this strategy Figure 4.9 displays the Brown Burn. This feature would create wet meadow and shrub habitat.

Figure 4.9. Swale at the Brown Burn, South of the Study Area.

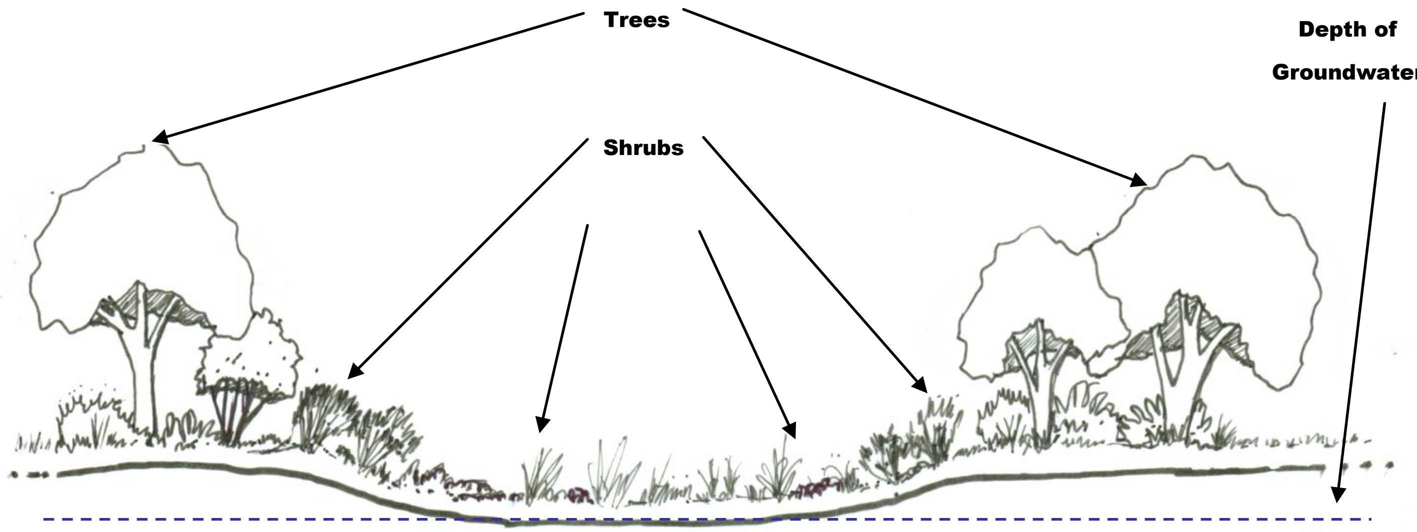


Figure 4.10. Schematic concept for Swale.

Figure 4.10 is a schematic design for a swale including a conceptual cross-section and provides generic information about the revegetation plan for these measures. A series of depressions, approximately one half acre in size, would be created within a five- to 10-acre area.
The number of depressions within each swale would be determined by site-specific conditions.

4.3.5 Riparian Gallery Forest Mosaic Restoration

Planting strategies to target a riparian gallery forest mosaic would include the following:

- **Seeding** with native grasses and forbs, such as Indian rice grass (*Oryzopsis hymenoides*), galleta grass (*Hilaria jamesii*), side oats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), sand dropseed (*Sporobolus cryptandrus*), and sunflower (*Helianthus annuus*) and in wetter areas, yerba mansa (*Anemopsis californicus*), emory sedge (*Carex emoryi*), and salt grass (*Distichlis stricta*). Seeding involves sowing seed via methods such as broadcasting, crimp and drill, or hydro-mulching. Other than the gel in the hydro mulch, no irrigation would be applied. Timing of seeding would be critical to the establishment of the vegetative cover. Late summer is usually the optimum time.

- **Bare root container or plug planting** with native shrubs, such as peach leaf willow (*Salix amygdaloides*), New Mexico olive (*Forestiera neomexicana*), four wing saltbush (*Atriplex canescens*), chamisa (*Chrysothamnus nauseosus*), false indigo (*Amorpha fruticosa*), golden currant (*Ribes aureum*), three leaf sumac, woodbine, and in wetter areas, coyote willow (*Salix exigua*), black willow (*Salix nigra* var. *gooddingii*), and seep willow (*Baccharis salicifolia*) would be an important strategy for establishing woody plants. Bare-root planting refers to planting a plant directly in the ground without a rootball. Container planting refers to planting small plants in small containers, and plug planting refers to planting small seedlings with soil or growth medium. The juvenile plants would be planted as bare root with hydro gel (a.k.a. Dri-Water™). Hydro-gel refers to containers filled with water-absorbing gel particles that absorb water and then slowly release it to the plants. Containers of gel are placed around the root zone of the plant at the time of planting and watered well. Replacements or refills of the containers might be necessary once or twice per growing season during the time of establishment (generally two years). Coyote willows can also be planted directly in wet areas as live sticks. Shrubs would be planted at various densities depending on what is currently at the location. If no native understory vegetation exists at a location, then shrub planting density would be higher (500 stems per acre or more). If existing native vegetation is growing in the area, then a lower density of native shrubs would be installed (100 to 500 stems per acre as needed).

- **Pole planting** of native trees, such as the Rio Grande cottonwood (*Populus fremontii* var. *wislizenii*), black willow (*Salix nigra* var. *gooddingii*), and peach leaf willow (*Salix amygdaloides*). Pole planting is the technique most frequently used in the restoration of riparian areas. Many of the pilot projects in the Bosque have used pole planting, and according to AOSD, they have a 90-percent success rate (Tony Barron, Pers. comm., 2002). Branches of cottonwoods and willows, 10 feet to 15 feet in length, are slipped into holes that have been augered through the soil to the water table. Little maintenance is required beyond taking precautions to protect the young trees from beavers. Trees would be planted at a fairly low density because cottonwoods exist throughout the study area. The trees would be supplemented in some areas as needed but at a very low density (10 to 50 stem per acre). Willow trees are lacking in some areas of the study area and would be planted at a higher density in those areas (25 to 75 stems per acre).

Planting strategies would not include planting larger plants, such as balled and burlapped or container trees, because they would not be successful in the study area without significant irrigation. Restoration projects occasionally include temporary irrigation, and it would be physically possible to flood irrigate portions of the Bosque from the drain if water rights were allocated for that purpose. However, the restoration would not include irrigation due to the cost and the lack of availability of water and dedicated water rights. Planting potted plants was also ruled out as a strategy because of cost (water and maintenance time). This method of planting refers to planting small container plants (1 to 5 gallon), accompanied by a pipe to the root zone though which water would be provided by hand from a truck until the plant is well established.

The overall restoration strategy is to revegetate the Bosque with shrubs and juvenile trees to re-create the missing native understory in Bosque forest woodland areas and the native shrub thickets in open areas. At the same time, gaps are to be left in between the revegetated areas to create edge habitat, the richest type of habitat, and to create firebreaks to limit the potential for catastrophic fire. Two types of features have been generated for revegetation of the Bosque, (1) Bosque patches, which restore the understory to the Bosque forest and woodland areas and (2) shrub thickets, which restore dense shrubby zones to open areas where existing vegetation has been cleared and removed.

Seeding would be applied wherever restoration occurs. In firebreak areas, seeding is the only revegetation strategy proposed. Bosque patch and shrub thicket areas would receive pole planting of trees and bare root, container, or plug planting of shrubs. Maintenance and adaptive management would be important to the long-term success of the revegetated areas. Ongoing removal of non-native stump sprouts and volunteers would be necessary in all planted areas. In firebreak areas, the vegetation would be mowed or "brush-hogged" periodically, in order to maintain the function as a firebreak and to keep out woody plants.

These different planting strategies would be combined in order to create the target mosaic mixture of different ecosystem types (Bosque forest, grass meadow, wet features). A typical potential Bosque forest patch is shown in Figure 4.11. Another Bosque forest with a smaller structure (more of a shrub community) is shown in Figure 4.12.

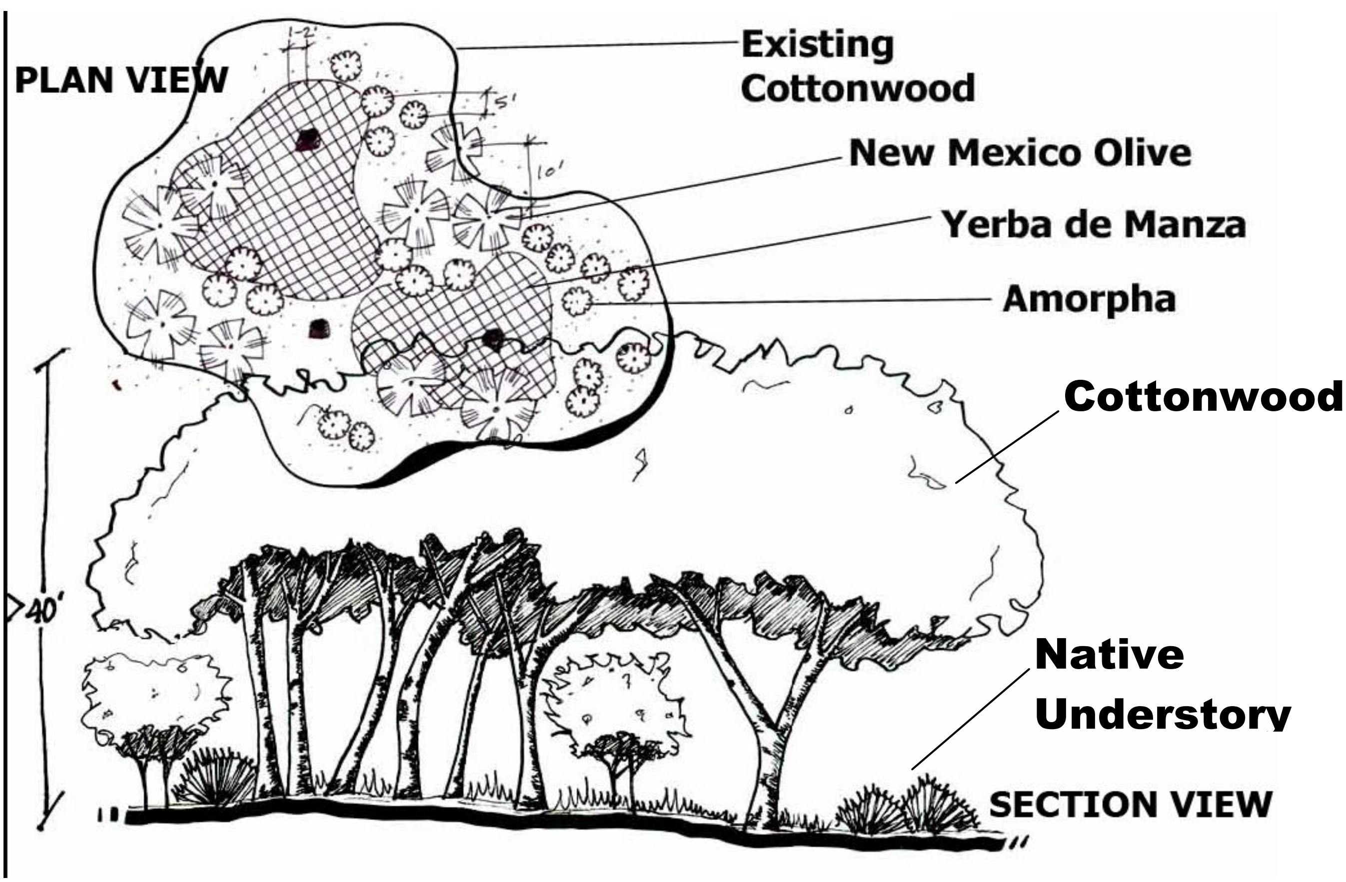


Figure 4.11. Schematic of a Bosque Forest.

Figure 4.12. Schematic Design of a Bosque Forest – Shrub Community.

4.4 Formulation of Measures and Alternative Plans

Restoration features have the potential to solve this study's particular problems and when combined could restore the Bosque ecosystem to a sustainable condition as a specific location. The features area often dependent upon factors such as position in the landscape, technical or economic considerations, and predicted environmental conditions. For instance, bank destabilization would only occur at the channel banks and high-flow channels could be located in areas where they would not impact levees. Likewise, some features could not occupy the same space such as wetland creation and establishment of cottonwood forest. Taken together, combinations of features that were compatible provide for all the components for a healthy Bosque Community.

The E-team combined features were combined based on implementability. Some features were dependent on conditions within the landscape. Ephemeral wetlands could be sustainable only if the bottom elevation was below the water table during low-flow conditions. High-flow channels could be located along historic river channels, oxbows, or acequias and would require suitable topography to allow the flow of water to the overbank areas when the river reached the appropriate water surface elevation.

In other instances, some features were dependent on other features to be sustainable. Vegetative features were often proposed in conjunction with water features as vegetation would need to be removed to allow water to move and to provide a needed hydrologic contribution. Cottonwood forest would require soil moisture provided by proximity to the river or periodic inundation via destabilized banks or high-flow channels. Management measures were clusters of dependent features at a particular location to form the smallest units of the evaluation process. Measures were evaluated independent of one another; however, the effect of the measures was cumulative, and the E-team calculated the ecosystem restoration benefits on a reach basis at the larger, landscape-level scale.

4.4.1 Management Measures

Measures represent a combination of several compatible features at a specific location that achieve functional and sustainable restoration at that site. In any given location, more than one measure might be possible but are mutually exclusive. Several measures were eliminated from further consideration early in the study due to constraints and feasibility. These included:

- Allow high flows to pass outside levees to restoration sites. Physical structures or gates would be required to allow water to pass through the levees without compromising flood risk management. This measure was not considered due to the effects on the current flood risk management system (USACE 2009).

- Restore cottonwood forest or other desirable Bosque community outside the levees. To sustain a plant community outside of the levee would require periodic irrigation to be sustainable. This would likely require allocation of water or use of recycled water.

- Increasing the amount of water in the river. Water delivery legislation and requirements preclude the use of additional water for ecosystem restoration measures.

- Restoration on a larger reach of the Rio Grande. The Corps authority under which this project is implemented requires participation from a non-Federal cost-share partner or sponsor. The current study involves several adjacent sponsors providing the opportunity to accomplish restoration on a significant area along the Rio Grande. Due to the sheer magnitude of this study and lack of interest or capability to cost share from additional partners at the time of study initiation, the Corps determined the study scope to be that which is presented in this document.

The first three measures listed above would add to the total area of restored Bosque; however, the measures would require active pumping of water or irrigation to be sustainable. Whereas these features would be valuable and meet some of the objectives of the study, the features that could be placed within the levees would more closely mimic the natural condition of the Bosque through their connection with the river channel and inclusion of all the functional elements for a healthy Bosque community. Measures within the levees would require less human involvement to maintain. Given the estimated financial constraints of the study, ample opportunities exist to implement functional and sustainable features within the levees.

Combinations of management measures or alternative plans have the potential to solve this study's particular problems and restore the Bosque ecosystem to a sustainable condition. Management measures are combinations of dependent and combinable features that are dependent upon factors such as position in the landscape, technical or economic considerations, and predicted environmental conditions. Each measure meets the criteria for effectiveness in that it would meet the objectives of the study for that localized area. However, the effect is cumulative, and the evaluation of ecosystem restoration benefits was calculated on a reach basis at the larger, landscape-level scale. For the project to be effective as a whole, some combination of numerous measures would need to be implemented, though it was not a requirement that measures be implemented in each reach. All measures are considered a positive benefit to the habitat and the project. Measures are considered an improvement as long as there is an increase in the HIS, but especially if the measure resulted in a score above 0.50 depending on the measure's baseline score (Table 4.3). A value of 0.5 to 0.59 provides „moderately high functionality.' Any value above that would provide better functionality.

The E-team formulated alternative plans from various combinations of management measures, added together, eliminated, rescaled, and otherwise modified so that the resultant suite of formulated alternative plans addressed the planning goals and objectives. A total of 20,736 separate plans could be formed from all possible combinations of management measures. Table 4.4 shows the number of management measures and the number of possible combinations of management measure available for each MRGB study reach. However, some measures were not compatible and could not be combined in the same plan. Two measures that occur in the same physical location could not be implemented simultaneously. The number of plans that are implementable is somewhat less than 20,000; however, additional screening reduced the number of plans to a manageable number.

Table 4.3. Goal HSI scores for each restoration component in each reach.

	BIOTA		WATER		LANDSCAPE		Overall	
	TY0	TY51	TY0	TY51	TY0	TY51	TY0	TY51
Reach 1	0.56	0.6	0.27	0.351	0.72	0.70	0.52	0.55
Reach 2	0.43	0.6	0.32	0.416	0.66	0.70	0.47	0.57
Reach 3	0.49	0.6	0.29	0.377	0.69	0.70	0.49	0.56
Reach 4	0.53	0.6	0.30	0.39	0.69	0.70	0.51	0.56
Reach 5	0.50	0.6	0.32	0.416	0.68	0.70	0.50	0.57

Table 4.4. All possible combinations of management measures resulted in many alternative plans.

Reach	Number of Management Measures	Number of All Possible combinations
1	13	8,192
2	13	8,192
3	8	256
4	11	2,048
5	11	2,048
	Total	**20,736**

Plans were formulated to include measures for the right banks, the left banks, and combinations on both banks of the river. A total of 5,632 plans were iteratively paired down to 56 final plans that were carried forward into detailed hydraulic, economic, and environmental analyses. The 56 plans equated to 11 to 13 plans per study reach, and each plan contains an alphabetic designation. The 56 alternative plans were considered during the final analysis to determine the recommended plan. Thirteen alternative plans were considered for Reach 1 (plans A through M), thirteen for Reach 2 (plans A through M), eight for Reach 3 (plans A through H), eleven for Reach 4 (plans A through K), and eleven for Reach 5 (plans A through K). Table 4.5 summarizes the plans, and Table 4.6 describes each plan for ecosystem restoration efforts in the MRGB. The process of "treat/retreat" involves thinning exotic vegetation either initially (treat) or treating resprouts in an area that has previously been treated (retreat).

The E-team developed a Habitat Quality goal using the HSI methodology to measure a successful result from the project. Individually, many of the measures meet the planning objectives in that they increase the value or area of habitat by some degree. Because each individual measure addressed a particular restoration goal, then any combination of measures or plans would meet the objectives. The E-team needed a metric that would quantify the amount of habitat improvement required for the project to be considered successful and effective. The E-team derived a relative HSI value based on reference sites and predicted achievable improvements that could be used to demonstrate that the project would function in a sustainable manner. The E-team based the goal HSI value on isolated reference sites in which these values were present or nearly present and based on the professional understanding and experience of the E-team to predict trends in hydro-geomorphology, Bosque (Riparian) Community Index Model requirements and Bosque ecology.

In an attempt to evenly distribute the restoration efforts across the study area (and within each reach), the E-team used simple rules to screen these plans further. Formulation focused on placing measures throughout the reach in an effort to distribute the restorative efforts as widely as possible. As a result, the integrity of travel corridors were enhanced and cumulative benefits would be maximized. An attempt was made to formulate plans for the right river banks, the left river banks, and combinations on either side of the river. In Reach 3, the last vestiges of marsh habitat in the MRG can be found only in a region colloquially referred to as the "San Antonio Oxbow." Because conditions still exist at this location to support a wetland and due to the scarcity of this type of habitat, the E-team considered the restoration of this wetland a base plan, and Plan 3-A restores the oxbow. Every alternative in Reach 3 includes the restoration of the oxbow as a primary consideration.

Given the study schedule and the resources available to complete the evaluation, the E-team screened the alternatives on the basis of the four standard planning criteria (*i.e.*, completeness, efficiency, effectiveness, and acceptability) (USACE 2000). To simplify the process, the E-team retained both the "maximum effort" and the "minimum effort" alternatives. Figures 4.13 through 4.17 display the maximum and minimum plans for Reaches 1 through 5 in the MRGB.

The alternatives were developed for purposes related specifically to the requirements of the Corps feasibility report. As such, the alternatives are not proposals for actual construction, nor are they of sufficient design detail to be constructed. Following the completion of the feasibility report, and compliance with appropriate environmental laws and public comment, if such action occurs, the Corps will produce detailed design analysis and prepare plans and specifications. The E-team formulated the alternatives to a level of detail sufficient to determine economic, technical, and environmental feasibility and identify resource issues associated with implementation to make possible an informed decision by the parties involved in plan implementation.

Table 4.5. Comparison of plans in each reach showing the quantity of measures in each plan.

Reach 1 Alternative Plans	A	B	C	D	E	F	G	H	I	J	K	L	M
Measures													
Bank Destabilization (total acres)	42	18	60	13	7	20	0	0	0	60	62	24	80
Swales and Trenches (total acres)	29	0	29	4	2	6	9	25	35	38	44	27	69
Water Features (total acres)	34	28	62	0	0	0	0	0	0	62	34	28	62
Treat Retreat Revegetation (total acres)	278	79	357	75	63	137	92	181	273	449	507	323	768
Jetty Jack Removal (total units)	2,004	334	2,338	334	334	668	334	668	1,002	2,672	3,006	1,336	4,008

Reach 2 Alternative Plans	A	B	C	D	E	F	G	H	I	J	K	L	M
Measures													
Bank Destabilization (total acres)	6	0	6	0	0	0	24	24	24	29	24	6	29
Swales and Trenches (total acres)	15	5	20	181	6	0	14	196	207	30	19	202	222
Water Features (total acres)	23	14	38	3	0	4	10	13	27	33	24	44	54
Treat Retreat Revegetation (total acres)	113	79	192	61	43	23	195	256	378	308	274	276	514
Jetty Jack Removal (total units)	0	0	0	1,000	1,000	1,000	1,000	2,000	3,000	1,000	1,000	2,000	4,000

Reach 3 Alternative Plans	A	B	C	D	E	F	G	H
Measures								
Bank Destabilization (total acres)	5	5	7	5	5	7	7	7
Swales and Trenches (total acres)	0	8	15	9	17	15	23	32
Water Features (total acres)	20	26	31	21	26	28	34	34
Treat Retreat Revegetation (total acres)	88	248	298	127	288	180	340	380
Jetty Jack Removal (total units)	800	1,600	2,400	800	1,600	1,600	2,400	2,400

Continued on next page

Table 4.5 Continued

Reach 4 Alternative Plans	A	B	C	D	E	F	G	H	I	J	K
Measures											
Bank Destabilization (total acres)	13	0	0	0	13	0	0	13	13	13	13
Swales and Trenches (total acres)	7	21	9	30	37	0	5	12	28	16	42
Water Features (total acres)	27	20	18	38	66	6	6	33	53	51	71
Treat Retreat Revegetation (total acres)	34	139	128	267	300	80	109	143	253	241	410
Jetty Jack Removal (total units)	0	400	0	400	400	0	0	0	400	0	400

Reach 5 Alternative Plans	A	B	C	D	E	F	G	H	I	J	K
Measures											
Bank Destabilization (total acres)	14	14	14	14	14	14	0	14	14	14	14
Swales and Trenches (total acres)	0	4	14	18	12	22	26	9	15	13	39
Water Features (total acres)	30	36	38	38	36	38	0	30	32	36	38
Treat Retreat Revegetation (total acres)	130	162	251	291	229	317	215	210	259	242	466
Jetty Jack Removal (total units)	0	0	0	0	0	0	0	0	0	0	0

Table 4.6. Alternative plan matrix for the ecosystem restoration efforts in the MRGB study.

Reach	Plan Name	Plan Description	Total Active Footprint (acres)[1]	Feature Types within the Measures: Bank Destabilization (total acres)	Swales and Trenches (total acres)	Water Features (total acres)	Treat Retreat Revegetation (total acres)	Jetty Jack Removal (total units)
Reach 1	Plan 1-A	Located on the southernmost extent of the reach. Activities on both the left and right banks. Water features include the construction of hi-flow channel(s), creation of wetlands in general, and the construction of a wetland specifically at the outfall. Several sets of swales (distributed across both banks) are proposed in conjunction with bank destabilization.	278	42	29	34	278	2,004
	Plan 1-B	Located in middle of the reach on the right bank. Water features include the construction of hi-flow channel(s) and the creation of wetlands. No swales are proposed, but bank destabilization is included.	79	18	0	28	79	334
	Plan 1-C	Combination of Plans A & B (benefits are non-additive)	357	60	29	62	357	2,338
	Plan 1-D	Located on the northernmost extent of the reach along the left bank. No water features are proposed, but bank destabilization in conjunction with a series of swales is included.	75	13	4	0	75	334
	Plan 1-E	Located on the northernmost extent of the reach along the right bank. No water features are proposed, but bank destabilization in conjunction with a series of swales is included.	63	7	2	0	63	334
	Plan 1-F	Combination of Plans D & E (benefits are non-additive)	138	20	6	0	138	668
	Plan 1-G	Located in middle of the reach on the left bank.. No water features or bank destabilization features are proposed, but a series of swales are included.	92	0	9	0	92	334
	Plan 1-H	Located in the southern section of the reach on the left bank. No water features or bank destabilization features are proposed, but a series of swales are included.	181	0	25	0	181	668

Reach	Plan Name	Plan Description	Total Active Footprint (acres)[1]	Feature Types within the Measures				
				Bank Destabilization (total acres)	Swales and Trenches (total acres)	Water Features (total acres)	Treat Retreat Revegetation (total acres)	Jetty Jack Removal (total units)
	Plan 1-I	Combination of Plans G & H (benefits are non-additive)	273	0	35	0	273	1,002
	Plan 1-J	Combination of Plans C & G (benefits are non-additive)	449	60	38	62	449	2,672
	Plan 1-K	Combination of Plans A & F & G (benefits are non-additive)	508	62	44	34	508	3,006
	Plan 1-L	Combination of Plans B & E & H (benefits are non-additive)	323	24	27	28	323	1,336
	Plan 1-M	All Plans Combined - (Maximum Footprint and Effort)	768	80	69	62	768	4,008
Reach 2	Plan 2-A	Located mid-reach (southern end) on the right bank. Water features include the construction of hi-flow channel(s), groundwater channel(s), and diversion of the outfall channel. Several sets of swales (distributed across both banks) are proposed in conjunction with bank destabilization.	113	6	15	23	113	0
	Plan 2-B	Located mid-reach (northern end) on the left bank. Water features include enhancing the ditch for wetland habitat and creating a wet meadow. A series of swales are proposed, but bank destabilization i omitted.	79	0	5	14	79	0
	Plan 2-C	Combination of Plans A & B (benefits are non-additive)	192	6	20	38	192	0
	Plan 2-D	Located on the northernmost end of the reach on both banks. Water features include the construction of hi-flow channel(s) and wetlands. Several sets of swales (distributed across both banks) are proposed, but bank destabilization is omitted.	61	0	181	3	61	1,000
	Plan 2-E	Located mid-reach on the right bank. No water features or bank stabilization features are proposed, but a series of swales is included.	43	0	6	0	43	1,000

Reach	Plan Name	Plan Description	Total Active Footprint (acres)[1]	Feature Types within the Measures				
				Bank Destabilization (total acres)	Swales and Trenches (total acres)	Water Features (total acres)	Treat Retreat Revegetation (total acres)	Jetty Jack Removal (total units)
	Plan 2-F	Located mid-reach (southern end) on the left bank. Water features include the creation of wetlands, but no bank destabilization or swales features are indicated.	23	0	0	4	23	1,000
	Plan 2-G	Located on the southernmost end of the reach on the right bank. Water features include the construction of hi-flow channel(s) and creation of wetlands. Swales and bank destabilization features are also included in the plan.	195	24	14	10	195	1,000
	Plan 2-H	Combination of Plans D & G (benefits are non-additive)	256	24	196	13	256	2,000
	Plan 2-I	Combination of Plans B & H & E (benefits are non-additive)	378	24	207	27	378	3,000
	Plan 2-J	Combination of Plans G & A (benefits are non-additive)	308	29	30	33	308	1,000
	Plan 2-K	Combination of Plans G & B (benefits are non-additive)	274	24	19	24	274	1,000
	Plan 2-L	Combination of Plans C & D & F (benefits are non-additive)	276	6	202	44	276	2,000
	Plan 2-M	All Plans Combined - (Maximum Footprint and Effort)	514	29	222	54	514	4,000
Reach 3	Plan 3-A	Located in the northern section of the reach in the area referred to commonly as the "Oxbow" along the right bank. Water features include the restoration of open water habitat (in the "Oxbow" itself), construction of a water control structure, and reconfiguring the South-end and Namaste outfalls. No swales have been proposed, but bank destabilization features are included.	88	5	0	20	88	800
Reach 3	Plan 3-B	Located in the northern portion of the reach (inclusive of the "Oxbow") along both banks. All features described above in Plan A above, as well as additional outfall wetlands and swales will be constructed.	248	5	8	26	248	1,600

Reach	Plan Name	Plan Description	Total Active Footprint (acres)[1]	Feature Types within the Measures				
				Bank Destabilization (total acres)	Swales and Trenches (total acres)	Water Features (total acres)	Treat Retreat Revegetation (total acres)	Jetty Jack Removal (total units)
	Plan 3-C	Located in the both the northern and southern portions of the reach (inclusive of the "Oxbow") along both banks. All features described above in Plans B above, as well as additional bank destabilization and swale features proposed. Additional water features include the reconnection of hi-flow channels, and the removal of a berm.	298	7	15	31	298	2,400
	Plan 3-D	Located in the both the northern and southern portions of the reach (inclusive of the "Oxbow") along both banks. All features described above in Plan A above, as well as a reconfiguration of the Duranes outfall and the construction of swales.	127	5	9	21	127	800
	Plan 3-E	Located in mid-reach and inclusive of the "Oxbow" along both banks. All features described above in Plan D above, as well as the construction of additional swales and the creation of outfall wetlands.	288	5	17	26	288	1,600
	Plan 3-F	Located in mid-reach and inclusive of the "Oxbow" along both ban All features described above in Plan A above, as well as additional ban destabilization and swale features. Additional water features includ removal of a berm, reconnection of hi-flow channels, the creation c outfall wetlands and the construction of an additional hi-flow channel.	180	7	15	28	180	1,600
	Plan 3-G	Located in the southern portion of the reach (inclusive of the "Oxbow") along both banks. All features described above in Plan F above, as well as the construction of additional swales and outfall wetlands.	340	7	15	34	340	2,400

Reach	Plan Name	Plan Description	Total Active Footprint (acres)[1]	Feature Types within the Measures				
				Bank Destabilization (total acres)	Swales and Trenches (total acres)	Water Features (total acres)	Treat Retreat Revegetation (total acres)	Jetty Jack Removal (total units)
	Plan 3-H	All Plans Combined - (Maximum Footprint and Effort)	380	7	32	34	380	2,400
Reach 4	Plan 4-A	Located in the southern portion of the reach along the left bank. Water features will be constructed in conjunction with bank destabilization and swales.	34	13	7	27	34	0
Reach 4	Plan 4-B	Located mid-reach along both banks. Numerous water features will be constructed including the removal of a berm, the construction of hi-flow channels and outfall wetlands. No bank destabilization is proposed, but swales are included.	139	0	21	20	139	400
Reach 4	Plan 4-C	Located mid-reach and in the northern portion of the reach along both banks. Numerous water features will be undertaken including the enhancement of wetland habitats, making connections to the river, creation of water features and the construction of hi-flow channels. No bank destabilization is proposed, but swales are included.	128	0	9	18	128	0
Reach 4	Plan 4-D	Combination of Plans B & C (benefits are non-additive)	267	0	30	38	267	400
Reach 4	Plan 4-E	Combination of Plans A & D (benefits are non-additive)	300	13	37	66	300	400
Reach 4	Plan 4-F	Located in the northernmost section of the reach along the left bank. Only 1 water feature is proposed - an outfall wetland. No bank stabilization or swales are included.	81	0	0	6	81	0
Reach 4	Plan 4-G	Contains not only Plan F's footprint, but also a small portion of the southern end of the reach along the left bank.	109	0	5	6	109	0
Reach 4	Plan 4-H	Combination of Plans A & G (benefits are non-additive)	143	13	12	33	143	0
Reach 4	Plan 4-I	Combination of Plans B & H (benefits are non-additive)	282	13	33	53	282	400
Reach 4	Plan 4-J	Combination of Plans A & C & F (benefits are non-additive)	241	13	16	51	241	0

Reach	Plan Name	Plan Description	Total Active Footprint (acres)[1]	Feature Types within the Measures				
				Bank Destabilization (total acres)	Swales and Trenches (total acres)	Water Features (total acres)	Treat Retreat Revegetation (total acres)	Jetty Jack Removal (total units)
	Plan 4-K	All Plans Combined - (Maximum Footprint and Effort)	410	13	42	71	410	400
Reach 5	Plan 5-A	Located in the southern section of the reach along the left bank. Water features include the construction of a hi-flow channel and several wetlands. Bank stabilization is proposed, but swales are omitted.	130	14	0	30	130	0
	Plan 5-B	Located in the southern section of the reach along the left bank. All features described above in Plan A above, as well as wetland enhancements, and connections established to both the wetland and the river. Swales are included in this plan as well.	162	14	4	36	162	0
	Plan 5-C	Building from Plan B, and extending north upward along both banks. All features described above in Plan B, as well as enhancement of the Black Mesa Outfall, and additional swales are proposed	251	14	14	38	251	0
	Plan 5-D	Building from Plan C, and extending north upward along both banks. All features described above in Plan C, as well as reconnecting the wetlands to each other, and additional swales are proposed	291	14	18	38	291	0
	Plan 5-E	Building from Plan B, and extending north upward along both banks. All features described above in Plan B, as well as additional swales are proposed	229	14	12	36	229	0
	Plan 5-F	Building from Plan C, and extending north upward along both banks. All features described above in Plan C, as well as reconnecting the wetlands to each other, and additional swales are proposed.	318	14	22	38	318	0

Reach	Plan Name	Plan Description	Total Active Footprint (acres)[1]	Feature Types within the Measures				
				Bank Destabilization (total acres)	Swales and Trenches (total acres)	Water Features (total acres)	Treat Retreat Revegetation (total acres)	Jetty Jack Removal (total units)
	Plan 5-G	Located throughout the reach along both banks. Although no water features or bank stabilization features are proposed, several swales are included.	215	0	26	0	215	0
	Plan 5-H	Building from Plan D along both banks, but absent the most southern tip of restoration activities and focusing on mid-reach restoration along the left bank rather than the right bank. All features described above in Plan D, but only half the acreage dedicated to swales, and water features are constrained to the hi-flow channel construction and wetland creation.	210	14	9	30	210	0
	Plan 5-I	Building from Plan C, but absent the most southern tip of restoration activities and focusing on the northern end of the reach along both banks. All features described above in Plan C, but slightly fewer swales, and water features are constrained to the hi-flow channel construction, the wetland creation, and the enhancement of the Black Mesa outfall..	259	14	15	32	259	0
	Plan 5-J	Building from Plan H, and extending south along both banks. All features described above in Plan H, as well as reconnecting the wetlands to each other, enhancing the north and south wetlands, and additional swales are proposed.	242	14	13	36	242	0
	Plan 5-K	All Plans Combined - (Maximum Footprint and Effort)	466	14	39	38	466	0

[1] *The active footprint is not necessarily equal to the sum of the footprints of the feature types – often these overlapped on the landscape. Plans formed from combinations of other plans assumed the sum of the respective footprints however outputs in the HSI analysis are non-additive and therefore represent a complete and separate plan.*

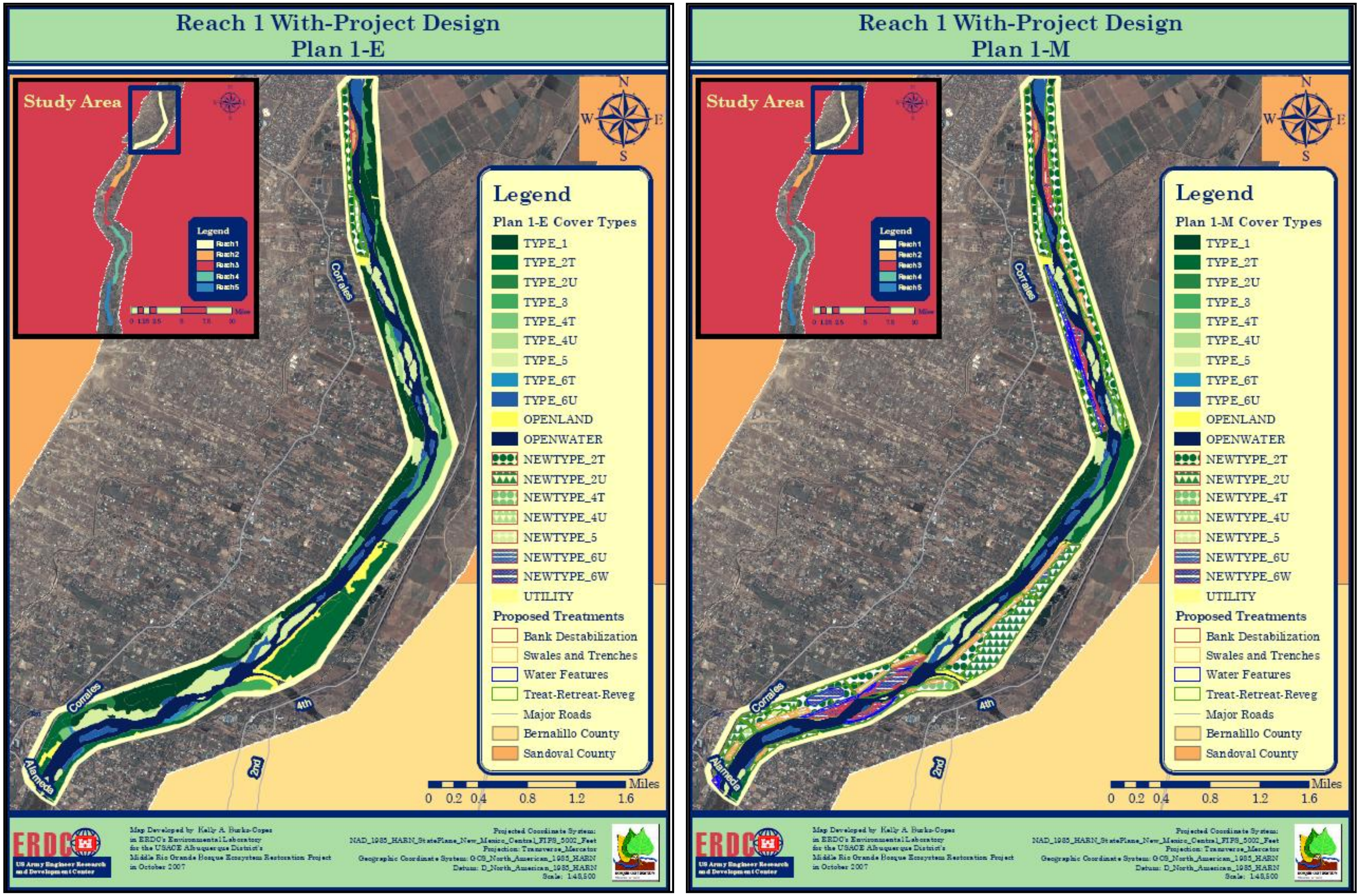


Figure 4.13. "Maximum" and "Minimum" plans for Reach 1 in the MRGB study.

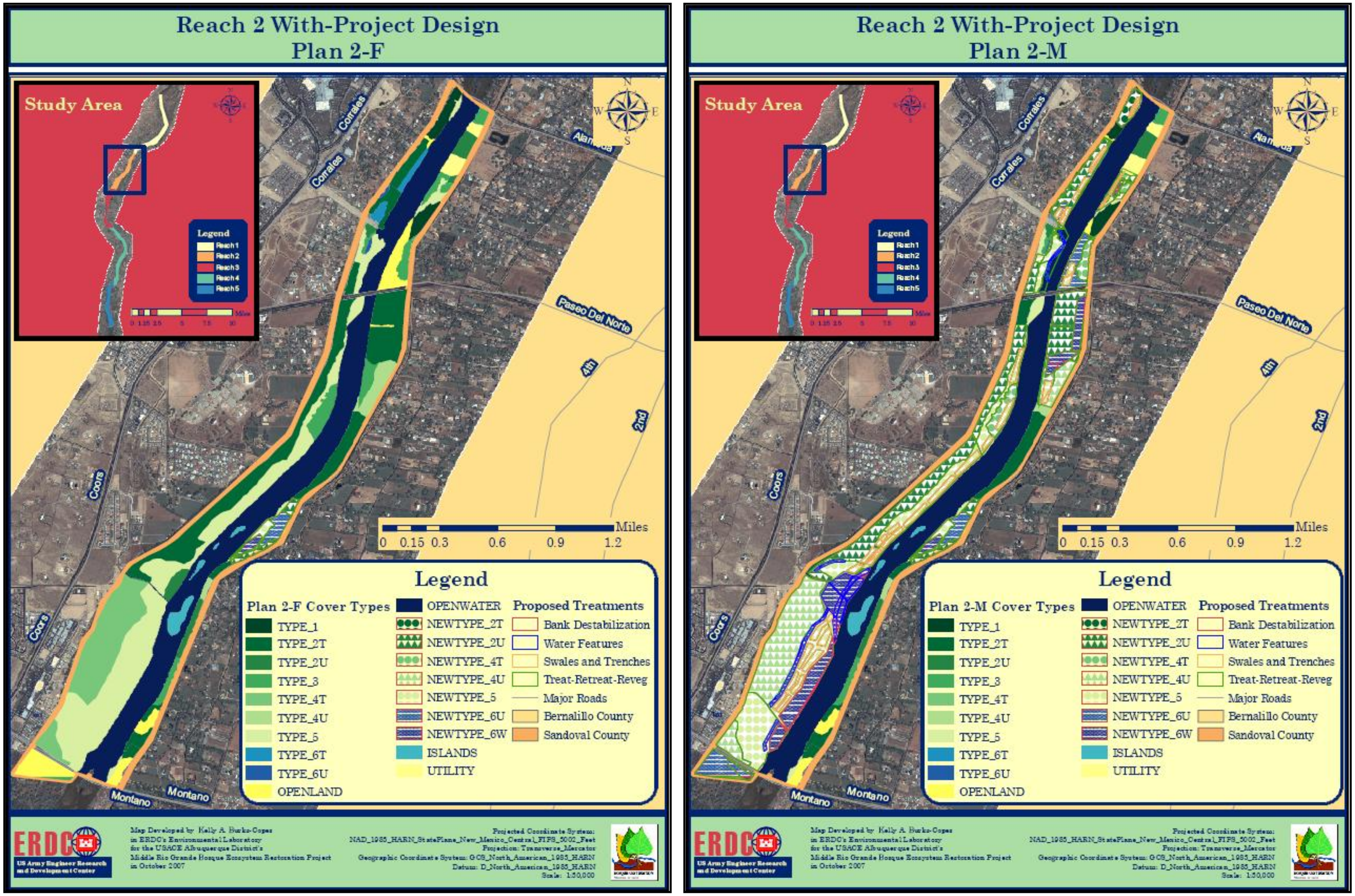


Figure 4.14. "Maximum" and "Minimum" plans for Reach 2 in the MRGB study.

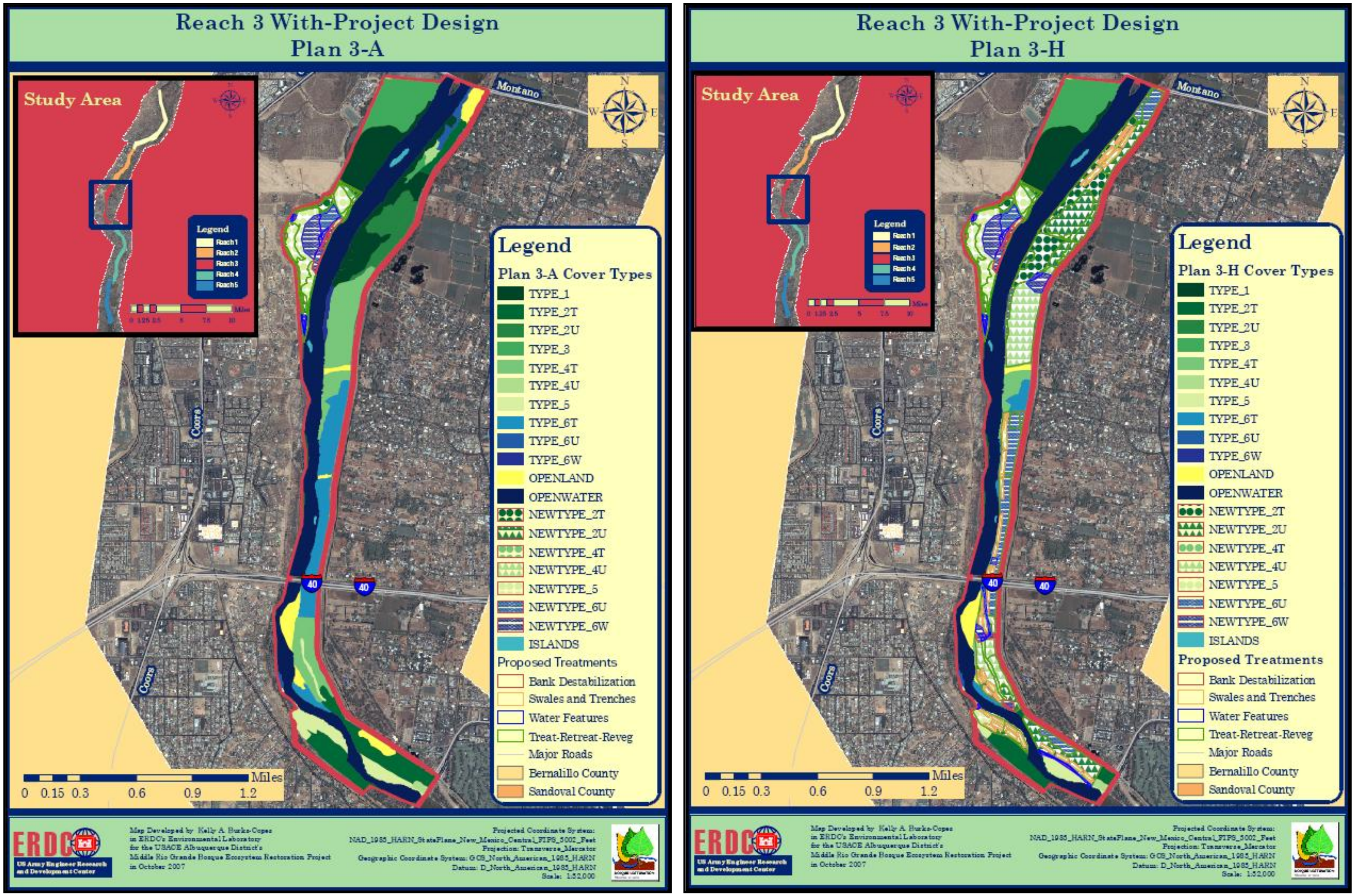


Figure 4.15. "Maximum" and "Minimum" plans for Reach 3 in the MRGB study.

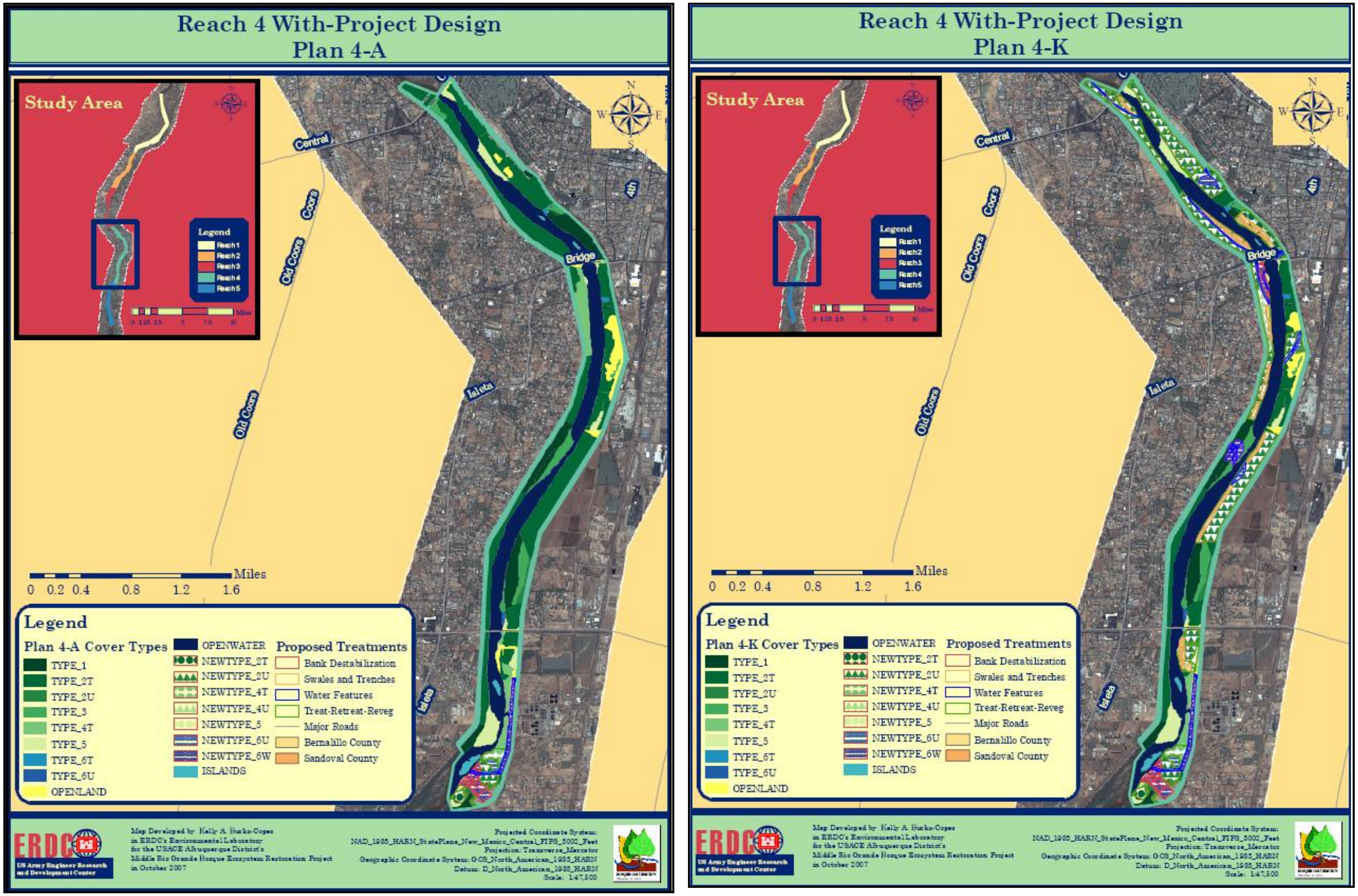


Figure 4.16. “Maximum” and “Minimum” plans for Reach 4 in the MRGB study.

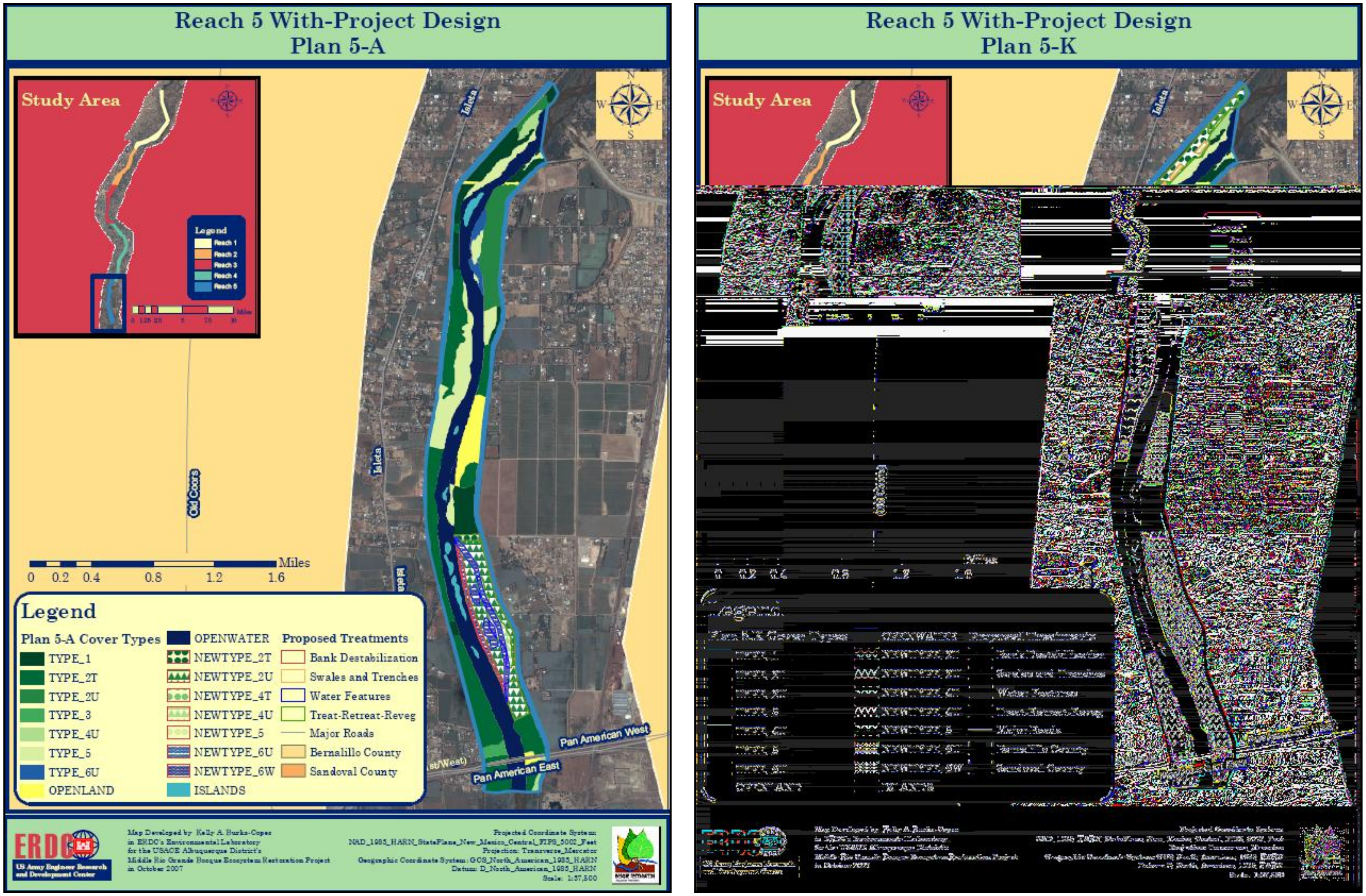


Figure 4.17. "Maximum" and "Minimum" plans for Reach 5 in the MRGB study.

4.5 Economic Analysis

4.5.1 Incremental Cost Analysis & Plan Evaluation

Between 1986 and 1987, the Corps Headquarters Office provided policy directing Corps districts to perform Incremental Cost Analysis (ICA) for all feasibility-level studies. The required ICA is a combination of both a Cost Effectiveness Analysis (CEA) and ICA. Together, the CEA/ICA evaluations combine the environmental results of various alternative designs with their associated costs and systematically compare each alternative on the basis of productivity. Cost effectiveness analyses focus on the identification of the least-cost alternatives and the elimination of the economically irrational alternatives (*e.g.*, alternative designs which are inefficient and ineffective). By definition, inefficient alternative designs produce similar environmental returns at greater expense. Ineffective alternative designs result in reduced levels of productivity for the same or greater costs. The ICA is employed to reveal and interpret changes in costs for increasing levels of environmental productivity.

In the ICA terminology, a series of scales (*i.e.*, variations) can be defined as modifications or derivations of the initial with-project conditions (*i.e.*, "Develop 10 acres of Low Quality Wetlands," "Develop 1,000 acres of High Quality Wetlands", *etc*.). Often, these scales are based on differences in intensity of similar treatments and can be combined under an alternative design class or category. During the first steps of CEA/ICA, all possible combinations of alternative designs and their scales are formed. Generally, intra-scale combinations (*i.e.*, combinations of variations within a single alternative design) are not allowed. These activities would occupy the same space and time.

The E-team assessed each plan using the metrics described earlier (HEP) and compared using the cost analyses. The sections below review the analyses and assumptions considered in the ecosystem assessment of benefits for the plans and describe the cost analyses process. The E-team developed acreage projections over the life of the project for each plan. The successional trends envisioned by the E-team in the without-project conditions were retained in the restoration plans to capture the cyclical nature of the Bosque ecosystem. Newly developed habitats were assigned "New" cover type codes in order to capture the burgeoning contribution to the restoration of the Bosque's structure and function.

4.5.2 Bosque Community (HSI) WP Trends

As mentioned previously, the E-team made the assumption that successional trends in the existing gallery forests and shrublands (Types 1-5) would continue. The E-team assumed these areas would continue to experience the ongoing successional changes experienced by the sites under the future without-project condition. For example, within these existing stands, some of the larger trees would be removed to open the canopy and allow for the introduction of younger trees to accelerate regeneration. The distance between the larger trees would be increased (fewer trees equates to a greater distance), and the areas would experience a slight increase in shrub and herbaceous canopy cover.

For all existing habitats (Types 1-6) subject to active rehabilitation, species lists for the planting schema were devised (USACE 2008a,b) that encouraged the introduction of native species, leading to significant increases in (native) species richness. Invasive species management would be implemented on a regular basis to reduce the numbers of exotics and invasives in the Bosque. In those areas where water features were planned, the hydrologic regime (duration, flooding frequency, wetted surface area, and depth to groundwater) would be improved, and the projected trends for these parameters were developed based on extensive hydrologic modeling performed on the designs (USACE 2008a,b). GIS-derived parameters (*i.e.*, patch size, distance between patches) were measured and incorporated into the analysis at TY1. Spatially-speaking, the patch sizes and distances between patches would continue to decline (even under these rehabilitative actions).

Newly developed forested cover types (New Types 1-4) were expected to achieve a sustainable setting by TY51. Representative community characteristics such as tree canopy cover, understory structure, and ground coverages would reach optimal conditions (*i.e.*, >50%, >40%, >80%, respectively) in 50 years. The E-team assumed that active invasive species management would maintain the level of desired ecosystem integrity necessary to perpetuate active recruitment and regeneration in the Bosque. The E-team deployed water features to support the creation of these ecotones when possible.

Newly developed shrublands (New Type 5) were expected to achieve a sustainable setting much earlier (by TY6). In these instances, representative community characteristics such as shrub canopy cover, tree canopy, and ground coverages would reach optimal conditions (*i.e.*, >50%, >50%, >75% respectively) within 5 years and remain in that state throughout the life of the project. Active invasive species management would maintain the level of desired ecosystem integrity necessary to perpetuate active recruitment and regeneration in the Bosque. Newly developed meadows/marshes (New Type 6s) were expected to achieve a sustainable condition much sooner (by TY6). Herbaceous canopies (forbs, grasses, and sedges) were expected to optimize (attain >20% coverage) by that time.

4.6 Cost Analysis

The E-team performed CEA and incremental ICA using the IWR Planning Suite software. A nested CEA/ICA costs analyses was performed and incremental "Best Buys" were determined for each reach. These Best Buys were then carried into a project-level cost analysis where combinations of Best Buy solutions for each reach were combined to generate a project-level solution. The sections below summarize the costs and CEA/ICA results generated as the E-team evaluated the suite of MRGB restoration alternatives in this nested approach.

Annualized costs were developed for the proposed restoration plans using a 4 5/8% interest rate and a 0.051634 amortization rate for construction (amortized over the 50-year period of analysis). These costs were added to the annualized Operation and Maintenance (O&M) costs for each measure and summed to generate the total annualized costs per measure.

4.6.1 Reach-Level Cost Effective Analysis and Results

Cost effective analyses identified the least-costly plans for each level of output. The three criteria used for identifying non-cost effective plans or combinations include: (1) the same level of output could be produced by another plan at less cost; (2) a larger output level could be produced at the same cost; or (3) a larger output level could be produced at the least cost. Table 4.7 shows the costs and outputs submitted to CEA/ICA analysis for the cost comparison of the reach-level solutions. Figure 4.18 displays the Average Annualized Habitat Units (AAHA) for each alternative plan.

Table 4.7. Costs and outputs submitted to CEA/ICA for the cost comparison of the reach-level solutions in the MRGB study (AAHU = Average Annualized Habitat Unit).

	Alternative Plan	Cost	Operation & Maint.	Annualized Cost	Total Avg. Annual Cost	AAHUs	Annualized Costs per Output ($/AAHU)
REACH 1	Plan 1-A	$7,108,722	$367,668	$367,052	$734,720	138	$5,324
	Plan 1-B	$425,270	$72,730	$21,958	$94,688	3	$31,563
	Plan 1-C	$7,533,992	$440,398	$389,010	$829,408	193	$4,297
	Plan 1-D	$1,049,631	$31,489	$54,197	$85,686	8	$10,711
	Plan 1-E	$672,318	$20,170	$34,714	$54,884	6	$9,147
	Plan 1-F	$1,721,949	$51,658	$88,911	$140,569	18	$7,809
	Plan 1-G	$1,092,684	$17,908	$56,420	$74,328	9	$8,259
	Plan 1-H	$2,518,227	$68,870	$130,026	$198,896	42	$4,736
	Plan 1-I	$3,610,912	$86,778	$186,446	$273,224	51	$5,357
	Plan 1-J	$8,626,677	$458,306	$445,430	$903,736	222	$4,071
	Plan 1-K	$9,923,355	$437,235	$512,383	$949,617	231	$4,111
	Plan 1-L	$3,615,815	$161,769	$186,699	$348,468	65	$5,361
	Plan 1-M	$12,866,852	$578,834	$664,367	$1,243,201	264	$4,709
REACH 2	Plan 2-A	$2,294,462	$68,834	$118,472	$187,306	146	$1,283
	Plan 2-B	$2,077,602	$66,902	$107,275	$174,177	155	$1,124
	Plan 2-C	$4,372,064	$135,736	$225,747	$361,483	155	$2,332
	Plan 2-D	$9,489,053	$199,290	$489,958	$689,248	139	$4,959
	Plan 2-E	$6,668,673	$13,679	$344,330	$358,010	143	$2,504
	Plan 2-F	$642,983	$20,240	$33,200	$53,440	139	$384
	Plan 2-G	$3,325,570	$89,326	$171,712	$261,038	151	$1,729
	Plan 2-H	$12,814,624	$288,615	$661,670	$950,286	153	$6,211
	Plan 2-I	$21,560,898	$369,197	$1,113,275	$1,482,472	153	$9,689
	Plan 2-J	$5,620,032	$158,159	$290,185	$448,344	162	$2,768
	Plan 2-K	$5,403,173	$156,227	$278,987	$435,215	172	$2,530
	Plan 2-L	$14,504,100	$355,266	$748,905	$1,104,170	159	$6,944
	Plan 2-M	$24,498,343	$458,271	$1,264,947	$1,723,218	176	$9,791

Table continued on next page

(Table 4.7 continued)

	Alternative Plan	Cost	Operation & Maint.	Annualized Cost	Total Avg. Annual Cost	AAHUs	Annualized Costs per Output ($/AAHU)
REACH 3	Plan 3-A	$2,492,563	$11,632	$128,701	$140,333	100	$1,402
	Plan 3-B	$4,022,416	$39,535	$207,693	$247,228	110	$2,256
	Plan 3-C	$4,690,824	$57,940	$242,206	$300,146	106	$2,842
	Plan 3-D	$2,999,754	$26,847	$154,889	$181,737	103	$1,761
	Plan 3-E	$4,529,608	$54,750	$233,882	$288,632	109	$2,647
	Plan 3-F	$3,816,182	$49,693	$197,045	$246,738	104	$2,383
	Plan 3-G	$5,346,036	$77,596	$276,037	$353,633	112	$3,167
	Plan 3-H	$5,853,227	$92,812	$302,226	$395,037	118	$3,358
REACH 4	Plan 4-A	$1,277,224	$38,317	$65,948	$104,265	36	$2,904
	Plan 4-B	$2,489,116	$68,476	$128,523	$196,999	40	$4,978
	Plan 4-C	$2,731,960	$67,639	$141,062	$208,701	39	$5,354
	Plan 4-D	$5,221,076	$136,115	$269,585	$405,700	63	$6,400
	Plan 4-E	$6,498,300	$174,431	$335,533	$509,965	85	$5,969
	Plan 4-F	$1,054,476	$31,634	$54,447	$86,081	34	$2,531
	Plan 4-G	$1,381,380	$41,441	$71,326	$112,768	39	$2,903
	Plan 4-H	$2,658,604	$79,758	$137,274	$217,032	62	$3,529
	Plan 4-I	$4,820,817	$138,427	$248,918	$387,345	80	$4,840
	Plan 4-J	$5,063,660	$137,590	$261,457	$399,047	70	$5,684
	Plan 4-K	$7,552,777	$215,873	$389,980	$605,853	108	$5,633
REACH 5	Plan 5-A	$3,333,124	$99,994	$172,102	$272,096	144	$1,893
	Plan 5-B	$4,203,149	$122,111	$217,025	$339,137	141	$2,404
	Plan 5-C	$5,078,081	$148,359	$262,202	$410,561	143	$2,879
	Plan 5-D	$5,434,831	$159,062	$280,622	$439,684	141	$3,108
	Plan 5-E	$4,838,731	$141,149	$249,843	$390,992	139	$2,822
	Plan 5-F	$5,713,664	$167,397	$295,019	$462,416	141	$3,288
	Plan 5-G	$1,957,685	$58,701	$101,083	$159,784	155	$1,031
	Plan 5-H	$4,048,101	$121,443	$209,020	$330,463	157	$2,098
	Plan 5-I	$4,564,806	$136,944	$235,699	$372,643	144	$2,590
	Plan 5-J	$4,918,126	$143,561	$253,943	$397,503	156	$2,548
	Plan 5-K	$7,035,766	$207,060	$363,285	$570,344	157	$3,638

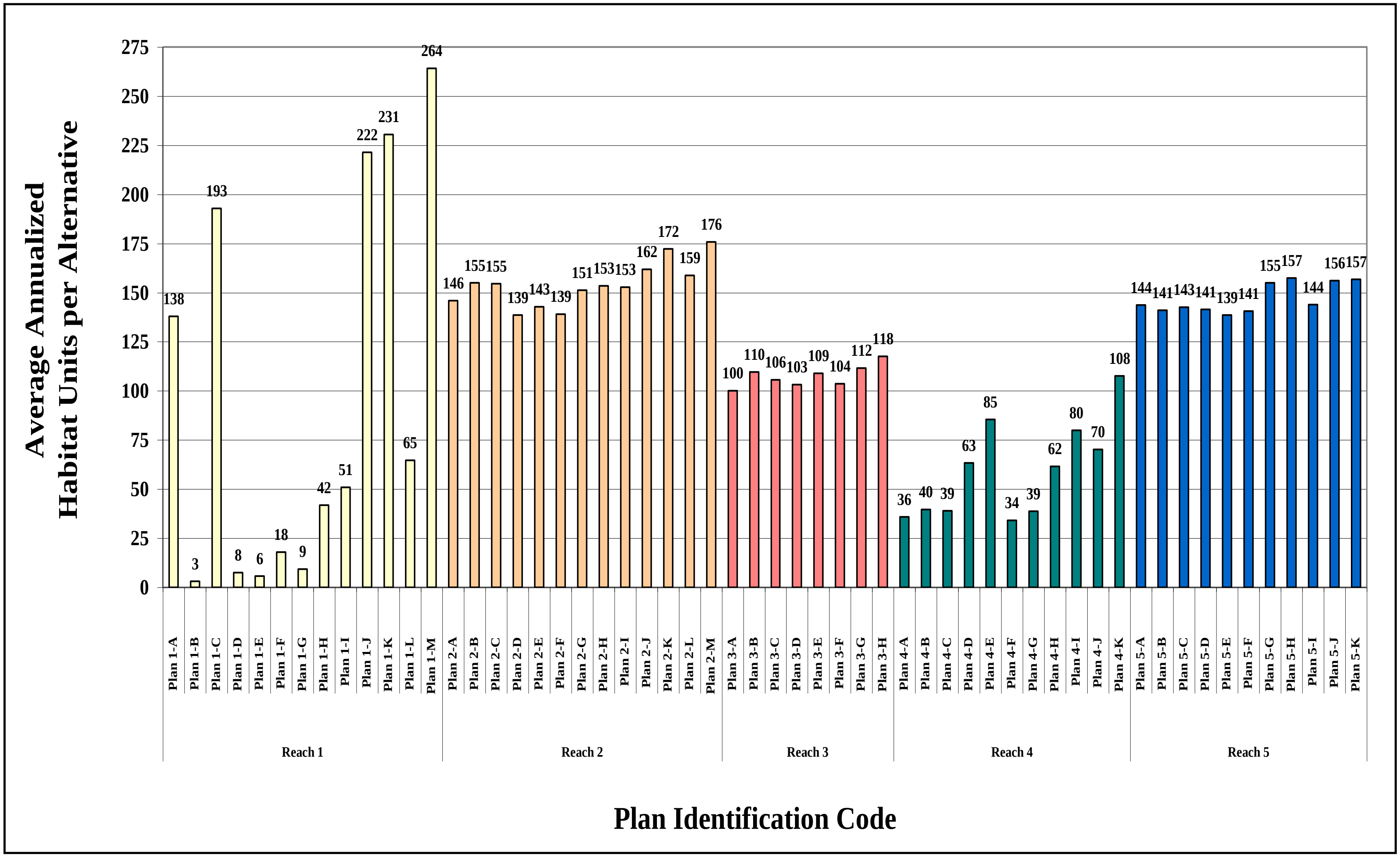


Figure 4.18. AAHUs for each Alternative Plan.

For demonstration purposes, the following pages show the process of CEA for Reach 1. For inputs and results of the other four reaches, refer to Appendix D, *Habitat Assessment Report*. Table 4.8 details the results of the CEA for Reach 1. The E-team considered twelve plans to be cost-effective in both analyses. The average annual costs ranged from $53,115 to $1,209,348 and produced between six and 264 Average Annualized Habitat Units (AAHUs) for this reach.

Table 4.8. Cost effective analysis results for Reach 1.

Count	Plan	Total Avg. Annual Cost	AAHUs	Annualized Costs per Output ($/AAHU)
1	No Action	$0	0	$0
2	Plan 1-E	$54,884	6	$9,147
3	Plan 1-G	$74,328	9	$8,259
4	Plan 1-F	$140,569	18	$7,809
5	Plan 1-H	$198,896	42	$4,736
6	Plan 1-I	$273,224	51	$5,357
7	Plan 1-L	$348,468	65	$5,361
8	Plan 1-A	$734,720	138	$5,324
9	Plan 1-C	$829,408	193	$4,297
10	Plan 1-J	$903,736	222	$4,071
11	Plan 1-K	$949,617	231	$4,111
12	Plan 1-M	$1,243,201	264	$4,709

ICA compared the incremental costs for each additional unit of output on a reach-by-reach basis. The first step in developing Best Buy plans was to determine the incremental cost per unit. The plan with the lowest incremental cost per unit over the future without-project condition was the first incremental Best Buy plan. Plans that had higher incremental costs per unit for a lower level of output were eliminated. The next step was to recalculate the incremental cost per unit for the remaining plans. This process was reiterated until the E-team determined the lowest incremental cost per unit for the next level of output. The intent of the incremental analysis was to identify large increases in cost relative to output.

Table 4.9 and Figure 4.19 detail the results of the incremental cost analyses for the Reach 1 plans. The analysis produced between four and five plans considered incrementally cost-effective. The average annual costs ranged from $881,039 to $1,209,348 and produced between 222 and 264 AAHUs for the Bosque. The same process was used in each reach.

Table 4.9. Incremental Cost Analysis results for the Reach 1 plans.

Incremental Results for the HEP Analysis							
Counter	Alternative	Annualized Output (AAHUs)	Annualized Cost	Average Cost ($/AAHU)	Incremental Cost ($)	Incremental Output (AAHUs)	Incremental Cost per Output ($/AAHU)
1	No Action	0	$0	-	-	-	-
2	Plan 1-J	222	$903,736	$4,071	$903,762	222	$4,071
3	Plan 1-K	231	$949,617	$4,111	$45,855	9	$5,095
4	Plan 1-M	264	$1,243,201	$4,709	$293,584	33	$8,897

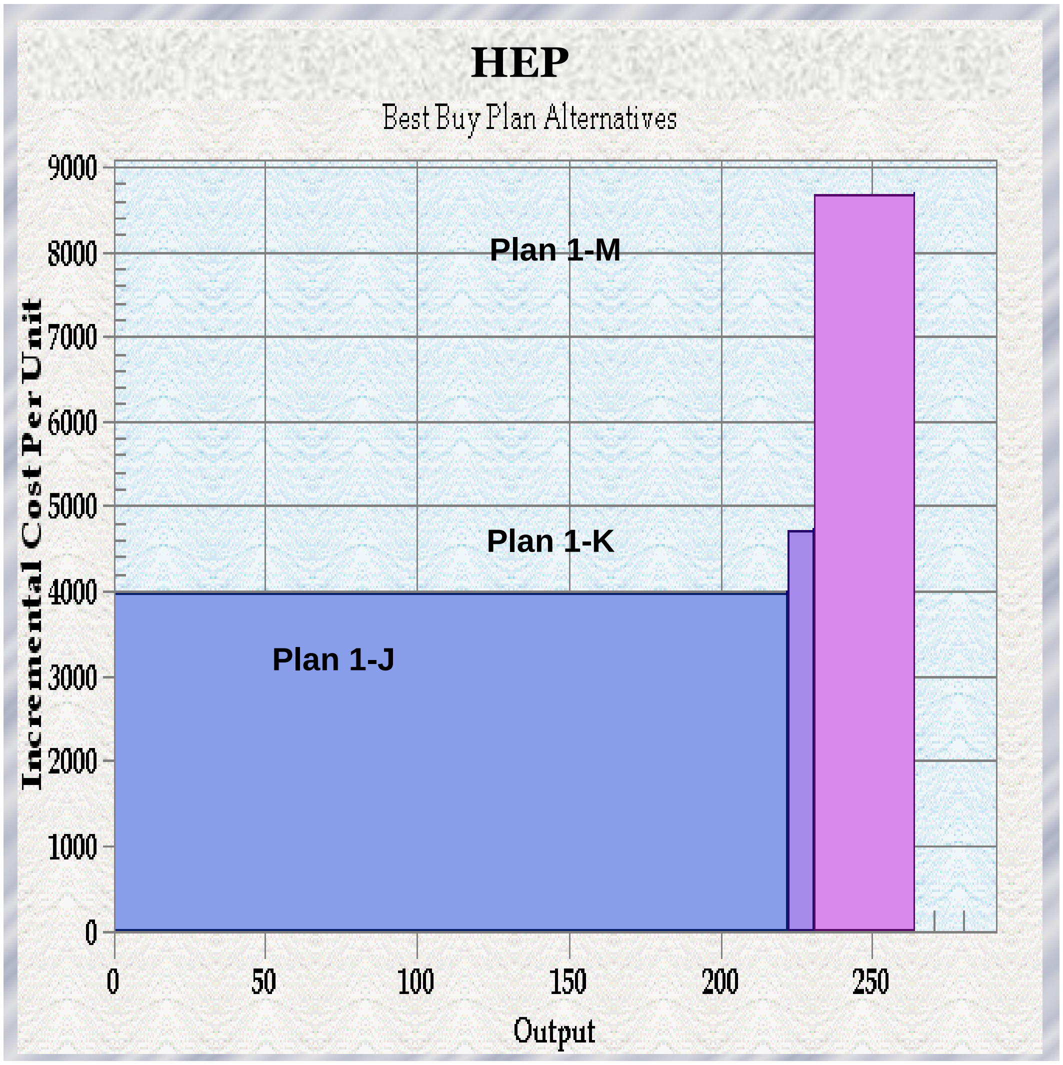


Figure 4.19. Incremental Cost Analysis results (graphical depiction) for the Reach 1 plans.

The Best Buy plan for Reach 1 would be plan 1-J, which produced more than 84% of the outputs for less than 23% of the incremental costs. The results indicate this plan could provide incrementally effective benefits and should be considered in the selection of a recommended plan.

Table 4.10 and Figure 4.20 provide the results of the HEP comparisons at the project level. As expected, a larger number of plans (15) were considered incrementally effective above and beyond the No Action plan. The average incremental cost per output ranged from $384 to $322,001 and incrementally produced between 4 and 222 outputs for the Bosque. The first five Best Buy plans omitted activity in at least one of the reaches, and, in particular, activities in Reach 1 were not considered incrementally effective until a threshold was met (Best Buy plans numbered above 6, where costs exceeded $2,755 as an incremental cost per output).

Table 4.10. ICA results for the entire MRGB project using the HEP .

Alternative	Average Annual Cost	Annual Cost	Incremental Cost	Output Above No Action (AAHU)	Total Output TY-51 (AAHU)	Incremental Output (AAHU)	Incremental Cost per Output
1=No Action Plan	$0	$0	$0	0	1353	NA	NA
2=Plans --, 2-F, --, --, --,	$53,440	$384	$53,440	139	1492	139	$384
3=Plans --, 2-F, --, --, 5-G	$213,224	$725	$159,784	294	1647	155	$1,031
4=Plans --, 2-F, 3-A, --, 5-G	$353,556	$897	$140,333	394	1747	100	$1,403
5=Plans --, 2-F, 3-A, 4-F, 5-G	$439,637	$1,027	$86,081	428	1781	34	$2,532
6=Plans --, 2-F, 3-A, 4-H, 5-G	$570,589	$1,204	$130,951	474	1827	46	$2,847
7=Plans 1-J, 2-F, 3-A, 4-H, 5-G	$1,474,325	$2,118	$903,736	678	2049	222	$4,071
8=Plans 1-K, 2-F, 3-A, 4-H, 5-G	$1,520,206	$2,156	$45,881	705	2058	9	$5,098
9=Plans 1-K, 2-B, 3-A, 4-H, 5-G	$1,640,943	$2,276	$120,737	721	2074	16	$7,546
10=Plans 1-M, 2-B, 3-A, 4-H, 5-G	$1,934,527	$2,566	$293,584	754	2107	33	$8,896
11=Plans 1-M, 2-B, 3-B, 4-H, 5-G	$2,041,422	$2,672	$106,895	764	2117	10	$10,690
12=Plans 1-M, 2-B, 3-B, 4-K, 5-G	$2,430,243	$3,068	$388,820	792	2145	28	$13,886
13=Plans 1-M, 2-K, 3-B, 4-K, 5-G	$2,691,281	$3,327	$261,038	809	2162	17	$15,355
14=Plans 1-M, 2-K, 3-H, 4-K, 5-G	$2,839,090	$3,475	$147,809	817	2170	8	$18,476
15=Plans 1-M, 2-K, 3-H, 4-K, 5-H	$3,009,769	$3,675	$170,679	819	2172	2	$85,340
16=Plans 1-M, 2-M, 3-H, 4-K, 5-H	$4,297,772	$5,222	$1,288,003	823	2176	4	$322,001

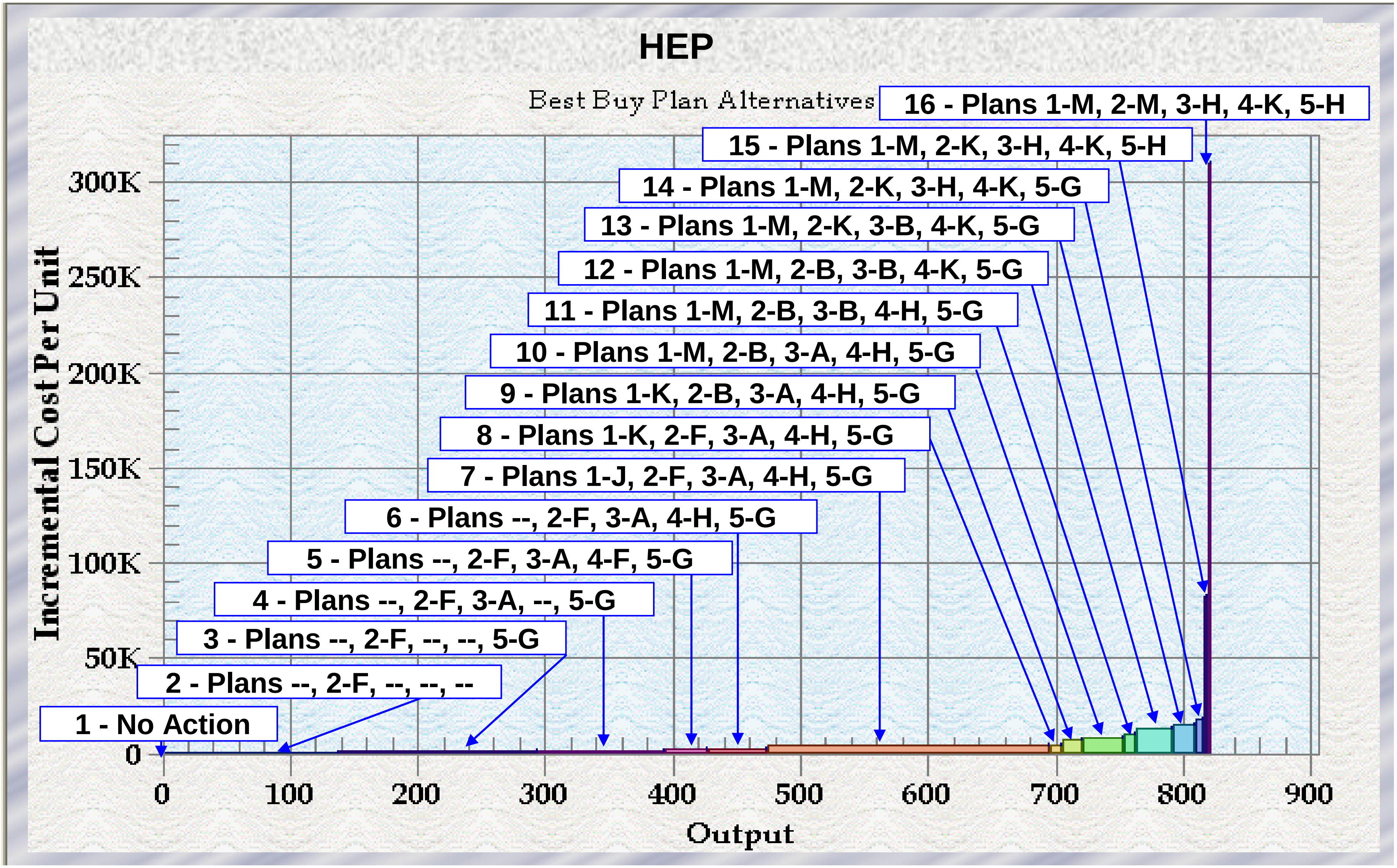


Figure 4.20. Best Buy Alternatives for the entire MRGB generated from ICA results.

Based on the results, Best Buy plans 3, 4, 7, 10, 12, and possibly 13 would be considered plans of interest. These plans produce a significant incremental output per cost compared to the rest of the Best Buy plans. In particular, Best Buy plans 2, 3, 4, and 7 each produce 100 or more AAHUs over the previous plan, whereas the next largest increment is plan 5 with 46 AAHU's. Best Buy plan 7 produces 222 AAHUs, the highest incremental output in this the array of alternatives, albeit at two to three times the cost per AAHU as Best Buy plans 2 through 6. Incremental costs rise at a nearly exponential rate from plan 2 to plan 3, plan 4 to plan 6, plan 6 to plan 10, and plan 10 to plan 13. This suggests that habitat unit costs will double each time the next larger plan of interest is chosen. Therefore, Best Buy plans 4 and 7 stand out in the plans of interest because the incremental cost is only 26% and 30%, respectively, more than the previous plan. Understanding that all these plans (excluding 2 and 16) are Best Buy plans, the maximum benefits per cost are in Best Buy plan 4 or Best Buy plan 7.

The next steps were to compare the plans of interest against the Federal and project specific goals to evaluate their acceptability and verify that the alternatives would not exceed the constraints of the project or cause significant negative impacts to the environment. The objectives presented in Section 1 include restoration goals as well as recreation and education goals. Therefore, for the comparison of Best Buy plans, restoration goals are addressed. A similar analysis of the recreation plan will be made for recreation and interpretation goals. An environmental, hydraulic, and hydrologic analysis of the final array of Best Buy plans is presented in sections 4.13 through 4.18.

The general feasibility criteria listed in the Federal guidelines for water resources projects are:

- *Completeness* – Does the plan include all necessary parts and actions to produce the desired results? Is the plan capable of being implemented and needs no further actions to fulfill the project?

- *Effectiveness* – Does the plan substantially meet the objectives? How does the plan measure up to the constraints?

- *Efficiency* – Does the plan maximize net NER benefits?

- *Acceptability* – Is the plan acceptable and compatible with laws and policies?

The CEA and ICA identify a set of plans that meet the criteria for efficiency. Table 4.11 presents the matrix of Best Buy plans as they relate to stated restoration objectives. Because each individual measure addressed a particular restoration, all the Best Buy plans meet the stated objectives. Only the No Action plan does not increase the value or area of habitat by some degree. Therefore, the E-team developed a Habitat Quality goal using the HSI methodology. When this criteria is applied only Best Buy plans 7 and above (plans 10 and 13) meet or exceed this criteria, and plan 7 is the first cost effective plan to meet the criteria for efficiency as well as effectiveness. All plans meet the criteria for completeness as the measures that make up each plan were evaluated for implementability prior to cost analysis.

Table 4.11. Matrix of Best Buy plans compared to project objectives.

	Best Buy Plans													
OBJECTIVES	No action	3	4	5	6	7	8	9	10	11	12	13	14	15
Improve habitat quality and increase the amount of native Bosque communities to a sustainable level	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Reestablish fluvial processes in the Bosque to a more natural condition.	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Restore hydraulic Processes between the Bosque and the river to a more natural condition.	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Reduce the risk of catastrophic fires in the Bosque.	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Protect, extend and enhance areas of potential habitat for listed species within the Bosque.	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Meet or Exceed overall habitat quality goal (HSI) of 0.56 in TY 51	NO 0 .36	NO 0.46	NO 0.50	NO 0.51	NO 0.51	YES 0.59	YES 0.60	YES 0.60	YES 0.60	YES 0.60	YES 0.62	YES 0.62	YES 0.62	YES 0.62

Comparing Tables 4.10 and 4.11, the plans of interest numbered above Best Buy plan 7 (plans 10 and 13) provide a reasonable increase in benefits per cost and meet the criteria for completeness. The question remains whether the added benefits justify the increase in cost. Plan 10 would provide an increase in the amount of habitat (58 AAHU) over plan 7; however, the overall HSI value of the project would increase from 0.59 to 0.60. The cost per AAHU would be double that of the cost per AAHU for plan 7. Any increase in habitat value is good; however, the increase in overall value and functionality of the project does not appear to support the increase in cost.

To determine acceptability and completeness, the plans must not exceed the constraints of the project or cause significant negative impacts to the environment. The plans must be acceptable to the non-Federal sponsor. Most of the constraints were incorporated during the formulation of the individual features; however, a hydrologic and hydraulic analysis verified the flood capacity effect of the plans of interest.

4.7 Hydrologic and Hydraulic Comparison of Alternative Plans

Because it is cost prohibitive to develop a hydraulic model for each potential alternative, the E-team modeled three alternative plans using the two-dimensional hydraulic FLO-2D model to compare effectiveness and sustainability of a range of reasonable plans. The "Maximum Effort" alternative, or plan 16 from the Best Buy plans (1-M, 2-M. 3-H, 4-K, 5-G), contains all of the restoration features considered during plan formulation. The hydraulic analysis verified that all features would function as planned and the entire suite of features would be sustainable in future years. The hydraulic analysis identified features that could cause water to stand against, and potentially damage, the levee.

The E-team developed the second and third models for intermediate Best Buy plan 7 (Moderate Effort-A [1-J, 2-F, 3-A, 4-H, 5-G]) and Best Buy plan 12 (Moderate Effort-B [1-M, 2-B, 3-B, 4-K, 5-G]). To represent the restoration features contained in each plan, the E-team modified the existing conditions FLO-2D 250-foot-grid model by making appropriate adjustments to the main channel cross-sectional geometry, the overbank grid elevations, and the roughness parameters. The E-team used the following five categories of restoration features to comparing the restoration alternatives:

- Water Features (300 cfs); Water surface elevation corresponds to the 300 cfs discharge.

- Water Features (3,500 cfs): Side channels at least one foot deeper than the water surface elevation correspond to the 3,500 cfs discharge.

- Bank Destabilization: Lowest excavation corresponds with the water surface elevation at the 3,500 cfs discharge.

- Swale Trench Excavation: Same as Bank Destabilization.

- Treat-Retreat-Revegetation: No change in elevation. Roughness adjusted accordingly.

The E-team delineated these features in their proposed spatial locations and overlaid the features onto the FLO-2D grid in ArcGIS to determine the grid elements to be modified. Figure 4.21 shows a schematic representation of the modifications of the existing conditions FLO-2D grid to represent the delineated channel and overbank restoration features. Figure 4.22 displays an example of the delineated FLO-2D grid elements used to represent the restoration alternatives in the vicinity of the North Diversion Channel in Albuquerque.

The water features (300 cfs) represent wetlands in which water is present in the water feature when the channel water surface elevation adjacent to the feature corresponds to a discharge of 300 cfs. The wetland features are designed to be sufficiently low to be hydraulically connected to the groundwater. The water features (3,500 cfs) are typically high-flow channels that follow historic high-flow paths in the overbanks. Grid elevations identified for these features were lowered one foot below the corresponding 3,500-cfs water surface elevation. The channel cross sections at the upstream and downstream ends of the features were also lowered to ensure that water would be conveyed from the channel into the features at the upstream end and from the overbank features back to the channel at the downstream end.

The bank destabilization features are connected directly to the river and were designed to provide habitat along the channel margins. Bank destabilization features were incorporated into the hydraulic model by lowering the FLO-2D grid elevation and bank elevations in the corresponding channel cross sections to the water surface elevation that corresponds to a discharge of 3,500 cfs.

The swale-trench features are low-elevation features in the overbanks designed to be connected to the groundwater. The features are not hydraulically connected to the main channel when flows are sufficiently low to be contained within the main channel; therefore, cross-section changes were not made for these features.

The treat-retreat-revegetation features remove non-native vegetation and revegetate with native vegetation without causing changes to the existing ground elevations. These features are represented in the hydraulic model by adjusting the overbank roughness of the grid elements. No elevation or cross-sectional adjustments were made for these features.

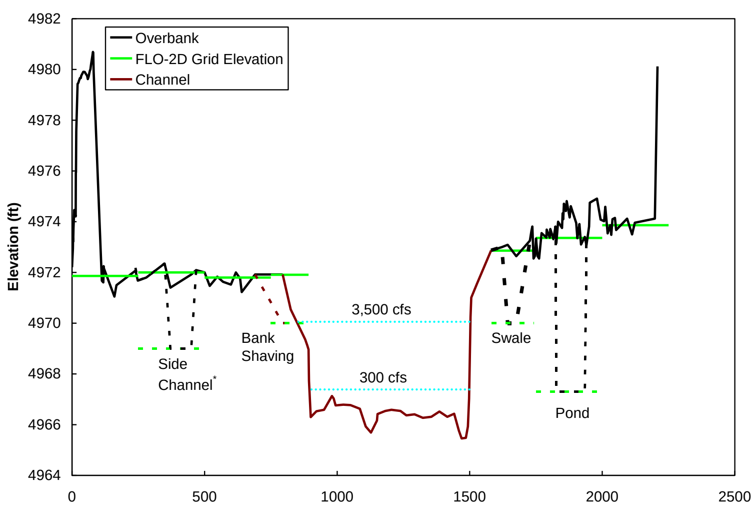


Figure 4.21. Schematic representation of FLO-2D grid modification to represent propo alternatives.

The channel widening caused by the bank destabilization features, and the associated increase in overbank flows, causes the channel water surface elevations along the reach to decrease compared to the existing conditions. As a result, the E-team used an iterative procedure to ensure that the designed restoration features are inundated at the desired 3,500 cfs water surface elevation. The E-team conducted the iteration procedure by running the Year 0 restoration alternatives at a discharge of 3,500 cfs and comparing the resulting water surface elevation to the elevation of the design feature. If the difference between the design elevation and the predicted water surface elevation was greater than approximately 0.05 feet, the elevation of the design feature was adjusted to the new predicted water surface elevation, and the simulation was repeated with the new design elevations. Typically, only one iteration was required for the design and water surface elevations to converge within the specified tolerance.

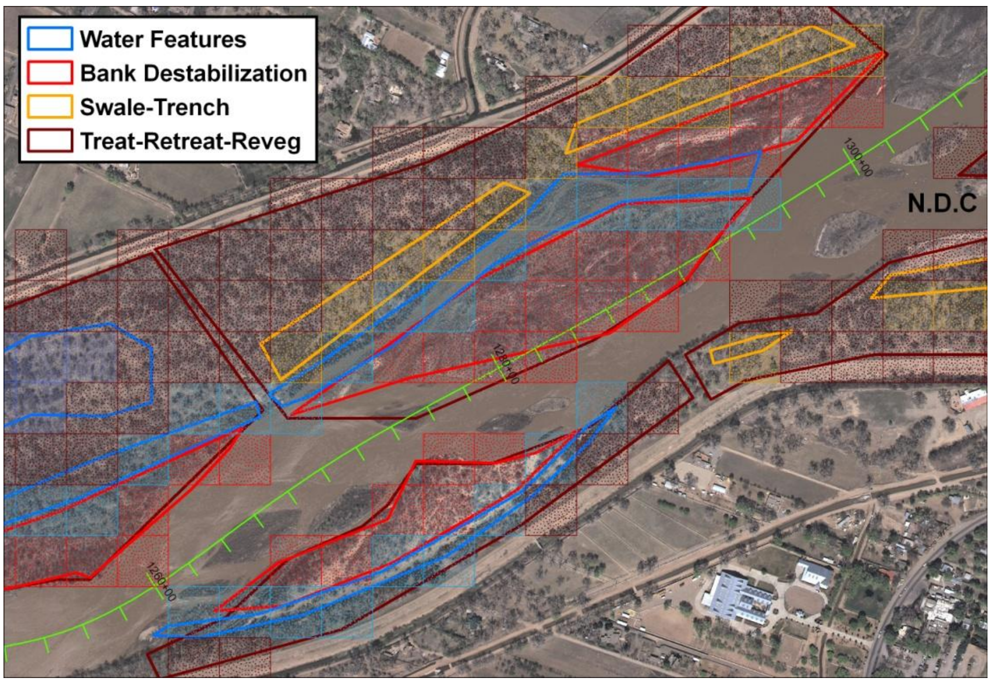


Figure 4.22. Example of delineated FLO-2D grid representing the restoration.

For the future conditions analysis, the overbank roughness (represented by the Manning's *n*-value in the hydraulic model) was adjusted to reflect the establishment and growth of vegetation within the features (Table 4.12). The E-team developed estimates of overbank roughness in consultation with the Corps based on evaluation of the observed vegetation growth in other restoration projects within the project reach. In general, the roughness values in the overbank treat-retreat-revegetation features will be low after the initial vegetation clearing (Year 0). The roughness will increase after replanting and will increase further as the vegetation becomes more established by Year 5. The E-team assumed that the plants are fully established by Year 20, and the roughness values remain constant for Years 20 through 50.

Table 4.12. Manning's n-values for delineated features for Years 0, 5, 20, 30, and 50.					
Feature	Year 0	Year 5	Year 20	Year 30	Year 50
Water features (300 cfs)	0.040	0.050	0.060	0.060	0.060
Water feature (3,500 cfs)	0.040	0.050	0.060	0.060	0.060
Bank destabilization	0.055	0.100	0.100	0.100	0.100
Swale trench	0.050	0.065	0.100	0.100	0.100
Overbank treat-retreat-revegetation	0.040	0.075	0.085	0.085	0.085

To reflect future channel conditions in the project reach under the modeled alternatives, changes in the channel cross sections associated with aggradation and degradation 5, 20, 30 and 50 years after project implementation were estimated using a HEC-6T sediment transport model. The E-team modeled the entire 50-year period and evaluated the cross-sectional geometry at 5, 20, 30, and 50 years to determine aggradation/degradation changes throughout the reach. Because of the uncertainty in how each specific cross section will change as the aggradation or degradation occurs, the model results were used to estimate a representative change in cross-sectional depth within each segment of the reach that exhibits consistent aggradation/degradation trends based on the detailed model results. Figures 4.23 and 4.24 show the predicted change in cross-sectional area and the assigned representative changes in channel depths for the 5- and 50-year conditions. The HEC-6T analysis indicates that both aggradational and degradational trends occur along the reach in Year 5. Over time, the aggradational areas shown in Year 5 change to stable or slightly degradational at Years 20 and 30, and a slight degradational trend occurs along the entire project reach over the 50-year simulation.

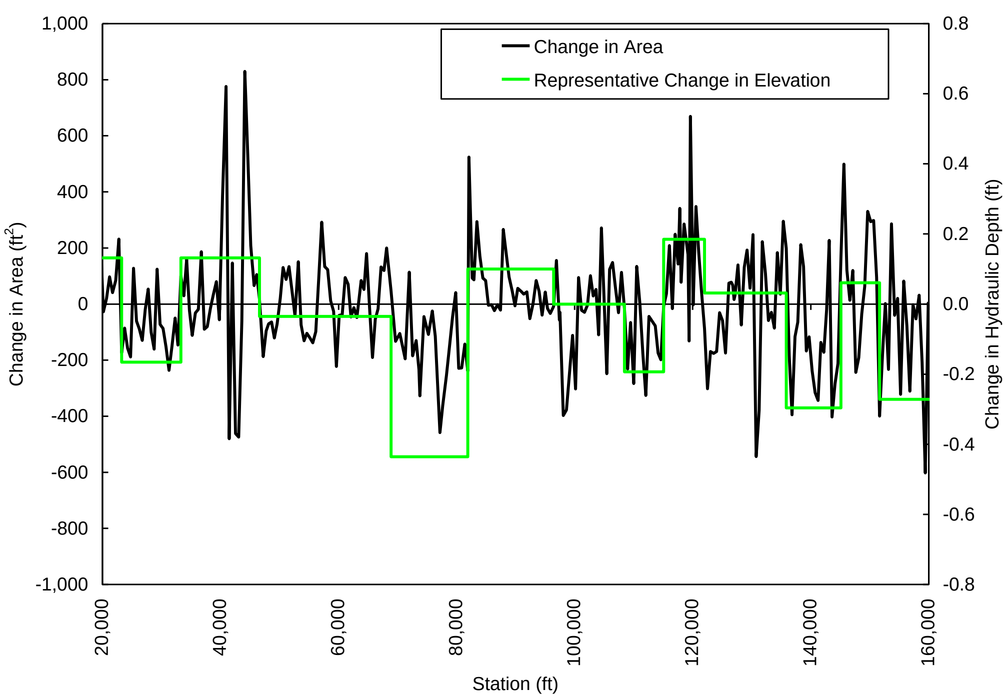


Figure 4.23. Predicted change in channel cross-section at Year 5.

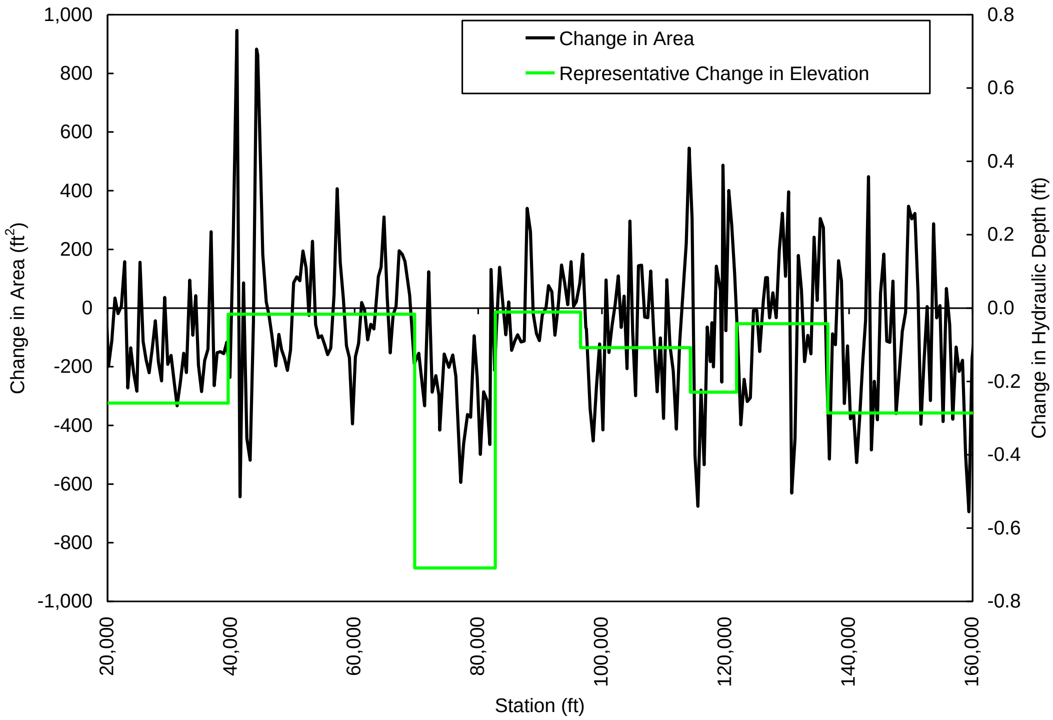


Figure 4.24. Predicted change in channel cross-section at Year 50.

4.7.1 Restoration Alternative Plan 16 Results

The amount of overbank inundation predicted by the hydraulic analysis for each simulation under the "Maximum Effort" alternative (Best Buy plan 16) was estimated for each reach based on the number of inundated grid elements (Table 4.13). These simulations also indicate that the predicted water-surface elevations would decrease slightly. This lowering is caused by the increased conveyance capacity associated with the restoration features, particularly the bank destabilization features that create a wider channel and the connected water features that allow more flow in the overbanks. The water features (3,500 cfs) are connected to the main channel and they are designed to convey flows into the overbank at discharges greater than 3,500 cfs. The following sections summarize the results of these simulations.

4.7.1.1 Channel Full Conditions

The channel-full flow simulations (6,000 cfs) indicate that the area of overbank inundation would increase significantly in all five reaches under the Best Buy plan 16 "Maximum Effort" alternative compared to existing conditions (Table 4.13). A combined total of 810 acres are inundated in Reaches 1 through 5 in Year 0 conditions for Alternate 1 as compared to 253.7 acres inundated in Reaches 1 through 5 for the existing condition. Alternative Plan 16 would result in a 219.3% increase in the area of inundation for Hydrology Scenario 1. The extent and maximum depth of inundation for this scenario are shown in Appendix A. On average, the water-surface elevations throughout the entire reach will decrease by 0.14 and 0.27 feet for the Year 0 and Year 50 conditions, respectively, compared to existing conditions.

Table 4.13. Summary of areas (acres) of inundation for existing conditions and Restoration Alternative Plan 16 (Years 0, 5, 20, 30 and 50).

Hydrology Scenario	Description	Future Channel Condition (yr)	Reach					
			1	2	3	4	5	Total
1	Channel Full Conditions	Existing	77.2	41.3	25.2	34.4	75.6	253.7
		0	204.6	182.2	122.6	125.5	175.1	810.0
		5	199.6	179.5	122.1	132.0	179.4	812.6
		20	196.1	176.1	122.6	124.1	174.2	793.1
		30	201.8	174.7	122.5	121.5	173.6	794.1
		50	196.3	174.8	122.4	121.2	172.7	787.4
2	Annual Spring Runoff	Existing	45.2	23.1	7.7	4.0	7.9	87.9
		0	175.8	109.3	88.0	62.3	77.7	513.1
		5	180.0	109.0	89.0	65.4	93.8	537.2
		20	178.8	110.0	86.7	53.1	70.1	498.7
		30	178.8	110.4	88.8	54.3	70.8	503.1
		50	175.5	108.7	89.5	54.0	73.0	500.7
4	100-Year Peak Snowmelt	Existing	84.4	59.9	14.6	133.4	364.9	657.2
		0	277.5	186.1	162.7	298.3	392.9	1,317.5

4.7.1.2 Average Annual Flow Hydrograph

The average annual flow simulations indicate that the amount of overbank inundation increases significantly in all reaches and for all five future channel conditions compared to existing conditions. A combined total of 513.1 acres are inundated in Reaches 1 through 5 in Year 0 conditions for alternative Best Buy plan 16 as compared to 87.9 acres inundated in Reaches 1 through 5 for the existing condition. Alternative Best Buy plan 16 would result in a 483.7% increase in the area of inundation for Hydrology Scenario 2.

The maximum amount of inundation generally occurs during Year 5 when a modest amount of channel aggradation occurs in some locations along the project reach. The extent, maximum depth, and duration of inundation for this scenario are shown in the Appendix A. On average, the water-surface elevations throughout the entire reach will decrease by 0.34 and 0.48 feet for the Year 0 and Year 50 conditions, respectively, compared to existing conditions.

4.7.1.3 1.0%-Chance Post-Cochiti Dam Snowmelt Hydrograph

The 1.0%-chance snowmelt hydrograph was simulated for the Year 0 conditions only. For this simulation, the amount of overbank inundation increases significantly in Reaches 1 through 4, and increases slightly in Reach 5 compared to existing conditions (Table 4.14). A combined total of 1317.5 acres are inundated in Reaches 1 through 5 in Year 0 conditions for Alternative Plan 16 as compared to 657.2 acres inundated in Reaches 1 through 5 for the existing condition. Alternative Best Buy plan 16 would result in 100.5% increase in the area of inundation for Hydrology Scenario 4. The extent, maximum depth, and duration of inundation for this scenario are shown in Appendix A. On average, the maximum water-surface elevations throughout the entire reach will decrease by 0.06 feet for the Year 0 conditions compared to existing conditions.

4.7.2 Restoration Alternative Plan 7 Results

The amount of overbank inundation for each simulation under the Moderate Effort-A Alternative (Alternative Best Buy plan 7) is summarized in Table 4.14.

Table 4.14. Summary of areas (acres) of inundation for existing conditions and Restoration Alternative Plan 7 (Years 0, 5, 20, 30 and 50).

Hydrology Scenario	Description	Future Channel Condition (yr)	Reach 1	2	3	4	5	Total
1	Channel Full Conditions	Existing	77.2	41.3	25.2	34.4	75.6	253.7
		0	145.2	46.1	31.3	55.5	85.5	363.6
		5	147.7	45.5	28.8	53.8	84.1	360.0
		20	146.7	45.4	28.6	53.9	83.3	357.8
		30	147.5	45.7	28.4	54.7	82.7	358.9
		50	148.9	45.5	28.6	54.8	82.8	360.5
2	Annual Spring Runoff	Existing	45.2	23.1	7.7	4.0	7.9	87.9
		0	113.3	25.2	16.6	30.7	42.9	228.7
		5	113.3	25.4	20.0	38.1	48.8	245.6
		20	111.8	26.0	16.7	30.6	28.7	213.8
		30	112.8	25.8	16.7	30.2	28.5	214.2
		50	111.6	25.8	16.9	29.6	28.1	212.1

4.7.2.1 Channel Full Conditions

The channel full flow simulations for alternative Best Buy plan 7 indicate that the amount of overbank inundation would increase in all reaches compared to the existing condition (Table 4.14). A combined total of 363.6 acres are inundated in Reaches 1 through 5 in Year 0 conditions for alternative Best Buy plan 7 as compared to 253.7 acres inundated in Reaches 1 through 5 for the existing condition. Alternative Best Buy plan 7 would result in a 43.3%

increase in the area of inundation for Hydrology Scenario 1. The extent and maximum depth of inundation for this scenario are shown in the Appendix A. On average, the water surface elevations throughout the entire reach decrease by 0.04 and 0.10 feet for the Year 0 and Year 50 conditions, respectively.

4.7.2.2 Average Annual Hydrograph

For the average-annual hydrograph, the amount of overbank inundation increases in all reaches and for all five future channel conditions compared to existing conditions. A combined total of 228.7 acres are inundated in Reaches 1 through 5 in Year 0 conditions for alternative Best Buy plan 7 as compared to 87.9 acres inundated in Reaches 1 through 5 for the existing condition. Alternative Best Buy plan 7 would result in a 160.2% increase in the area of inundation for Hydrology Scenario 2. The extent and maximum depth of inundation for this scenario are shown in the Appendix A. On average, the maximum water-surface elevations throughout the entire reach decrease by 0.24 and 0.39 feet for the Years 0 and 50 conditions, respectively.

4.7.3 Restoration Alternative Plan 12 Results

The amount of overbank inundation for each simulation under the Moderate Effort-B Alternative (Alternative Best Buy plan 12) is summarized in Table 4.15.

Table 4.15. Summary of areas of inundation for existing conditions and Restoration Alternative Plan 12 (Years 0, 5, 20, 30 and 50) (acres).

Hydrology Scenario	Description	Future Channel Condition (yr)	Reach					
			1	2	3	4	5	Total
1	Channel Full Conditions	Existing	77.2	41.3	25.2	34.4	75.6	253.7
		0	190.6	45.4	49.0	96.6	85.3	466.8
		5	193.4	44.6	47.9	94.4	84.4	464.8
		20	192.5	45.3	44.4	95.1	88.1	465.4
		30	194.0	45.0	48.2	95.6	83.6	466.4
		50	192.4	45.7	43.9	91.3	82.3	455.6
2	Annual Spring Runoff	Existing	45.2	23.1	7.7	4.0	7.9	87.9
		0	165.8	40.3	39.5	73.6	41.0	360.2
		5	158.1	37.5	45.6	74.4	37.3	352.9
		20	145.3	40.0	45.5	67.7	21.4	319.9
		30	147.7	38.1	45.0	79.6	22.6	333.0
		50	144.1	37.6	41.5	65.2	19.1	307.6

4.7.3.1 Channel Full Conditions

The channel full flow simulations for alternative Best Buy plan 12 indicate that the amount of overbank inundation would increase in all reaches compared to the existing condition. A combined total of 466.8 acres are inundated in Reaches 1 through 5 in Year 0 conditions for alternative Best Buy plan 12 as compared to 253.7 acres inundated in Reaches 1 through 5 for the existing condition. Alternative Best Buy plan 12 would result in a 84.0% increase in the area of inundation for Hydrology Scenario 1. The extent and maximum depth of inundation for this scenario are shown in the Appendix A. On average, the water surface elevations throughout the entire reach decrease by 0.02 and 0.12 feet for the Year 0 and Year 50 conditions, respectively.

4.7.3.2 Average Annual Hydrograph

For the average-annual hydrograph, the amount of overbank inundation increases in all reaches and for all five future channel conditions compared to existing conditions. A combined total of 360.2 acres are inundated in Reaches 1 through 5 in Year 0 conditions for alternative Best Buy plan 12 as compared to 87.9 acres inundated in Reaches 1 through 5 for the existing condition. Alternative Best Buy plan 12 would result in a 309.8% increase in the area of inundation for Hydrology Scenario 2. The extent and maximum depth of inundation for this scenario are shown in the Appendix A. On average, the maximum water surface elevations throughout the entire reach decrease by 0.26 and 0.41 feet for the Years 0 and 50 conditions, respectively.

4.8 Sustainability of Restoration Features

The E-team conducted an analysis of the overbank sediment transport characteristics to evaluate the long term sustainability of restoration features. Overbank flows will cause sediment deposition on the floodplain, and sediment deposition will occur in the proposed channel restoration features, particularly after the vegetation has established. An estimate of the amount and rate of sediment deposition within the features was made for restoration alternative Best Buy plan 16 (Maximum Effort alternative) under the Hydrology Scenario 4 (1.0%-chance post-Cochiti Dam snowmelt hydrograph) in order to evaluate the long-term sustainability of the proposed features.

Table 4.16 summarizes the total amount of predicted overbank inundation and the design area of each type of restoration feature in each reach. In restoration alternative Best Buy plan 16, approximately 232 acres of swale features, 95 acres of water-channel feature, and 174 acres of water-pond features occur. The bank features are not included in the analysis because they are designed to erode in order to increase channel sinuosity and are not considered permanent features. The predicted areas of overbank inundation under Hydrology Scenario 4 measure 278, 186, 163, 298, and 393 acres for Reaches 1 through 5, respectively. The swale features, water-channel features, and water-pond features account for 18, 7, and 13 percent of the total inundation area.

Table 4.16. Summary of total predicted area of inundation for the Maximum Effort Conditions for the 5 study reaches (SR).						
Total Inundation	SR1	SR2	SR3	SR4	SR5	Total
Area	277.5	186.1	162.7	298.3	392.9	1317.5
Inundation Area for each Restoration Feature Class						
Swale	92.8	28.8	37.2	34.3	39.1	232.2
Water-Channel	45.5	13.2	8.4	6.9	20.7	94.6
Water-Pond	16.6	33.3	86.3	23.8	14.2	174.2
Percentage of Inundation Area						
Swale	33%	15%	23%	11%	10%	18%
Water-Channel	16%	7%	5%	2%	5%	7%
Water-Pond	6%	18%	53%	8%	4%	13%
Total	56%	40%	81%	22%	19%	38%

The E-team estimated the amount of overbank sedimentation that would occur during Hydrology Scenario 4 from the amount of sediment in the main channel water column that would be conveyed onto the overbank. This estimate represents an upper limit of sediment transport in the overbanks, as sediment transport rates would be higher near the channel margins and would drop rapidly further away from the channel. The estimates were made based on one representative restoration site that was selected in each reach (Table 4.17). The Rouse suspended sediment concentration profile equation (Vanoni 1977) was applied with the main channel hydraulic results from the FLO-2D model and a representative particle size of 0.5 mm to assess the characteristics of the sediment concentration profile at the five representative reach sites at a discharge of 7,000 cfs (the Cochiti Reservoir release and dominant discharge in Hydrology Scenario 4).

Table 4.17. Location of representative restoration locations.		
Reach	Station	Description
SR-1	126,858	Just below the North Diversion Channel
SR-2	81,531	Just below Interstate 40 Bridge
SR-3	76,092	Just upstream of Central Ave. Bridge
SR-4	66,432	Just upstream of Barelas Bridge
SR-5	9,183	Just upstream of Interstate 25 Bridge

An example of the predicted cumulative sediment transport profiles in the main channel for Reach 3 at 7,000 cfs is shown in Figure 4.25. The square symbols represent the elevation in the water column at which flows would be conveyed into the channel features (designed to the 3,500-cfs water surface elevation), and the circular symbols represent the top of bank elevations. For Reach 3, approximately 34 percent of the bed-material load is carried in the portion of the water column above the elevation of the channel feature design elevation, and 7 percent of the bed-material load is carried in the portion of the water column above the bank elevation. Figure 4.26 shows the predicted cumulative sediment transport profiles in the main channel for each of the representative sites at Reaches 1 through 5 for 7,000 cfs. Based on this analysis, 30 to 38 percent of the bed-material load (average is 35 percent) is carried in the portion of the water column above the elevation of the channel feature design elevation, and between 5 and 22 percent (average is 12 percent) of the bed-material load is carried in the portion of the water column above the bank elevation.

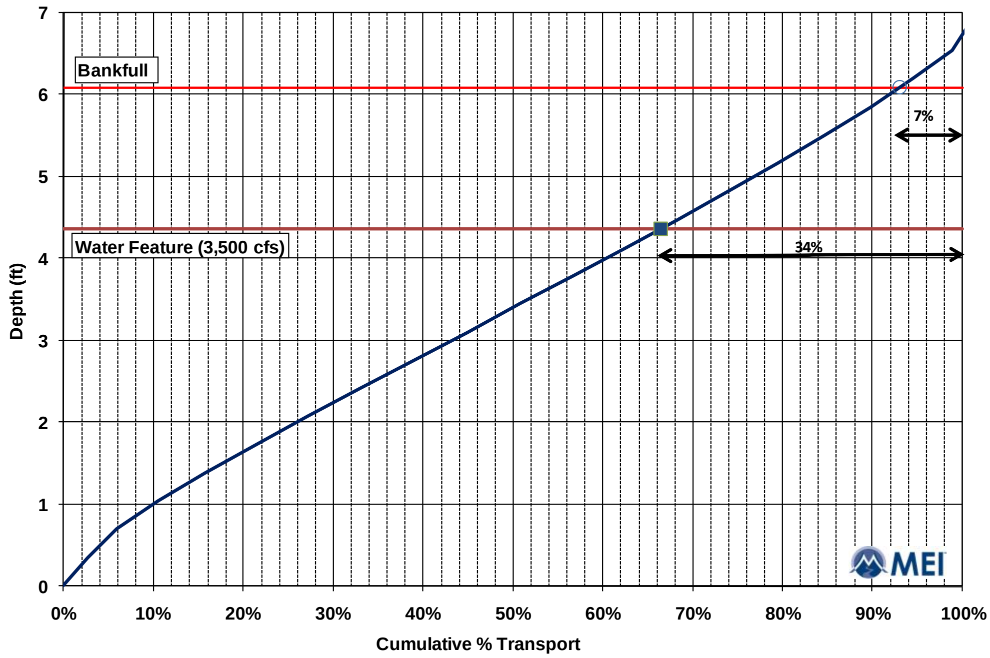


Figure 4.25 Cumulative percent of bed material above the channel bed at 7,000 cfs.

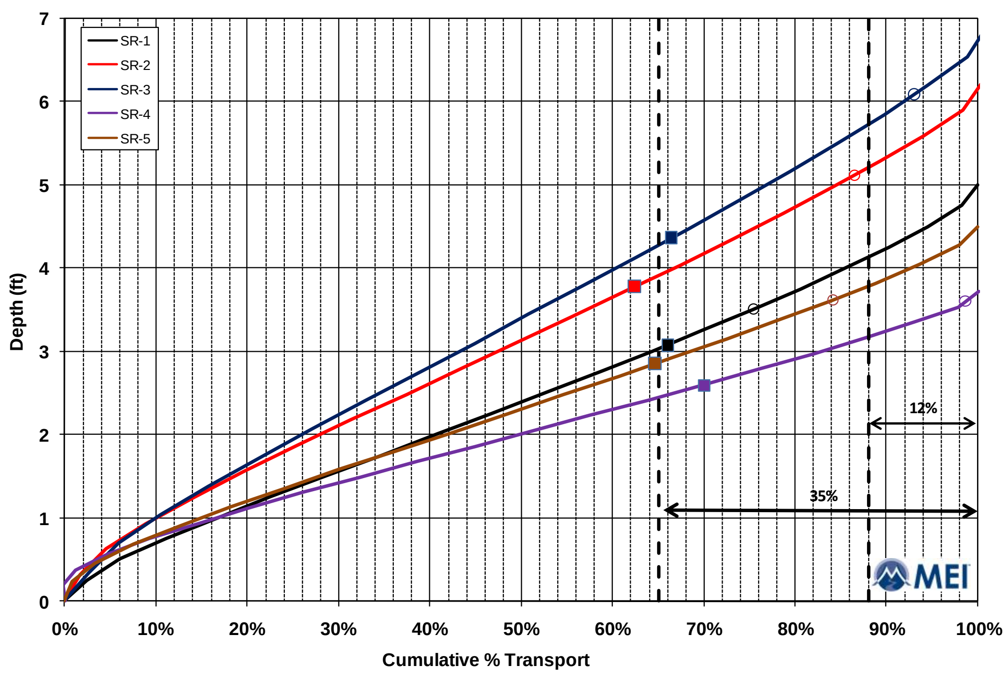


Figure 4.26 Cumulative percent of bed material above the channel bed at 7,000 cfs.

The E-team estimated the depth of sediment deposition on the overbank during the 1.0%-chance post-Cochiti Dam snowmelt hydrograph by integrating the reach sediment-rating curves over the period of the hydrograph (approximately 102 days at 7,000 cfs) to obtain the total volume of sediment and dividing by the reach inundation area to obtain the inundation depth (Table 4.18). Assuming that 12 percent of the suspended bed-material load of the main-channel is transported onto the overbank, the predicted average depth of sedimentation on the overbanks is 0.19, 0.25, 0.29, 0.14, and 0.12 feet for Reaches 1 through 5, respectively. Because the restoration features are designed to be lower than the surrounding overbank elevation, the features would receive more sediment deposition than the higher surrounding overbanks due to the higher roughness values created by the vegetation and the associated decreased velocities. Assuming that the sediment deposition rate is five times higher in the restoration features than on the overbank features, the predicted average depth of sedimentation would increase to 0.9, 1.2, 1.4, 0.7, and 0.6 feet for Reaches 1 through 5, respectively.

Table 4.18. Predicted overbank sedimentation depths for the Maximum Effort, 1.0%-chance post-Cochiti Dam snowmelt event.

Reach	Sediment Transport Main Channel (tons/day)	Sediment Transport Channel Features (tons/day)	Average Overbank Sedimentation Depth (feet)	Five Times Average Sedimentation Depth (feet)
1	12,181.07	1,461.73	0.19	0.9
2	12,644.97	1,517.40	0.24	1.2
3	13,239.62	1,588.75	0.29	1.4
4	11,885.03	1,426.20	0.14	0.7
5	13,048.20	1,565.78	0.12	0.6

For the channel restoration features, the E-team assumed that 35 percent of the suspended bed-load would be conveyed into the features. The estimated amount of sedimentation in the channel features is 0.6, 0.7, 0.9, 0.4, and 0.4 feet for Reaches 1 through 5, respectively (Table 4.19). Given that the 1.0%-chance post-Cochiti Dam snowmelt hydrograph duration is approximately 102 days (3.4 months) above 7,000 cfs, the predicted amount of overbank deposition appears reasonable and relatively low during the 1.0^%-chance post-Cochiti Dam snowmelt event. Furthermore, given that the predicted depth of overbank is an upper limit and the depth of deposition is significantly less than the depth of the features, the overbank features should not be unreasonably affected by sediment deposition over the 50-year life of the project.

Table 4.19. Predicted sedimentation depths in the channel features (3,500-cfs features) for the Maximum Effort, 1.0%-Chance post-Cochiti Dam snowmelt event.

Reach	Sediment Transport Main Channel (tons/day)	Sediment Transport Channel Features (tons/day)	Average Overbank Sedimentation Depth (feet)
1	12,181.07	4,263.37	0.6
2	12,644.97	4,425.74	0.7
3	13,239.62	4,633.87	0.9
4	11,885.03	4,159.76	0.4
5	13,048.20	4,566.87	0.4

4.8.1 Summary of Hydrologic and Hydraulic Analysis Results

The E-team conducted the hydraulic modeling using FLO-2D and a 250-foot grid to evaluate depth, extent, and duration of overbank inundation for existing conditions and for five restoration alternatives (Maximum Effort, Minimum Effort, Moderate Effort, Moderate Effort-A, and Moderate Effort-B). The analysis was conducted for initial channel conditions after construction of the project (Year 0) and four future channel conditions to evaluate the effects of aggradation or degradation on overbank inundation 5, 20, 30, and 50 years after construction of the restoration features.

Existing conditions were simulated using four hydrology scenarios (Table 4.20). Hydrology Scenario 3, the 10,000 cfs high-flow hydrograph, was modeled only for the purpose of determining the effect of a high-flow release through the project area under existing conditions. Hydrology Scenarios 1 and 2 were simulated for all five alternatives in years 0, 5, 20, 30, and 50 to provide the area of inundation over the period of analysis for the restoration flows expected during that period. Hydrology Scenario 4 was modeled for three of the alternatives (Maximum Effort, Minimum Effort, and Moderate Effort) in year 0 to indicate the area of inundation that would occur in a large event. The summary of results for the restoration alternatives with existing conditions are shown in Table 4.20.

Table 4.20 Summary of Hydrologic Scenarios.		
Hydrologic Scenario	Description	Peak Discharge (cfs)
1	Active channel-full flow	6,000
2	Post-Cochiti annual spring hydrograph	3,770
3	10,000 cfs post-Cochiti hydrograph	10,000
4	100-year post-Cochiti hydrograph	7,750

The hydraulic and sediment-transport results for the existing conditions model were used to perform a channel-stability analysis; results of the analysis indicate that the bed-material transport capacity is relatively consistent from reach to reach; however, a slight net degradational tendency occurs in the absence of tributary sediment contribution for the study reach for all three of the individual storm hydrographs analyzed.

The team conducted an analysis of the overbank sediment-transport characteristics to evaluate the long-term sustainability of restoration features. The amount of overbank sedimentation that would occur for restoration alternative Best Buy plan 16 (Maximum Effort alternative) under Hydrology Scenario 4 (1.0%-chance post-Cochiti Dam snowmelt hydrograph) was estimated from the amount of sediment in the main channel water column that would be conveyed onto the overbank for the duration of the hydrograph. The amount of sediment deposition on the overbank appears to be relatively low during the 1.0%-chance post-Cochiti Dam snowmelt hydrograph. Given the relatively low amount of deposition during this large event, the overbank features are not expected to be unreasonably affected by sediment deposition over the 50-year life of the project.

The Rio Grande through this reach is used for conveyance of regulated flows for downstream irrigation and water deliveries to meet compact requirements. Project water features have been designed to operate at the water levels expected during an average water year. The average water year flows have been determined from historical data and are expected to continue into the future if water compact deliveries are to be met. Because the restoration features were not designed for (or dependent upon) extreme events, climate change would not be expected to affect them dramatically so long as water availability is sufficient to meet compact requirements (see also section 5.12 Climate Change).

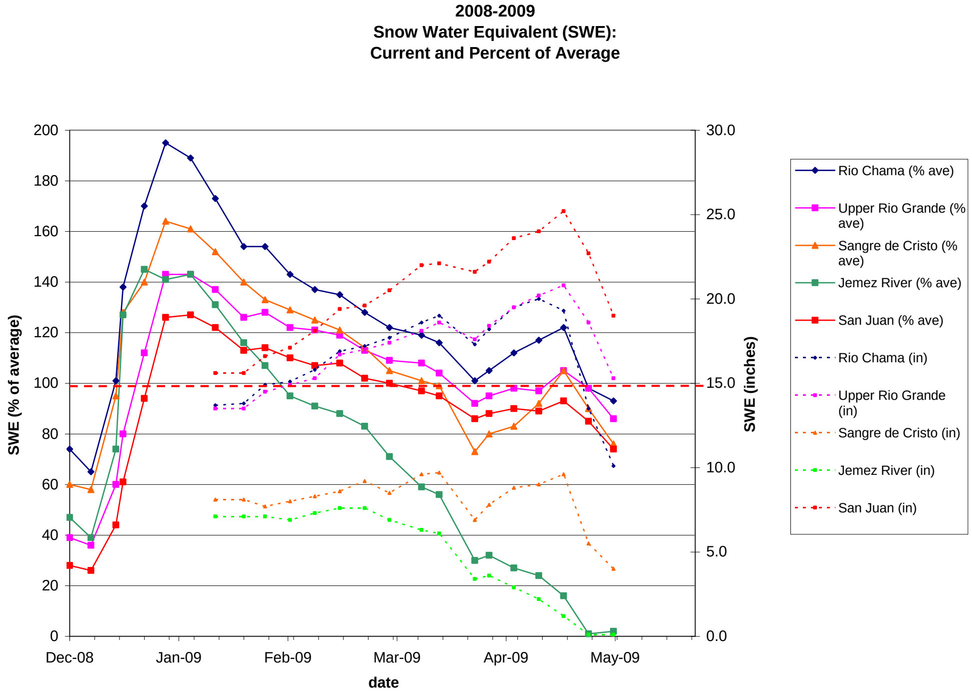


Figure 4.27. 2008-2009 Snow-Water Equivalent.
(Provided by Interstate Stream Commission, January 2010)

4.9 Effects to Existing Flood Control Structures

Within the study area, levees on both sides of the river provide flood risk management to the neighboring residential, commercial, and agricultural community. A study requirement is to avoid impact to the integrity or function of the levees. The proposed project will not raise the water surface elevation during flood events and does not affect existing levee performance in terms of annual exceedance probability, long-term risk, or conditional non-exceedance probability. However, the integrity of the levee could be affected by long periods of contact with standing water. Impacts to flood damage reduction structures due to long-term inundation against the levees have been evaluated. Best Buy plans 7 and 12 did not show any inundation against the levees for the lower flow conditions. If, during final design, inundation against the levee is identified, the Corps will implement mitigative steps to alleviate this condition. These measures could include the addition of soil to raise the ground level near levees. The maximum design effort (Best Buy plan 16) would cause negative impacts to flood damage reduction structures at various locations across the project reach. During bank full and the 1.0%-chance post-Cochiti Dam snowmelt flow levels, the levee is inundated at depths up to 4 feet for periods greater than 100 days in numerous locations. This condition would require protections added to the levee prior to the construction of the proposed feature creating the inundation. Table 4.21 lists the summary of total inundation area for the existing conditions and for the five restoration reaches.

Table 4.21. Summary of total inundation area for existing conditions and for the five restoration alternatives.

Alternative	Description	Hydrologic Event / Future Channel Condition	Channel Full Flow (Steady-state)	Annual Snowmelt Hydrograph	1.0%-Chance Post-Cochiti Dam Snowmelt Hydrograph
	Existing Conditions	Year 0	253.7	87.9	657.2
		Year 5	251.0	88.1	
		Year 20	246.6	86.4	
		Year 30	247.3	87.9	
		Year 50	243.9	86.3	
1	Maximum Effort	Year 0	796.0	513.1	1,317.5
		Year 5	806.4	537.2	
		Year 20	789.5	498.7	
		Year 30	786.3	503.1	
		Year 50	783.5	500.7	
4	Moderate Effort-A	Year 0	363.7	228.7	
		Year 5	360.0	245.6	
		Year 20	357.8	213.8	
		Year 30	358.9	214.2	
		Year 50	360.5	212.1	
5	Moderate Effort-B	Year 0	466.8	360.2	
		Year 5	464.8	352.9	
		Year 20	465.7	319.9	
		Year 30	466.7	333.0	
		Year 50	455.6	307.6	

4.10 Evaluation of Alternatives for Environmental Resources

By design, all of the alternatives presented would benefit vegetation, wildlife, and environmental quality to some degree. Section 4.6 discusses how the alternative plans meet the project objectives which are environmental in nature. Table 4.10 presents the results in AAHU and overall HSI for each alternative plan. Only the Best Buy plans numbered 7 and above meet the goal for habitat value 50 years after implementation. In addition, Best Buy plans numbered 6 and below all lack a measure in one or more of the study reaches. The consequence is to miss additive benefits of the combination of measures in all reaches. That is, greater distance and separation between measures reduces connectivity and function as a corridor or the ability of some wildlife species to make use of the entire project area.

4.11 Risk and Uncertainty

Uncertainty and variability are inherent in water resources planning; therefore, an assessment of uncertainty is made to provide a basis for decision making. Uncertainty is described as being difficult to predict the outcome or unable to provide a probability distribution for an outcome. Alternatively, if a reasonable probability distribution can be formed for an outcome, this is described as risk. The degree of risk and uncertainty generally differs among various aspects of a project and over time. Whereas the functioning of a high-flow channel is relatively certain at a predicted water surface elevation due to the accuracy of hydrology models, the frequency at which that water surface elevation will be reached is dependent on hydrologic conditions and, therefore, difficult to predict.

The risk exists for water features in restoration alternatives to fill with sediment over the period of analysis. The team performed calculations to verify that all outputs in habitat value (HIS) were valid over the period of analysis. Similarly, the hydraulic analysis validated inundation area and duration for overbank events. Based on these analyses, the restoration features and habitat outputs (AAHU) based on periodic inundation was validated. These restoration features are still dependent on adequate precipitation in the Rio Grande watershed above the project to realize these outputs.

Several restoration features are dependent on hydrologic conditions. The success of exotic tree (salt cedar, Russian olive) control using standard methods varies between 65% and 85% mortality of treated plants. Dry conditions for the first year to two years following treatments increase success rates while wet conditions promote resprout or recovery of damaged plants. For the purposes of the MRG study, recent control methods were proposed with proven success rates of 75 to 85%. Costs for treatment and retreatment were based on these figures. The Corps will phase implementation in such a way that not all areas will be treated the same year. To prevent a simultaneous loss of these habitats throughout the study area, the Corps will stagger treatment over three years. Within a three year period, the risk of experiencing all dry conditions or all wet conditions is minimal; therefore, a median success rate was used to develop costs and schedules.

Similar treatment methods for revegetation is dependent on environmental conditions during planning. To minimize risk, irrigation will be used to establish new trees outside of swales. Because swales are excavated to groundwater depth, no irrigation is necessary. Grass seeding will take place to correspond with monsoon seasons; however, a particularly dry year could cause low success of seeding and require re-seeding in a wetter year. Because this would occur on a year where little or no rainfall is received, the risk is minimal.

4.12 System of Accounts

The comparison and evaluation of alternatives involves the consideration of the effects of the plans on planning objectives and constraints. The following discussions address the differences and similarities between the future without project conditions and the alternatives. The four national accounts are considered in the comparison and evaluation of alternative plans, as are the associated evaluation criteria. In the 1970 Flood Control Act, Congress identified four equal national accounts for use in water resources development planning. The accounts are National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). Policy in the 1970s regarded making contributions to only two of these, NED and EQ, as national objectives.

Because the primary outputs for the MRGB project would be ecosystem restoration, benefits are realized for the EQ as well as OSE accounts. Benefits of recreation are accounted for within the NED Account. Benefits to the RED are realized from both the restoration and recreation components.

4.12.1 Environmental Quality (EQ)

All of the Best Buy plans would contribute to the EQ account by increasing the amount and quality of high-value habitat in the study area by their respective quantity of outputs. All Best Buy plans provide an increase in habitat and benefits to the EQ account as quantified by AAHU's in Table 4.10. Benefits to the EQ account increase with plan outputs as do the costs for the project and incremental costs for each AAHU. As described earlier, only Best Buy plans 7 and above will meet the improvement objective of the study. Benefits would increase in the following criteria as the amount and quality of habitat increases:

- Water Quality: Reconnection of the river channel to overbank area would provide some improvements to water quality through natural filtration in riparian areas. An increase in wetland area, particularly those located at storm water outfalls, would provide filtration of water and break down some pollutants through biologic processes.

- Air Quality: An increase in the number and acres of plants would contribute to absorption of carbon dioxide and release of oxygen in this urbanized area. The Bosque acts as a heat sink during warmer months and provides a corridor of shady, relatively moist environment that contrasts with the urban asphalt and concrete.

- Wildlife: The increase in habitat diversity would provide for an increase in diversity and density of wildlife species.

- Endangered Species: The two listed endangered species would benefit from project implementation due to improved habitat function and increased area of suitable habitat.

- Noise: A temporary increase in noise would occur due to construction and would potentially increase in duration with an increased project size. The Bosque itself acts as a noise sink.

The larger the project, the more benefits accrue to the account. This is quantified both in total AAHU and incremental costs per AAHU in Table 4.10. The cost effective analysis has provided a measure of efficiency to determine what the cost of these outputs would be.

4.12.2 Other Social Effects (OSE)

Other Social Effects (OSE) is a measure of impacts to the community in terms of satisfaction, well-being, and happiness. A new project could impact the state of community education, health, social connectedness, standard of living, and happiness. Primary affects to OSE from the proposed restoration would benefit health, standard of living and education by providing a public area of improved aesthetics and air quality and by providing recreational and educational opportunities. Significant benefits to the community would occur from the facilities provided from the recreation component of the project, from the increase in quality of the recreational experience, and from educational opportunities within the project area.

Goals of the project include:

- Create opportunities for educational or interpretive features, while integrating recreational features that are compatible with ecosystem integrity

- Engage the public in the restoration of the Bosque ecosystem by garnering public input and involvement

The proposed project would improve existing trails, create additional access points, provide educational amenities such as signage and kiosks, and provide amenities such as benches and picnic tables for an improved recreational experience. Habitat improvements would also enhance the recreational experience through those criteria listed under the AQ account and the aesthetic quality of the Bosque. The relatively open cottonwood gallery forest or a view over a wetland is generally more pleasing than a view obstructed by thick brush 10 to 20 feet high. Habitat improvements would provide the opportunity to view wildlife considered rare outside of this Bosque.

Additional access points provide access to the benefits of the project for people living outside the immediate vicinity. The existing and additional access provides the opportunity for the area to become a destination for recreational and educational activities. The additional opportunities and improved experience increase the overall standard or living for the entire community of Albuquerque.

The scoping and public involvement has provided contribution from the local community to the study objectives. The objectives were incorporated within the constraints of the project and reflected in the array of project alternatives. Further involvement through public meetings and public involvement of monitoring will continue to engage the community and encourage public ownership of the project.

4.12.3 Regional Economic Development (RED)

The Regional Economic Develop (RED) account registers changes in the distribution of regional economic activity that result from each of the proposed alternative plans. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output, and population. The proposed project would benefit these criteria and have the potential to increase recreation and tourism-related industry and property value immediately adjacent to the project area. Table 4.22 presents impacts from the Best Buy plans to local business, employment, and local government finances.

Table 4.22. Project Impacts to Regional Economic Development.

Best Buy Plan Alternative	Total Project Cost	Business and Industry	Employment	Financing required from the Local Sponsor
No Action Plan	$0	No Impact	No Impact	No Impact
Plan 1 - --, 2-F, --, --, --,	$2,478,947	Little to no impact at this scale.	There would be a temporary increase in employment during construction consistent with the project cost. Long term O&M would provide some benefits.	LERR&D at approximately $1,315,000 O&M. $50,000/yr
Plan 2- --, 2-F, --, --, 5-G	$5,222,055			
Plan 3 - --, 2-F, 3-A, --, 5-G	$5,093,231			
Plan 4 - --, 2-F, 3-A, 4-F, 5-G	$10,192,167	Increased recreation and tourist visitation to the area might increase revenues of local businesses.		
Plan 5 - --, 2-F, 3-A, 4-H, 5-G	$12,439,871			
Plan 6 - 1-J, 2-F, 3-A, 4-H, 5-G	$24,527,570			
Plan 7 - 1-K, 2-F, 3-A, 4-H, 5-G	$26,344,476			
Plan 8 - 1-K, 2-B, 3-A, 4-H, 5-G	$28,354,665			

Best Buy Plan Alternative	Total Project Cost	Business and Industry	Employment	Financing required from the Local Sponsor
Plan 9 - 1-M, 2-B, 3-A, 4-H, 5-G	$32,479,093	Increased recreation and tourist visitation to the area might increase revenues of local businesses.	There would be a temporary increase in employment during construction consistent with the project cost. Long term O&M would provide some benefits.	LERR&D at approximately $1,315,000 O&M. $50,000/yr
Plan 10 - 1-M, 2-B, 3-B, 4-H, 5-G	$34,474,601			
Plan 11 - 1-M, 2-B, 3-B, 4-K, 5-G	$41,480,438			
Plan 12 - 1-M, 2-K, 3-B, 4-K, 5-G	$46,140,227			
Plan 13 - 1-M, 2-K, 3-H, 4-K, 5-G	$48,705,559			
Plan 14- 1-M, 2-K, 3-H, 4-K, 5-H	$51,634,650			
Plan 15 - 1-M, 2-M, 3-H, 4-K, 5-H	$78,390,802			

4.12.4 National Economic Development (NED)

The Federal objective of water and related land resources planning is to contribute to National Economic Development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable Executive orders, and other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units, and contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation. Contributions to NED include increases in the net value of those goods and services that are marketed and those that might not be marketed.

4.13 Interpretive and Recreational Enhancements

The education, interpretation, and recreational aspects of the Bosque are critical to long-term restoration and sustainability. Additional improvements such as benches, signs, and wildlife observation blinds would greatly enhance this resource. Involving the community through educational and recreational features will help to insure that a healthy Bosque remains a priority for the stakeholder agencies as well as for environmental sustainability. Establishing formal points of access and trails will restore more of the Bosque to quality habitat as well as reclaiming and revegetating duplicate trails and trails through core wildlife areas. The essential criteria in this case are to ensure a balance of access and facilities throughout the extent of the study area to avoid wildlife disruption and to concentrate recreational amenities near major public access areas.

For the Interpretive and Recreational Enhancements feature the following management measures have been generated:

- Improve select existing primitive trails
- Provide additional benches
- Provide additional picnic tables
- Improve some existing parking and access areas
- Provide bridges over proposed water features to maintain trail continuity
- Provide additional access point with a bridge over an irrigation canal
- Provide interpretive kiosks at access points
- Provide interpretive signage in key recreation areas

4.13.1 Current Supply of Similar Recreational Facilities

Residents of Albuquerque have ready access to a wide array of places in the metropolitan area where they can engage in outdoor recreational activities such as hiking, bicycling, picnicking, wildlife observation, and other outdoor pursuits. However, the Rio Grande Bosque is a unique natural feature in the city and the surrounding region. It is the only riparian area of any significant size and, as such, accounts for a substantial part of the wildlife habitat in the area and a critical urban oasis for residents and visitors. The cottonwood trees with the shrub and herbaceous undergrowth (both native and exotic) provide a relatively cool and shady refuge from the surrounding desert grasslands and city pavement.

The AOSD estimates the number of people who annually use the various open space areas that it manages; however, visitors to major public open space areas, such as the Bosque, are difficult to track due to areal extent and the existence of multiple points of access. The Elena Gallegos Open Space Park in the Sandia foothills is able to better track numbers of visitors because visitors pay a user fee at an entrance gate, permitting Open Space staff to count the number of vehicles entering the area. The Elena Gallegos Open Space facility covers 640 acres and offers an extensive network of trails that wind through pinion and juniper woodlands as well as toilet facilities. Trails are accessible to hikers, bicyclists, and equestrians. A wildlife blind provides opportunities for wildlife observation at a water hole. Visitors can also picnic at several developed sites.

The Rio Grande Nature Center State Park visitor center is located adjacent to the study area approximately two miles north of the Interstate 40 Bridge in Reach 3. The park amenities include a trail system along the river, classrooms, and an extensive library with a wetland viewing area. The park also offers naturalist-led hikes, Bosque exploration, exhibits, hands-on activities, teacher workshops, seasonal classes and special events. In addition to the signed–in visitors, over 8,000 school children visit each year on school-sponsored field trips and another 2,000 to 3,000 people attend classes and special walks such as the full moon walks, owl prowls, and weekend bird and nature walks. Because these visitors are attending special activities, they are not always counted on the sign-in sheet. The drop in visitation noted above might be due partly to seasonal closures of the Bosque in times of drought and high fire danger. Tourists account for 35% to 40% of the RGNCSP visitation and the park is considered one of the top ten attractions in Albuquerque, especially for wildlife watchers and birders. In 2003, the park received recognition from Rand McNally as one of the "Best of the Road" attractions in the southwest and nationwide for 2004.

Another outdoor recreational area that draws visitors from throughout the nation as well as the community is the Petroglyph National Monument, which is part of the National Park System. This facility covers 7,232 acres along the west side of Albuquerque and contains an estimated 25,000 petroglyphs (images carved into the volcanic stone by native peoples and early Spanish settlers). Visitors learn about the park's natural and cultural features and the schedule of activities at the visitor center. Several trails provide opportunities for viewing the petroglyphs and the area's unique geology and wildlife. Other amenities include picnic tables, restrooms, and a water fountain.

Table 4.23 shows the estimated number of visitors to Albuquerque Open Space Areas, including the Elena Gallegos Open Space, the Petroglyph National Monument, the Rio Grande Nature Center State Park, and the Albuquerque Bosque Trail. In the case of the first three, the numbers do not reflect the visitors that do not enter through the visitor center; therefore, the actual number of visitors to these areas is probably significantly higher.

Table 4.23. Estimated Visitors to Open Space Facilities.

Year	Petroglyph National Monument	Rio Grande Nature Center State Park (RGNCSP)	Elena Gallegos Open Space	Albuquerque Bosque Trail
FY 1997	58,436	34,187	-	
FY 1998	61,013	37,025	-	
FY 1999	53,282	34,804	-	
FY 2000	61,170	-	-	
FY 2001	60,608	28,577	131,000	
FY 2002	53,299	26,718	110,822	
FY 2003	52,266	-	115,000*	
FY 2005	-	-	-	317,876
Average	**53,722**	**32,262**	**118,941**	**317,876**

The linear nature of the Bosque, river, and associated spoil-bank levees, irrigation canals, and drains provides a unique setting for recreational features. The Bosque system through Albuquerque contains the Albuquerque Bosque Trail (ABT), a shared-use path running along the top of an engineered levee and along the east bank of the Rio Grande. This paved trail runs north to south for a distance of approximately 19 miles, with a northern terminus at Alameda Boulevard and a southern terminus at Albuquerque's South Diversion Channel. Parallel and adjacent to that trail is a maintenance road with a gravel and aggregate surface. The maintenance road serves MRGCD and City of Albuquerque official vehicles, but also provides a suitable surface for runners, pedestrians, and a relief route when the Bosque Trail becomes crowded. The Bosque Trail is unique not only for its proximity to the Bosque and the Rio Grande, but for the fact it represents the largest contiguous stretch of recreational trail with no traffic crossings in the Middle Rio Grande region.

Along the Albuquerque Bosque Trail, many spur and loop trails branch into the Bosque. In most cases, these trails are primitive dirt paths that access the river bank or wind through the Bosque. The use of informal trails in some places has caused deterioration of vegetation and disrupted wildlife habitat. Elimination of informal trails and additional improvements such as benches, signs, and wildlife observation blinds would greatly enhance this resource. Formal trails have been established at major access points such as the RGNCSP and the Albuquerque Biopark.

4.13.2 Current Use and Conditions of Similar Recreational Facilities

The study area lies within the RGVSP. Visitor counts for the state park visitor center are provided in Table 4.23. Estimated use of the Albuquerque Bosque Trail is presented in the Cost Benefit analysis below.

4.13.3 Recreation Cost-Benefit Analysis

The recreation features proposed as part of the MRGB will occur adjacent to or within close proximity of the Albuquerque Bosque Trail and in many cases are accessed through part of the trail. In most cases trails proposed for improvement in this study are "spur" trails to the Albuquerque Bosque Trail or loop from the asphalt trail through portions of the Bosque and back to Bosque Trail. In a few instances, improved trails are located on the opposite side of the river from the Bosque Trail with their own access points. The access points to the Albuquerque Bosque Trail, such as parking lots, are also access points to the recreation features proposed in the recreation portions of this project. For these reasons, visitor use along the Albuquerque Bosque Trail is used to assess recreation demand and value of the proposed recreation features.

This recreation analysis follows the National Economic Development (NED) benefit evaluation procedures contained in ER 1105-2-100, Appendix E, Section VII. Because the recreation features identified in the proposed project are of a small scale, the unit day value (UDV) method of benefit evaluation was selected for this analysis.

The unit day value method (UDV) was used to assign a dollar value to current use of the study area as well as to future use after completion of the proposed improvements. Point values were assigned based on measurement standards described for the five criteria of activities, facilities, relative scarcity, ease of access, and aesthetic factors. Values were determined for both the existing and future with project conditions. These values were then compared to tables provided in Economic Guidance Memorandum 09-03 to obtain the UDV value. UDV values are then multiplied by user days to obtain the recreation value for the study area with and without the proposed project.

The UDV calculations require an estimate of five criteria when evaluating the without and with-project recreation experience. A discussion of each of those five criteria follows:

- **Recreation Experience** – This criterion tries to explore what recreation opportunities exist at the site. In the case of the Albuquerque Bosque Trail, several general activities are common to the region such as hiking (walking, running), horseback riding, cycling, wildlife viewing, and canoeing/kayaking. The contiguous nature of the trail system and the lack of breaks made by crossing vehicular traffic creates a recreation experience uncommon to the region, and the scenic nature of the Bosque adds to the high quality of the recreation experience. A proposed feature within the recreation plan is a kayak/canoe launch area, which would add to the unique experiences found within the Albuquerque metropolitan area.

- **Availability of opportunity** – This criterion evaluates the uniqueness of the recreation experience by identifying the number and proximity of available substitutes. The Bosque Trail and adjacent Bosque habitat represent a unique environmental feature within the urbanized Albuquerque metropolitan area. The proposed kayak/canoe launch within the Bosque would represent a singularly unique recreation opportunity for residents in the region. The Bosque and Rio Grande provide a unique opportunity for wildlife viewing relative to upland habitats throughout the region. Habitat improvements proposed would increase the opportunity by increasing the diversity of habitats as well as diversity and in some cases abundance of wildlife. Restoration measures would also provide better visibility into the Bosque along trails.

- **Carrying capacity –** This criterion evaluates the ability of the recreation facilities to handle the existing and projected demand. Excessively crowded facilities diminish the recreation experience for users. Similarly facilities that cannot handle the increased visitation also experience a diminished recreation experience. The proposed plan includes several parking lot improvements and one new parking area, park benches, tables, and improved surfaces for nature trails to both guide users through the natural environment and provide extra facilities for recreation visitors. This increase in net carrying capacity is expected to be more than adequate for any increased visitation.

- **Accessibility –** This criterion examines the relative ease by which users can get to and through the recreation site. The proposed plan includes an additional MRGCD canal crossing from the east side of the study area as well as additional parking facilities for users.

- **Environmental –** This criterion measures the esthetic value of the recreation experience. The Bosque habitat, as mentioned throughout this report, represents a unique and highly-prized habitat that exists within the Albuquerque metropolitan area. Efforts to improve the Bosque habitat are naturally expected to increase that esthetic value.

4.13.4 UDV Evaluation of the existing and proposed project condition

From the previous discussion of the five criteria used for establishing a value of the recreation experience afforded by the Albuquerque Bosque, the proposed project would touch each of these criteria in a beneficial direction. Table 4.24 presents an estimate of the Unit Day Valuation of the without and with-project condition.

Table 4.24. UDV point valuation in the with and without-project condition.

UDV Criteria	Description	Without Project	With Project	Assumptions
Recreation experience	Several general activities; more than one high quality (*eg*. kayak) activity	17	18	Bike, walk, run, picnic, wildlife watching, horseback riding, canoe/kayak. Canoe/kayak is high quality. Almost 19 contiguous miles of asphalt without traffic crossings is high quality. Increase due to additional kayak launch.
Availability of Opportunity	One or two within 1 hr travel time; none within 45 min.	8	9	Urban resource for multiple activities. Increase due to addition of kayak launch and parking lot.
Carrying capacity	Adequate facilities to conduct without deterioration of the resource or activity experience	8	10	Increase due to addition of parking, and access point, benches and tables as well as improvement of trails.
Accessibility	Good access, high standard road to site, good access within site	15	16	Increase due to additional parking lot and access across irrigation canal.
Environmental	Above average aesthetic quality; any limiting factors can be reasonably rectified	8	12	Increase due to removal of non-native trees (visibility), increase in habitat types and wildlife diversity. Addition of water features.
	Total	56	65	

Converting these point values into dollars per EGM 10-3, the without-project condition is worth $7.93 per visit and the with-project condition is worth $8.42 per visit. Therefore, the benefits attributable to planned recreation features are worth $0.49 per visit.

4.13.5 Recreation usage in the existing and proposed project condition

The Albuquerque Bosque Trail represents the most significant recreation feature in the study area. Walk Albuquerque conducted a visitation survey of the Albuquerque Bosque Trail in September, 2005. That survey was conducted on a Tuesday morning between 7 and 9 am, Tuesday evening between 4 and 6 pm, and Saturday between 8 am and 6 pm. Table 4.25 presents the raw count from that survey.

Table 4.25. Summary of Walk Albuquerque visitation survey of the Albuquerque Bosque Trail in September, 2005.

	Tues 13 Sep 2005			Thur 15 Sep			Sat 17 Sep		
	Northbound	Southbound	TOTAL	Northbound	Southbound	TOTAL	Northbound	Southbound	TOTAL
6-7									
7-8	35	48	83						
8-9	26	36	62				106	82	188
9-10							79	110	189
10-11							97	77	174
11-12 noon				30	32	62	75	77	152
12 noon-1				32	26	58	55	42	97
1-2							37	42	79
2-3							28	22	50
3-4							20	20	40
4-5	19	13	32				25	11	36
5-6	51	40	91				22	19	41
6-7:30									
Total	**131**	**137**	**268**	**62**	**58**	**120**	**544**	**502**	**1046**

The survey count alone is insufficient to describe the recreation usage for the Albuquerque Bosque Trail. The Walk Albuquerque report indicates that recreation visits preceded and followed the survey times because the morning twilight started around 6:22 and evening twilight ended at 7:35 that week. The report indicates an estimate of recreation use was established for the weekend, which is provided (highlighted) in Table 4.26. To fill in the weekday gaps, an estimate of weekday trail use was made as a proportion of the weekend trail use based on the surveyed times that overlapped the weekend and weekday samples.

Table 4.26. Extrapolation of total trail visitation based on Walk Albuquerque survey.

	Extrapolated Bosque Trail Use		
	Weekday	Weekend Day	Weekday % of weekend
	TOTAL	TOTAL	TOTAL
6-7	20	34	48.91%
7-8	83	128	64.84%
8-9	62	188	32.98%
9-10	70	189	36.88%
10-11	60	174	36.88%
11-12 noon	62	152	40.79%
12 noon-1	58	97	59.79%
1-2	60	79	74.34%
2-3	40	50	74.34%
3-4	30	40	74.34%
4-5	32	36	88.89%
5-6	91	41	221.95%
6-7:30	51	51	100.00%
Total	**719**	**1259**	

An average daily count of 719 weekday and 1,259 weekend day visitors seems a conservative estimate of recreation usage of the Albuquerque Bosque Trail for several reasons. The survey was conducted on a non-holiday weekend during the school year. Summertime usage of the trail increases such that crowding occurs during peak visitation hours (early morning and late afternoon) when temperatures are mild. This survey also does not account for pedestrian traffic occurring entirely north or south of the survey point (roughly the midpoint of a 19-mile length), which would represent additional unique visits to the study area. Further, special events taking place along the Bosque Trail like the Run for the Zoo, which brought 9,400 registered participants in 2009 (http://www.bioparksociety.org/runforthezoo, accessed 1/12/2010) and the Duke City Marathon, which brought 3,107 individual participants and 124 teams of two or more members in 2009 (https://www.runraceresults.com/secure/raceresults.cfm?ID=RCLS2009, accessed 1/12/2010) as well as numerous benefit walks, running and cycling events that take place throughout the year are uncounted in this evaluation.

4.13.6 Benefit determination of the proposed recreation features

This evaluation started with an evaluation of the value of the existing, without-project, recreation experience in the study area. Table 4.27 developed an estimate of the without- and with-project UDV values. Multiplying the benefits identified in Table 4.27 by the extrapolated annual visitation established in Table 4.26 provides the annual benefit of the proposed recreation features. Applying the extrapolated daily visitation to a typical year of 260 weekdays and 104 weekend days gives a conservative estimate of trail usage of 317,876 annual visits (Table 4.28). Table 4.29 provides the cost of the proposed recreation project.

Table 4.27. Unit Day Values for with and without project.

Without-Project UDV Value (points)	Without-Project Value (dollars)	With-Project UDV Value (points)	With-Project Value (dollars)	Benefits (dollars)	Annual Benefits	Benefit Cost Ratio
56	$7.93	65	$8.42	$0.49	$155,123	1.36
Errors due to rounding						

Table 4.28. Estimated annual trail visitation for Albuquerque Bosque Trail.

Weekday users	719	Weekend users/day	1,259
# Weekdays	260	# Weekend days	104
Annual Weekday users	186,940	Annual Weekend Users	130,936
		Persons Per Year	317,876

Table 4.29. Cost of the proposed recreation project.

Cost of Proposed Interpretive & Recreational Features	
Total Construction Cost	$1,644,200
Interest During Construction (24 months, 4.125%)	$68,291
Average Annual Construction Cost (4.12%, 50 years)	$81,430
Average Annual OMRRR	$7,500
Total Average Annual Cost	$88,930

4.13.7 Sensitivity Analysis of Recreation Benefits

From the previous discussion of the five criteria used for establishing a value of the recreation experience afforded by the Albuquerque Bosque, the proposed project would touch each of these criteria in a beneficial direction. However, the qualitative improvement's translation to the UDV point values is unclear. Therefore, multiple scenarios were developed to evaluate the impact of the proposed project on the existing recreation facilities. One scenario assumes the existing facilities have relatively low point values (the "minimum points" scenario), and the proposed recreation features provide a significant boost to the quality of the recreation experience. Another scenario assumes the recreation experience has a relatively high starting value (the "most likely" scenario) and the proposed recreation features are somewhat less beneficial than described in the "minimum points" scenario. This analysis will run a matrix of starting conditions and beneficial "point boosts" to establish a range of values and consider the possibility that the recreation plan is not justified per the NED benefit evaluation procedures. This analysis will explore the impact of the UDV point boost expected through implementing the proposed project. Table 4.30 presents an evaluation of the without- and with-project condition for both scenarios.

The Corps expects that the restoration efforts in the Bosque will improve the environmental aesthetic. The features of the recreation plan (benches, picnic tables, additional trails, a boat launch, parking lot) are expected to touch each of the other criteria in the UDV assessment in a positive fashion. Table 4.31 presents a minimum and most likely point assessment of the marginal benefits attributed to the proposed recreation features.

Economic Guidance Memorandum (EGM) 10-3 outlines the general and specialized recreation valuation for UDV point values for FY 2010. The guidance outlines the value of the recreation experience per visit based upon the point values assessed. Table 4.32 is a reprint of the guidance converting points to dollar values (FY 2010 price level):

Table 4.30. Minimum and most likely point valuation.

Criteria	Description of criteria	Minimum Points in Without Project Condition		Most Likely Points in Without Project Condition	
		Without Project	With Project	Without Project	With Project
Recreation experience	Several general activities; more than one high quality (eg. kayak) activity	14	18	17	18
Availability of Opportunity	One or two within 1 hr travel time; none within 45 min.	7	10	8	9
Carrying capacity	Adequate facilities to conduct without deterioration of the resource or activity experience	6	10	8	10
Accessibility	Good access, high standard road to site, good access within site	11	16	15	16
Environmental	Above average aesthetic quality; any limiting factors can be reasonably rectified	8	12	8	12
	Total	46	66	56	65

Table 4.31. UDV marginal effects in the with-project condition.

Criteria	With Project Conditions that prompt increase in UDV.	Min.	Likely
Recreation experience	Bike, walk, run, picnic, wildlife watching, horseback riding, canoe/kayak. Cycling is High Quality, and added Canoe/kayak is High Quality. Almost 19 contiguous miles of asphalt trail without traffic crossings. Multiple parking lots. Increase due to adding kayak launch	**1**	**4**
Availability of Opportunity	Urban resource for multiple activities. Increase due to addition of kayak launch and parking lot.	**1**	**3**
Carrying capacity	Increase due to adding parking lot, benches, tables and upgrade of trails	**2**	**4**
Accessibility	Increase due to additional canal crossing and parking lot.	**1**	**5**
Environmental	Factors to be rectified include non-native species (low visibility), fire risk, increased diversity of wildlife	**4**	**4**
	Total	**9**	**20**

Table 4.32. FY 2010 price level taken from Economic Guidance Memo (EGM) 10-3.

Point Values	**General Recreation Values (1)**	**General Fishing and Hunting Values (1)**	**Specialized Fishing and Hunting Values (2)**	**Specialized Recreation Values other than Fishing and Hunting (2)**
0	$3.54	$5.09	$24.81	$14.40
10	4.21	5.76	25.47	15.28
20	4.65	6.2	25.92	16.39
30	5.32	6.87	26.58	17.72
40	6.65	7.53	27.25	18.83
50	7.53	8.2	29.9	21.26
60	8.2	9.08	32.56	23.48
70	8.64	9.52	34.56	28.35
80	9.52	10.19	37.21	33
90	10.19	10.41	39.87	37.66
100	10.63	10.63	42.09	42.09

(1) Points from Table 1 in attachment.
(2) Points from Table 2 in attachment.

The probability is low that any recreation opportunities would line up perfectly with any 10-point increment; therefore, a linear interpolation of point values is necessary to measure the value afforded by the recreation experience. Table 4.33 presents the marginal point values for the General Recreation Values identified in EGM 10-3.

Table 4.33. Marginal point values for the General Recreation Values identified in EGM 10-3.

Point Values	General Recreation Values (1)	Marginal $/point
0	$3.54	
10	4.21	$0.07
20	4.65	$0.04
30	5.32	$0.07
40	6.65	$0.13
50	7.53	$0.09
60	8.2	$0.07
70	8.64	$0.04
80	9.52	$0.09
90	10.19	$0.07
100	10.63	$0.04

As the foregoing illustrates, a single point in the Unit Day Value computation can have a value of between 4 and 13 cents per visit. Applying those values to the minimum and most likely values imparted by the proposed project gives a range of values of the proposed recreation plan. A nine-point increase in UDV would be worth somewhere between $0.36 and $1.17 per recreation visit. A 20-point increase crosses two point value thresholds, and would be worth between $1.10 and $2.20 per recreation visit.

The without-project condition was evaluated in the UDV framework using the five criteria and was assessed a value of 46 or 56 points having a value of $7.18 or $7.93 per visit, respectively. The proposed project is anticipated to increase that value between nine and 20 points, which would provide a benefit of between $0.49 and 1.29 per recreation visit. Those values fall to the lower bounds of the possible values described above and will represent a reasonable estimate of the benefits of implementing the recreation plan. Table 4.34 shows the project benefits for the two marginal point scenarios.

Table 4.34. Project benefits with two marginal point scenarios.

Without-Project UDV Value (points)	Without-Project Value (dollars)	With-Project UDV Value (points)	With-Project Value (dollars)	Benefits (dollars)
		+9 pts.		
46	$7.18	55	$7.87	$0.69
56	$7.93	65	$8.42	$0.49
		+20 pts.		
46	$7.18	66	$8.46	$1.29
56	$7.93	76	$9.17	$1.24

4.13.8 Sensitivity analysis of benefits of the proposed recreation features

This evaluation started with scenarios to evaluate the value of the existing, without-project, recreation experience in the study area. The "minimum points" scenario was a fairly conservative estimate of the relative worth of the Albuquerque Bosque habitat and recreation facilities. The "most likely" scenario was a bit more generous in assessing the value of the without-project recreation experience. Table 4.27 developed two estimates of the with-project UDV values. Multiplying the benefits identified in Table 4.34 by the extrapolated annual visitation established in Table 4.28 provides the annual benefit of the proposed recreation features. However, to acknowledge the uncertainties in assessing UDV point values in the without- and with-project condition, this analysis developed a matrix of possible without- and with-project UDV point values and computed the benefits against the estimate of visitation developed above. The range of UDV point values in the without- and with-project condition, as well as potential minimum and maximum scores associated with nine and 20 point UDV value boosts, is provided in Table 4.35.

Table 4.35. Annual benefit of the proposed recreation features.

Without-Project UDV Value (points)	**Without-Project Value (dollars)**	**With-Project UDV Value (points)**	**With-Project Value (dollars)**	**Benefits per visit (dollars)**	**Annual Benefits**	**BCR**
		+9 pts.				
46	$7.18	55	$7.87	$0.69	$218,381	1.91
56	$7.93	65	$8.42	$0.49	$155,123	1.36
		+20 pts.				
46	$7.18	66	$8.46	$1.29	$408,789	3.58
56	$7.93	76*	$9.17	$1.24	$392,895	3.44
Absolute minimum boost (9 pts. X $0.04/pt.)				$0.36	$114,435	1.00
Absolute maximum boost (9 pts. X $0.13/pt.)				$1.17	$371,915	3.25
Absolute minimum boost (20 pts., 10 pts. @ $0.07/pt., 10 pts. @ $0.04/pt.)				$1.10	$349,664	3.06
Absolute maximum boost (20 pts., 10 pts. @ $0.13/pt., 10 pts. @ $0.09/pt.)				$2.20	$669,327	6.12
**This combination exceeds the limits for project Accessibility per EGM 10-03, and is not valid.*						
***Errors due to rounding.*						

The cost of the proposed recreation project is in Table 5, above and remains unchanged in this sensitivity analysis.

4.13.9 Reasonableness of results

Based upon the project cost and the range of benefits that can be attributed to the recreation features, the Corps assumed, absent agreement of the value of the existing and proposed project features, that the proposed recreation plan provides benefits to the existing Albuquerque Bosque Trail Users in excess of costs, and represents a feature with positive net benefits within the ecosystem restoration plan. The evaluation makes no effort to quantify any increased visitation due to the attractiveness of the proposed project, which would only increase claimable benefits.

The under represented visitor use of similar public facilities in the Albuquerque area demonstrate a high demand for recreational use of recreational facilities within the project area. A conservative estimate of visitor use of the project provides a favorable benefit for the cost of the recreation component of the project. Improvement of the Bosque habitat and creation new access points would increase visitation. Additionally, an increase in visitor use would be expected to provide a higher degree of community investment and reduction in detrimental activities such as creation of informal trails.

4.14 Summary and Conclusions

So what do the results of these multiple analyses offer to the Corps decision makers and their stakeholders in their search for a recommended plan? Generalities can be drawn easily enough. Overall, the Corps can expect that the proposed MRGB ecosystem restoration efforts will provide significant benefits in terms of Bosque habitat; including a 67-80% improvement over the No Action Plan when features are implemented in all five reaches (Table 4.36)

Furthermore, a comparison of the proposed restoration initiatives to a “virtual” reference conditions (one in which the components of the HSI Bosque model are optimized at a 1.0 by the first year of evaluation, and the maximum number of acres are restored in each reach), shows that the proposed Best Buy plans numbered 7 and above can achieve approximately 39% of the maximum potential. Merely considering the level of quality or integrity achieved given the final HSI outputs for the proposed plans, the majority of the plans achieve at least a 0.59 HSI by the end of the study period where “high or good functionality” is achieved at a 0.6 HSI based on interpretative descriptions provided earlier in this report. As discussed in earlier chapters, the MRGB’s primary goal is to provide the necessary engineering, economic, and environmental plans in a timely manner to establish viable ecosystem restoration projects that would restore the structure and function of the Bosque, while providing a solution acceptable to the public, local sponsors, and the Cops (USACE 2002, 2003a, 2007, 2008a). Given the results documented in the previous chapters of this report, the Corps can reasonably assume that this goal can be met. Under the final array of ecologically productive, incrementally effective alternative scenarios, the Bosque community can increase in both quantity and quality as a direct result of reconnecting the hydrology to the system and re-establishing a dynamic mosaic of multi-aged stands of cottonwood forests, coyote willow shrublands, wet meadows, wetlands, oxbow ponds, and open water areas with a variety of depths and flows. Table 4.36 is a final comparison of possible restoration initiatives with respect to gains beyond the No Action Plan, as well as comparisons to a “virtual” reference condition, and thresholds of HSI productivity.

Table 4.36. Final comparison of possible restoration initiatives with respect to gains beyond the No Action Plan, as well as comparisons to a "virtual" reference condition, and thresholds of HSI productivity.

HEP Outputs and Total Cost for Alternative Best Buy Plans						
Best Buy Plan No.	Alternative	Annualized Outputs (AAHU)	Total Plan Costs[1]	Improvement Over the No Action Plan2	Percent of Virtual Reference[3]	Final HSI[3]
1	No Action Plan	0	$0	0%	0%	0.36
2	Plans --, 2-F, --, --, --,	139	$2,478,947	13%	6%	0.41
3	Plans --, 2-F, --, --, 5-G	294	$5,222,055	29%	12%	0.46
4	Plans --, 2-F, 3-A, --, 5-G	394	$5,093,231	38%	16%	0.5
5	Plans --, 2-F, 3-A, 4-F, 5-G	428	$10,192,16	42%	22%	0.51
6	Plans --, 2-F, 3-A, 4-H, 5-G	474	$12,439,87	44%	23%	0.51
7	Plans 1-J, 2-F, 3-A, 4-H, 5-G	696	$24,527,57	67%	39%	0.59
8	Plans 1-K, 2-F, 3-A, 4-H, 5-G	705	$26,344,47	68%	40%	0.6
9	Plans 1-K, 2-B, 3-A, 4-H, 5-G	721	$28,354,66	69%	40%	0.6
10	Plans 1-M, 2-B, 3-A, 4-H, 5-G	754	$32,479,09	71%	41%	0.6
11	Plans 1-M, 2-B, 3-B, 4-H, 5-G	764	$34,474,60	72%	41%	0.6
12	Plans 1-M, 2-B, 3-B, 4-K, 5-G	792	$41,480,43	76%	42%	0.62
13	Plans 1-M, 2-K, 3-B, 4-K, 5-G	809	$46,140,22	78%	42%	0.62
14	Plans 1-M, 2-K, 3-H, 4-K, 5-	817	$48,705,55	79%	42%	0.62
15	Plans 1-M, 2-K, 3-H, 4-K, 5-	819	$51,634,65	79%	42%	0.62
16	Plans 1-M, 2-M, 3-H, 4-K, 5-	823	$78,390,80	80%	42%	0.62

[1] Project costs were calculated based on costs of similar efforts or common actions for the area.

[2] Values are comparison of total Habitat Units (HUs) over the life of the project, but not annualized.

[3] Values derived through relative weighting of reach contribution by area.

Given these results and based on the hydrologic, hydraulic, and environmental analyses performed, the Best Buy plans 7 through 16 will meet the criteria for completeness and acceptability as well as effectiveness and efficiency. Because Plan 7 is the first incrementally cost effective plan to meet all of these criteria, Plan 7 is identified as the National Ecosystem Restoration (NER) plan and becomes the Recommended Plan to be carried forward for a detailed analysis.

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SECTION 5 - THE RECOMMENDED PLAN

5.1 The Recommended Plan

The Recommended Plan is Best Buy plan 7 generated by the Incremental Cost Analysis. This is also the NER plan since it is the first incrementally cost effective plan to meet all of the USACE planning criteria and study objectives. The Recommended Plan represents the most cost-effective aggregation of restoration features that best meet the objectives of the restoration project. Figures 5.1 through 5.5 show maps of the study area and the proposed treatments associated with the Recommended Plan for Reaches 1 through 5, respectively.

5.1.1 Summary Description of Restoration Features

Table 5.1 presents the quantity and average cost of restoration measures that would be implemented by the Recommended Plan in each reach. Due to the area covered and extent of the Recommended Plan, a brief summary of the project features is discussed here. A detailed description of each feature and location is found in the Model Documentation Report (Appendix C).

The Recommended Plan would include restoration of 916 acres of the Middle Rio Grande Bosque by enhancing hydrologic function (by constructing wet features such as high-flow channels, willow swales, and wetlands) and restoring native vegetation and habitat by removing jetty jacks, exotic species/fuel reduction, and riparian gallery forest restoration. In addition, recreational use of the Bosque would be improved by creating designated trails with benches, signs, and other interpretive features.

5.1.2 Summary of Recreation Features

Recreational features proposed will be developed in conjunction with MRGCD and the AOSD, who would ultimately perform the long term operation and maintenance of the recreation features. The recreation plan was developed in compliance with the Corps policy and guidance for recreation amenities as part of a restoration project. Goals of the recreation enhancement are to:

- Build on existing recreation features while eliminating redundant and informal trails
- Provide additional access points
- Provide educational appurtenances to the area

In addition to the creation of three additional access points with parking areas, the remainder of the features would be enhancements of the existing trail system. Benches, Picnic tables and educational kiosks or signage would be distributed throughout the project in proximity to access points. Foot bridges would be used to improve access across irrigation drains in one location and to reconnect existing trails across high-flow channels once the channels are completed. No separable lands will be acquired for recreation.

Table 5.1. Costs of Recreation Features.

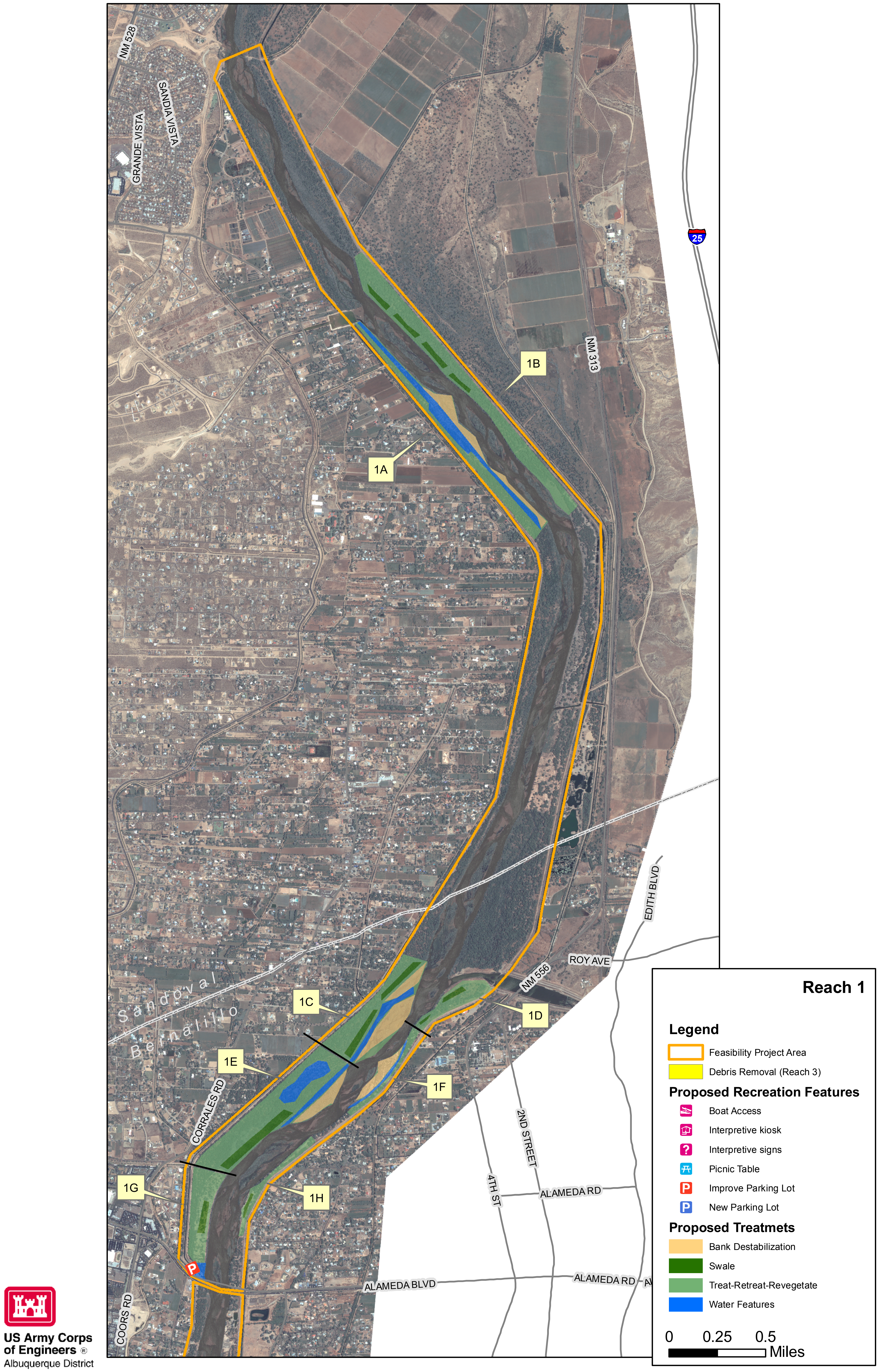
	Unit	Quantity	Unit Cost	Construction Cost
Trails	LF	76,000	$2.37	180,120
Benches	ea	30	$2,786	$83,580
Picnic Tables	ea	12	$3,121	$37,452
Parking Improvement	Acre	8	$104,025	$832,200
Foot Bridge	ea	7	$46,440	$325,080
Kiosk	ea	4	$37,152	$148,608
Signage	ea	20	$1,858	$37,160
TOTAL				**$1,644,200**

5.1.3 Implementation Process

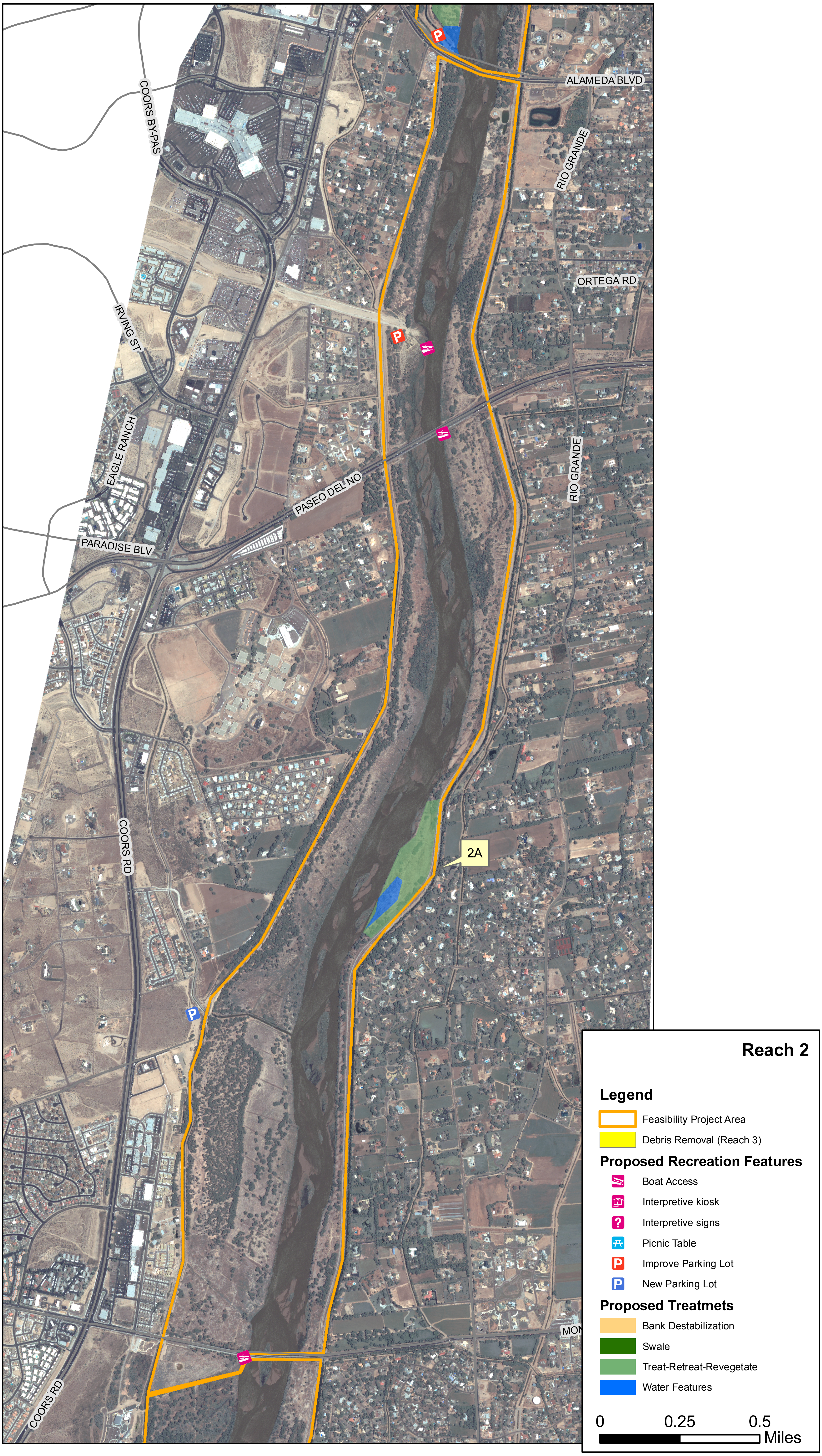
Due to the scope of the project and anticipated funding availability, implementation would likely take place over five to ten years. The project would be phased to efficiently make use of available funds and accomplish tasks requiring sequential implementation. Whereas bank destabilization and side channel building at any one action area can be accomplished in a relatively short time (a few months), this activity would take place at only one or two areas simultaneously in order to minimize impacts to water quality. Removal of non-native species and revegetating with native species is generally a multiple year effort. Once the initial removal takes place, a follow-up treatment is often required six months to a year later to eliminate trees that resprout from roots or stumps. Planting of native species might not be prudent until the follow-up treatments have been performed. In some areas, removal of non-native species or jetty-jacks would be required to allow access to construct other features.

Access to all work areas will be along the levee. A right-of-way access from MRGCD will be required for levee use, staging areas, storage areas, excess spoil, disposal sites, and construction. Staging would occur in adjacent open areas that are available from the sponsor, MRGCD. Any additional access and subsidiary staging areas to facilitate construction activities would be coordinated with local land managers, if needed.

Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



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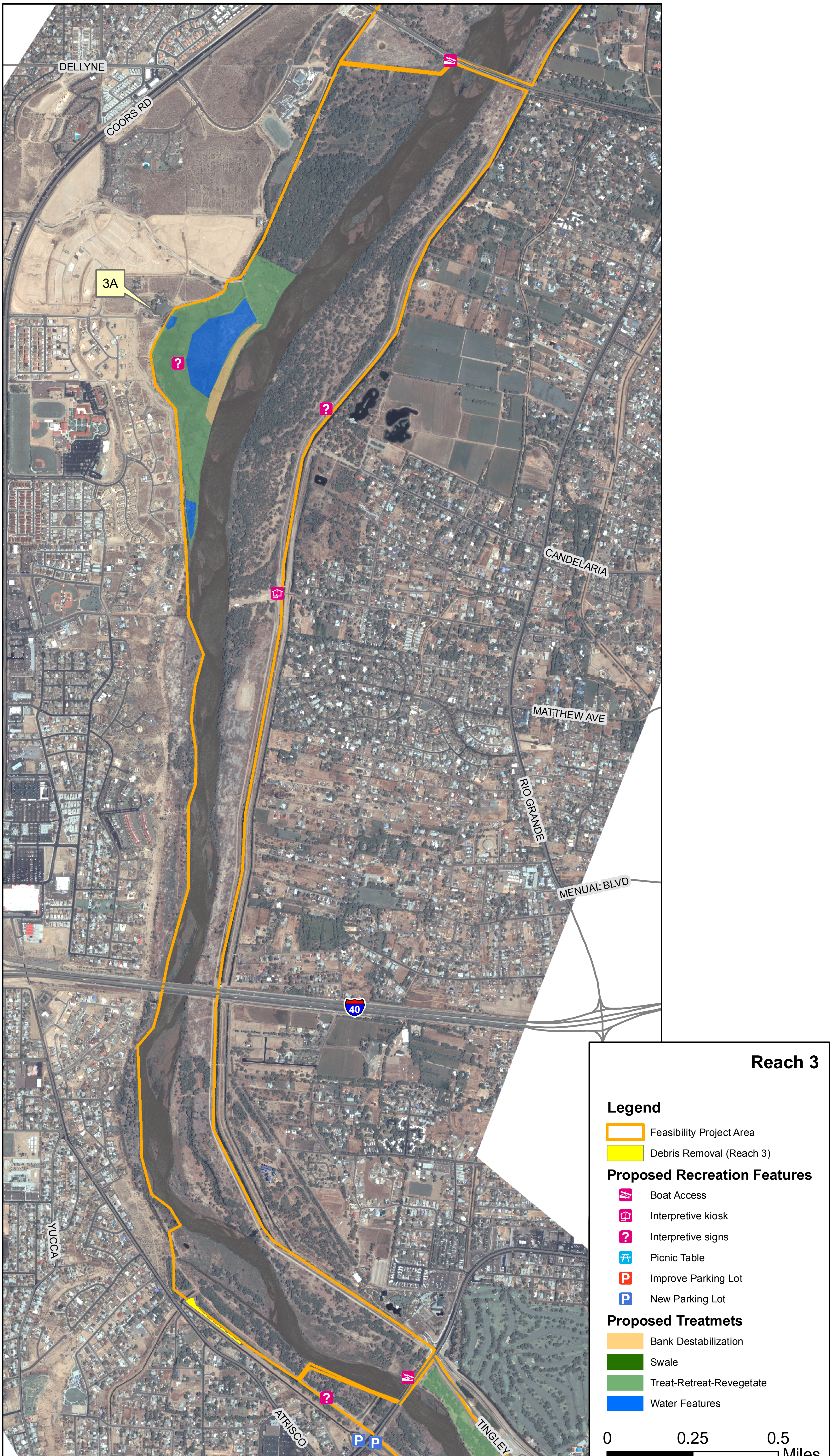
Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



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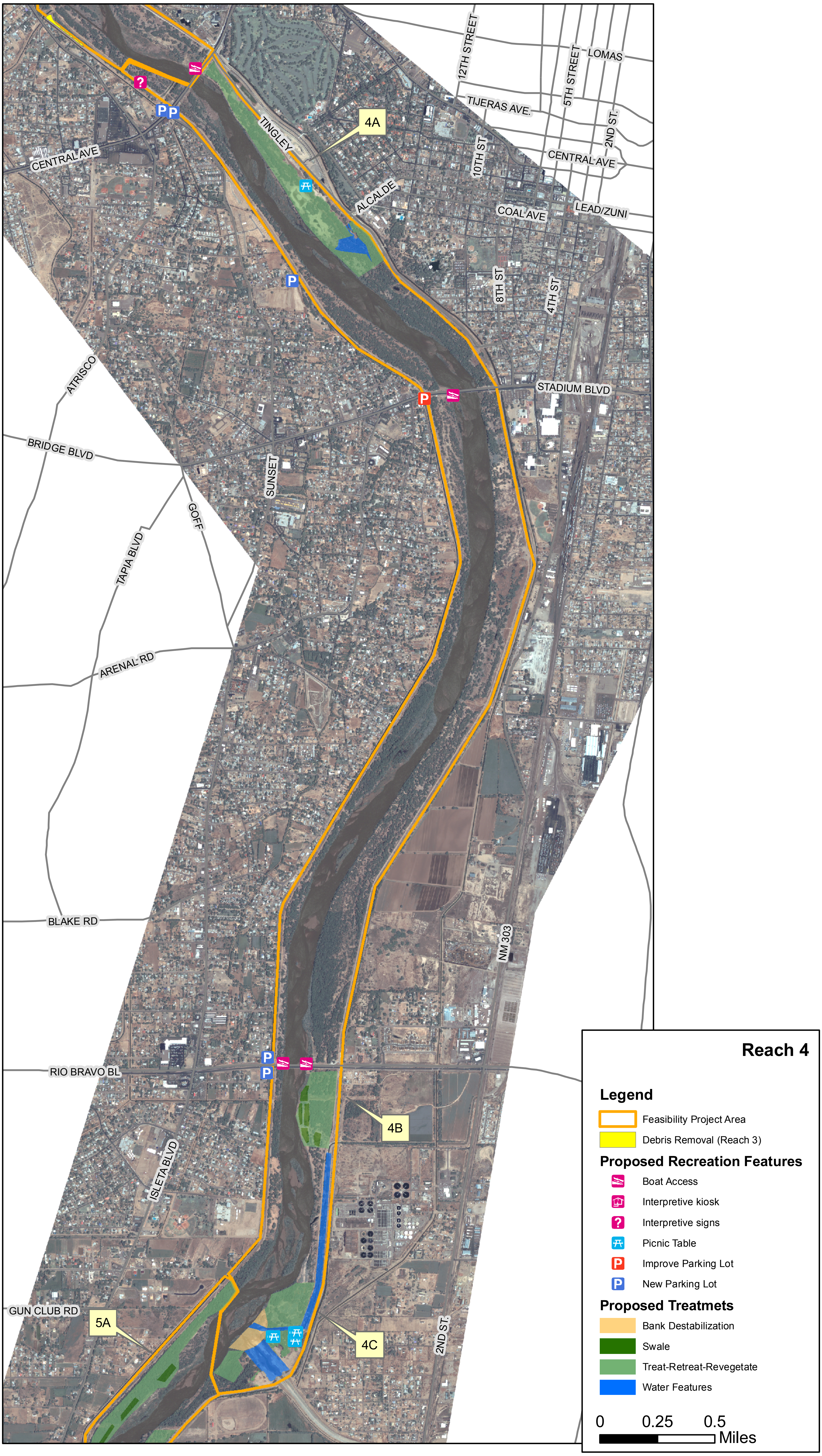

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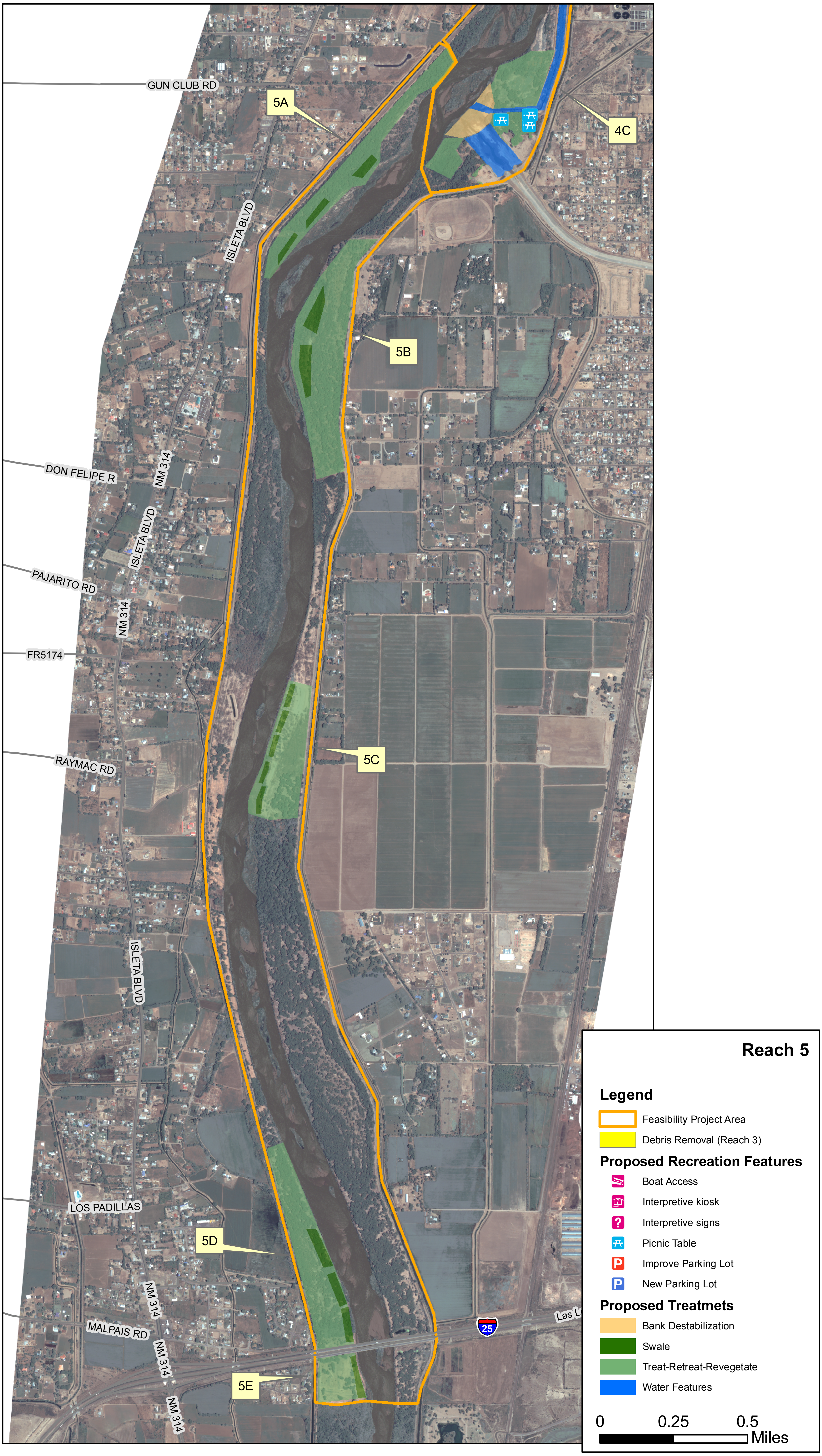
Albuquerque District

Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



US Army Corps of Engineers ®
Albuquerque District

Construction of all features would primarily be scheduled during the typical low flow seasons on the MRG (fall and winter). However, any work scheduled during the nesting season (May 1 through August 30) would require nesting bird surveys. Fuel reduction and exotic thinning (treat, retreat, revegetation) would take place initially, followed by the construction of water features, and finally the construction of recreation features. Water features would be constructed within the Bosque and then connected to the river in order to reduce sediment contribution to the river. If flows are adjacent to the inlet/outlet of the water feature (*i.e.*, high-flow channels), the flows within the river might need to be diverted using a port-a-dam or similar device. Excess soil generated by the construction of these features would be made available to the local managing agencies (MRGCD, Reclamation, and AOSD) for their use. Material would be hauled to local areas for use or stockpiled at their facilities for future use. Best Management Practices (BMPs) would be employed throughout the project to protect water and air quality.

5.1.4 Treatment Methods

A number of methods exist for reducing fuel loads and treating non-native vegetation that have been and are being used in the Middle Rio Grande and throughout the Southwest. These methods include both manual and mechanical treatment methods, which are described below. Follow-up treatment with herbicides or root ripping are also options. Removal of non-native vegetative species would take place between September and April of each year when possible to avoid bird nesting seasons.

- Manual treatment - Using this method, dead material would be piled up and/or processed by cutting into small pieces using a chain saw. Large material would be hauled off, some for use as fire wood. Smaller material would be chipped using a chipper on site. Chips would either be tilled into the ground prior to revegetation or hauled off depending on the density. No more than four inches of chipped material would be left on site. The stump of any live non-native trees that is cut would be treated immediately with herbicide if not entirely removed. This method would be used in areas where the Bosque is not very wide and equipment would not fit or areas containing a large number of native trees and shrubs to protect.

- Mechanical treatment - Mechanical control entails the removal of aerial portions of the tree (trunk and stems) by large machinery such as a tree shear or large mulching equipment. Both dead material and live non-native trees could be treated mechanically. Where possible, trees would be removed with root-ball intact. Otherwise, the stump would be treated immediately with herbicide. Material would be processed as stated above. Large material would be hauled off and smaller material would be chipped.

- Combination treatment - The most efficient methodology for treatment of dead material and non-native vegetation is usually a combination of manual treatment, mechanical treatment, and herbicide. Some areas might be very thick, and the use of manual methods allows them to be opened up for machinery access. Then mechanical equipment can take over while hand crews can move ahead of machinery to keep areas open to work in without damaging native vegetation. The methodology to be implemented at each location will be evaluated on a site-by-site basis and adaptively managed.

Once the initial removal of non-native species has occurred, or in areas where AOSD crews have already removed standing non-native vegetation, resprouting of non-native vegetation will occur. These resprouts would be treated with either herbicide or by root-ripping prior to revegetating the area with native species. Also, thinning and removal of non-native vegetation under this Recommended Plan would include herbicide treatment in many locations. Herbicide application would be used where root ripping is not an option. Herbicide would be immediately applied to the plant using a backpack sprayer, hand application with a brush, or other equipment that allows direct application.

Jetty jack removal is also proposed at the locations shown in Figures 5.1 through 5.5. Removal of the jetty jacks would be completed in conjunction with fuel reduction and thinning of non-native vegetation where not already complete in order to minimize disturbance. Where tieback lines are removed, new anchors would be installed to insure remaining bank lines would not migrate from their current position. Jetty jacks to be salvaged would be stockpiled on site during construction and removed prior to the completion of construction. The Corps, MRGCD and Reclamation have determined that the jetty jacks identified for removal in this Recommended Plan can be removed with a low impact based on the proposed revegetation.

Wetland features would be seeded and planted with appropriate plant species as described in Section 4 and include rushes, salt grass, and willows. In areas where the overstory cottonwoods remain, understory Bosque plants such as New Mexico olive and *Amorpha* would be planted. Willows, seep willows, and native grasses would be planted in open areas. In conjunction with the planting, the final trails would be laid out and constructed, and other recreational and interpretive features would be installed into the restored landscape.

5.2 Effects on Existing Flood Control Structures

The Recommended Plan does not create inundation issues not already existing during bank full flows. The Recommended Plan does create inundation areas not already existing during the 1.0%-chance snowmelt flow, where, in some areas, the water is three feet deep for more than 50 days. The newly inundated levee regions might require protections prior to construction of the proposed features causing the inundation, especially in areas where inundation can be expected to last several days. Hydraulic modeling for the Recommended Plan indicates that the majority of the project does not cause an increase in the inundation duration at lower flows. Conditions will be evaluated during design and measures will be taken to protect existing flood risk management structures from the effects of inundations. Boring logs for the existing flood risk management structures are contained in Appendix G.

5.3 Significance of the Recommended Plan

he Recommended Plan provides for the intent and, in many cases, the letter of several Federal environmental laws, directives, and executive orders concerning restoration and conservation efforts. The Recommended Plan also improves the resource needs as described in Section 1.2 and throughout the document. The Recommended Plan would improve the scarce native riparian habitat to a more pristine state, including a mosaic of habitat types. The Recommended Plan would provide habitat for the numerous migratory birds that use the area for nesting and stopover, provide additional potential habitat for listed species, and increase sustainability of the Bosque by creating connections between the Bosque and river. The Recommended Plan also meets the goals of increasing the HSI above 0.56, which is an increase in habitat value for all reaches. Increasing the habitat value above at least 0.5 would provide additional and/or improved habitat for all species. A value of 0.5 to 0.59 provides „moderately high functionality’ (discussed in Appendix D).

Table 5.2. Assessment of Recommended Plan Compared to Federal Laws, Regulations and Guidance.

North American Waterfowl Mgmt. Plan	56 Acres of permanent wetlands used for feeding and roosting sites will be created as well as 200 to 330 acres of temporary flooded forest.
Executive Order No. 11990 (Protection of Wetlands)	Under the definition of this law and EO, much of the riparian Bosque would be considered wetland. Through this project, over 2,000 riparian and aquatic acres would be improved and protected.
North American Wetlands Conservation Act of 1989	
Executive Order No. 11988 of May 1977 (Floodplain Management)	The project retains flood protections while improving function and increasing high value habitats.
Endangered Species Act of 1973, as amended	The project improves habitat and between 200 and 330 acres of overbank flooding essential to RGSM hatching and rearing. The project would also provide improved habitat for SWWF migration and provide additional acres of wet soil habitats used by SWWF for feeding.
Bald Eagle Protection Act of 1940	The project would ensure existing and future roost sites for migratory eagles. The restoration would indirectly benefit the eagle from water quality and higher fish availability.
Migratory Bird Conservation Act of 1929, and associated treaties	The restoration will provide a variety of high quality habitats that will benefit migratory birds using the MRG as a travel corridor and breeding site. Habitat improvements will benefit neotropical migrants by providing essential feeding and resting habitats.
Migratory Bird Treaty Act of 1918	

The importance of the MRG Bosque is readily seen from the efforts and resources committed by state and local governments to restoration of the MRG Bosque. The commitment of the State of New Mexico to conservation and restoration of the MRG Bosque is recognized from designation of the MRG State Park, participation in the study, and use of lands for the restoration efforts. The commitment by the City of Albuquerque to maintain restoration features, once implemented, demonstrates how the City values the MRG Bosque as a resource. The commitment of the Middle Rio Grande Conservancy District is evident through their continued financial and technical support of the MRGB study as well as other restoration efforts within the MRG.

Table 5.3. Restoration outputs generated by the Recommended Plan.

Project Reach	Proposed Treatment	Quantity	Units	Total AAHUs Created	Average Annual Cost per AAHU
Reach 1 Plan J	Bank Destabilization	60	acres	**222**	**$3,969**
	Swales and Trenches	48	acres		
	Water Features	62	acres		
	Treat Retreat Revegetation	449	acres		
	Jetty Jack Removal	2,672	units		
Reach 2 Plan F	Bank Destabilization	0	acres	**139**	**$372**
	Swales and Trenches	0	acres		
	Water Features	4	acres		
	Treat Retreat Revegetation	23	acres		
	Jetty Jack Removal	1,000	units		
Reach 3 Plan A	Bank Destabilization	5	acres	**100**	**$1,336**
	Swales and Trenches	0	acres		
	Water Features	20	acres		
	Treat Retreat Revegetation	88	acres		
	Jetty Jack Removal	800	units		
Reach 4 Plan H	Bank Destabilization	13	acres	**62**	**$3,414**
	Swales and Trenches	12	acres		
	Water Features	33	acres		
	Treat Retreat Revegetation	143	acres		
	Jetty Jack Removal	0	units		
Reach 5 Plan G	Bank Destabilization	0	acres	**155**	**$998**
	Swales and Trenches	26	acres		
	Water Features	0	acres		
	Treat Retreat Revegetation	215	acres		
	Jetty Jack Removal	0	units		
Totals	Bank Destabilization	78	acres	678	
	Swales and Trenches	85	acres		
	Water Features	119	acres		
	Treat Retreat Revegetation	918	acres		
	Jetty Jack Removal	4,472	units		

5.4 Ecological Resources

For the Recommended Plan, revegetation of areas that AOSD has already worked in would be a primary objective. Revegetation of areas proposed to be thinned under this project would also be revegetated in a timely manner. Current discussions among professionals of riparian restoration include a conceptual mosaic for future vegetative conditions. The prescription for Bosque landscape alteration centers on re-creating a patchy mosaic of native riparian trees and open spaces along the narrow active floodplain of the Middle Rio Grande (Crawford and Grogan 2004). Although the present straightened and levee-bordered river would require that the mosaic be somewhat linear, it would otherwise resemble the pattern of scattered cottonwood groves interspersed by open spaces that once characterized the wider historic floodplain (Horgan 1984).

Open areas between the patches would support grasses and shrubs and widely spaced individual trees or groves useful for animals moving between the patchy woodlands. This combination of tree reduction (which is already occurring and is being proposed within this project) and increased open space would reduce overall evapotranspiration (ET) in the altered landscape and potentially increase water in the shallow aquifer. The conceptual mosaic is still evolving and would be site specific; however, an overall breakdown of vegetative communities would include approximately 30% shrub community, approximately 50% tree community (with 25% being tree with grass understory and the other 25% being tree with shrub understory), 16% grassland/herbaceous community, and 4% as wet meadow/wetland community. Burned areas being revegetated first would be analyzed by land managers to determine how this mosaic community is establishing and refine that as needed for other locations. In creating this future conceptual mosaic, revegetation strategies would be implemented. All sites would be tested for depth to groundwater, soil salinity, and soil texture. Existing topography would be coupled with this information to develop revegetation strategies for each project area.

Long-term benefits proposed by the project include reduction in fire potential, potential water savings, potential decreased soil salinity, and increased wildlife habitat value over the long-term. Fuel loads in the Middle Rio Grande have built up over the last 50 years or more due to the lack of flooding and the disconnect between the river and the Bosque. Flood flows used to carry away debris and allow for quicker processing of vegetative material. A reduction in these fuel loads, especially in the ladder fuels (which create a ladder between the floor of the Bosque and the cottonwood canopy), can greatly reduce the chance of a catastrophic fire were one to occur. This older material is extremely dry and flammable. Removal and processing of this material is crucial to preventing future fires.

Salt cedar are fire-adapted species and have long taproots that allow them to intercept deep water tables and interfere with natural aquatic systems. Salt cedar disrupts the structure and stability of native plant communities and degrades native wildlife habitat by successfully competing and replacing native plant species; monopolizing limited sources of moisture; and increasing the frequency, intensity, and effect of fires and floods. Although it provides some shelter, the foliage and flowers of salt cedar provide little food value for native wildlife species that depend on nutrient-rich native plant resources (Muzika and Swearingen 1999). Birds prefer to nest in native vegetation that contains their preferred physical structure and food source. Overall, the possible short term ill effects resulting from non-native vegetation removal and the

Recommended Plan would be strongly mitigated through the replacement of salt cedar with a younger, more diverse native riparian community, which would add to biodiversity at the landscape level.

Salt cedar control in mixed salt cedar/native Bosque would reduce stress to native species, which are competing with exotic vegetation, and would reduce wildfire hazards (Taylor 1999). Substrate for native species regeneration within these sites would also be provided as a result of salt cedar control and decreased salinity of the soil. This alternative would maximize the production of indigenous species such as salt grass, willow, and native wet meadow species, to potentially support greater numbers of native bird species and other wildlife. Individual locations within the Recommended Plan might have a varied revegetation strategy in order to aim toward the conceptual mosaic and stay within current water demands. Replacing dead material and non-native vegetation with a mosaic of native vegetation should lead to a system of less water use, decreased fire danger, and increased diversity of native species for use by wildlife. Therefore, the long-term affects of replacing the non-native dominated vegetation system with native dominated species is proposed to outweigh the short-term negative effects, which would be caused by the Recommended Plan.

5.4.1 Fish and Wildlife

The proposed work would occur during the winter, which is when Bald Eagles might be in or near the Recommended Plan area. In order to minimize the potential for disturbing Bald Eagles using adjacent habitat, the following guidelines would be employed. If a Bald Eagle is present within 0.25 mile upstream or downstream of the active construction site in the morning before activity starts, or is present following breaks in project activity, the contractor would be required to suspend all activity until the bird leaves of its own volition; **conversely,** a Corps biologist, in consultation with the USFWS, would determine that the potential for harassment is minimal. However, if a Bald Eagle arrives during construction activities or if an eagle is greater than 0.25 mile away, construction need not be interrupted. Also, cottonwood snags or other large trees present along the riverbanks that might serve as potential roost habitat would be left intact as part of this project. Implementation of these measures would preserve undisturbed Bald Eagle use of roost, foraging, and perching sites in the riparian area adjacent to the project sites.

Common fish species in the project area include river carpsucker (*Carpiodes carpio*), flathead chub (*Platygobio gracilis*), mosquitofish (*Gambusia affinis*), and red shiner (*Cyprinella lutrensis*; Platania, 1993). Less common fish species in the project area include longnose dace (*Rhinichthys cataractae*), channel catfish (*Ictalurus punctatus*), fathead minnow (*Pimephales promelas*), white sucker (*Catostomus commersoni*), and the Federally listed Rio Grande silvery minnow (*Hybognathus amarus*).

The peak nesting season for birds is April through August. The Migratory Bird Treaty Act (MBTA) (16 U.S.C. 703, et seq.) is the primary legislation in the United States established to conserve migratory birds (USFWS 2004). The list of the species protected by the MBTA appears in title 50, section 10.13, of the Code of Federal Regulations (50 CFR 10.13). The MBTA prohibits taking, killing, or possessing of migratory birds unless permitted by regulations promulgated by the Secretary of the Interior. The USFWS and the Department of Justice are the

Federal agencies responsible for administering and enforcing the statute. In order to minimize potential effects on nesting birds in the project area, clearing of live vegetation would occur only between September and April.

A Memorandum of Agreement (MOA) between the Federal Aviation Administration, the U.S. Air Force, the U.S. Army, the U.S. Environmental Protection Agency, the USFWS, and the U.S. Department of Agriculture to Address Aircraft-Wildlife Strikes was signed by the Department of the Army in 2002. The agreement was signed in reference to Advisory Circular (AC) 150/5200-33 (1997). Criteria were developed for siting wildlife attractants for a distance of 5,000 feet for airports serving piston-powered aircraft and 10,000 feet for airports serving turbine-powered aircraft. The Recommended Plan is within approximately 12,000 feet of the Albuquerque International Airport at the south end of the project boundaries. The Recommended Plan is approximately 25,000 feet east of the Double Eagle II Airport (which is on the west side of Albuquerque). The Albuquerque International Airport is within the recommended five-mile approach and departure airspace. The Airport currently implements procedures to reach altitudes well above the Bosque canopy to attempt to avoid waterfowl and other birds utilizing the Bosque. Therefore, the Recommended Plan is within compliance of this MOA and AC.

Other wildlife such as arthropods, mammals, amphibians, and reptiles would also be displaced during implementation of the Recommended Plan. The potential exists to affect amphibian species in the Bosque due to herbicide use. The New Mexico Department of Game and Fish suggested that risks of toxicity to this fauna could be avoided by eliminating the use of herbicide use during the month of September. Therefore, herbicide use within the project area would take place only between October and April.

Because the ultimate goal is to revegetate with native species, which would create a healthier ecosystem in the long term for native wildlife, these short-term effects of the project would be outweighed by the long-term benefits to all species. Implementation of the BMPs and timelines mentioned above would also aid in protecting species. Therefore, the Recommended Plan would have short-term negative affects on wildlife with long-term positive benefits. The variability of habitat types would also provide different niches for different groups of wildlife (birds, herpetofauna, fish, small mammals, and arthropods).

A Fish and Wildlife Coordination Act Report (CAR) is under development by the U.S. Fish and Wildlife Service for this project. The Corps recently coordinated with USFWS on the Ecosystem Restoration at Route 66 Project. The Corps anticipates that similar recommendations would be provided for this Recommended Plan. Therefore, recommendations that were provided by USFWS for the Ecosystem Restoration at Route 66 Project to prevent and reduce adverse project effects on fish and wildlife resources during construction, operation, and maintenance of the proposed project would be adhered to for the Recommended Plan. Any changes to these recommendations based on future contribution from USFWS would be noted.

5.4.2 Special Status Species

5.4.2.1 Rio Grande silvery minnow

Designated Critical Habitat for the species (68 Federal Register 8087: 8135) encompasses nearly the entire project area. Work would not take place in the main channel; however, work would take place along the bank and might result in erosion or other contributions into the river. When work is to occur close to the bank of the river, BMPs would be enforced to prevent erosional contribution to the river. These BMPs would include, but would not be limited to, the use of silt fences adjacent to the riverbank to prevent erosion to the river, fueling of vehicles would not take place inside the levees, and equipment and vehicles would be cleaned prior to entering the Bosque.

Additionally, this project is being constructed to provide potential habitat for the RGSM and would create additional suitable nursery habitat through the creation of high-flow channels with embayments, which would help with the population. High-flow channels would provide habitat in the form of ephemeral side channels (embayments) for the RGSM and potential refuge during spawning, egg, and juvenile stages. This project would be closely monitored to determine the benefits for the RGSM, which are proposed to occur as an outcome of the Recommended Plan.

Therefore, the Recommended Plan might affect, but is not likely to adversely modify, designated Critical Habitat of the Rio Grande silvery minnow, and might provide positive benefits to the species. The Corps has informally coordinated with USFWS in regard to this species because USFWS was a participant on the E-team. The Corps will submit a Biological Assessment to the USFWS in regards to the proposed effects discussed above.

5.4.2.2 Southwestern Willow Flycatcher

Southwestern Willow Flycatcher surveys have been conducted at locations within the Recommended Plan area that contained potentially suitable breeding habitat (as identified with USFWS) per the standard protocol (Sogge *et al.* 1997, as amended). These surveys were conducted in 2004 through 2006 under the Bosque Wildfire Project. Specific sites have been surveyed since that time under this and other projects. The Tingley Bar was surveyed under the Albuquerque Biological Park, and the San Antonio Oxbow has been surveyed each year as part of this Recommended Plan.

Southwestern Willow Flycatcher has been detected at the Tingley Bar site in 2004 and 2005. Both detections were during the first survey period (May). Single individuals responded to the tape play-back at two locations within the site. These locations were approximately 800 feet apart. The first individual was heard and observed singing in a clump of salt cedar along the riverbank. The second individual was heard singing in a dense clump of tall coyote willow on the river bar, about 150 feet from the edge of the river. No additional observations of Southwestern Willow Flycatcher occurred at this location, and the Corps presumes that these individuals were migrants. SWFL has also been detected at the San Antonio Oxbow in 2007 and 2008 during the first survey period (May). No additional observations were made during the remainder of the survey period. Therefore, the Corps presumes that these individuals were also migrants.

Based on these surveys and other surveys performed in the past within the project areas (by other entities), it is highly unlikely that nesting Southwestern Willow Flycatcher would occupy the project area during the construction period, which is proposed to begin in 2012 and continue through 2017. It is very possible that migrants would be present in the project area in spring and fall. Surveys at the locations where migrants have been detected would continue each year as they have in the past. If nesting Flycatchers are detected on any locations where work is proposed under this Recommended Plan, then consultation with USFWS would be initiated.

Also, creation of willow swales in the Recommended Plan would provide potential habitat for the SWFL. Over time, these would create willow stands of the preferred density and stature for SWFL. Restoration proposed in the San Antonio Oxbow would improve potential habitat where migrants have been detected for the past three years.

Therefore, the Corps has determined that the proposed work might affect, but is not likely to adversely affect, the Southwestern Willow Flycatcher. Designated Critical Habitat was determined for SWFL in November 2005, but is not in the project area. Construction of the features described above might beneficially affect the SWFL. The Corps has informally coordinated with USFWS in regard to this species because USFWS was a participant on the E-team. The Corps will submit a Biological Assessment to the USFWS in regards to the proposed effects discussed above.

5.4.2.3 Yellow-billed Cuckoo

Habitat potentially suitable for nesting of Yellow-Billed Cuckoo is present in the Recommended Plan area, primarily in the form of dense salt cedar stands; therefore, the habitat is limited. Yellow-Billed Cuckoo has been noted to nest late into October (D. Krueper, personal communication). Surveys for nests in potential habitat would occur through October prior to construction. This habitat would be thinned and revegetated during this project, creating potentially suitable habitat in the future. Therefore, the Recommended Plan might affect, but is not likely to adversely affect, the Yellow-Billed Cuckoo during implementation and could have a long-term positive effect.

5.4.2.4 Brown-Headed Cowbirds

Brown-headed Cowbirds were observed at all of the sites throughout the survey.

5.5 Water Quality

A Section 404 (b)(1) guidelines analysis has been completed for Nationwide Permit 33 (Temporary Construction, Access, and Dewatering), due to the potential need to dewater at the bank of the river when constructing the high-flow channels, and for Nationwide Permit 27 (Stream and Wetland Restoration Activities) for work that would take place in the San Antonio

Oxbow to restore wetland function in that habitat as part of implementing the Recommended Plan. All conditions under Nationwide Permits 33 and 27 would be adhered to during construction. A water quality certification under Section 401 of the Clean Water Act (CWA) would be required. The Corps would coordinate with the New Mexico Environment Department (NMED) regarding activities and schedules to allow the opportunity for monitoring water quality conditions during project implementation.

A Storm Water Pollution Prevention Plan (SWPPP) for the project would be developed by the Corps. The contractor would be required to adhere to this plan and is required to file a Notice of Intent (NOI) with the Environmental Protection Agency. Through this NOI, the contractor performs all work in accordance with the nationwide NPDES permit prior to commencement of construction activities. Compliance with these requirements would ensure that the Recommended Plan would have no significant effect on the water quality of the Rio Grande. Water quality would be monitored throughout the project. Silt fences (without lead weights) would be installed prior to construction in all areas and other standard BMPs would be implemented. All construction activities would be in compliance to all applicable Federal, state and local regulations.

A short-term adverse effect on water quality might occur during construction along the banks of the river; however, that portion of construction would take place during low flows of the river. Once the water features have been constructed, many of them would provide a benefit to water quality. Those water features where wetland plants are installed would provide improved water quality as the wetland plants take up materials in the water passing through the feature (such as storm water passing through wetlands constructed near these features, or sediment laden water passing through the high-flow channels). Therefore, there would be a minor short-term adverse effect on water quality during construction only and a positive long-term benefit to water quality by implementation of the Recommended Plan.

5.6 Air Quality and Noise

All vehicles involved in construction of the Recommended Plan would be required to have passed a current New Mexico emissions test and have required emission control equipment (if required).

Because there would be ground disturbance during construction of all features in the Recommended Plan, BMPs to minimize air quality disturbance would be employed. These include trucking out of material by covering trucks to avoid fugitive dust violations, maintaining and sweeping public trails to keep them free of debris and dust, and wetting down work areas. Speed limits on levee roads would be limited to 15 miles per hour, which would also minimize dust. A fugitive dust permit would be obtained from the City of Albuquerque. All work areas would be continually wet down to minimize dust. Any sediment deposited on the paved trail due to construction would be swept as needed. Therefore, short-term impacts to air quality are anticipated during construction but would be abated to the extent possible using BMPs as described above. There would be no long-term adverse effects to air quality by the Recommended Plan.

Equipment to be used during construction would include pieces generating a fair amount of noise. This noise would be somewhat abated in adjacent neighborhoods due to the buffering by the levee road when work is taking place in the Bosque. Travel on the levee roads to and from work locations would also create noise during the project. The project would take place during normal work hours between 7:00 am and 5:00 pm in order to minimize disturbance. All OSHA and local municipality requirements (as described above) would be adhered to. Therefore, there would be minor, short-term noise impacts by the Recommended Plan during construction, which would occur only during normal working hours.

5.7 Cultural Resources

This project required a significant amount of preliminary planning, and the Corps determined that, within the Recommended Plan's 916 acre area of potential effect (APE), there were 33 historic properties (historic archaeological sites), no prehistoric archaeological sites and no American Indian traditional cultural properties (TCPs) within or adjacent to any of the current project areas. The project intent is to avoid known historic sites. The cultural resources survey documented five historic properties, four of which are short earthen ditch remnants from the historic period and one is either a historic ditch segment or possibly a recent fire break. None of these ditch remnants is shown on historic Reclamation Service maps of the Rio Grande Valley that date to 1922.

As abandoned segments of acequia or drainage systems, these ditch remnants lack integrity in that they no longer function as originally intended. They are in a deflated, weathered, and un-maintained condition and, therefore, their form and the full extent of their alignment are in question. These ditch remnants have been adequately documented in the field and are not considered to be eligible for nomination to the National Register of Historic Places under criterion (d) of 36 C.F.R. 60.4 as sites that have yielded, or may be likely to yield, information important in prehistory or history. These ditch remnants might, however, be considered as contributing, non-eligible portions of larger as yet undefined historic irrigation or drainage system(s) that might be eligible for nomination under criterion a of 36 C.F.R. 60.4. Further historic and archival research is necessary to make this determination. These sites will be avoided during project implementation.

Two historic properties, portions of the Barelas Drains, LA145193, and the Griegos/Gallegos Acequia remnants, LA145195, are known from previously surveyed areas in the APE. Both are abandoned segments of historic irrigation or drain ditches. Both have been determined eligible for nomination to the National Register of Historic Places under criteria a and d. These ditch alignments are being planned for incorporation into the project design to be re-utilized to enhance riparian habitat and wetland vegetation. The proposed use of these properties is consistent with previous restoration projects in the area. These historic earthen irrigation and drainage structures were cut off by the construction of the flood control levees and riverside drains in the 1930s and were abandoned within the Rio Grande Floodway/floodplain (Estes 2005).

American Indian Tribes/Pueblos that have indicated they have concerns within Bernalillo and Sandoval Counties have been previously contacted regarding several extensive and on-going riparian habitat restoration projects in the general project area, including the Bosque Wildfire

Project and the Ecosystem Restoration at Route 66, Albuquerque, New Mexico, Section 1135 Project. No previous concerns have been brought to the attention of the Corps. Consistent with the Department of Defense's American Indian and Alaska Native Policy, signed by Secretary of Defense William S. Cohen on October 28, 1998, and based on the State of New Mexico Indian Affairs Department and Historic Preservation Division's 2008 Native American Consultations List, American Indian Tribes/Pueblos that have indicated they have concerns within Bernalillo and Sandoval Counties were contacted regarding the Recommended Plan. These include the Pueblo de Cochiti, the Comanche Indian Tribe, the Hopi Tribe, the Pueblo of Isleta, the Pueblo of Jemez, the Jicarilla Apache Nation, the Pueblo of Laguna, the Navajo Nation, the Ohkay Owingeh, the Pueblo of San Felipe, the Pueblo of San Ildefonso, the Pueblo of Sandia, the Pueblo of Santa Ana, the Pueblo of Santa Clara, the Pueblo of Santo Domingo, the White Mountain Apache Tribe, the Pueblo of Ysleta del Sur, and the Pueblo of Zia. The Corps has received six responses to our scoping letters from the White Mountain Apache Tribe, Hopi Tribe, Pueblo of Laguna, Pueblo of Santa Clara, Navajo Nation, and the Pueblo of Isleta. None of the tribal responses expressed concerns regarding the Recommended Plan.

This project is located in New Mexico within Bernalillo and Sandoval Counties where the population of residents that are adjacent to the project area boundary is 61,816. The Bosque currently provides a limited ecosystem habitat to wildlife as well as limited recreational opportunities to the surrounding community.

In 1994, Executive Order 12898 (Federal Action to Address Environmental Justice in Minority Populations and Low Income Populations) mandated that "each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. Further, it mandated that each Federal agency responsibility set forth in the Order shall apply equally to Native American programs.

5.8 Environmental Justice

Due to the Recommended Plan's value as a wildlife habitat, improving the natural environment will increase the benefit the surrounding community and urbanized areas. No displacement, relocation, economic, or any adverse action to minority or low-income populations of the community would result from the Recommended Plan. Though some homeless encampments might need to be removed as part of implementation of the Recommended Plan, this would allow the area to be safer for public use as well as provide local public assistance to those individuals. The surrounding populations will benefit from the Recommended Plan with improvements to the study area and enhancement of their quality of life through ecosystem restoration and recreational efforts. Reversing ecological degradation and re-creating a healthy natural environment creates more sustainable live, work, and play opportunities for the people of the community.

During the scoping process for the project, a number of public meetings were held and contribution was solicited from the public. Public contribution was provided during meetings and/or after via mail or e-mail and was used to develop alternatives, especially those providing public access and use of the Bosque.

The following table shows the demographics of the project area population in relation to county- and state-wide data. When comparing the demographics of the immediate surrounding tract populations with the state- and county-wide data, it is evident that the statistics remain similar, including the statistics that the majority of the population is Hispanic/Latino at 57.8% and that poverty levels remain below 10%.

Table 5.4. Middle Rio Grande Floodplain Environmental Justice.

Middle Rio Grande Floodplain Environmental Justice		Race				Below Poverty Level			Age		
	Total Population	White	Hispanic & Latino	American Indian & Alaskan Native	Other	0-17 years	18-64 years	65 and older	0-17 years	18-64 years	65 and older
New Mexico	1,819,046	44.7%	42.1%	8.9%	2.6%	7.0%	9.9%	1.5%	27.9%	60.4%	11.7%
Bernalillo County	556,678	48.3%	42.0%	3.5%	4.2%	4.6%	8.0%	1.0%	25.3%	63.3%	11.5%
Valencia County	66,152	39.6%	55.0%	2.5%	1.4%	6.9%	8.7%	1.1%	29.9%	59.7%	10.3%
Project Area	61,816	35.6%	57.8%	8.2%	1.2%	6.6%	8.6%	1.6%	28.7%	59.3%	11.3%

This Recommended Plan would create some economic opportunities through ecotourism, education, and recreational sites, as well as promoting programs for resource conservation and protection. Executive Order 12898 requires that "to the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies and activities on minority populations and low-income populations…". The project would not disrupt or displace any residential or commercial structures. The work has been reviewed for compliance with this Order and it has been determined that the Recommended Plan would not adversely affect the health or environment of minority or low-income populations. From north to south, the Recommended Plan area borders high- to low-income neighborhoods. The Recommended Plan benefits all income brackets by increasing ecosystem restoration along the whole project area.

5.9 Aesthetics

The Recommended Plan includes removing jetty jacks, reducing fuel loads, and thinning of non-native vegetation, creation of water features, and revegetation with native species. In order to accomplish these goals, construction within the Bosque would include machinery of varying sizes. This would cause short-term negative affects to aesthetics during construction. Post-construction, some visual effects would be noticed depending on the level of work required. Therefore, negative, short-term impacts by the Recommended Plan to aesthetics would occur during construction and for a short time after construction; however, these impacts would decrease over a short period of time. The Recommended Plan would have a long-term positive effect on aesthetics by removing what many might deem as „unsightly' jetty jacks, burned and/or dead material and creating new wetland and other water features. Revegetation with native species would further increase the aesthetics of the site after a few years of maturation.

5.10 Floodplains and Wetlands

The majority of wetland communities within the Recommended Plan area would be avoided during implementation of the Recommended Plan. Wet meadow areas would be created during the revegetation phase, which would increase the wetland acreage in the project area. The San Antonio Oxbow is, however, one location where restoration features are proposed in order to improve the overall function of the wetland. Therefore, the Recommended Plan would have a minor adverse impact on the San Antonio Oxbow during construction of features to improve the function. The remaining features to be implemented in the Recommended Plan would not affect existing wetland habitat.

Removal of the non-native vegetation might allow the floodplain to expand. Because excavation of the bank to reconnect channels and bank destabilization are proposed as part of the restoration, an impact to the existing floodplain would occur. The constructed inlets and outlets of the high-flow channels would be formed and protected with vegetation to hold it in place. Therefore, the Recommended Plan might affect the floodplain; however, these impacts are anticipated to be positive and not significant.

5.11 Hazardous, Toxic and Radioactive Waste

All work planned to construct the Recommended Plan would be conducted in accordance with Federal, state, and local pollution control laws. Requirements would include the contractor's storage and use of fuels, herbicides, and other potential contaminants and the implementation of the NPDES permit for storm water pollution prevention from construction activities. There would be no adverse effect to or by HTRW by the Recommended Plan.

5.12 Climate Change

The Upper Rio Grande Water Operations Model (URGWOM) has investigated this issue extensively and information for the Albuquerque reach is summarized below. URGWOM is a computational model developed through an interagency effort and is used to simulate processes and operations of facilities in the Rio Grande Basin in New Mexico from the Colorado state-line to El Paso, Texas (flood control operations only below Caballo Dam) and complete accounting calculations for tracking the delivery of water allocated to specific users. URGWOM is not a water supply model, a climate model, a water rights model, a rainfall/runoff model, a hydraulic model, or a groundwater model. URGWOM is used to complete daily timestep rulebased simulations to forecast operations, deliveries, and resulting flows through the end of a calendar year with forecasted inflows computed using a Forecast Model. While this model is continually updated, specific forecast runs can only be done on an annual basis based on the current year’s snowmelt. Based on this information and other information available through URGWOM, there is a general assumption that water would be flowing through the Albuquerque reach under future climate change scenarios but the timing, duration and peak of those flows could more variable than they currently are.

The Rio Grande through this reach is used for conveyance of regulated flows for downstream irrigation and water deliveries to meet compact requirements. Project water features have been designed to operate at the water levels expected during an average water year. These average water year flows have been determined from historical data and are expected to continue into the future if water compact deliveries are to be met. Since the restoration features were not designed for (or dependent upon) extreme events, climate change would not be expected to affect them dramatically so long as water availability is sufficient to meet compact requirements. These features will continue to operate to some level even if the timing, duration and peak of these flows become more variable in the future. Since the maintenance component to this project is key, adaptive management would be utilized as needed based on changes related to climate change and/or other factors. Continued coordination with water management scenarios and their implementation will also be key to successful riparian restoration efforts (Seavy et al., 2009).

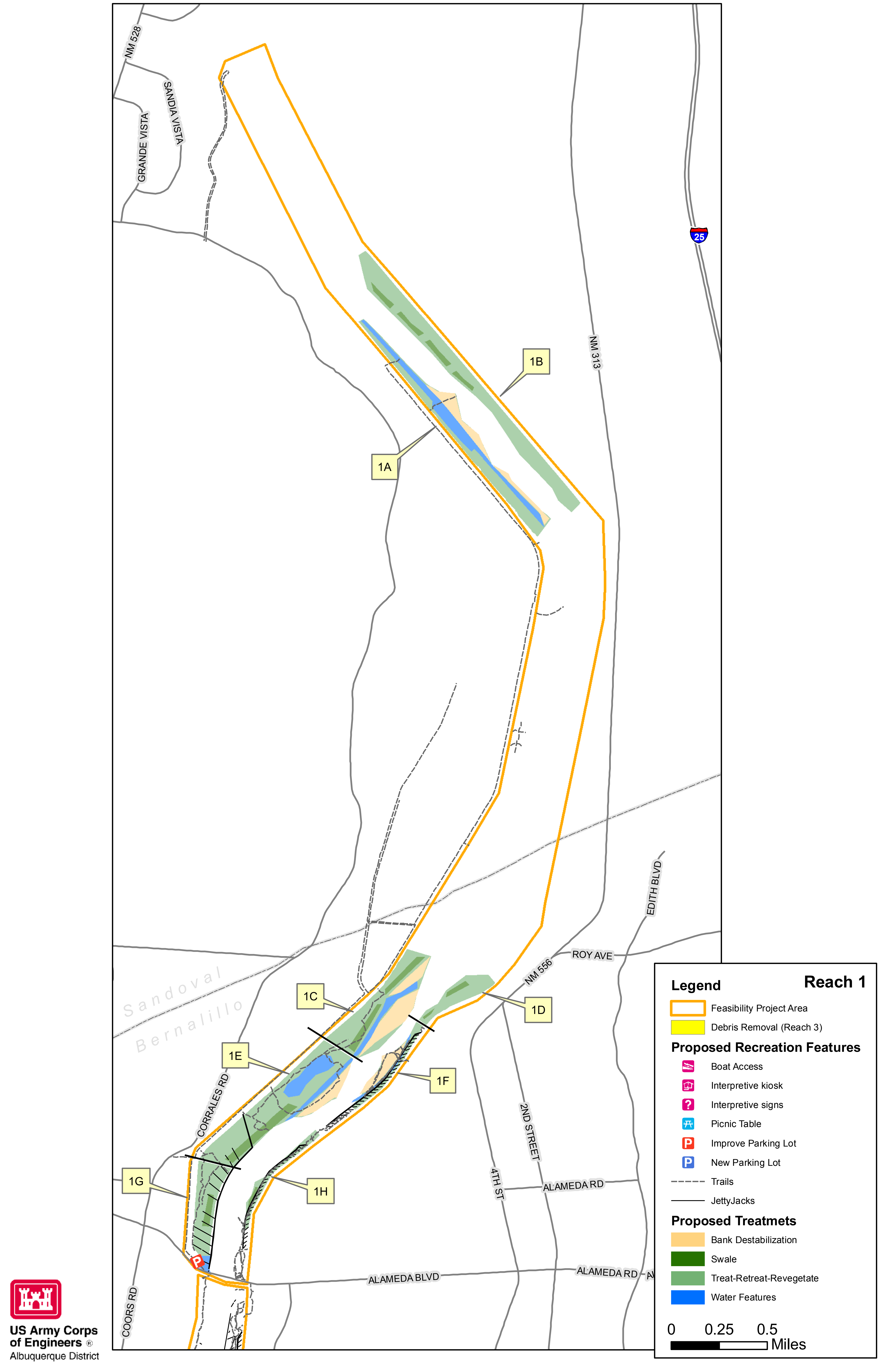
5.13 Preferred Recreation Plan

The unit day value method was used to assign a dollar value to current recreational use of the study area as well as to future recreational use after completion of the proposed improvements. Table 5.5 shows the general recreation costs and benefits for the study area before and after improvement, and the resulting user day dollar values range of $7.18 to $7.93 and $7.87 to 8.42, respectively (USACE Economic Guidance Memo 09-03). Total annual benefits are calculated at a range of $114,435 to $371,915 and are on the conservative end of the estimate. These figures are less than the estimated annual cost of $102,816; therefore, the increased benefits of recreational use would significantly exceed the cost of the recreation features. Figures 5.6 through 5.9 display the proposed recreation features included in the Preferred Recreation Plan.

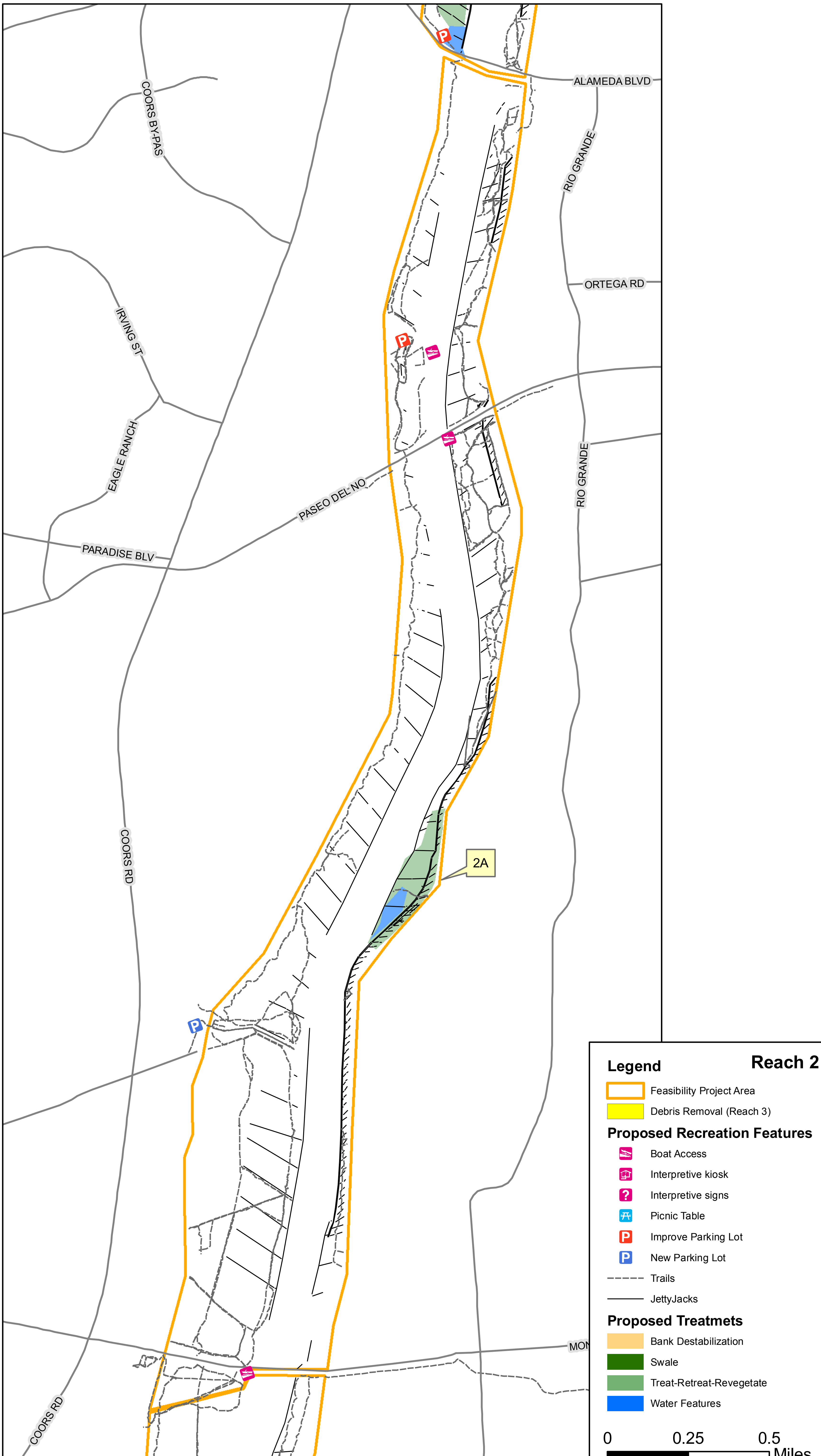
Table 5.5. Annual benefit of the proposed recreation features.

Without-Project UDV Value (points)	Without-Project Value (dollars)	With-Project UDV Value (points)	With-Project Value (dollars)	Benefits per visit (dollars)	Annual Benefits	BCR
		+9 pts.				
46	$7.18	55	$7.87	$0.69	$218,381	1.91
56	$7.93	65	$8.42	$0.49	$155,123	1.36
		+20 pts.				
46	$7.18	66	$8.46	$1.29	$408,789	3.58
56	$7.93	76	$9.17	$1.24	$392,895	3.44
		Outlier values associated with +9 pts.		$0.36	$114,435	1.0
				$1.17	$371,915	3.25
		Outlier values associated with +20 pts.		$1.10	$349,664	3.06
				$2.20	$669,327	6.12

Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



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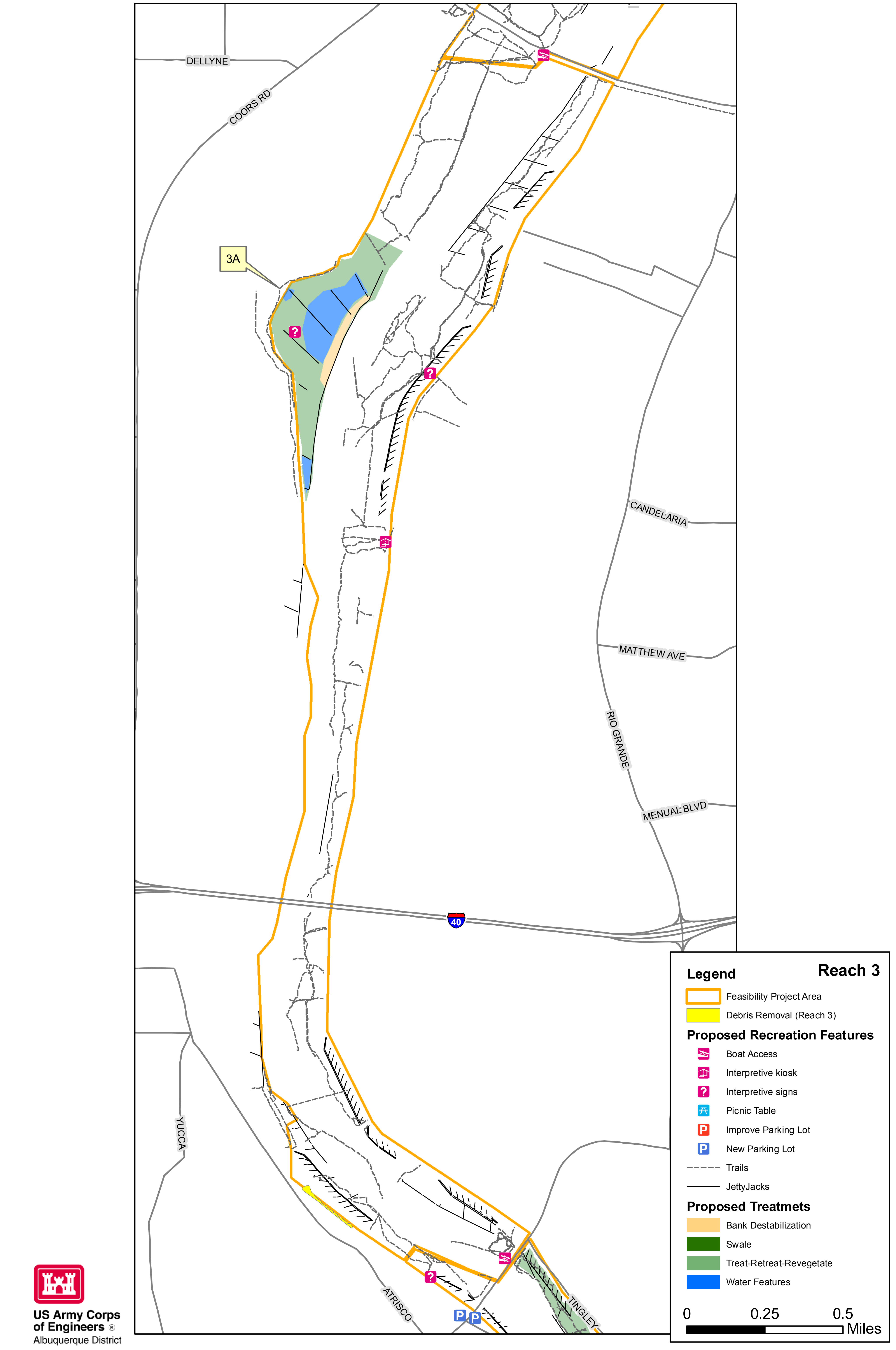
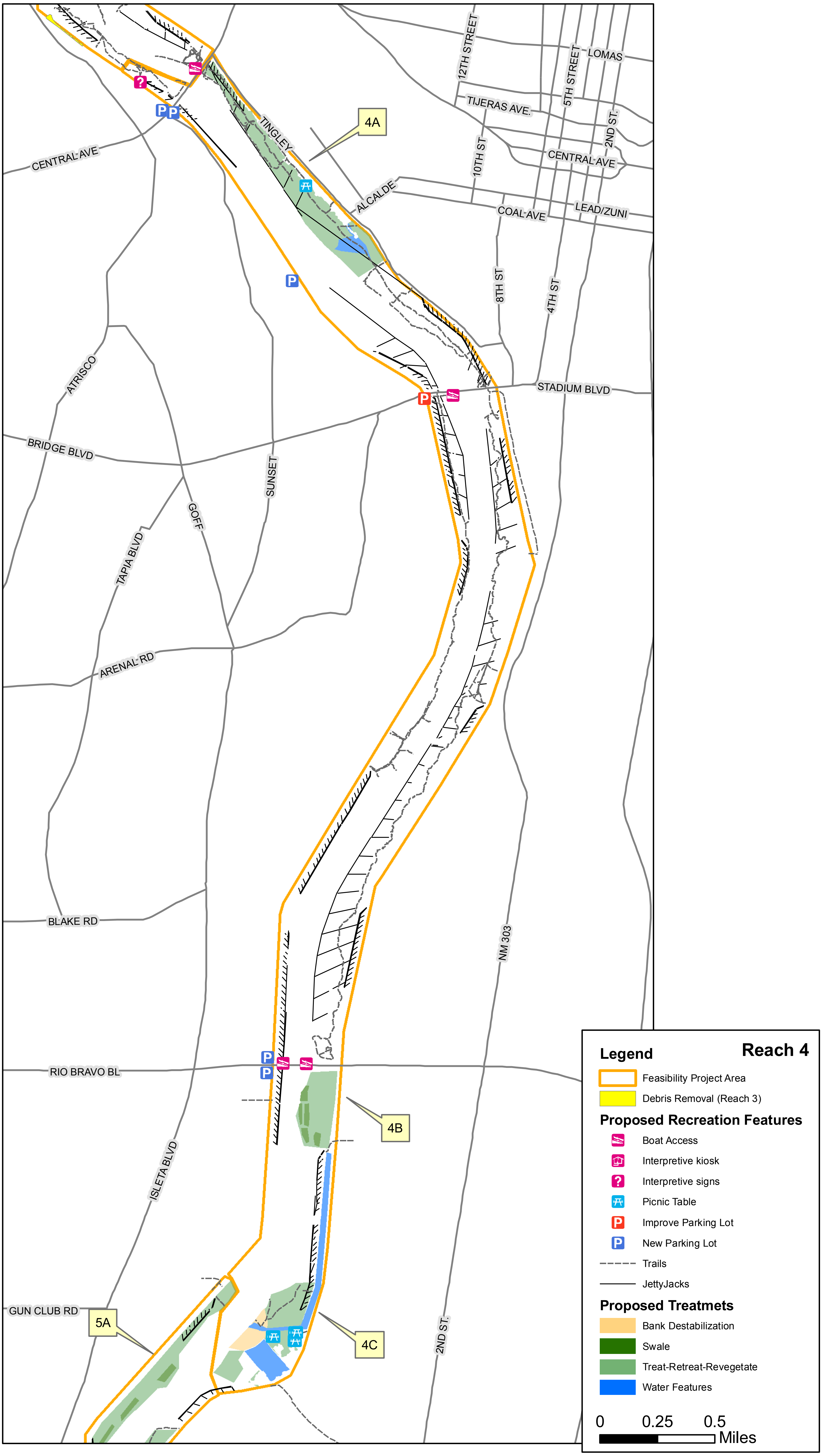
Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



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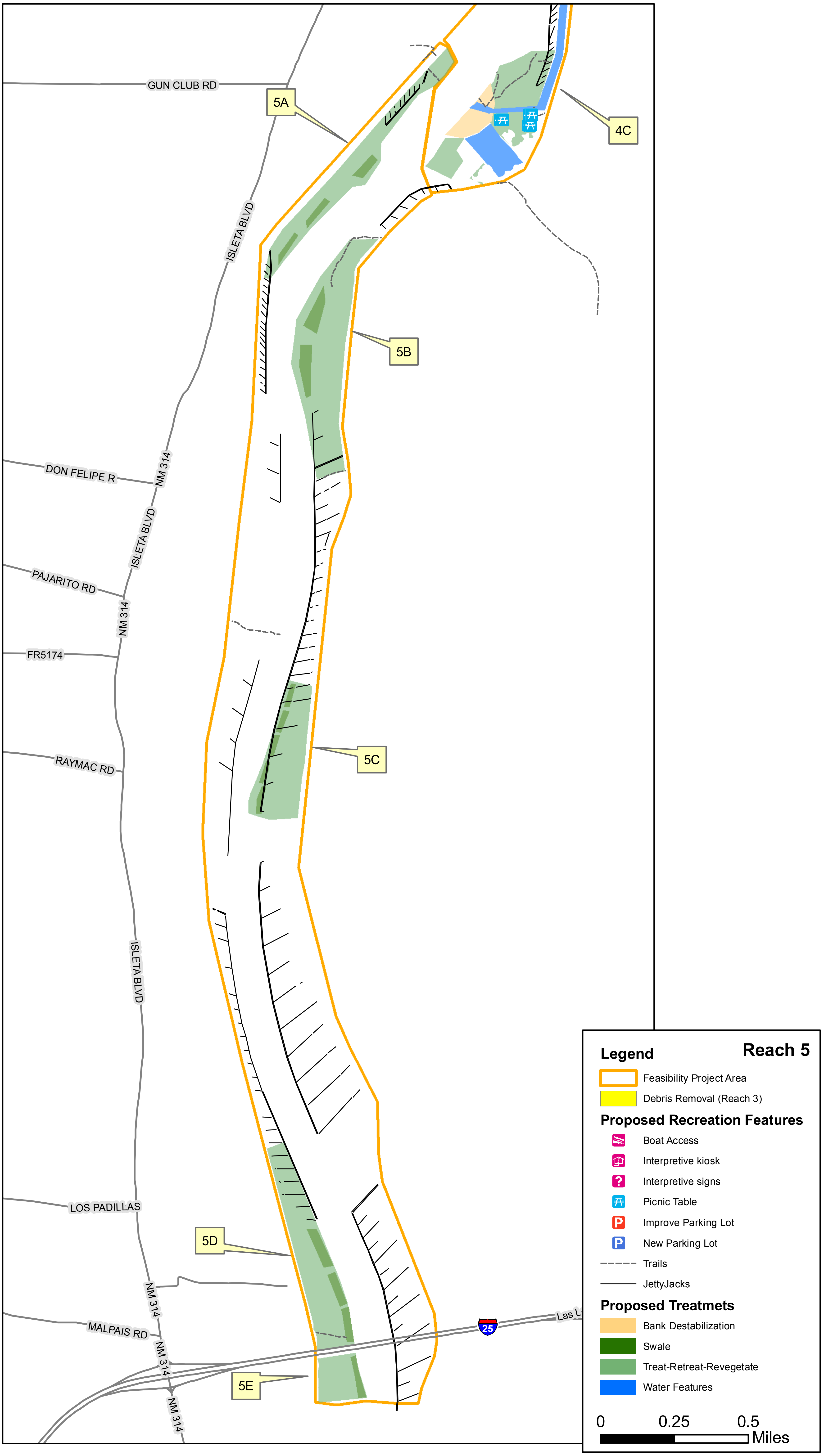
Middle Rio Grande Bosque Restoration Project - Recommended Plan #7



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5.14 Operation and Maintenance Considerations

Upon completion of project construction, the local sponsor will assume responsibility for Operations, Maintenance, Repair, Rebuild, and Rehabilitate (OMRR&R). Upon completion, the Corps will complete an Operations and Maintenance manual for the project that summarizes all OMRR&R requirements. Currently, the annual costs for OMRR&R are estimated to be approximately $52,000. This amount includes the following:

- Spraying and removal of resprouts and seedlings from non-native plants. With approximately 1,836 acres of treat/retreat of vegetation, the cost is broken down by square mile of spraying and removal for resprouts. Therefore, the cost for this item would be 1,836acres/640acres/square mile x $10,000 = $28,687

- Replacement of native plants that fail to become established. Based on previous experience with the Rio Grande Nature Center, this activity is not expected to experience many native plant failures per acre, therefore, the Corps used a lump sum amount of $5,000 per year.

- Maintenance of firebreaks. This activity requires the reblading and clearing for firebreaks. This lump sum estimate is $5,000 per year.

- Maintenance of the water features (removal of sediment and vegetation as it builds up in the features). The cost for this maintenance is based on sediment removal. Currently, the area of the Rio Grande associated with the restoration is at equilibrium. Sediment removal would be limited to the inlets and outlets of the channels. It is estimated that 500 cubic yards of sediment would be removed annually at a cost of $10 per cubic yard, which equates to an annual cost of $5,000.

- Maintenance of recreational features such as natural surface trails, signage, benches and tables, and parking facilities. The cost of maintenance of recreational features is primarily derived from the maintenance of the trails. This involves adding natural surface materials in areas of the trails that have experienced damage. The cost is estimated at 50 cubic yards of material at $150 per cubic yard per year equals $7,500.

5.15 Monitoring and Adaptive Management

Recent Corps guidance, *Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007) – Monitoring Ecosystem Restoration*, requires that a plan be developed for monitoring the success of the ecosystem restoration. This monitoring plan shall:

> *(1) include a description of the monitoring activities to be carried out, the criteria for ecosystem restoration, and the estimated costs and duration of the monitoring; and*

(2) specify that the monitoring shall continue until such time as the Secretary determines that the criteria for ecosystem restoration success will be met.

The guidance also states that "an adaptive management plan (*i.e*., a contingency plan) will be developed for all ecosystem restoration projects".

Post-project monitoring is a crucial requisite of the adaptive management process, as performance feedback might generate new insights into ecosystem response and provide a basis for determining the necessity or feasibility of subsequent design or operational modifications. Success should be measured by comparing post-project conditions to the restoration project purpose and needs and to pre-project conditions.

Monitoring also provides the feedback needed to establish protocols and make adjustments where and when necessary to achieve the desired results. Monitoring of the Corps Bosque Wildfire and Albuquerque Biological Park Wetlands projects has provided information that has been useful in developing goals and alternatives for this project. Monitoring from those projects will also aid in design.

Two types of monitoring are proposed to evaluate project success and to guide adaptive management actions. The first type, termed "Validation Monitoring", would involve various degrees of quantitative monitoring aimed at verifying that restoration objectives have been achieved for both biological and physical resources. Specific hypotheses addressing type and amount of functional improvements anticipated over specified time periods would be developed and tested as project success criteria. The second type of monitoring, termed "Effectiveness Monitoring" would be implemented to confirm that project construction elements perform as designed. For example, effectiveness monitoring would be used to evaluate percent survival of native plant material installed, to determine if high-flow channels convey water at predicted flow levels, *etc*. The Corps would use one or both types of monitoring to guide adaptive management of proposed projects and to guide future restoration designs. See Appendix F for the complete Monitoring and Adaptive Management Plan.

5.16 Real Estate Requirements

Real estate required for the Recommended Plan includes lands in the bosque owned or managed by the City of Albuquerque, the Village of Corrales, Sandia Pueblo, State Land Office and the MRGCD/USBR. The MRGCD has been a non-Federal sponsor for several district projects, has expressed strong support for this project, and will provide appropriate easements. Required lands consist of standard and non-standard estates. The MRGCD/USBR owned lands are standard estates, whereas lands owned by Pueblo of Sandia, the City of Albuquerque, and the State of New Mexico are non-standard estates for which an environmental ecosystem easement will be acquired. MRGCD will not acquire the City of Albuquerque lands in fee because MRGCD has cooperative working agreements with the landowner regarding the maintenance and operation of the lands and the MRGCD‟s facilities upon the lands. The Sandia Pueblo is a sovereign nation which does not sell its lands without the involvement of the Department of the Interior, Bureau of Indian Affairs.

All work will occur within the right of way of the Albuquerque levee system. All access to the sites will be by public roadway and along the levee roadway; rights of use will be required for the use of levee roadway. Access permits might be required from the Sandia Pueblo and the Village of Corrales in the northern portion of the project. Access in the remaining areas for surveying, staging, and construction activities will be obtained from the MRGCD and Bureau of Reclamation. MRGCD owns fee or easement rights for irrigation water delivery and drainage purposes; these rights would be used for temporary access for exploration and testing, surveying, staging, construction, and monitoring activities associated with the proposed project to avoid the need to obtain cost prohibitive permanent ownership of the properties. Recreation features will be located within the easement required for the ecosystem restoration. Appendix B presents the complete Real Estate Plan.

5.17 Project Costs

The feasibility level cost estimate summary per ER1105-2-100, Appendix H, Amendment No. 1, page H-49, is shown in Table 5.6. The costs generated in the table were derived from the Micro Computer Aided Cost Estimating Software (MCACES). Please refer to the Engineering Analysis for detailed MCACES information. The differences between the MCACES total project cost estimate and the costs presented in Table 5.6 are due to methodological differences and guidance requirements for grouping and displaying costs. The costs generated by the MCACES also differ from those listed in the Best Buy plans in Section 4 due to timing of the ICA inputs and inherent methodological differences between the ICA and the MCACES.

Table 5.6. Middle Rio Grande Bosque Feasibility Study-Cost Sharing.

Middle Rio Grande Bosque Feasibility Study-Cost Sharing October 2010 Price Level			
Item	Federal Cost	Non-Federal Cost	Total Cost
Ecosystem Restoration (ER)			
PED	$994,000.00	$0.00	$994,000.00
CM	$1,426,000.00		$1,426,000.00
Lands, Easements, Relocations, Right of Way, and Disposal Sites	$0.00	$1,314,000.00	$1,314,000.00
Ecosystem Restoration	$19,762,000.00	$0.00	$19,762,000.00
Subtotal	$22,182,000.00	$1,314,000.00	$23,496,000.00
Interest During Construction	$708,000,00	$0.00	$708,000.00
Total ER Cost	$22,890,000.00	$1,314,000.00	$24,204,000.00
Recreation			
PED	$86,000.00	$0.00	$86,000.00
CM	$124,000.00		$124,000.00
Lands, Easements, Relocations, Right of Way, and Disposal Sites	$0.00	$0.00	$0.00
Recreation Features	$1,647,000.00	$0.00	$1,647,000.00
Subtotal	$1,857,000.00	$0.00	$1,857,000.00
Interest During Construction	$61,000.00	$0.00	$61,000.00
Recreation Subtotal	$1,918,000.00	$0.00	$1,918,000.00
Total Project Investment Cost	$24,808,000.00	$1,314,000.00	$26,122,000.00
OMRR&R			$52,000

Fully Funded Estimate as of October 2010 price level. All figures rounded. As specified in the Real Estate Plan, there will be no LERRD credit for this project (Appendix B).

5.18 Cost Sharing Requirements

In accordance with Public Law 111-8, Section 114, construction cost will be at 100% Federal expense. The non-Federal sponsor is responsible for the provision of lands, easements, rights of way, relocations and disposal areas and post project operations and maintenance. Federal implementation of the recommended project would be subject to the non-Federal sponsor agreeing to comply with applicable Federal laws and policies, including, but not limited to, the items of cooperation listed below:

- Shall not use funds from other Federal programs; including any non-Federal contribution required as a matching share; therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purposes is authorized.

- Provide during construction, 100% of total project investment costs (excluding costs of the first item listed above) in excess of $25,000,000.00.

- Provide all lands, easements, and rights of way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights of way to enable the disposal of dredged or excavated material as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the ecosystem restoration features;

- Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights of way or the addition of facilities which might reduce the outputs produced by the ecosystem restoration features, hinder operation and maintenance of the project, or interfere with the project's proper function;

- Shall not use the ecosystem restoration features or lands, easements, and rights of way required for such features as a wetlands bank or mitigation credit for any other project;

- Keep the recreation features, and access roads, parking areas, and other associated public use facilities, open and available to all on equal terms;

- Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4605), and the regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

- For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and state laws and regulations and any specific directions prescribed by the Federal government;

- Give the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

- Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

- Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 CFR Section 33.20;

- Comply with all applicable Federal and state laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying, and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

- Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal government determines to be subject to the navigation servitude, only the Federal government shall perform such investigations unless the Federal government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

- Assume, as between the Federal government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal government determines to be required for construction, operation, and maintenance of the project;

- Agree, as between the Federal government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

- Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

The MRGCD requested the current proposed project and would serve as the local cost-sharing sponsor of the project. The cost-sharing requirements and provisions would be formalized with the signing of a Project Partnership Agreement (PPA) between the MRGCD and the Department of the Army following approval of this feasibility report. In the PPA, the sponsor would agree to provide all lands, easements, rights of way, relocations and disposal costs.

The basic criteria for the non-Federal cost-sharing responsibilities for this project are provided by Section 3118 of Public Law 110-114, as amended by Section 114 of Division C of Public Law 111-8 at new subsection (d):

> *Cost Sharing- Any requirement for non-Federal participation in a project carried out in the bosque of Bernalillo County, New Mexico, pursuant to this section shall be limited to the provision of lands, easements, rights-of-way, relocations, and dredged material disposal areas necessary for construction, operation and maintenance of the project.*

The total project first cost is estimated at approximately $24,041.000. This differs from the total investment cost shown in table 5.6 by the interest during construction.

Table 5.7. Non-Federal Sponsor Requirements.

Non-Federal Sponsor Requirements	
Total Requirements	$1,314,000.00
Non-Federal lands, easements, and rights of way	$1,314,000.00
Non-Federal Betterments	$0

5.19 Consistency with Project Purpose

The construction and operation of the Recommended Plan would be consistent with Engineer Regulation 1105-2-100, specifically, "The objective of ecosystem restoration is to restore degraded ecosystem structure, function and dynamic processes to a less degraded, more natural condition. Restored ecosystems should mimic, as closely as possible, conditions which would occur in the absence of human changes to the landscape and hydrology". The project would also be consistent with the authorized purposes and current operation of the Middle Rio Grande Flood Control Project, Corrales Levee Project, Albuquerque Levees, Jemez Canyon and Cochiti Dams. Activities proposed within the MRGB project would not raise the Base Flood Elevation (1.0%-chance flood water surface elevation) of the floodway either during or after the project is completed, thus the Recommended Plan would not result in increased erosion of the existing levees. Features of the project would include removal of jetty jacks, but this would be accomplished only after an analysis has been completed which determines that the jetty jacks are no longer functioning properly. Additionally, the features of the proposed project would not alter the extent or frequency of damaging discharges within or downstream from the project reach.

5.20 Conclusions and Recommendations

The studies documented in this report indicate that the Middle Rio Grande Bosque Restoration, New Mexico, as described in the recommended plan, is technically possible, sustainable, economically justified and environmentally and socially acceptable. The Middle Rio Grande Conservancy District (MRGCD), as the local sponsor, has cost shared in this feasibility study and agreed to participate in the implementation of the Recommended Plan as stated in the Items of Local Cooperation in section 5.20.2 below.

5.20.1 The Recommended Plan

The Recommended Plan, also the NER plan, represents the most cost-effective aggregation of restoration features that best meet the objectives of the restoration project. The Recommended Plan would restore 916 acres of the Middle Rio Grande Bosque and provide 678 average annual habitat units by enhancing hydrologic and restoring native vegetation communities. The restoration would provide a 67-80% improvement in habitat value over the future without project condition. In addition, recreational use of the Bosque would be improved by creating designated trails with benches, signs, and other interpretive features.

The Recommended Plan provides for the intent and, in many cases, the letter of several Federal environmental laws, directives, and executive orders concerning restoration and conservation efforts. The Recommended Plan would improve the scarce native riparian habitat to a more natural state, including a mosaic of habitat types. The Bosque habitat community can increase in both quantity and quality as a direct result of reconnecting the hydrology to the system and re-establishing a dynamic mosaic of multi-aged stands of cottonwood forests, coyote willow shrublands, wet meadows, wetlands, oxbow ponds, and open water areas with a variety of depths and flows. The restored habitats would benefit numerous migratory bird species that use the area for nesting and stopover, provide additional potential habitat for Federal and State listed species, and increase sustainability of the Bosque by creating connections between the Bosque and river.

The recommended plan consists of:

- Construction of wet features in the floodplain, such as high-flow channels (side channels that connect to the main river only during peak flows), willow swales, and wetlands. These features will enhance the movement of overbanking flows through the floodplain, and will facilitate the movement of water from storm drain outfalls in ways that create new riparian habitat while reducing the risk of damage to flood control structures.

- Improvements to the complexity and diversity of the water/land interface for fish and invertebrate species. This will be accomplished through in-channel work, including bank destabilization.

- Restoration of native vegetation and habitat through augmentation, the reduction of exotic and invasive species, the restoration of native riparian gallery forests, and the removal of Kellner jetty jacks. Jetty jack removal will restore sediment mobility in the active channel, providing substrate favorable for the natural establishment of native vegetation.

- Changes to the vegetation canopy structure through reductions in understory density will reduce the incidence of catastrophic fire formation and spread. Understory thinning and jetty jack removal will also improve floodplain access by emergency vehicles and personnel to contain the spread of fires.

- Construction of recreation facilities, including 76,000 linear feet of trail improvements, Benches, picnic tables, kiosks, signage and access improvements.

Proposed Treatment	Quantity	Units	Total AAHUs Created	Average Annual Cost per AAHU
Bank Destabilization	78	acres		
Swales and Trenches	85	acres		
Water Features	119	acres	678	$2,174
Treat Retreat Revegetation	918	acres		
Jetty Jack Removal	4,472	units		

Total project first costs for the recommended plan of $24 million and the fully-funded estimate of $24.8 million are within the $25 million authorized for federal spending.

5.20.2 Items of Local Cooperation

In accordance with Public Law 111-8, Section 114, construction cost will be at 100% Federal expense. Federal implementation of the recommended project would be subject to the non-Federal sponsor agreeing to comply with applicable Federal laws and policies, including, but not limited to, the items of cooperation listed below:

- Shall not use funds from other Federal programs; including any non-Federal contribution required as a matching share; therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purposes is authorized.

- Provide during construction, 100% of total project investment costs (excluding costs of the first item listed above) in excess of $25,000,000.00.

- Provide all lands, easements, and rights of way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights of way to enable the disposal of dredged or excavated material as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the ecosystem restoration features;

- Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights of way or the addition of facilities which might reduce the outputs produced by the ecosystem restoration features, hinder operation and maintenance of the project, or interfere with the project's proper function;

- Shall not use the ecosystem restoration features or lands, easements, and rights of way required for such features as a wetlands bank or mitigation credit for any other project;

- Keep the recreation features, and access roads, parking areas, and other associated public use facilities, open and available to all on equal terms;

- Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4605), and the regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material, and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

- For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and state laws and regulations and any specific directions prescribed by the Federal government;

- Give the Federal government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

- Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

- Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 CFR Section 33.20;

- Comply with all applicable Federal and state laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying, and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

- Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal government determines to be subject to the navigation servitude, only the Federal government shall perform such investigations unless the Federal government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

- Assume, as between the Federal government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal government determines to be required for construction, operation, and maintenance of the project;

- Agree, as between the Federal government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

- Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

The MRGCD requested the current proposed project and would serve as the local cost-sharing sponsor of the project. The cost-sharing requirements and provisions would be formalized with the signing of a Project Partnership Agreement (PPA) between the MRGCD and the Department of the Army following approval of this feasibility report. In the PPA, the sponsor would agree to provide all lands, easements, rights of way, relocations and disposal costs.

The basic criteria for the non-Federal cost-sharing responsibilities for this project are provided by Section 3118 of Public Law 110-114, as amended by Section 114 of Division C of Public Law 111-8 at new subsection (d):

> *Cost Sharing- Any requirement for non-Federal participation in a project carried out in the bosque of Bernalillo County, New Mexico, pursuant to this section shall be limited to the provision of lands, easements, rights-of-way, relocations, and dredged material disposal areas necessary for construction, operation and maintenance of the project.*

I hereby submit the Middle Rio Grande Bosque Restoration, NM Final Feasibility Report for approval by the Assistant Secretary of the Army for Civil Works. I confirm that the report complies with all applicable policy and laws in place at the time of its completion.

Jason D. Williams
Lieutenant Colonel, U. S. Army
District Commander

SECTION SIX - BIBLIOGRAPHY

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