Rio Grande, Sandia Pueblo to Isleta Pueblo, CO, NM, TX Ecosystem Restoration Feasibility Study and Environmental Assessment

Appendix F

Environmental Resources

U. S. Army Corps of Engineers

Albuquerque District

US Army Corps of Engineers ®
Albuquerque District

Section 404 (b) (1) Evaluation – Middle Rio Grande Bosque, Sandia to Isleta Restoration Project

I. Project Description

The Proposed Action would includes 261 acres of the bosque that would be restored 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 exotic species/fuel reduction and riparian gallery forest restoration.

a. Location

The Proposed Action Area includes the bosque within Albuquerque was designated as the *Rio Grande Valley State Park* through the Park Act of 1983 and is cooperatively managed by the City of Albuquerque, Open Space Division (OSD) and the MRGCD. That is, the bosque is offered protection as a State Park but without state operating funds and is administered by OSD and MRGCD through formal agreements.

b. General Description

See above.

c. Authority and Purpose

Authorization

The Rio Grande, Sandia Pueblo to Isleta Pueblo, CO, NM, TX Ecosystem Restoration Feasibility Study is being conducted as the first study under the Rio Grande Environmental Management Program (RGEMP) for the Rio Grande basin. The RGEMP has been authorized by Section 5056 of the Water Resources Development Act of 2007 (WRDA 2007), as amended by Section 4006 of the Water Resources Reform Development Act of 2014 (WRRDA 2014). The RGEMP is established for the planning, construction, and evaluation of measures for fish and wildlife habitat rehabilitation and enhancement; and implementation of a long-term monitoring, computerized data inventory and analysis, applied research, and adaptive management program in consultation with the States of Colorado, New Mexico, and Texas, and other appropriate entities.

Purpose and Need

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 Rio Grande Environmental Management Program, Sandia to Isleta (RGEMP-I) 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.

d. General Description of Dredged or Fill Material

During construction of the proposed high flow channels, a temporary diversion structure may need to be placed at the bank of the Rio Grande, which is a water of the United States.

(1) General Characteristics of Material (grain size, soil type)

Soils along the bank of the river are fine-grained alluvial silts, sands, and gravels. Soils derived from these deposits in the Study Area are Torrifluvents, Calciorthids and Torriorthents (Soil Conservation Service 1974). Grain size is therefore very small.

(2) Quantity of Material (cu. yds.)

The approximate quantify of material to be removed is approximately 19,025 cubic yards from each high-flow channel. This material would be removed and used within the site to build up berms along the channel or other features (such as the outfall channel habitat) but some of this dredged material would be hauled off site.

(3) Source of Material

No material would be placed during the construction of this project.

e. Description of the Proposed Discharge Site(s)

No material would be discharged during construction of this project.

(1) Location (map)
(2) Size (acres)
(3) Type of Site (confined, unconfined, open water)
(4) Type(s) of Habitat
(5) Timing and Duration of Discharge

f. Description of Disposal Method (hydraulic, drag line, etc.)

This material would be removed and used within the site to build up berms along the channel or other features (such as the outfall channel habitat) but none of this dredged material would be placed. If excess material exists, it would be hauled off site and deposited at an approved location.

II. Factual Determination

There would be short-term effects on waters of the United States during dredging of the inlet and outlet of the high flow channels. If needed, a coffer dam would be placed at the bank edge and pushed out into the water to create a 'work zone' during construction of the inlet and outlet of the high-flow channels. Sediment dredged within this area would be removed as described in Section f and would not be allowed to discharge or be placed in the river.

a. Physical Substrate Determinations

(1) Substrate Elevation and Slope – Substrate elevation is in line with the bank of the river and a steep slope exists. This would be modified to allow a connection of the existing high flow channel to the river.

(2) Sediment Type – Sediments are those described in d. (1) as well as in river sediments consisting of organic and inorganic solid materials.

(3) Dredged/Fill Material Movement - Movement of dredged material would be limited by the methodology of removal as well as the installation of the coffer dam where needed.

(4) Physical Effects on Benthos (burial, changes in sediment type, etc.) – Benthos would be affected during dredging of the material at the bank of the river.

(5) Other Effects – Fish may also be affected by the dredging. The installation of the coffer dam will assist in minimizing effects to fish.

(6) Actions Taken to Minimize Impacts –

- If a disposal site is needed (other than on site outside of the river), a site that has been previously used for dredged material would be utilized.
- As described above, a coffer dam would be placed in the river and dewatered (if needed) in order to create a work zone.
- Work area would be monitored for fish or invertebrates present. If any are found, they would be placed back into the river.
- Construction of the diversion structures (coffer dam or other) would be performed during low-flow conditions outside of the spring runoff and summer thunderstorm seasons.
- Sediment and erosion controls would be used to prevent bank and streambed erosion if storm evens occur during the construction period and before stream banks are permanently stabilized.

b. Water Circulation, Fluctuation and Salinity Determinations

There would be minimal impact to the water within the main channel of the river since the coffer dam would be installed at the edge of the bank for the work zone.

(1) Water – There would minimal, short-term effects to water quality during the installation and removal of the coffer dam for high-flow channel construction. Water quality would be monitored before, during and after installation and removal of coffer dams in order to determine any major changes in the following:

(a) Salinity – No change in salinity is expected.

(b) Water Chemistry (Ph, etc.) – Ph and dissolved oxygen may change slightly due to this action.

(c) Clarity – Clarity would be affected during and after installation and removal of the coffer dam.

(d) Color – Color would be affected during and after installation and removal of the coffer dam.
(e) Odor – There may be an additional odor due to the excavation of river and/or wetland sediments.
(f) Taste – Taste of water may be siltier due to this action.
(g) Dissolved Gas Levels – DO levels may drop during and after installation and removal of the coffer dam.
(h) Nutrients – Nutrient levels may change during and after installation and removal of the coffer dam.
(i) Eutrophication – Eutrophication may be affected during and after installation and removal of the coffer.
(j) Others as Appropriate

(2) Current Patterns and Circulation - Current patterns of flow and circulation would be affected during and after installation and removal of the coffer dam as follows:

(a) Current Patterns and Flow – Patterns and flow at the bank edge would be disturbed during and after installation and removal of the coffer dam.
(b) Velocity – Velocity would be slightly affected during and after installation and removal of the coffer dam. Since the coffer dam would be fairly small in size, water would be diverted around it.
(c) Stratification – Stratification may be affected as the water column is stirred up during and after installation and removal of the coffer dam.
(d) Hydrologic Regime – Hydrologic regime would be fairly unaffected.
(3) Normal Water Level Fluctuations (tides, river stage, etc.) - Normal water level would not be affected.
(4) Salinity Gradients – NA.

(5) Actions That Will be taken to minimize impacts:
- Water quality would be monitored before, during and after construction in order to determine any major changes in water chemistry.
- Care would be taken to minimize effects on water quality and flow during installation of the coffer dam.
- Construction of the diversion structures (coffer dam or other) would be performed during low-flow conditions outside of the spring runoff and summer thunderstorm seasons.
- Sediment and erosion controls would be used to prevent bank and streambed erosion if storm evens occur during the construction period and before stream banks are permanently stabilized.

c. <u>Suspended Particulate/Turbidity Determinations</u>

(1) Expected changes in suspended particulates and turbidity levels in vicinity of disposal site – Suspended particulates and turbidity levels would increase during and after installation and removal of the coffer dam.

(2) Effects – There would be minimal short-term effects to suspended particulates and turbidity during and after installation and removal of the coffer dam.

(a) Light Penetration – Light penetration would be affected for a short period of time during and after installation and removal of the coffer dam.

(b) Dissolved Oxygen – Dissolved oxygen (DO) may drop during and after installation and removal of the coffer dam. DO would be monitored during and after installation and removal of the coffer dam.

(c) Toxic Metals and Organics – Toxic metals and organics are not anticipated to occur due to construction.

(d) Pathogens – Pathogens are not anticipated to be found due to construction.

(e) Aesthetics – Aesthetics would be altered for a short time during construction.

(f) Others as Appropriate

(3) Effects on Biota – Macroinvertebrates, microinvertebrates, amphibious and/or fish species may be affected by these short term impacts to water quality based on suspended particulates and/or turbidity. Since this impact would be limited to a short period of time during and after installation and removal of the coffer dam, the following factors should not be affected:
(a) Primary Production, Photosynthesis
(b) Suspension/Filter Feeders
(c) Sight Feeders

(4) Actions taken to minimize impacts:

- Care would be taken to minimize effects on suspended particulates and turbidity in the water during installation of the coffer dam by pushing the water column out from the edge of the bank slowly.
- This area would be monitored for amphibians, fish or invertebrates present. If any are found, they would be placed back into the river.
- Construction of the diversion structures (coffer dam or other) would be performed during low-flow conditions outside of the spring runoff and summer thunderstorm seasons.
- Sediment and erosion controls would be used to prevent bank and streambed erosion if storm evens occur during the construction period and before stream banks are permanently stabilized.

d. Contaminant Determinations - Contaminants would not be increased due to construction of this project. Therefore, the required determinations pertaining to the presence and effects of contaminants can be made without testing.

e. Aquatic Ecosystem and Organism Determinations - Since there is no anticipated addition of contaminants due to construction, the following would not be affected by construction of the project due to contaminants.

(1) Effects on Plankton
(2) Effects on Benthos
(3) Effects on Nekton
(4) Effects on Aquatic Food Web
(5) Effects on Special Aquatic Sites

(a) Sanctuaries and Refuges – Not applicable.

(b) Wetlands – Wetlands would be avoided during construction of the high-flow channels. There is no wetland habitat adjacent to the channel where excavation to connect the channel to the river would take place. Dredging along the bank of the river would occur and therefore, this analysis concludes that activities would be covered under Nationwide Permit #33.

Construction of high flow channels and one bank destabilization feature would occur. This work would be covered under Nationwide Permit 27, Aquatic Habitat Restoration, Establishment and Enhancement Activities.

(c) Mud Flats – Not applicable.

(d) Vegetated Shallows - Not applicable.

(e) Coral Reefs – Not applicable.

(f) Riffle and Pool Complexes – Installation of the coffer dam to excavate the channel may have a short-term effect on riffle and pool complexes during construction only.

(6) Threatened and Endangered Species - Refer to Section 6.8 of the DEA.

(7) Other Wildlife – Refer to Section 6.7.3 of the DEA.

(8) Actions to Minimize Impacts – Actions to minimize impacts as described in the DEA would be implemented including the following:

- All conditions for Nationwide 33 and 27 would be adhered to during construction.
- BMPS's discussed in reference to the Rio Grande silvery minnow would be implemented as follows:
- The use of silt fences adjacent to the riverbank to prevent erosion to the river.
- Work zones to the river would be blocked when constructing the High-Flow Channels.
- Fueling of vehicles would not take place inside the levees.

- Storage of equipment and vehicles would not occur in the bosque.
- The proposed work would occur during the winter, which is when Bald Eagles may be in or near the Proposed Action Area. In order to minimize the potential for disturbing Bald Eagles utilizing 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; or an USACE 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.

f. Proposed Disposal Site Determinations – Any excess excavated material would be hauled to an approved site.

(1) Mixing Zone Determination – Not applicable.

(2) Determination of compliance with applicable water quality standards – All standards listed in the Nationwide Permits 33 and 27, 401 water quality certification, and Section 402 (p) of the CWA would be adhered to during construction.

(3) Potential effects on human use characteristic – Human use would not be affected by the proposed project.

(a) Municipal and Private water supply – The proposed project is not within or adjacent to municipal or private water supplies.

(b) Recreational and commercial fisheries - Not applicable.

(c) Water related recreation – No recreational resources would be affected by the proposed project.

(d) Aesthetics – As discussed above, water quality would be affected during construction. Turbidity would be increased for a short duration.

(e) Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and similar preserves – The proposed project is within the Rio Grande Valley State Park. All rules and regulations of the Park would be adhered to during construction.

g. Determination of Cumulative Effects on the Aquatic Ecosystem – There are five high-flow channels proposed within the project. They are located within the 26-mile project area. Implementation of the Proposed Action would likely take place

over two years. Construction of water features (high-flow channels) would be phased in order to minimize impacts to water quality. All actions to minimize impacts as described above would be implemented in order to reduce this cumulative effect as much as possible. Also, each channel would be constructed from the downstream end to the upstream end so that no sediment loosened by the construction would outflow into the river. It would all be removed before the upstream end is excavated and the coffer dam removed.

h. Determination of Secondary Effects on the Aquatic Ecosystem - There is no placement of fill proposed within this project, therefore, there no secondary effects on the aquatic ecosystem are anticipated.

III. Findings of Compliance or Non-Compliance with the restrictions on discharge

a. Adaptation of the Section 404(b) (1) Guidelines to this Evaluation – Not applicable.

b. Evaluation of Availability of Practicable Alternatives to the Proposed Discharge site which would have less adverse impact on the aquatic ecosystem

There is no discharge sites proposed within the project.

c. Compliance with applicable state water quality standards

The proposed action is in compliance with applicable state water quality standards. Concurrence (and a 401 water quality certificate, if required) from the New Mexico Environment Department would be obtained prior to start of construction.

d. Compliance with applicable toxic effluent standard or prohibition under Section 307 of the Clean Water Act

Not applicable.

e. Compliance with Endangered Species Act of 1973

The proposed project is in compliance with the Endangered Species Act of 1973. Effects on listed species have been determined and are discussed in Section 6.8 of the DEA. A Biological Assessment requesting concurrence would be submitted to the U.S. Fish and Wildlife Service, if required.

f. Compliance with specified protection measures for marine sanctuaries designated by the Marine Protection, Research and Sanctuaries Act of 1972

Not applicable.

g. Evaluation of Extent of Degradation of the Waters of the United States

(1) Significant adverse effects on human health and welfare – No significant adverse effects on human health or welfare would occur due to the proposed project.

(a) Municipal and private water supplies – No effect to municipal or private water supplies would occur from the proposed project.

(b) Recreation and commercial fisheries – No effect to recreation or commercial fisheries would occur from the proposed project.

(c) Plankton – Plankton would not be affected by the proposed project.

(d) Fish - Fish species may be affected by these short term impacts to water quality based on suspended particulates and/or turbidity.

(e) Shellfish – Shellfish would not be affected by the proposed project.

(f) Wildlife – Wildlife would not be affected by the proposed project.

(g) Special Aquatic sites – No applicable.

(2) Significant adverse effects on life stages of aquatic life and other wildlife dependent on aquatic ecosystems – There would not be significant adverse effects on life stages of aquatic life and other wildlife dependent on aquatic ecosystems.

(3) Significant adverse effects on aquatic ecosystem diversity, productivity and stability - There would not be significant adverse effects on aquatic ecosystem diversity, productivity and stability.

(4) Significant adverse effects on recreational, aesthetic, and economic values - There would not be significant adverse effects on recreational, aesthetic, and economic values.

h. <u>Appropriate and practicable steps taken to minimize potential adverse impacts of the discharge on the aquatic ecosystem</u> – All of the actions to minimize potential adverse impacts of the proposed project as listed above include:

- If a disposal site is needed (other than on site outside of the river), a site that has been previously used for dredged material would be utilized.
- As described above, a coffer dam would be placed in the river and dewatered (if needed) in order to create a work zone.
- This area would be monitored for fish or invertebrates present. If any are found, they would be placed back into the river proper.
- Construction of the diversion structures (coffer dam or other) would be performed during low-flow conditions outside of the spring runoff and summer thunderstorm seasons.

- Sediment and erosion controls would be used to prevent bank and streambed erosion if storm evens occur during the construction period and before stream banks are permanently stabilized.
- Water quality would be monitored during construction in order to determine any major changes in water chemistry.
- Care would be taken to minimize effects on water quality and flow during construction.
- Care would be taken to minimize effects on suspended particulates and turbidity in the water during installation of the coffer dam by pushing the water column out from the edge of the bank slowly.
- This area would be monitored for amphibians, fish or invertebrates present. If any are found, they would be placed back into the river proper.
- All conditions for the Nationwide Permits 33 and 27 would be adhered to during construction.
- BMPS's discussed in reference to the Rio Grande silvery minnow would be implemented as follows:
- The use of silt fences adjacent to the riverbank to prevent erosion to the river.
- Work zones to the river would be blocked when constructing the High-Flow Channels.
- Fueling of vehicles would not take place inside the levees,
- Storage of equipment and vehicles would not occur in the bosque.
- The proposed work would occur during the winter, which is when Bald Eagles may be in or near the Study Area. In order to minimize the potential for disturbing Bald Eagles utilizing 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; or an USACE 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.

i. <u>On the basis of the guidelines, the proposed disposal site(s) for the discharge of dredged or fill material</u>

(1) Specified as complying with the requirements of these guidelines, with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects on the aquatic ecosystem.

ERDC/EL TR-EMRRP-09-X

Environmental Laboratory

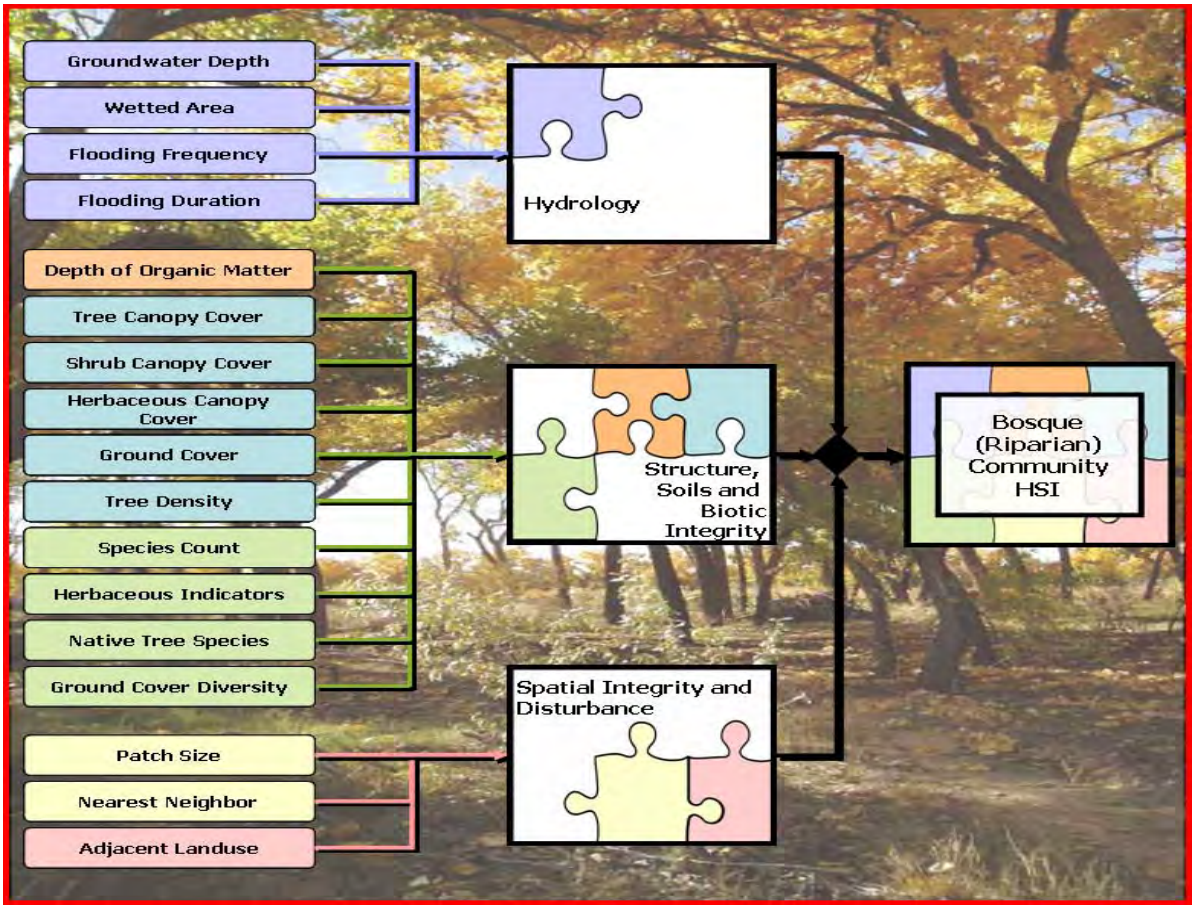
US Army Corps of Engineers®
Engineer Research and Development Center

A Bosque Riparian Community Index Model for the Middle Rio Grande, Albuquerque, New Mexico

Model Documentation
Draft Report

Kelly A. Burks-Copes and Antisa C. Webb

December 2009



System-Wide Water Resources Program
Habitat Based Ecological Response Models

ERDC/EL TR-SWWRP-09-X
December 2009

A Bosque Riparian Community Index Model for the Middle Rio Grande, Albuquerque, New Mexico

Model Documentation

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Draft report

Prepared for U.S. Army Corps of Engineers

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Abstract: Over the last century, the Middle Rio Grande was subjected to significant anthropogenic pressures producing a highly degraded ecosystem that today is poised on the brink of collapse. In 2002, the U.S. Army Corps of Engineers (USACE) (Albuquerque District) was authorized to study the river and prepare an Environmental Assessment (EA), as required under the tenets of the National Environmental Policy Act (NEPA), to evaluate the effects of proposed ecosystem restoration alternatives on the watershed's significant resources. As part of the process, a multi-agency, multi-disciplinary evaluation team was established to formulate alternatives that would address three critical problems: 1) hydrological alternations, 2) bosque (riparian) ecosystem degradation, and 3) the loss of key ecological services to the surrounding community. Between 2005 and 2008, this team designed, calibrated, and applied a community-based index model for the bosque riparian ecosystem using field and spatial data gathered from 27 reference sample sites scattered across the watershed. This unique community was modeled using 23 individual variables combined into numerous predictive community functional components (i.e., Biotic Integrity, Hydrology, and Spatial context) capable of capturing the changes to ecosystem integrity in response to changes in land and water management activities proposed by the study. The intent of this document is to provide the scientific basis upon which the model was developed, and describe the 3-year long process the team undertook to complete this effort. Although some results are presented here to demonstrate and verify the veracity of the model's calibration and subsequent outputs, readers interested in the application of this model on the Middle Rio Grande project must refer to our second report entitled, "Middle Rio Grande Bosque Ecosystem Restoration Feasibility Study Habitat Assessment Using Habitat Evaluation Procedures (HEP): Analyses, Results And Documentation" (Burks-Copes and Webb 2009).

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Figures and Tables

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Preface

This report provides the documentation of newly developed community-based index model [based on the Habitat Evaluation Procedures (HEP)] model for the Middle Rio Grande as it runs through the heart of Albuquerque, New Mexico.

The work described herein was conducted at the request of the U.S. Army Engineer District, Albuquerque, New Mexico. This report was prepared by Ms. Kelly A. Burks-Copes and Ms. Antisa C. Webb, U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Vicksburg, Mississippi. At the time of this report, Ms. Burks-Copes and Ms. Webb were ecologists in the Ecological Resources Branch.

Many people contributed to the overall success of the production of the model documentation. The authors wish to thank the following people for their hard work and persistence during the intensive months over which the project was assessed: Ms. Jennifer Emerson (Bowhead Information Technology Services), Ms. Ondrea Hummel (Albuquerque District), and Mr. Seth Jones (Galveston District). We also thank Dr. Andrew Casper (ERDC), Ms. Kristine Nemec (formerly of the Kansas City District), and Mr. Todd Kaplan (Parametrix) for their comprehensive review of the report.

This report was prepared under the general supervision of Ms. Antisa C. Webb, Chief, Ecological Resources Branch and Dr. Edmond J. Russo, Chief, Ecosystem Evaluation and Engineering Division. At the time of publication of this report, Dr. Beth Fleming was Director of EL.

This report should be cited as follows:

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1 Introduction

The desiccated landscape of the Southwest brings to mind tumbleweeds blowing along dusty grounds, ancient petroglyphs carved in dark caves and canyon walls, cattle skulls blanching under the merciless sun, and sidewinders slithering between the cacti. But running through these harsh and arid region are ribbons of lush green; narrow corridors where rivers and streams, some ephemeral, some continually flowing, have slaked the parched desert to give rise to rare yet significant riparian ecosystems rich with life (Figure 1).

Figure 1. The arid Southwest often appears to be a desolate landscape, yet the presence of water offers an opportunity for fish and wildlife to find a niche (photo from www.wanapiteicanoe.com/trips.asp?ID=39 MAY 2008).

While only occupying a mere fraction of the land area, these riparian corridors support both the largest concentrations of animal and plant life, and the majority of species diversity in the desert Southwest (Johnson and Jones 1977, Johnson et al. 1985, Knopf et al.1988, Ohmart et al. 1988, Dahl 1990, Johnson 1991, Minckley and Brown 1994, Noss et al. 1995, American Bird Conservancy 2008) (Figure 2).

Figure 2. Riparian corridors immediately adjacent to rivers in the arid southwest offer lush habitat for fish and wildlife species.[1]

Perhaps one of the more notable riparian ecosystems is found along the Rio Grande. Arising in the San Juan Mountains of southwest Colorado, the river flows southwest through the middle of New Mexico and into Texas along the Texas-Mexico border emptying finally into the Gulf of Mexico. The Rio Grande offers one of the more ecologically complex, highly resilient, and culturally significant resource in semi-arid western United States (Figure 3).

[1] Photo take from http://www.domney.com/ (MAY 2008)

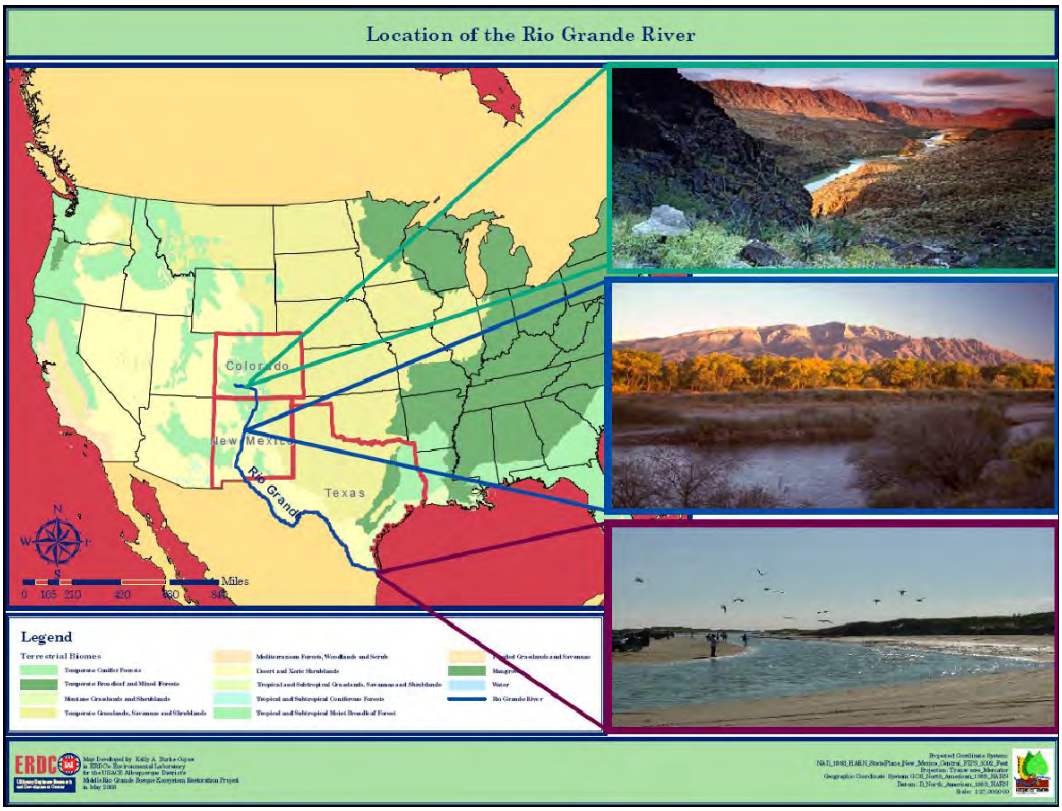


Figure 3. Location of the Rio Grande in the arid Southwest. Images capture the changing characteristics of the river as it flows from Colorado (top), through New Mexico (middle), and down into Texas (bottom) on its way to the Gulf of Mexico.

Historically, the Rio Grande was considered a braided, aggrading stream that meandered freely across a wide floodplain much larger than the current floodway ecosystem. As it meandered through time and space, the Rio Grande created and renewed the unique cottonwood riparian gallery forest communities. “Bosque” was the Spanish word that was used traditionally in the southwest to describe these unique wooded riparian ecosystems (Figure 4).

Figure 4. Cottonwood riparian gallery forests ablaze with fall colors along the Rio Grande.[1]

Over the last century, the Middle Rio Grande was subjected to significant anthropogenic pressures producing a highly degraded ecosystem that today is poised on the brink of collapse. Water management and flow regulation along the Middle Rio Grande during this century has decoupled the linkage between the floodplain and the river and resulted in extensive changes in the riparian forest ecosystem (Ellis et al. 1996). The elimination of flooding has disrupted the functional integrity of these disconnected forests and contributed to the decline of the Rio Grande Valley cottonwood. 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 Middle Rio Grande valley (Hink and Ohmart 1984; Howe and Knopf, 1991).

[1] Photo taken from http://joemonahansnewmexico.blogspot.com/uploaded_images/New%20Mexico%20-%20Rio%20Grande-794868.jpg MAY 2008)

Study Background

In 2002, the USACE Albuquerque District was authorized to conduct a Reconnaissance study focused on a 17-mile long stretch of the Rio Grande flowing through the city of Albuquerque, New Mexico (USACE 2002, 2003a, 2007b, 2008a) (Figure 5).

Figure 5. The Rio Grande flows through the heart of Albuquerque (seen in the background at the base of the mountains) on its way south to the Gulf of Mexico.

The reconnaissance study determined that there was a federal interest in participating in cost-shared feasibility studies to investigate ecosystem restoration, educational/ interpretive opportunities and low-impact recreational opportunities for the Rio Grande floodway as it passes through Albuquerque, New Mexico. In 2004, a Feasibility Cost Sharing Agreement was signed between the Middle Rio Grande Conservancy District (MRGCD), as the non-Federal Sponsor, and the USACE subsequently initiated the feasibility phase of the study. The purpose of this feasibility phase study was to determine if there was a Federal

(USACE) interest in addressing the water resource problems and opportunities in the Middle Rio Grande area of Bernalillo County, New Mexico.[1]

In 2004, the USACE Albuquerque District contacted the U.S. Army Engineer Research and Development Center's Environmental Laboratory (ERDC-EL) to assist in these endeavors. The Middle Rio Grande study documentation identified and recommended effective, affordable and environmentally sensitive ecosystem restoration features throughout the middle reach of the Rio Grande system (USACE 2002, 2003a, 2007b, 2008a). The goal was to provide the necessary engineering, economic and environmental plans in a timely manner to establish viable projects that would be acceptable to the public, local sponsors and USACE. The intent of this collaborative effort was to provide a framework for making decisions that would result in the restoration of the bosque ecosystem's structure and function.

The District has prepared an Environmental Assessment (EA), as required under the tenets of the National Environmental Policy Act (NEPA), to evaluate the benefits of the proposed ecosystem restoration measures in the study area (USACE 2008b). As part of the process, a multi-agency evaluation team was established to (1) identify environmental issues and concerns; (2) evaluate the significance of fish and wildlife resources and select resources; (3) recommend and review environmental alternatives and studies; and (4) evaluate potential benefits of the proposed plans.

Purpose of the Model

Planning, management, and policy decisions require information on the status, condition and trends of these complex ecosystems and their components at various scales (e.g. local, regional, watershed and system levels) to make reasonable and informed decisions about the planning management and conservation of sensitive or valued resources. One well accepted solution has been to develop index models that assess ecosystems at varying scales. By definition, index models are comprehensive, multi-scale, grounded in natural history, relevant and helpful, able to integrate

[1] An a complete list of acronyms and a glossary have been provided in *Appendix A* and *Appendix B* of this report.

terrestrial and aquatic environments, flexible and measurable (Andreasen et al. 2003). Determining the value of diverse biological resources in this study required a method that captured the complex biotic patterns of the landscape, rather than merely focusing on a single species habitat or suitability requirements within the study area. In effect, the Ecosystem Assessment Team (E-Team) made the decision to assess ecosystem benefits using community-based (functional) models rather than employing a series of species- or guild-based models.

Ecosystem functions are defined here as a series of processes that take place within an ecosystem. These include the storage of water, transformation of nutrients, growth of living matter, and diversity of plants, and they have value for the community itself, for surrounding ecosystems, and for people. Functions can be grouped broadly as habitat, hydrologic, water quality, and spatial integrity although these distinctions are somewhat arbitrary and simplistic. For example, the value of a wetland for recreation (hunting, fishing, bird watching) is a product of all the processes that work together to create and maintain the ecosystem. Not all communities perform all functions nor do they perform all functions equally well. The location and size of a community may determine what functions it will perform. For example, the geographic location may determine its habitat functions, and the location of community within a watershed may determine its hydrologic or water-quality functional capacity. Many factors determine how well a community will perform these functions: climatic conditions, quantity and quality of water entering the system, and disturbances or alteration within the community or the surrounding landscape. Disturbances may be the result of natural conditions, such as an extended drought, or human activities, such as land clearing, dredging, or the introduction of invasive species.

The purpose of this modeling effort was to broadly capture existing, (baseline) conditions of the communities, and compare changes that would occur to the resources present given different project scenarios or alternatives under the standard USACE planning paradigm (USACE 2000). The model was used to facilitate plan formulation based upon project benefits. The purpose of the model was not to exhaustively capture the full range of all chemical, physical, and biological characteristics of the project area, but to provide tools for making comparisons between potential plans in order to select plans with the highest benefits. Planning

decisions for the feasibility study were subsequently made based on the results of the model applied with the well received and respected Habitat Evaluation Procedures (HEP) (USFWS 1980a-c) framework.

Contribution to the Planning Effort

The model then, helped to characterize the baseline conditions (in a quantitative manner) of the numerous ecological resources throughout the watershed. The HEP method assisted the study team in the projection of change to fundamental ecosystem processes[1] (without which, ecosystem restoration itself could not happen), as the multiple alternative scenarios were proposed. The study team designed the HEP assessments to evaluate the future changes both in quantity (acres) and quality (community habitat suitability) of aquatic, wetland and terrestrial ecosystems simultaneously. Outputs were calculated in terms of annualized changes anticipated over the life of the project (aka period of analysis).

As noted earlier, the E-team was convened early in the evaluation process.[2] Scientists from the U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL) facilitated the efforts. Representatives from the Albuquerque District, U. S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), Bureau of Reclamation (BOR), Interstate Stream Commission (ISC), New Mexico Department of Game and Fish (NMDGF), New Mexico State Forestry Division (NMSFD), Natural Heritage New Mexico (NHNM), Rocky Mountain Research Station (RMRS), Middle Rio Grande Conservancy District (MRGCD), City of Albuquerque Open Space Program, University of New Mexico (UNM), and Parametrix consultants actively participated in the assessment process. The remainder of this document focuses on the development of the community-based Habitat Suitability Index (HSI) model developed by the E-Team for the Middle Rio Grande Bosque Ecosystem Restoration (MRGBER) feasibility study.

[1] There are four fundamental ecosystem processes – water cycling, mineral cycling, solar energy flow, and community dynamics (aka succession).
[2] A list of E-Team participants can be found in *Appendix D*.

Planning Model Certification

As an aside, the USACE Planning Models Improvement Program (PMIP) was established to review, improve, and validate analytical tools and models for USACE Civil Works business programs. In May of 2005, the PMIP developed Engineering Circular (EC) 1105-2-407, Planning Models Improvement Program: Model Certification (USACE 2005). This EC requires the use of certified models for all planning activities. It tasks the Planning Centers of Expertise to evaluate the technical soundness of all planning models based on theory and computational correctness. EC 1105-2-407 defines planning models as,

> "*. . . any models and analytical tools that planners use to define water resources management problems and opportunities, to formulate potential alternatives to address the problems and take advantage of the opportunities, to evaluate potential effects of alternatives and to support decision-making.*"

Clearly, the community-based HSI model developed for the study must be either certified or approved for one-time use. The Albuquerque District initiated this review in 2008 and received a memo from the USACE Eco-PCX granting one-time-use approval in April 2009 (*Appendix C*). Information necessary to facilitate model certification/one-time-use approval is outlined in Table 2 of the EC 1105-2-407 (pages 9-11). To assist the reviewers in the certification effort for the model, the authors have developed an appendix to crosswalk the EC checklist requirements and this report (*Appendix C*).

For purposes of model certification, it is important to note that the model must be formally certified or approved for one-time-use, but the methodology under which it is applied (i.e., HEP) does not require certification as it is considered part of the application process. HEP in particular has been specifically addressed in the EC:

> "*The Habitat Evaluation Procedures (HEP) is an established approach to assessment of natural resources, developed by the US Fish and Wildlife Service in conjunction with other agencies. The HEP approach has been well documented and is approved for use in Corps projects as an assessment framework that combines resource quality and quantity over time, and is appropriate*

throughout the United States." (refer to Attachment 3, page 22, of the EC)

The authors used the newly developed **Habitat Evaluation and Assessment Tools** (**HEAT**) (Burks-Copes et al. 2008) to automate the calculation of habitat units for the MRGBER study. This software is not a "shortcut" to HEP modeling, or a model in and of itself, but rather a series of computer-based programming modules that accept the input of mathematical details and data comprising the index model, and through their applications in the HEP or the Hydrogeomorphic Wetland Assessment (HGM) processes, calculates the outputs in responses to parameterized alternative conditions. The **HEAT** software contains two separate programming modules – one used for HEP applications referred to as the **EXpert Habitat Evaluation Procedures** (**EXHEP**) module, and a second used in HGM applications referred to as the **EXpert Hydrogeomorphic Approach to Wetland Assessments** (**EXHGM**) modules. The authors used the **EXHEP** module to calculate outputs for the MRGBER study. The developers of the **HEAT** tool (including both the **EXHEP** and **EXHGM** modules themselves) are pursuing certification through a separate initiative, and hope to have this tool through the process in the next year barring unforeseen financial and institutional problems.

The authors used **IWR Planning Suite**[1] to run the cost analyses for the restoration plans in the MRGBER study which was certified in 2008.

Report Objectives

This document describes the development of the community-based HSI model for the bosque (riparian) community located along the banks of the Middle Rio Grande River running the heart of Albuquerque, New Mexico. The objectives of this report are to:

1. Briefly characterize the Middle Rio Grande watershed, within the study area, in central New Mexico;

[1] http://www.pmcl.com/iwrplan/

2. Characterize the bosque community used in the HEP evaluations and its applicable cover types;
3. Present the relationships of habitat maintenance components for the index model; and
4. Define and justify the selection of assessment variables and their associated curve calibrations used to characterize the components of the model.
5. Provide critical information to reviewers to facilitate the future certification/one-time-use approval of the index model.

Report Structure

This report is organized in the following manner. *Chapter 1* provides the background, objectives, and organization of the document. *Chapter 2* provides a brief overview of HEP, and the method in which the model will be applied, including the procedures recommended for development and application of the HSI model. *Chapter 3* discusses the evolution of the model in terms of conceptual development, offers critical insight into the characterization of the community, provides details regarding the key functional components of the HSI model in particular (and its mathematical representations), and then concludes with the construction and testing of the HSI model over the last three years. *Chapter 4* offers insight into the HSI model's calibration approach, and offers descriptions of the assessment variables used to characterize the community including definitions, rationale for selection, and specific sampling guidelines. *Chapter 5* summarizes the model findings and discusses future research initiatives to expand its utility and context.

Several appendices are attached to this document. *Appendix A* is a list of acronyms used throughout this document. *Appendix B* is a glossary of commonly used terms regarding HSI model and the HEP evaluation. *Appendix C* offers a crosswalk between the standard requirements and information necessary to certify/approve the use of the model. *Appendix D* contains a point of contact for the formal minutes documenting the decisions made during the initial model development workshops and offers a complete list of E-Team participants. *Appendix E* provides individual index curves for the variables used in the model. *Appendix F* offers field data protocols and a crosswalk between the region's more notable vegetative classification system (Hink and Omart 1984) and the classification used in the index model described here. *Appendix E* contains

the model review forms and documents the review comments provided by the Albuquerque District and the workshop participants as the planning study proceeds through review.

2 HEP Overview

The HEP Process

The HEP methodology is an environmental accounting process developed to appraise habitat suitability for fish and wildlife species in the face of potential change (USFWS 1980 a-c). Designed to predict the response of habitat parameters in a quantifiable fashion, HEP is an objective, 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. When applied correctly, HEP provides an impartial look at environmental effects, and delivers measurable products to the user for comparative analysis.

In HEP, a Suitability Index (SI) is a mathematical relationship that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type. 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. In HEP, an HSI model is a quantitative estimate of habitat conditions for an evaluation species or community HSI models combine the SIs of measurable variables into a formula depicting the limiting characteristics of the site for the species/community on a scale of 0.0 (unsuitable) to 1.0 (optimal).

Statement of Limitations

The HEP methodology can provide a rational, supportable, focused, and traceable evaluation of habitat functionality. However, the user must understand the basic HEP tenets as defined in supporting literature (USFWS 1980a-c) prior to attempting application of the methodology. Outcomes derived under HEP are dependent on the user's ability to predict future conditions and the reliability of resource data used. The user should understand that HEP is not a carrying capacity model and cannot comprehensively predict future species and species population sizes. Furthermore, HEP is not designed to compare across evaluation elements (e.g. compare prairie habitat to forest habitat). The user should not expect

HEP to provide the only predictive environmental response to project development scenarios, and should understand the limitations of the methodology's response to predictive evaluations prior to its application.[1]

HSI Models in HEP

Users can select several indicator species to evaluate overall site fitness. In the HEP process, species are often selected on the basis of their ecological, recreational, spiritual, or economic value. In other instances, species are chosen for their representative value (i.e., one species can "represent" a group or guild of species which have similar habitat requirements). Most of these species can, in turn, be described using single or multiple habitat models and a single HSI mathematical formula. In some studies, several cover types are included in an HSI model to accurately reflect the complex interdependencies critical to the species' or community's existence. Regardless of the number of cover types incorporated within an HSI model, any HSI model based on the existence of a single life requisite requirement (e.g. food, water, cover or reproduction), uses a single formula to describe that relationship.

Some species are insufficiently examined using the simplistic approach. In these instances, a more detailed model can emphasize critical life requisites, increase limiting factor sensitivity, and improve the predictive power of the analysis. Multiple habitats and formulas are often necessary to calculate the habitat suitability of these more comprehensive HSI models. The second type of HSI model is used to capture the juxtaposition of habitats, essential dependencies, and performance requirements such as reproduction, roosting needs, escape cover demands, or winter cover that describe the sensitivity of a species or community. Multiple formula models require more extensive processing to evaluate habitat conditions.

Habitat Units in HEP

HSI models can be tailored to a particular situation or application and adapted to meet the level of effort desired by the user. Thus, a single model (or a series of inter-related models) can be adapted to reflect a site's

[1] Additional support for the HEP methodology has been provided in *Appendix C˛2 Technical Quality, a. Theory*.

response to a particular design at any scale (e.g., species, community, ecosystem, regional, or global dimensions). Several agencies and organizations have adapted the basic HEP methodology for their specific needs in this manner (Inglis et al. 2006, Gillenwater et al. 2006, and Ahmadi-Nedushan et al. 2006). HEP combines both the habitat quality (HSI) and quantity of a site (measured in acres) to generate a measure of change referred to as Habitat Units (HUs). Once the HSI and habitat quantities have been determined, the HU values can be mathematically derived with the following equation: HU = HSI x Area (acres). Under the HEP methodology, one HU is equivalent to one acre of optimal habitat for a given species or community.

Capturing Changes Over Time in HEP Applications

In studies spanning several years, Target Years (TYs) must be identified early in the process. Target Years are units of time measurements used in HEP that allow users to anticipate and direct significant changes (in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be a TY = 1 and a TY = X_2. TY1 is the first year land- and water-use conditions are expected to deviate from baseline conditions. TYX_2 designates the ending target year. A new target year must be assigned for each year the user intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses, and between the baseline and future analyses. In studies focused on the long-term effects, HUs generated for indicator species are estimated for several TYs to reflect the life of the project (aka period of analysis). In such analyses, future habitat conditions can be estimated for both the without-project (e.g., No Action Plan) and with-project conditions. Projected long-term effects of the project are reported in terms of Average Annual Habitat Units (AAHUs) values. Based on the AAHU outcomes, alternative designs can be formulated and trade-off analyses can be simulated to promote environmental optimization.

Developing Index Models for HEP

Based on the USFWS's Ecological Service Manual (ESM) series on HEP (USFWS 1980 a-c), there are 11 steps involved in the application of HEP when assessing an environmental project:

1. Build a multi-disciplinary E-Team;
2. Define the project;
3. Map the site's cover types (CTs);
4. Select, modify and/or create index model(s);
5. Conduct field sampling;
6. Perform data management and statistical analyses;
7. Calculate baseline conditions;
8. Set goals and objectives, and define project life and TYs;
9. Generate Without-project (WOP) conditions and calculate outputs;
10. Generate With-project (WP) conditions and calculate outputs; and
11. Report the results of the analyses.

However, this document only addresses the development of the model used in the HEP process for this study. For further detail on each of the 11 steps, refer to the Burks-Copes and Webb 2009 habitat assessment report for the MRGBER study.

Steps in Model Development

Community assessment was identified as a priority for the District's upcoming feasibility study. However, few HSI community models were published and available for application. ERDC-EL proposed a strategy to the District to develop community models for the MRGBER study. The strategy entailed five steps:

1. Compile all available information that could be used to characterize the communities of concern.
2. 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) of the system that could be combined in a meaningful manner to "model" the communities. In the workshop, it was important to outline study goals and objectives and then identify the desired model endpoints (e.g., outputs of the model). It was also critical for the participants to identify the limiting

factors present in the project area relative to the model endpoints and habitat requirements .The outcome of the workshop was a series of mathematical formulas that were identified as functional components (e.g., Hydrology, Vegetative Structure, Diversity, Connectivity, Disturbance, etc.) which were comprised of variables that were:

a. biologically, ecologically, or functionally meaningful for the subject,
b. easily measured or estimated,
c. able to have scores assigned for past and future conditions,
d. related to an action that could be taken or a change expected to occur,
e. were influenced by planning and management actions, and
f. independent from other variables in each model.

3. Develop both a field and a spatial data collection protocol (using Geographic Information Systems or GIS) 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
4. Present the model results to an E-Team and revise/recalibrate the model based on their experiences, any additional and relevant regional data, and application directives.
5. Submit the model to both internal ERDC/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.

Model Review Process

The process described in *Appendix G* is currently being implemented to assure that quality control is an integral part of model development and document production. In essence, a laboratory-directed model review process is underway, one that involves both direct-line supervisors of the model authors, and peer reviews by researchers and planning personnel outside of the model development team. It is important to note that the

District will be responsible for incorporating the ERDC-EL documents into their integrated feasibility study reports and documents.

3 Community-based HSI Models

As described earlier in *Chapter 2* of this report, index models can quantify the effects of change in a given ecosystem setting and can be used to account for restoration gains under the HEP assessment paradigm. This chapter describes the bosque (riparian) community found along the middle Rio Grande in central New Mexico (running through Albuquerque), and describes the process by which the E-Team developed and tested the resultant community-based HSI model. A general description of both the variables and their relationship to one another are described for the model as well. The goal of this chapter is to characterize the E-Team's effort to capture the character of the bosque ecosystem using a traditional index model-based approach.

Model Development Workshops

A series of ten workshops were held over the course of three years (2005-2008) to develop the model and characterize baseline conditions of the study area prior to plan formulation and alternative assessment for the ecosystem restoration study. A community-based index model (**Bosque Riparian Community**) was developed under this paradigm. 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.[1] In the first workshop, the E-Team was briefed on the project scope and opportunities by the District planners. Land and water management activities (e.g., hydrologic alterations, urban development and agricultural production) were identified as the system's key anthropogenic drivers. The stressors (i.e., physical, chemical and biological changes to system structure and function) were identified and grouped into four categories: 1) hydrologic alteration, 2) geomorphic and topographic alteration, 3) urban encroachment and agricultural use, and 4) exotic species introductions. Each stressor altered ecosystem integrity within a water, soils, habitat and/or landscape context. For example, hydrologic alterations to the channel have caused changes not only in

[1]A list of E-Team participants can be found in *Appendix D*.

flooding frequency and duration, but have altered ecosystem function and structure across the basin. Urban encroachment has exacerbated these problems by reducing infiltration, increasing storm water runoff, and increasing disturbance regimes system-wide. These changes have ultimately led to opportunities for exotic species invasions reducing spatial complexity on a landscape scale. The direct and indirect effects of these alternations are as obvious as they are numerous – reduced hydrologic pulsing, reduced sediment transport, fragmentation, and loss of biodiversity.

Coupling Conceptual Modeling and Index Modeling

Conceptual models are proving to be an innovative approach to organize communicate, and facilitate analysis of natural resources at the landscape scale (Harwell et al. 1999, Turner et al. 2001, Henderson and O'Neil 2004, Davis et al. 2005, Ogden et al 2005, Watzin et al. 2005, Alvarez-Rogel et al. 2006). By definition a conceptual model is a representation of relationships among natural forces, factors, and human activities believed to impact, influence or lead to an interim or final ecological condition (Harwell et al. 1999, Henderson and O'Neil 2004). In most instances these models are presented as qualitative or descriptive narratives and illustrated by influence diagrams that depict the causal relationships among natural forces and human activities that produce changes in systems (Harwell et al. 1999, Turner et al. 2001, Ogden et al. 1005, Alvarez-Rogel et al. 2006). No doubt, conceptual models provide a forum in which individuals of multiple disciplines representing various agencies and outside interests can efficiently and effectively characterize the system and predict its response to potential alternatives in a descriptive manner. In theory and practice, conceptual models have proved an invaluable tool to focus stakeholders on developing ecosystem restoration goals given recognized drivers and stressors. These in turn are translated into essential ecosystem characteristics that can be established as targets for modeling activities.

For purposes of this study, a systematic framework was developed that coupled the traditional USACE planning process with an index modeling approach derived from a sound conceptual understanding of ecological principles and ecological risk assessment that characterized ecosystem integrity across spatial and temporal scales, organizational hierarchy, and ecosystem types, yet adapted to the project's specific environmental goals.

Ideally, the development of conceptual models involves a close linkage with community-index modeling, and produces quantitative assessment of systematic ecological responses to planning scenarios (Figure 6).

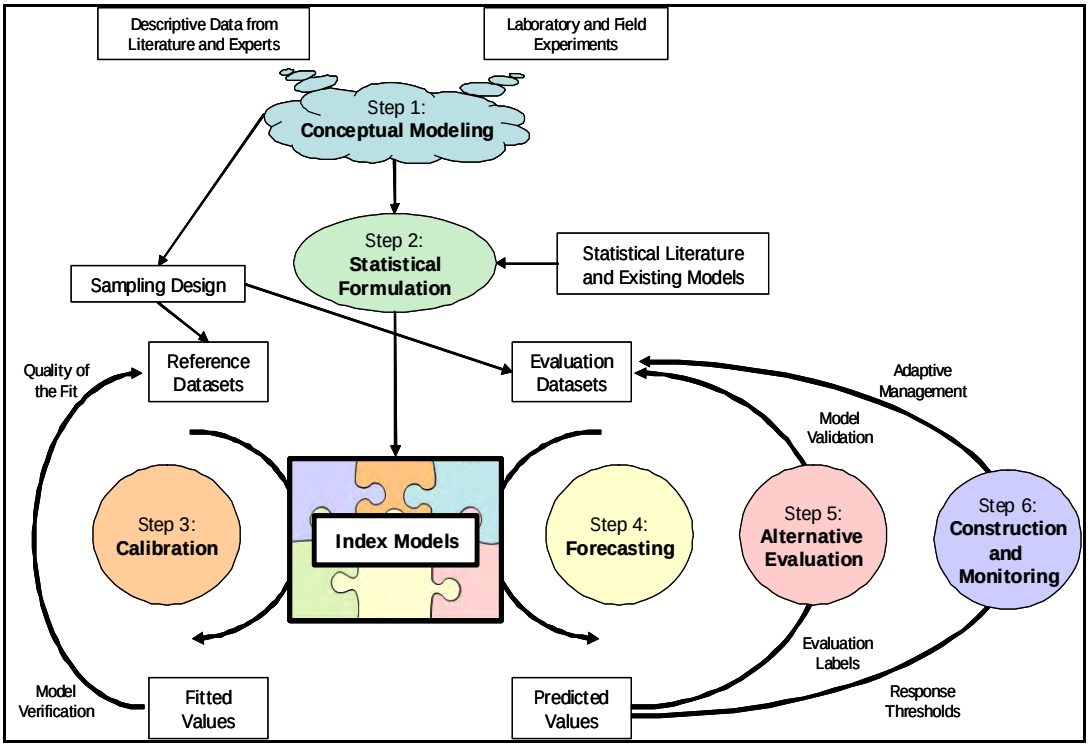


Figure 6. Overview of the successive steps (1-6) of the community-based index model building and application process for ecosystem restoration, where two data sets (one for calibration and one for alternative evaluations) are used (adapted from Guisan and Zimmerman 2000).[1]

Under this MRGBER modeling paradigm, conceptual modeling led to the choice of an appropriate scale for conducting the analysis and to the selection of ecologically meaningful explanatory variables for the subsequent environmental (index) modeling efforts. The model was calibrated using reference-based conditions and modified when the application dictated a necessary change.

As a first step in the index model development process, ERDC-EL developed a conceptual model to illustrate the relationships between these

[1] It is important to note here that the same models used to evaluate alternatives should be used in the future to monitor the restored ecosystem and generate response thresholds to trigger adaptive management under the indicated feedback mechanism. As such, the District can use the models developed early-on in the process to adaptively manage the system over the long-term.

system-wide drivers and stressors and tried to highlight the ecosystem responses to these pressures across the entire Rio Grande-Albuquerque watershed (Figure 7).

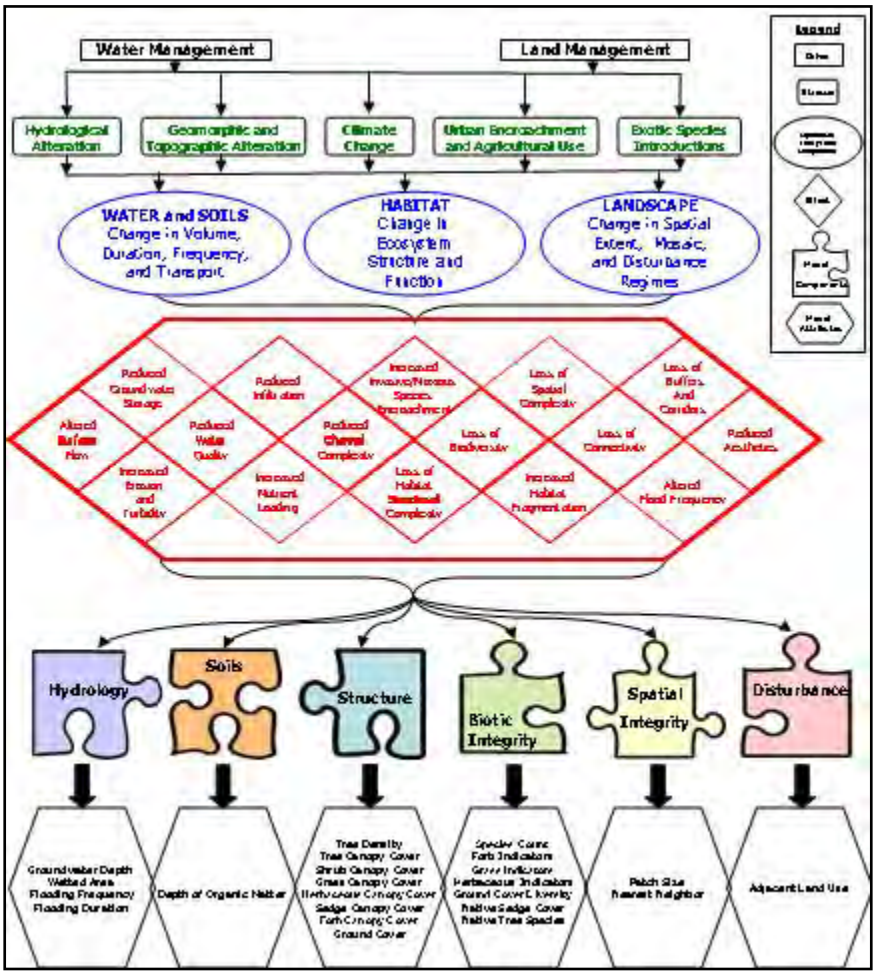


Figure 7. A conceptual model for the MRGBER.

Conceptually speaking, the “Significant Ecosystem Components” (water, soils, habitat, and landscape) were characterized by parameters responsive to project design. These parameters or variables (hydroperiod, vegetative cover, disturbance, etc.) were grouped in a meaningful manner to quantify the functionality of the community in the face of change based on expert opinion and scientific literature. The effort to combine the variables in mathematical algorithms could then be viewed as community index modeling under the HEP paradigm. For purposes of organization, the community based index model was constructed from combinations of components – an analogy used was one of puzzle building. The individual model components were represented as “pieces” of the ecosystem puzzle,

that when combined captured the essence of the system's functionality (Figure 8).

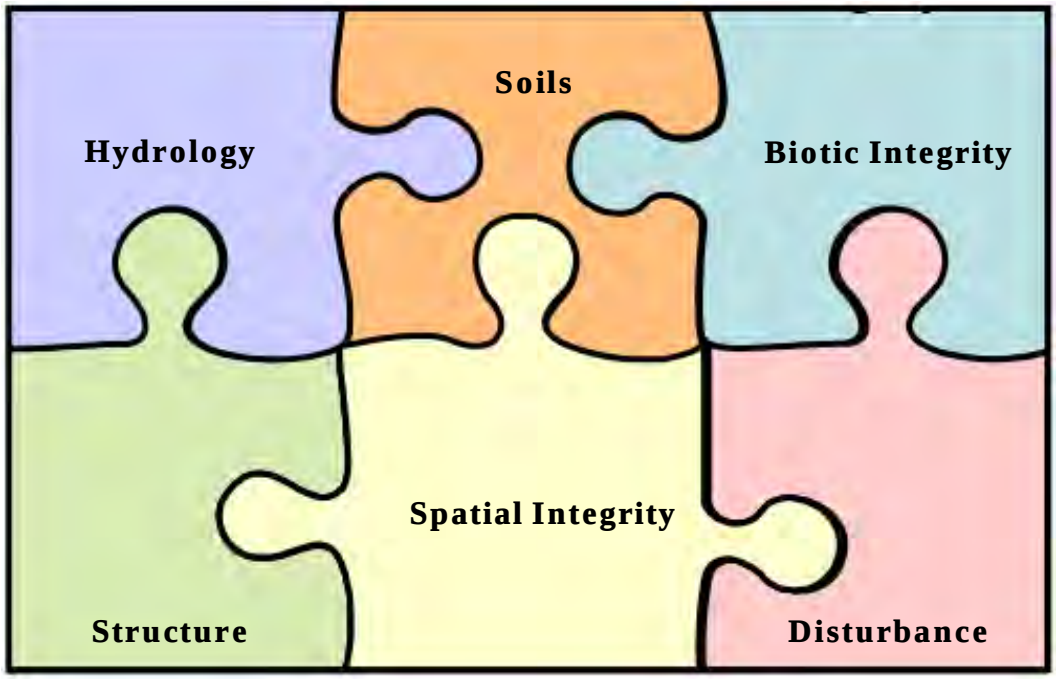


Figure 8. Within the conceptual modeling building framework, the various model components (color-coded for organization purposes) are pieced together to capture the essence of community functionality using the ecosystem puzzle analogy.

Vegetation communities in the area ranged from riparian forests, shrublands, savannahs, meadows, open marshes to the river itself. Out of this effort a bosque (riparian zone) community model arose. Subsequent refinement of the model led to the identification of contributing ecosystem components, and a description of associated variables (with suggested sampling protocols) that can be used to measure ecosystem restoration benefits. The accuracy and utility of the proposed model was "tested" (e.g., validated and verified) with specific field and planning exercises on the District's ongoing ecosystem restoration feasibility study. The application led ERDC-EL to modify the model several times over the course of the study to accommodate broader planning specifications.

Bosque Riparian Community Characterization

River systems and their attendant wetland/riparian communities, referred to as "bosques" in New Mexico (derived from the Spanish word for forest), provide significant resources for both humans and wildlife in the semi-arid

western United States. Water resource management activities –diversions, dams, levees, drains, channelization and jetty jack installation–by Federal agencies and other entities, as well as ongoing urbanization, have significantly altered the hydrologic system and degraded the ecosystem function and value of the Rio Grande within New Mexico. The bosque is unique; it is a thin line of significant riparian habitat in an arid landscape of the Southwest. The habitat quality, although diminished over the past few decades, still remains one of the most significant in the region. The uniqueness of the Rio Grande system and its critical value as wildlife habitat emphasize its significance as a critical resource. Over 300 species of birds, mammals, amphibians and reptiles live in the bosque - more than double those found in any other major ecosystem in the State. In fact, the bosque serves as a critical migration route for thousands of North American birds moving along the Central Flyway.

Functional riparian systems such as the Middle Rio Grande bosque are becoming increasingly rare in the Southwest. Such systems located in the center of an urban area are rarer still. The Rio Grande with its bosque is a green ribbon that weaves together different communities of the Albuquerque metropolitan area both figuratively and physically, connecting the present-day urbanites to the original inhabitants in the region. For decades the bosque has provided ecosystem services (for example, water filtration, urban heat island mitigation, etc.) for Albuquerque and its neighboring communities. It also continues to provide unique aesthetic, cultural, educational and recreational opportunities for citizens and visitors to the region. The health of the region's many species of wildlife, as well as its human inhabitants, rests on the long-term health and viability of the Rio Grande bosque. Below we detail the classic character of New Mexico's bosque as it peppers the banks along the Rio Grande flowing through the heart of the city.

Reference Domain for the Models

It is important to note that the model developed in this study is applicable to a specific domain: the riparian habitat between the levees along the 17-mile stretch of Rio Grande flowing through Albuquerque, New Mexico (Figure 9).

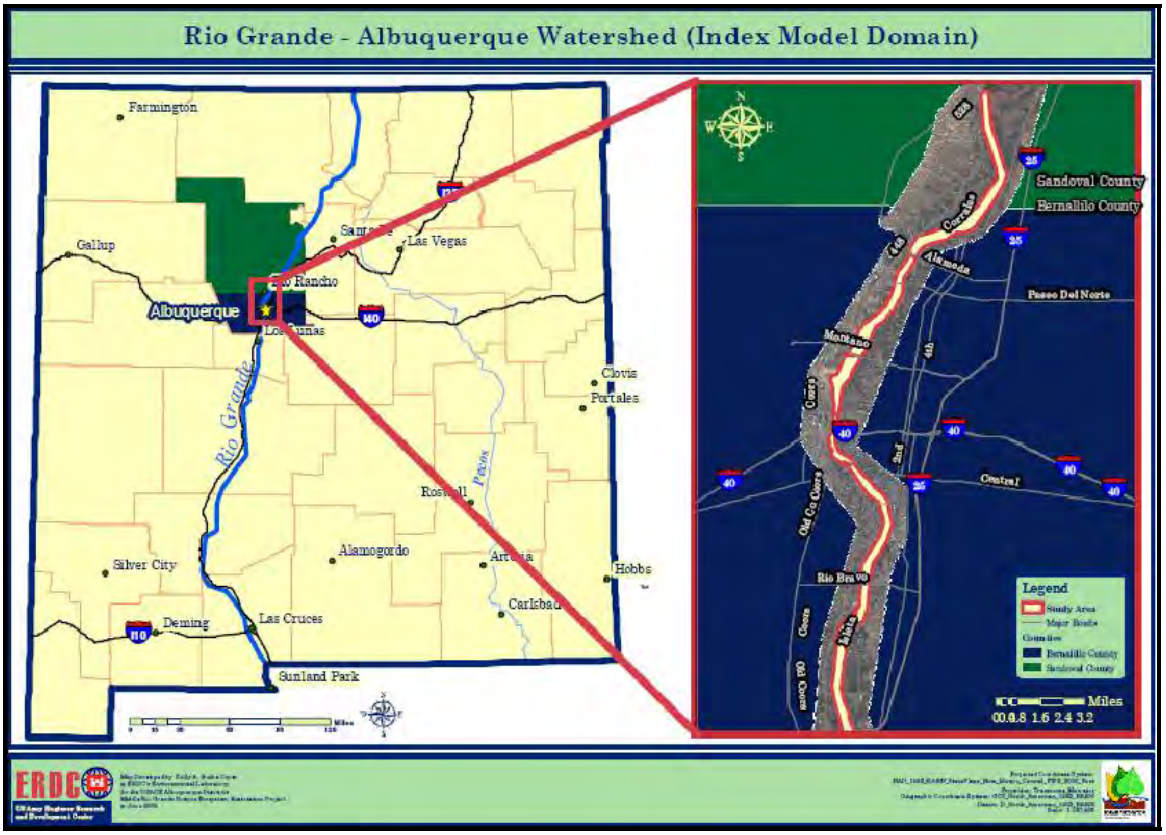


Figure 9. Reference domain for the Rio Grande-Albuquerque watershed index model.

The outflow of the city's North Diversion Channel forms the northern boundary of each model's domain, while the southern boundary is formed by the northern limits of the Pueblo of Isleta. The area is delimited on the east and west by the flood control levees, although the areas adjacent to the levees within the original floodplain have been considered in the calibration of the model.

The study area roughly corresponds to the *Rio Grande Valley State Park*, which runs through the center of Albuquerque and the County of Bernalillo. The park was dedicated for public uses and conservation purposes, and is one of the last intact cottonwood gallery forests along the Rio Grande. The bosque forest therein is one of the most biologically rich areas in the state and arguably one of the largest cottonwood riparian galleries in the southwestern United States (USACE 2002, 2003a, 2007b, 2008a,b).

The area is maintained as a part of the Middle Rio Grande Flood Control Acts of 1948 and 1950 and is within the Facilities of the *Middle Rio*

Grande Project (USACE 2002, 2003a, 2007b, 2008a,b). The bosque area within Albuquerque was designated as the *Rio Grande Valley State Park* through the Park Act of 1983 and is cooperatively managed by the City of Albuquerque Open Space Department and the MRGCD (Figure 10). 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. *Sandia Pueblo* lands are managed by the Pueblo.

Figure 10. Parks maintained inside the MRGBER Study Area.

By definition, the model presented here can be applied within this physical and ecological domain. In all likelihood, the model can be used several miles upstream or downstream of this narrowly defined area. However, any attempt to port this model to other locations outside this domain will likely require a recalibration of the parameters and algorithms associated with the tool.

Climatic Characterization

Albuquerque's climate is usually sunny and dry, with low relative humidity.[1] Brilliant sunshine defines the region, averaging more than 300 days a year; periods of variably mid and high-level cloudiness temper the sun at other times. Extended cloudiness is rare. The city has four distinct seasons, but the heat and cold are mild compared to the extremes that occur more commonly in other parts of the country.

Winters are rather brief but definite; daytime highs range from the mid-40s to upper 50s Fahrenheit, while the overnight lows drop into the low 20s to near 30 by sunrise; nights are often colder in the valley and uppermost foothills by several degrees, or during cold frontal passages from the Great Basin or Rocky Mountains (Table 1).

Table 1. Weather averages for Albuquerque, New Mexico.[2]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Record high	70°F (21°C)	78°F (26°C)	89°F (32°C)	89°F (32°C)	98°F (37°C)	107°F (42°C)	105°F (41°C)	101°F (38°C)	100°F (38°C)	91°F (33°C)	77°F (25°C)	72°F (22°C)
Average high	48°F (9°C)	55°F (13°C)	62°F (17°C)	71°F (22°C)	80°F (27°C)	90°F (32°C)	92°F (33°C)	89°F (32°C)	82°F (28°C)	71°F (22°C)	57°F (14°C)	48°F (9°C)
Average low	24°F (-4°C)	28°F (-2°C)	34°F (1°C)	41°F (5°C)	50°F (10°C)	59°F (15°C)	65°F (18°C)	63°F (17°C)	56°F (13°C)	44°F (7°C)	32°F (0°C)	24°F (-4°C)
Record low	-17°F (-27°C)	-6°F (-21°C)	6°F (-14°C)	12°F (-11°C)	28°F (-2°C)	37°F (3°C)	44°F (7°C)	45°F (7°C)	30°F (-1°C)	21°F (-6°C)	-7°F (-22°C)	-8°F (-22°C)
Precipitation inches (mm)	0.49 (12.4)	0.44 (11.2)	0.61 (15.5)	0.50 (12.7)	0.60 (15.2)	0.65 (16.5)	1.27 (32.3)	1.73 (43.9)	1.07 (27.2)	1.00 (25.4)	0.62 (15.7)	0.49 (12.4)

The occasional snowfall, associated with low pressure areas, fronts and troughs, often melts by the mid-afternoon; over half of the scant winter moisture occurs in the form of light rain showers, usually brief in duration. In the much higher and colder Sandia Mountains, moisture falls as snow; many years have enough snow to create decent skiing conditions at the local ski area.

[1] Information retrieved from Wikipedia (http://en.wikipedia.org/wiki/Albuquerque,_New_Mexico#Climate) in September of 2008.
[2] Weather.com - Monthly Averages for Albuquerque, NM (SEPTEMBER 2008).

Spring time starts off windy and cool, sometimes unsettled with some rain and even light snow, though spring is usually the driest part of the year in Albuquerque. March and April tend to see many days with the wind blowing at 20 to 30 mph (32 to 48 km/h), and afternoon gusts can produce periods of blowing sand and dust. In May, the winds tend to subside, as temperatures start to feel like summer. Summer daytime highs range from the upper 80s to the upper 90's, while dropping into the low 60s to low 70s overnight; the valley and uppermost foothills are often several degrees cooler. Fall sees mild days and cool nights with less rain, though the weather can be more unsettled closer to winter.

Albuquerque's climate is classified as arid (BWk or BWh, depending on the particular scheme of the Köppen climate classification system[1] one uses), meaning average annual precipitation is less than half of evaporation, and the mean temperature of the coldest month is above freezing (32). Only the wettest areas of the Sandia foothills are barely semi-arid, where precipitation is more than half of, but still less than, evaporation; such areas are localized and usually lie above 6,000 feet (1,800 m) in elevation and often in arroyo drainages, signified by a slightly denser, taller growth of evergreen oak - juniper - pinon chaparral and rarely, woodland, often mixed with taller desert grasses. These elevated foothill areas still border arid areas, best described as desert grassland or desert shrub, on their west sides.

The mountains and highlands to the north and east of the city create a "rain shadow" effect, due to the drying of descending air movements; the city usually receives very little rain or snow, averaging 8-9 inches (216 mm) of precipitation per year. Valley and west mesa areas, farther from the mountains are drier, averaging 6-8 inches of annual precipitation; the Sandia foothills tend to lift any available moisture, enhancing precipitation to about 10-17 inches annually. Most precipitation occurs during the summer monsoon season (also called a chubasco in Mexico), typically starting in early July and ending in mid-September.

[1] http://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification (SEPTEMBER 2008).

Vegetative Characterization

An ecosystem's vegetation at any given time is determined by a variety of factors, including climate, topography, soils, proximity to bedrock, drainage, occurrence of fire, and human activities. Because of the temporal and spatial variability of these factors and the sensitivity of different forms of vegetation to these factors, the system's character is one of dynamic, changing juxtapositions (i.e., a fluid mosaic). For details regarding the historical conditions of the study area, refer to the District's documents (USACE 2002, 2003a, 2007b, 2008a,b). Of particular concern for this effort, is the state of the vegetative communities within the model domain (Figure 11).

Figure 11. At stake - the dwindling cottonwood-dominated bosque community.[1]

To fully quantify the habitat conditions for this area, it is useful to divide the project into manageable sections and quantify these in terms of acres per habitat type. This process, referred to as "cover typing," allows the user

[1] Photo taken from abqstyle.com/albuquerque_photo/000023.html (MAY 2008).

to define the differences between vegetative "types" (e.g., forest, shrublands, wet/dry meadows, 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 and common landuse practices in a specific and orderly fashion that accommodates USACE's plan formulation process. 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. Six general plant vegetation categories were developed by Hink and Ohmart (1984), based on the height of the vegetation and the make-up of the understory or lower layers:[1]

[1] In actuality, the Hink and Omart classification requires field biologists to identify vegetation at the species level, and has generated a unique naming convention based on these characterizations. Those familiar with the Hink and Omart system should refer to *Appendix F* to see a crosswalk for cover types used in this assessment and the detailed Hink and Omart classification.

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

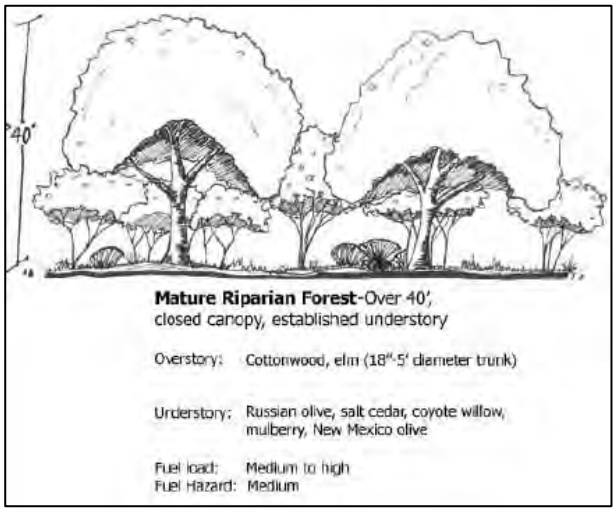


Figure 12. Classic examples of Type I (Mature Riparian Forests) vegetation in the study area.

- **Type II: Mature Riparian Forests** with tall trees exceeding 40 feet in height and nearly closed canopies, but limited sapling and shrub understory;

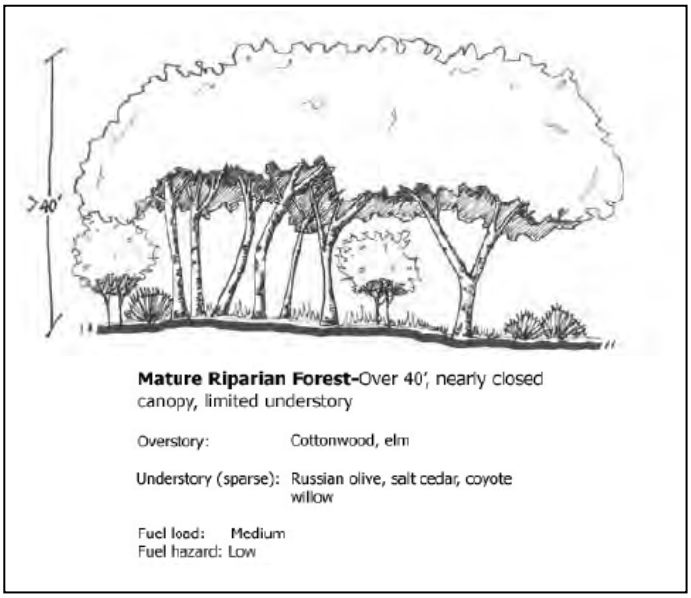


Figure 13. Classic examples of Type II (Mature Riparian Forests) vegetation in the study area.

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

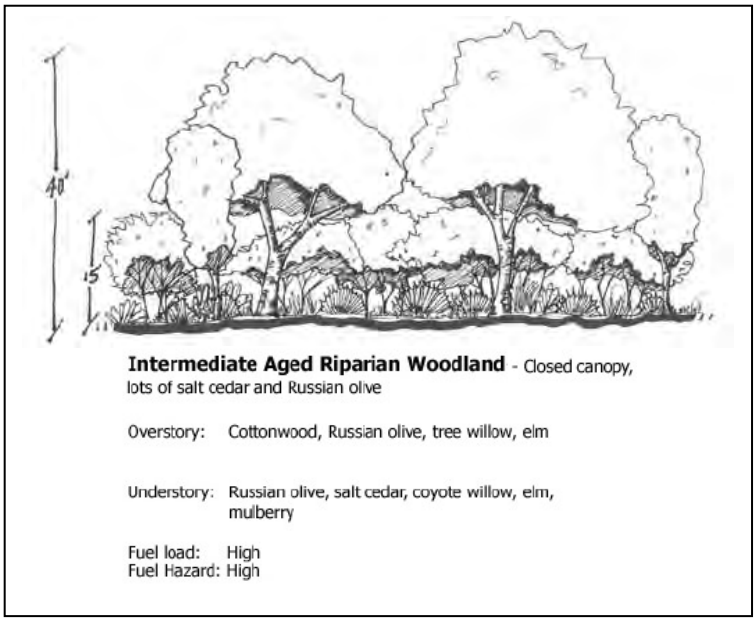


Figure 14. Classic examples of Type III (Intermediate-aged Riparian Woodlands) vegetation in the study area.

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

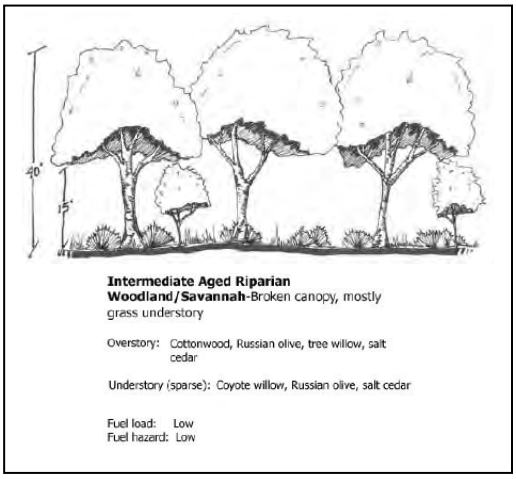


Figure 15. Classic examples of Type IV (Intermediate-aged Riparian Woodland/Savannahs) vegetation in the study area.

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

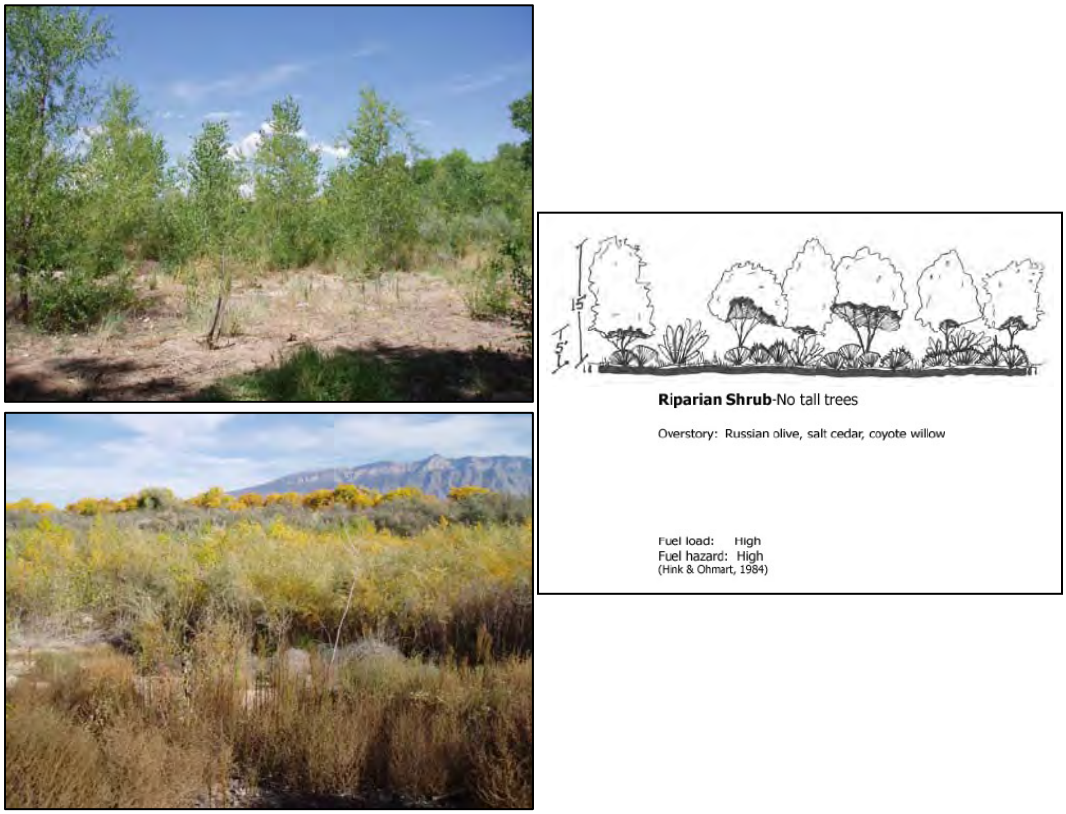


Figure 16. Classic examples of Type V (Riparian Shrubs) vegetation in the study area.

- **Type VI: Dry Grass Meadows and Wet Marshes** are 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 River that are vegetated with cattail, bullrush, sedges, watercress and algae.

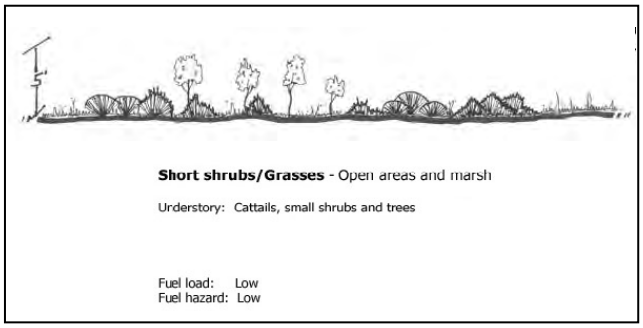


Figure 17. Classic examples of Type IV (Dry Grass Meadows and Wet Marshes) vegetation in the study area.

It should be noted, that severe fires took place in June 2003 burning 253 acres (Figure 18), and as a result, the City of Albuquerque Open Space Division (AOSD) initiated an extensive thinning project to prevent future fires in the Albuquerque area.

Figure 18. Location of 2003 bosque fires (map taken from USACE 2007b).

Unfortunately, two more fires occurred in 2004 - one between Rio Bravo and Interstate-25 (I-25) on both sides of the river burning approximately 63 acres and the other south of Bridge Blvd. on the east side of the river, burning approximately 18 acres (USACE 2007b) (Figure 19).

Figure 19. The nighttime sky is aglow with the firelight coming off the bosque wildfires.

Prior to these recent fires and in between them, the City has been thinning most areas within the Rio *Grande Valley State Park*. To date, approximately 2,300 of the 3,000 bosque acres in the park have been "treated" in some way by the AOSD, Ciudad Soil and Water Conservation District (SWCD), the Corps (through the Bosque Wildfire Project) and other agencies and private organizations. Some areas 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 Type I, III, and V woodlands. Recently-created Type II 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.

Because the "treated" habitats were significantly different in terms of vegetative cover, infiltration, etc., from the "untreated" cover types in the region, the E-Team made a decision to capture these differences by dividing several of the Hink and Omart categories (namely Types II, IV,

and VI) into "Treated" and "Untreated" classifications (designated by "U's") to better capture the degraded habitat conditions in "fire managed" areas within the study boundary (Figure 20).[1]

Figure 20. Untreated forests (left) carry extensive fuel loads susceptible to catastrophic fires. The District and stakeholders actively reduce fuel loads to reduce the risk (right). These areas have reduced functionality (lower habitat suitability).

Open areas not associated with the model have been mapped, and offer potential areas of restoration and rehabilitation within the study area. To complete the characterization, a series of "Newly Developed" coverages were created as placeholders for conversion of the open areas and existing degraded areas into newly restored wetland (riparian) habitats. In the MRGBER study, twenty four unique habitat types were (i.e., cover types or CTs) were identified and mapped across the entire project study area (Table 2).

[1] Because the Albuquerque District knew that the fires and treatments had caused significant changes to the existing vegetation in the study area, an effort was undertaken to ground-truth and remap the reach in 2005 (again using the Hink and Ohmart 1984 methodology and classification scheme). Details of this effort are described in USACE 2007b. The 2005 updated mapping was used for this assessment.

Table 2. Cover types identified and mapped for the MRGBER study area.

No.	Code	Cover Type (and Land Use) Description
1	TYPE_1	H&O Class I not treated - MATURE RIPARIAN FOREST (Over 40' – closed canopy, established understory).
2	TYPE_2T	H&O Class II treated - MATURE RIPARIAN FOREST (Over 40' – nearly closed canopy, limited understory).
3	TYPE_2U	H&O Class II not treated - MATURE RIPARIAN FOREST (Over 40' – nearly closed canopy, limited understory).
4	TYPE_3	H&O Class III not treated - INTERMEDIATE AGED RIPARIAN WOODLAND (Closed canopy, lots of salt cedar and Russian olive).
5	TYPE_4T	H&O Class IV treated - INTERMEDIATE AGED RIPARIAN WOODLAND/SAVANNAH (Broken canopy, mostly grass understory).
6	TYPE_4U	H&O Class IV not treated - INTERMEDIATE AGED RIPARIAN WOODLAND/SAVANNAH (Broken canopy, mostly grass understory).
7	TYPE_5	H&O Class V Shrublands not treated - RIPARIAN SHRUB (no tall trees).
8	TYPE_6T	H&O Class VI dry (grass) meadow treated - SHORT SHRUBS/GRASSES – Open areas.
9	TYPE_6U	H&O Class VI dry (grass) meadow not treated - SHORT SHRUBS/GRASSES – Open areas.
10	TYPE_6W	H&O Class VI wet meadow not treated - SHORT SHRUBS/GRASSES – Open areas and Marsh.
11	OPENLAND	Open Areas
12	OPENWATER	Open Water
13	NEWTYPE_1	Newly Developed Type 1
14	NEWTYPE_2T	Newly Developed Type 2T
15	NEWTYPE_2U	Newly Developed Type 2U
16	NEWTYPE_3	Newly Developed Type 3
17	NEWTYPE_4T	Newly Developed Type 4T
18	NEWTYPE_4U	Newly Developed Type 4U
19	NEWTYPE_5	Newly Developed Type 5
20	NEWTYPE_6T	Newly Developed Type 6T
21	NEWTYPE_6U	Newly Developed Type 6U
22	NEWTYPE_6W	Newly Developed Type 6W
23	ISLANDS	Islands
24	UTILITY	Utility Areas

Cover types identified as "NEW" refer to newly developed areas proposed in conjunction with construction of proposed alternatives.

The existing cover types were subsequently mapped using a Geographic Information System (GIS) (and ground-truthed during the 2005 field season) (Figure 21).

Figure 21. Baseline cover type map for the project study area. [1]

[1]GIS shapefiles are available upon request - contact the District POC (Ondrea Hummel, contact information can be found in *Appendix D*).

Of the 5, 321 acres mapped within the project boundary, the majority of the habitat was characterized as either Type I (Mature Riparian Forest – 2,111 acres) or Open Water (1,526 acres). (Figure 22).

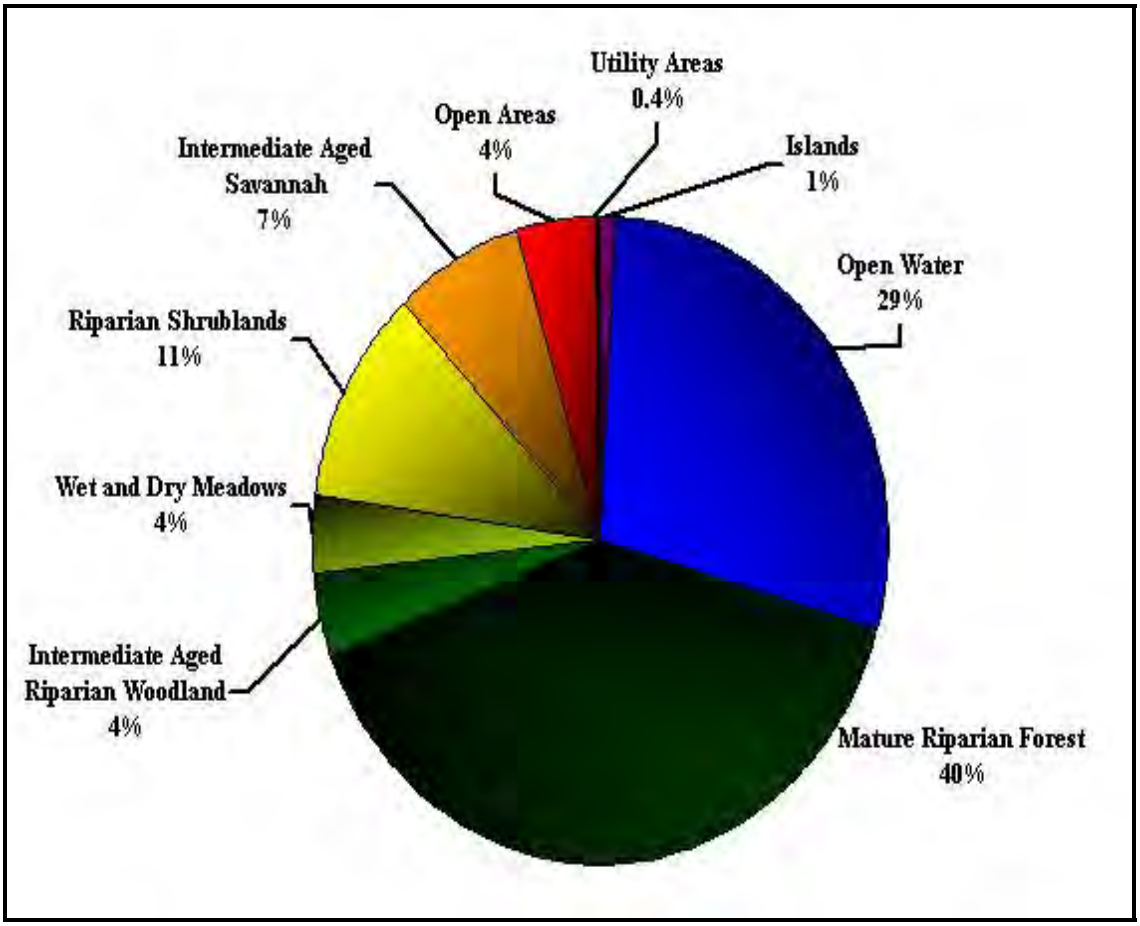


Figure 22. Acreage distribution of cover types in the MRGBER study area.

The remaining Hink and Omart categories, namely Types II-VI, were relatively evenly represented (4-11%, 1,384 acres collectively), with the remaining acreages tied up in utility areas and open areas (253 acres or 4.4%).

Hydrologic Characterization

Riparian wetlands develop and are maintained through time as the hydrologic cycle interacts with the landscape (Figure 23).

Figure 23. The hydrologic connection to the bosque is readily apparent. The diversity and health of the riparian community hinges on the restoration of natural flood pulsing to facilitate sediment deposition and subsequent cottonwood recruitment.[1]

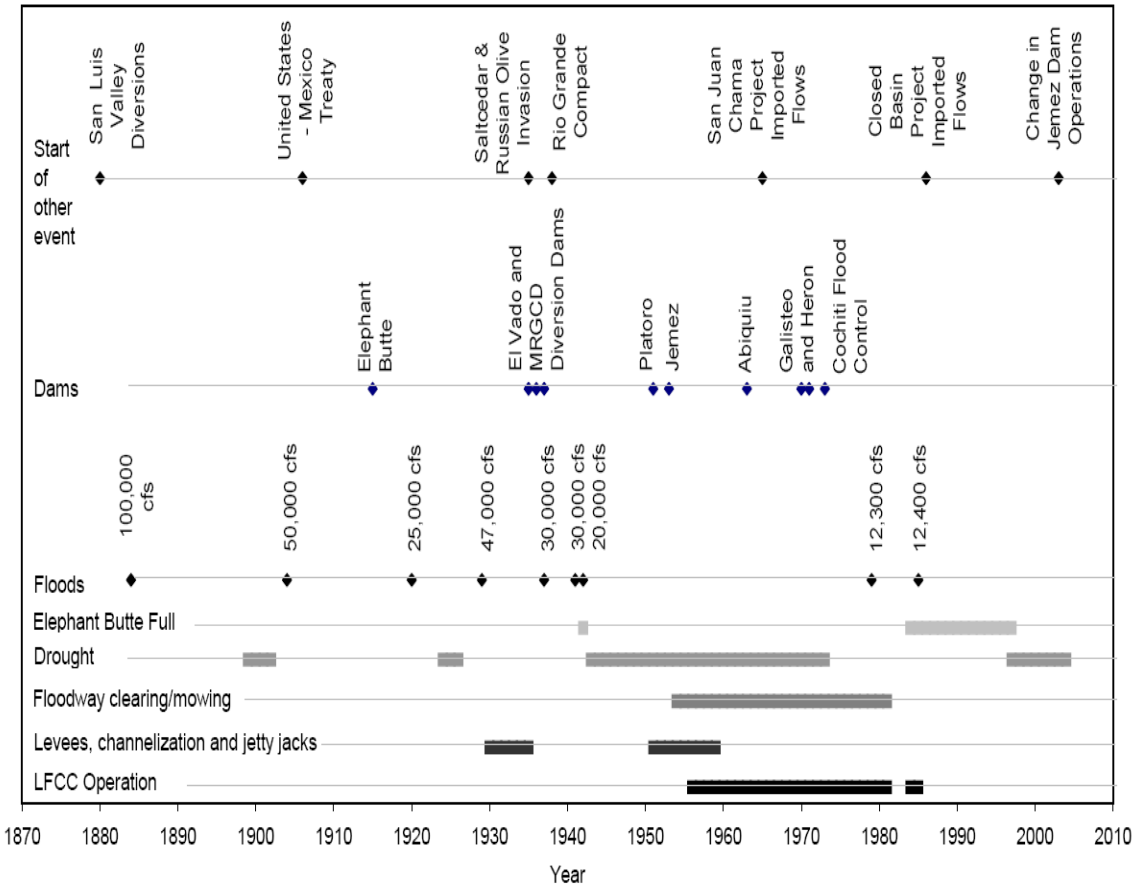
These ecosystems then are the local manifestation of broader, large-scale processes (Bedford 1996). They occur in particular hydrogeological settings where characteristics of the landscape and climate favor the accumulation or retention of surface water and/or soil water (Winter 1988, Winter and Llamas 1993). By hydrogeologic setting, we refer here to the position of the bosque in the landscape with respect to the flows of surface water, ground water, and the geological characteristics that control the flow of water. These geological characteristics include surface relief, land surface slope, thickness and permeability of soils, and the composition, stratigraphy, and hydraulic properties of the underlying geological materials (Bedford 1996). Together, climate and the hydrogeologic setting determine the key variables that lead to the development and maintenance of the bosque community. Depending on

[1] Image from http://flickr.com/photos/58969260@N00/1972259609/ (SEPTEMBER 2008).

the climatic setting and hydrogeologic position in the landscape, riparian wetlands receive varying proportions of their water supply from precipitation, ground water, and surface flooding.

Natural flows in the Rio Grande system are derived from two primary sources: (1) snowmelt originating predominately from the upstream, higher elevation portions of the watershed and (2) summer thunderstorms that tend to be more localized and concentrated at lower elevations (USACE 2007a). Under natural, unconstrained river conditions, the annual flow volume varies significantly from year to year, depending on climatic conditions (Waltemeyer 1987). Annual variations in the timing and volume of streamflow in the Rio Grande are strongly influenced by the El Niño-southern oscillation through its modulation of the seasonal cycles of temperature and precipitation and their effects on snow accumulation and melting (Lee et al. 2004). These cycles can be several years to decades long and can result in extended drought or wet periods. An extended period of below average precipitation occurred from the early 1940s through the mid 1970s and above average precipitation from 1981 through the mid 1990s (National Oceanic and Atmospheric Administration [NOAA] 2002). The annual flood regime varies significantly from year to year due to this natural variability in climate and precipitation.

Human activities affecting flows in the Rio Grande system have been documented back to the arrival of Spanish settlers in the late 16th century (Wozniak 1997). Significant changes in the Rio Grande occurred during the past century in response to a combination of human-induced factors (Figure 24).



Notes: cfs = cubic feet per second; LFCC = Low Flow Conveyance Channel; MRGCD = Middle Rio Grande Conservancy District

Figure 24. Timeline of human activities since 1880 that have affected the Rio Grande (USACE 2007a).

These alterations to the environment equate to significant changes in land use through time and space. Construction of reservoirs, changes to and expansion of historic irrigation conveyance systems, upland drainage networks, and bank stabilization have all served to modify the flow regime of the Rio Grande and associated groundwater recharge dynamics (Hansen and Gorbach 1997; Scurlock 1998; Wozniak 1997). Many of these alterations have resulted in the general tendency for extending runoff hydrographs, reducing peak-flow runoff events, limiting dry-channel vegetative colonization (i.e., new channel formation), and limiting lateral channel migration; resulting in a persistent and additive transition away from a more natural disturbance regime (USACE 2007a). These characteristics now dominate the nature and behavior of the Rio Grande. The eight major dams listed in Figure 24 affect flows in the river by storing and releasing water in a manner that generally decreases the flood peaks

and alters the timing of the annual hydrograph, but they do not necessarily cause significant changes in the annual flow volume.

The hydrologic characteristics of the Middle Rio Grande Reach have been characterized primarily based on flow records collected during the past century (USACE 2002, 2003a, 2007b, 2008a). These records provide a means of quantifying the most significant changes that occurred as a result of upstream flow regulation and storage, imported flows, cycles of drought and above average precipitation, and changes in land use. The following natural and human-caused hydrologic characteristics are particularly important to the existing geomorphology of the reach:

- Flows during the spring snowmelt season in April, May, and June typically make up more than half of the total annual runoff in the system. On an average annual basis, the total runoff volume was higher during the past four decades than it was in the earlier recorded period due to a combination of imported flows and higher than average precipitation during portions of that period (USACE 2007a).

- Flows associated with frequently occurring floods in the 1.5- to 10-year range are generally believed to have the most significant influence on channel form (Wolman and Gerson 1978). The morphologic characteristics of rivers in arid environments such as the Rio Grande are also strongly affected by larger, less frequent floods that create a disturbance regime that effectively “resets the clock” by altering the characteristics that develop during the intervening lower flow periods (Graf 1988). In spite of the increase in total runoff, both the average annual maximum mean daily flow (which is used to represent the mean annual flood peak) and the infrequent, large magnitude peak discharges have decreased in all reaches downstream from Cochiti Dam, presumably due to the presence of upstream dams (USACE 2007a).

The river and adjacent environs respond to cycles of drought and above average precipitation that occur over periods of several years through a variety of mechanisms, including changes in riparian vegetation, channel narrowing during drought periods, and channel widening through bank erosion and migration during wet periods. Generally, these processes vary

widely over both time and space and represent a fundamental organizing force throughout the river system. Over the passage of time, different flow regimes (both high and low) have shaped the riparian plant community by means of deposition and scour; however, widespread and large-scale human alterations in the last century have muted this pattern and disrupted the natural disturbance regime (Crawford et al. 1993; Hansen and Gorbach 1997; Scurlock 1998; Wozniak 1995).

Geomorphic Characterization

River systems are often described as being in a state of dynamic equilibrium. The equilibrium actually results from a series of processes that are predicated on change. Even when large-scale hydrological factors are essentially constant over a short period of time, changes can be happening in subareas as small as the outside bank of a meander or as large as many river miles upstream or downstream from a tributary inflow. Likewise, this state of dynamic equilibrium can withstand climatic deviations from the norm that persist for periods ranging from several decades to one-day flood events (Crawford et al. 1993). Leopold et al. noted that the geomorphic processes triggered in response to a change in the magnitude or duration of a variable, regardless if it was naturally caused or human induced, will be the same (1964). A river system is constantly adjusting, trying to achieve a new equilibrium between its discharge and sediment load (Bullard and Wells 1992).

Historically, the Rio Grande River in this region was a heavily braided, aggrading stream meandering freely across a wide floodplain much larger than the current floodway ecosystem. As it meandered through time and space, the river created and renewed a mosaic of riparian communities from cottonwood riparian gallery forest and coyote willow shrublands, to wet meadows, oxbow ponds, and open water areas (Figure 25).

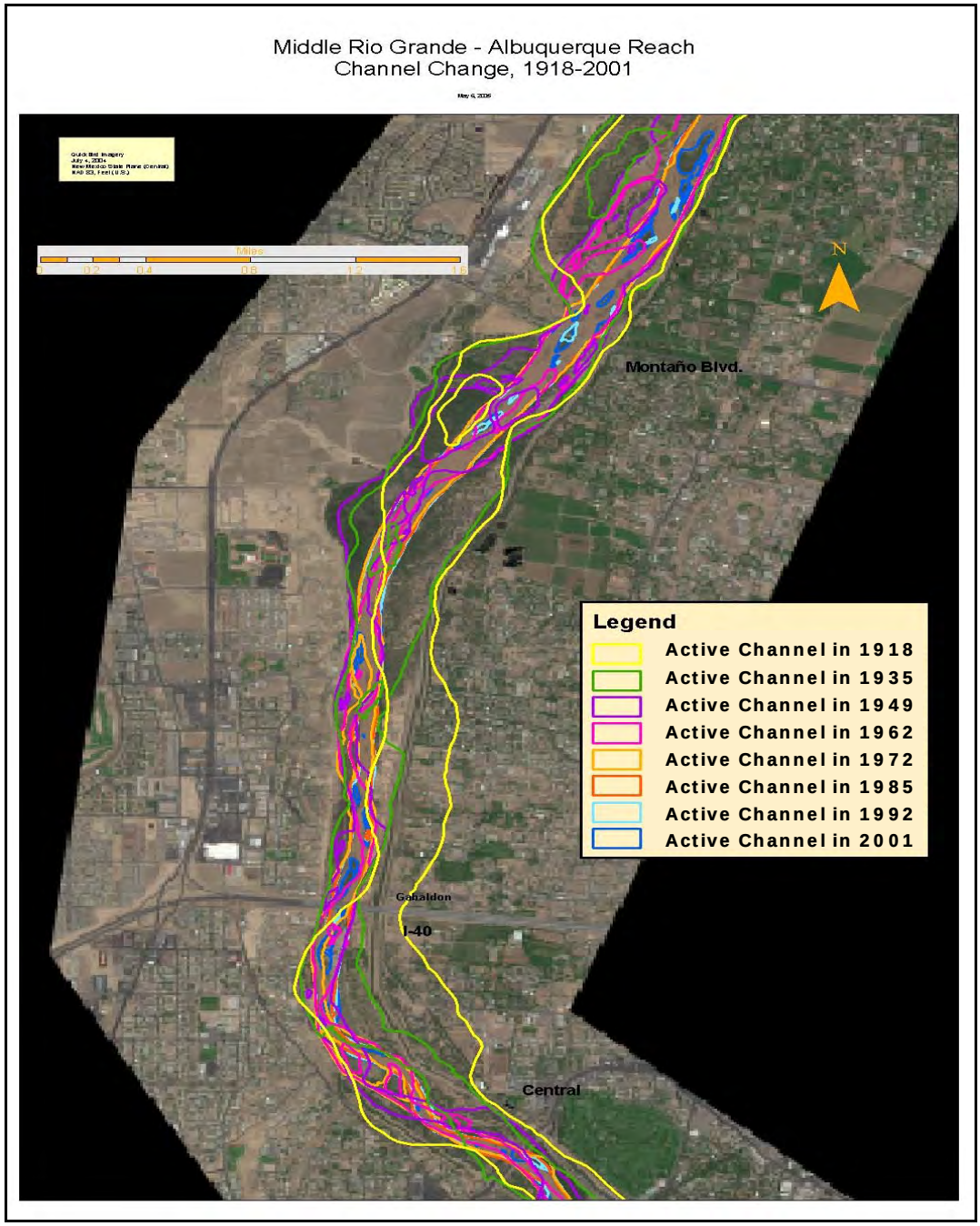


Figure 25. The Rio Grande River was once a heavily braided stream meandering across the arid area.

As a result of several channelization projects (installation of levees and jetty jacks) the river has become constrained to a single, narrow floodway throughout much of the Middle Rio Grande, resulting in an approximately 85 percent loss of the original floodplain (Earth Reflections 2003). Figure 26 shows the approximate location of the historic 500-year floodplain in

Albuquerque. The current floodplain is generally confined within the levees, which are also shown on the figure. Historically it was bounded by lower terraces, then by 300 to 500-foot high mesas. The mesas slope gently upward to the foot of the mountain ranges (predominantly to the east) or to plateau highlands (predominately to the west).

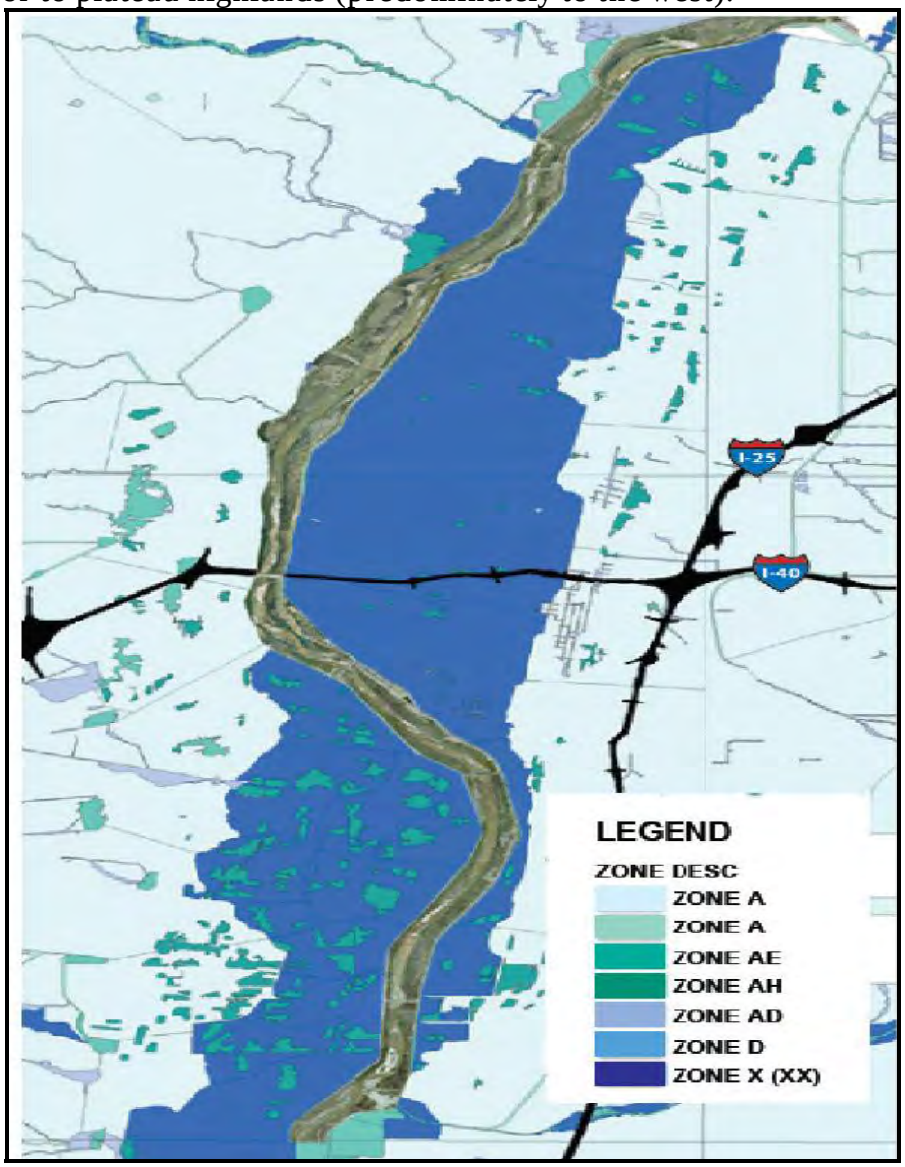


Figure 26. The historic 500-year floodplain of the Middle Rio Grande was once much wider than its current channelized state.

Past flood control and drainage projects implemented were widely successful in rejuvenating the declining agricultural communities and providing opportunities for expanding settlements. This occurred, however, at the expense of wetlands and marshes, which were dramatically

reduced in number and extent (Berry and Lewis 1997, Crawford et al. 1996, Leopold 1964, Hanson 1997). Although there are several small areas and former side channels in the area that function as seasonal wetlands, there are no longer any wetlands of significant size in the region.

Changes in seasonal discharges patterns have strongly impacted channel-forming processes. Discharge is the dominant variable that affects channel morphology, but sediment transport, channel bed & 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 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. However, the levee systems have confined the sediment and increased the rate of aggradation in the floodway. Additionally, channel stabilization activities which included the installation of jetty jacks during the 1950s and 1960s contributed to building up and stabilizing the over-bank areas in the existing bosque (Figure 27).

Figure 27. Jetty jacks lined along the bank of the Rio Grande trap sediment and plant material during flooding events, stabilized over-bank areas over the course of several years.

Construction of dams at Jemez Canyon (1953), Abiquiu (1963), Galisteo Creek (1970), and Cochiti (1973) were expected to slow aggradation or reverse the trend and promote degradation in the Middle Rio Grande Valley. The flood control improvements have reduced the sediment load in the Middle Rio Grande and accomplished flood control objectives for much of the river valley. This 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 over-bank flows into the Rio Grande Bosque.

Currently within the area, the Rio Grande is predominantly a sand bed river with low, sandy banks. There are numerous sandbars, and the river channel tends to be straight due to jetty jack fields and levee placement (Crawford et al. 1993) (Figure 28).

Figure 28. The middle Rio Grande is often characterized by numerous sandbars and a straight channel resulting from the placement of jetty jack fields and levees.

In this area, the river is typified by a uniform channel width averaging approximately 600 feet. Approximately two feet of degradation has occurred in the Albuquerque reach (due to flood control measures upstream) with no significant change in bed material (Mussetter 2006).

The slope of the riverbed is less than 0.01 feet per foot (Tashjian 1999). At flows less than the bankfull, the river is establishing a sinuous configuration within the cleared floodway.

Habitat Suitability Index (HSI) Model

The mix of water sources, and the geologic materials through which they move before reaching the riparian zone, combine to determine the elemental composition, nutrient status, and biodiversity of the unique bosque community (Figure 29).

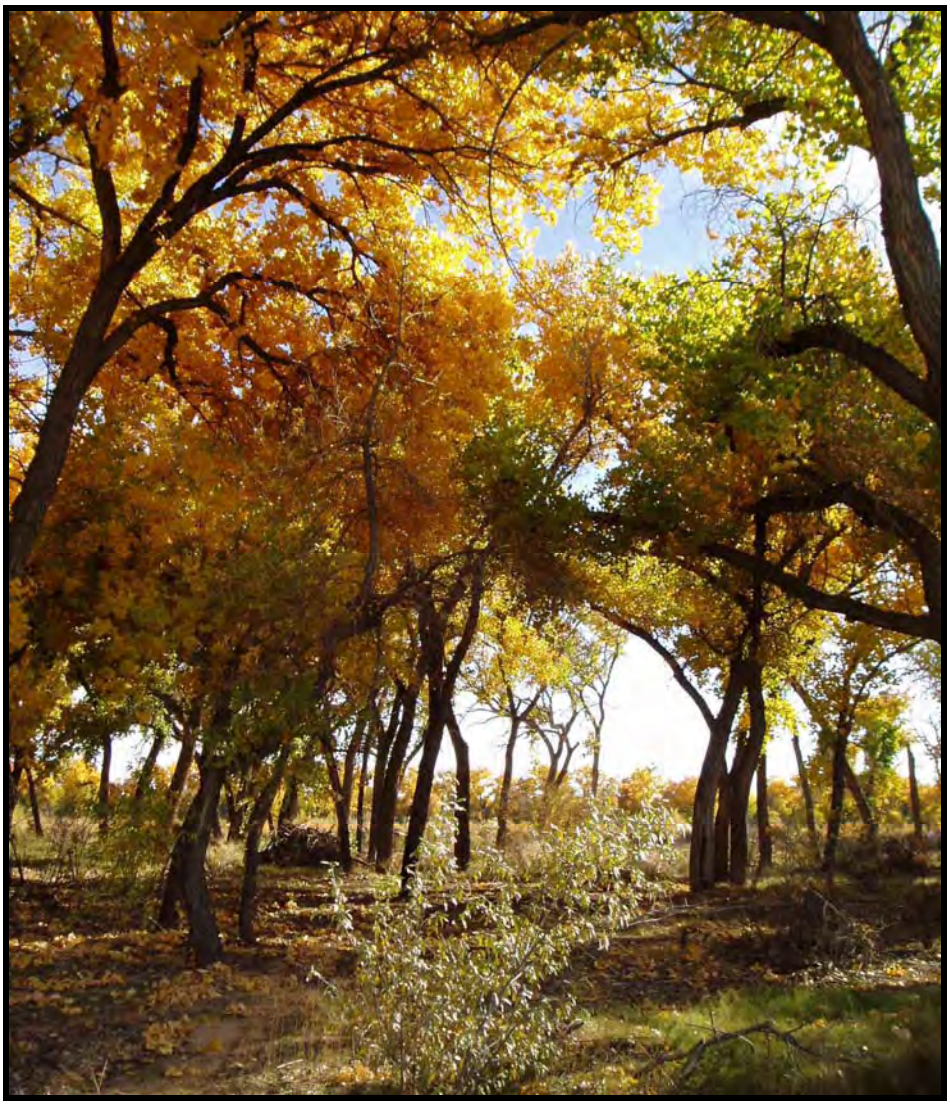


Figure 29. The challenge for the E-Team was to develop a model robust enough to capture the unique character of the Middle Rio Grande's bosque community.

The amount of groundwater inflow relative to precipitation, and geologic materials through which the ground water flows, dictate the biogeochemistry of the bosque community. And finally, the nature and spatio-temporal dynamics of water within the bosques and between the bosque and adjacent ecosystems dictates the functionality and integrity of these unique systems. In particular, the movement of water within the bosque, the flows of water between the bosque and adjacent systems, and the consequent exchange of materials (e.g., sediments, nutrients, propagules) that occur within the bosque and the adjacent systems literally shape these unique ecosystems.

Model Components

For the Bosque Riparian Community HSI Model three model components (i.e., Hydrology; Structure/Soils/Biotic Integrity; and Spatial Integrity/Disturbance) were identified as the key functional indicators necessary to model the integrity of this unique community. The following sections describe the underlying principles governing the selection of these critical functional components and provide a customized flow-diagram to indicate how they were combined to develop a HEP-compatible index model for the ecosystem restoration application.

Functional Component #1: Hydrology (RIP-HYDRO)

Water operations at the various facilities on the Rio Grande affect the surface and groundwater available to the riparian ecosystem. Periodic overbank flooding is necessary to the health of established native plant communities and literally "...creates the distribution of different communities and age classes" (Scurlock 1998). Regulated flood flows may prevent the overbank floods necessary to scour away existing vegetation and make new seedbeds for cottonwoods and other native trees (Scurlock 1998). Riparian areas that seldom receive overbank flooding show a definite lack of both structural and species diversity. Canopy trees tend to be mature, same-aged stands that are not regenerating. The understory becomes littered with deadfall, a fuel load that inhibits growth of desirable grasses, forbs, and other understory species (Figure 30).

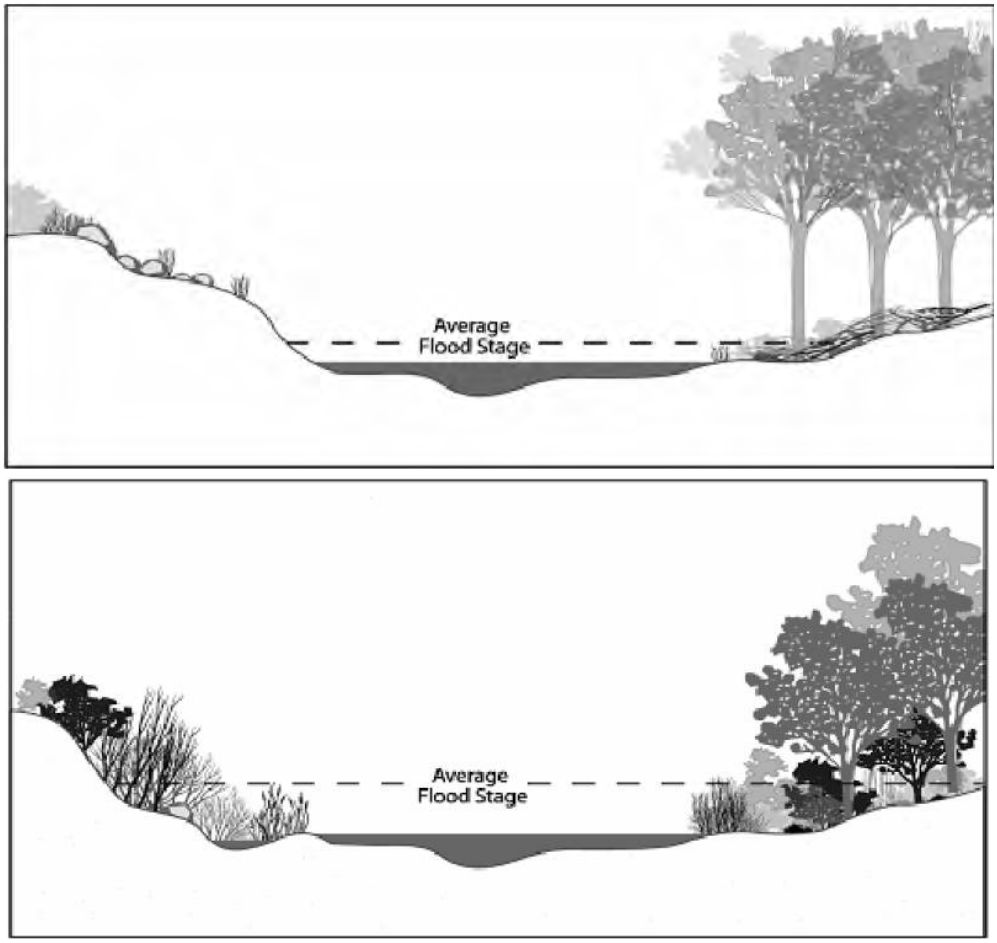


Figure 30. Vegetation response to no overbank flooding (above) versus regular flooding in the riparian zone (below) (USACE 2007a).

Restricted flow regimes changed the nature of riparian areas in the Rio Grande, adversely affecting cottonwood and other native plants. Many areas of the Rio Grande floodplain, both inside and outside the levees, contain relic stands of mature cottonwood and willow that have not flooded for several decades. Riparian vegetation that is not regularly flooded is more vulnerable to encroachment by non-native salt cedar and is extremely vulnerable to fire because of the accumulation of debris that occurs with reduced peak flow events (Ellis et al. 1996). The timing, duration, and magnitude of peak flows are critical to habitat creation and maintenance. Peak flow variability contributes to the diversity of vegetation and wildlife. Seasonally flooded riparian zones exhibit both structural and species diversity in the canopy and understory. Banks are scoured and reshaped, forming depressions that support vital wetland areas and associated species.

Thus, the physical characteristics of natural rivers and their associated bosque riparian communities are strongly controlled by the magnitude, duration and timing of the natural, unconstrained flows that pass through them (Schumm 1977). The natural flows are in turn controlled by the climatic, geologic, and physical characteristics of the contributing watershed (Lee et al. 2004). These natural physical characteristics can be significantly altered by human activities that change infiltration and runoff patterns; that store and release water in ways that alter the natural runoff cycle and change the sediment supply; and that constrain the river to protect adjacent property from flooding and erosion (USACE 2007a). In terms of the bosque's HSI model, indicators of hydrologic function include depth to groundwater, flooding frequency and duration, as well as ratios of wetted area for depressional wetlands. The existing form of the Rio Grande's bosque community results from a combination of these factors (Figure 31).

Figure 31. Hydrology dictates the functionality of the bosque ecosystem.

Functional Component #2 Structure/Soils/Biotic Integrity (RIP - BIOINTEG)

Today, the bosque is comprised of a dynamic mosaic of cottonwood forests, coyote willow shrublands, wet meadows, wetlands, oxbow ponds, and open water areas with a variety of depths and flows. These wetlands and riparian forests rely entirely upon periodic flooding events to regenerate soils and create new substrates for vegetative colonization. Unlike many upland areas, the primary natural disturbance regime at work in the Rio Grande ecosystem is flooding. As a patchwork of wetlands, open water, wet meadows and woodlands, these riparian areas provide habitat to a greater number of wildlife species than any other ecological community in the region and serve as a critical travel corridor for many species, especially migratory birds moving with the change of seasons.

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, starting about 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) (Figure 32).

Figure 32. Along the banks of the Middle Rio Grande, anthropogenic pressures have resulted in an extremely degraded bosque community subject to catastrophic fires, exotic species encroachment and a loss of vegetative recruitment in the cottonwood riparian community. In 50 years, the bosque could be completely devoid of riparian forest without intervention.

In ecological terms, the cumulative effects of these activities have resulted in a disruption of the original hydrologic (hydraulic) regime. This overbank flooding regime is key to the decomposition of leaf litter and dead wood, which are both fire hazards and obstacles to riparian forest regeneration. With the onset of these periodic flooding events, dissolved salts are flushed from the system, nutrients are cycled into the ecosystem, and soils are renewed. Without flooding, and with the increase demand on water resources in the region, the river banks have destabilized and now “perched” above the river itself (Figure 33).

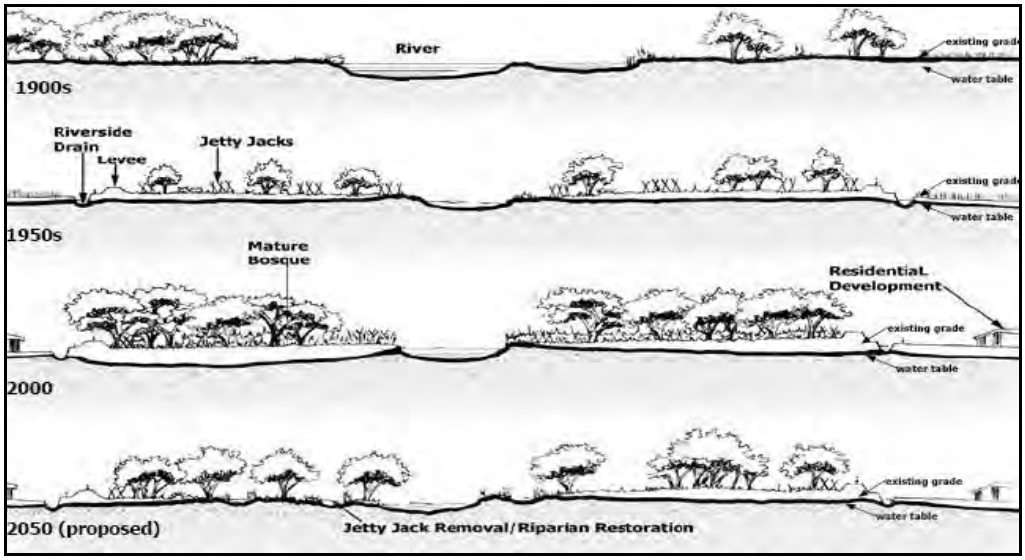


Figure 33. Flood protection projects (e.g., levees, riverside drains and jetty jacks) have reduced the Rio Grande's original floodplain to fraction of its size in the study area (USACE 2003a).

Structural changes in the riparian vegetation were rapid and easily detected. For example, the valley lost over half its wetlands in just 50 years (Crawford et al. 1993). Similarly, cottonwood germination, which requires scoured sandbars and moisture provided by high river flows (Stromberg et al. 1991, Scott et al. 1993) has decreased, resulting in limited establishment of new trees and a predicted decline in the regional population (Howe and Knopf 1991).

Ultimately these conditions have favored the encroachment of exotic species. Salt cedar (*Tamarix ramosissima*), Siberian elm (*Ulmus pumila*), Russian olive (*Elaeagnus angustifolia* L.), tree-of-heaven (*Ailanthus altissima*), and Bermuda grass (*Cynodon dactylon*) have colonized large portions of the bosque, outcompeting and replacing the native species. These exotics do not rely upon the spring flooding regime to reproduce, consume more water than the natives, compound the fire hazards in the area, and fail to provide critical habitat for many key wildlife species. Without significant restoration and changes in the current water management, these exotics may dominate riparian forests within the next 50 to 100 years (Howe and Knopf 1991).

In terms of the bosque's HSI model, the vegetative species compositions of living plant biomass within the bosque dictate the ecological integrity of the ecosystems and suggest whether the systems can support animal

populations and guilds. The emphasis of the HSI model was therefore placed upon the dynamics of the plant community as revealed by the vegetative diversity (presence of natives and indicator species) and community structure of the habitats (Figure 34).

Figure 34. Vegetative indicators, particularly cover, densities, native species dominance and biodiversity, capture the bosque community's habitat potential.

Healthy bosque ecosystems possess a natural complexity of physical features that provide a greater variety of niches and more intricate interactions among species. Local structural complexity increases with increased canopy cover, tree densities, vegetative layering, and accumulation of organic matter. The vegetation's physical characteristics and structures within the system dictate the habitat suitability of a system to support animal populations and guilds as well. The emphasis of the model is to capture the system's ability to provide physical space for its numerous terrestrial and aquatic inhabitants to meet key life requisite requirements (breeding, feeding and cover) (Figure 35).

Figure 35. Structural complexity offers numerous benefits to resident wildlife in the bosque community.

Functional Component #3: Spatial Integrity and Disturbance (RIP-SPATIAL)

At the landscape level, the bosque has a characteristic pattern and connectivity of habitat patches (Figure 36).

Figure 36. The San Antonio Oxbow offers an ideal perspective from above illustrating the classic bosque mosaic of unique patches of forested habitat ribboned throughout with wetland (meadow and marsh) complexes.

The number of and the juxtaposition of these patches supports the movement of species and the transfer of materials (energy and nutrients) among habitats [U.S. Environmental Protection Agency (USEPA) 1999]. The relevance of landscape structure to biodiversity is now well accepted, thanks to the voluminous literature on habitat fragmentation (Noss 1990 and numerous references therein). Landscape features such as patch size, heterogeneity, and connectivity within the riparian zone can be major controllers of species composition and abundance, and of population viability for sensitive species (Noss and Harris 1986). Furthermore, landscape pattern has been shown to strongly influence ecological processes and characteristics (McGarigal and Marks 1995). Turner (1989) describes how spatial structure influences most fundamental ecological processes, and how landscape planning and management, in turn, influences landscape structure.

To adequately characterize the bosque's ecosystem functions, the system's "place" in the landscape must be captured along with the processes that "shape" the system (i.e., key corridors and habitat fragmentation) (Figure 37).

Figure 37. Fragmentation and urban encroachment is a common problem for the bosque ecosystem.

Therefore, landscape-level characteristics (i.e., patch size and nearest neighbors as well as the levels of disturbance immediately adjacent to the system) were thought to dictate whether flora and fauna would find the bosque ecosystem serviceable. In general, high levels of disturbance were thought to perturb sensitive species and reduce the system's ecological integrity.

Model Flow Diagram

A flow diagram best illustrates the final model's design arising from the workshop and application efforts (Figure 38).

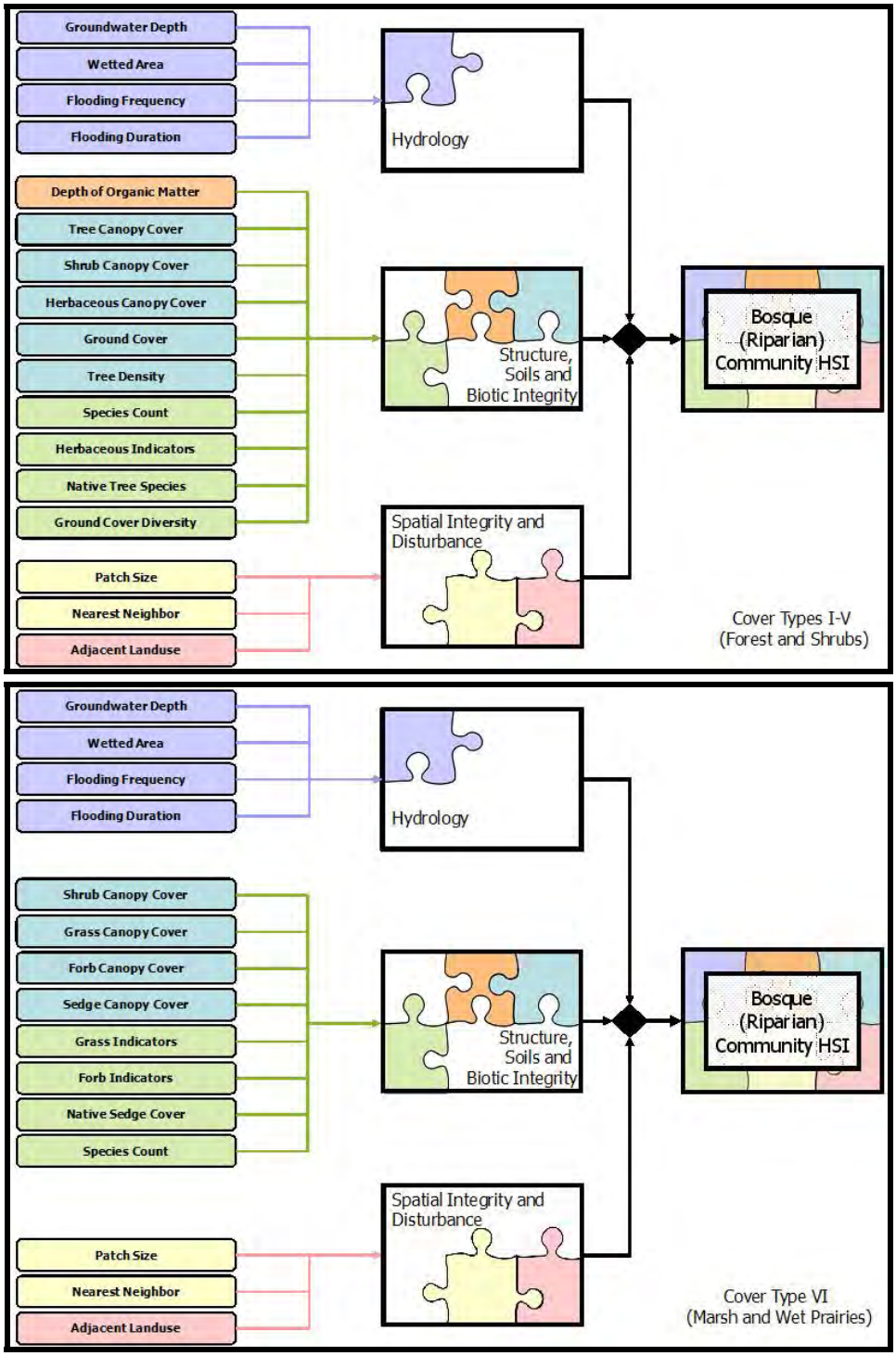


Figure 38. Flow diagram depicting combinations of model components and variables to form the Bosque community index model in the MRGBER study. There are two versions of the model depending on the cover types being evaluated. Types I-V use the upper diagram, and Types VI us the lower diagram.

Variables were selected as indicators of functionality, and have been color coded here to correlate their use in specific model components (i.e., purple = hydrologic parameters, orange = soil characteristics, etc.). Again, these model components are combined in a meaningful manner mathematically to characterize the existing reference conditions found in the watershed, and to capture the effects of change under proposed design scenarios (refer to the section below). The rationale for including variables in the model is presented in greater detail in *Chapter 4*.

Model Formulas

With this information in hand, ERDC-EL (with review and oversight from 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 MRGBER application (Table 3).

Table 3. Index formulas for the MRGBER Bosque community model.

Model Component	Variable Code	CT Code	Formulas
Hydrology (RIP-HYDRO)	DEPTHGW WETTEDAREA FLOODFREQ DURATION	ALL	$\frac{\left(V_{FLOODFREQ} \times V_{DURATION}\right)^{1/2} + V_{DEPTHGW} + V_{WETTEDAREA}}{3}$
Structure, Soils, and Biotic Integrity (RIP-BIOINTEG)	CANTREE CANSHRUB CANHERB DISTBIGTR NATIVETREE INDICATHB SPPCOUNT COVGRND CTGRNDCOV DEPTHOM	TYPE_1 TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5	$\frac{\left\{3 \times \left[\left(\frac{\left(\left(V_{CANTREE} \times V_{NATIVETREE}\right) \times V_{DISTBIGTR}\right)^{1/2} + V_{CANSHRUB}}{2}\right) \times V_{SPPCOUNT}\right]^{1/2}\right\} + \left(V_{CANHERB} \times V_{INDICATHB}\right) + V_{DEPTHOM} + \left[\left(V_{COVGRND} \times V_{CTGRNDCOV}\right)^{1/2}\right]}{6}$
	CANSHRUB CANGRASS CANFORB CANSEDGE INDICATGR INDICATFB NATIVESDG SPPCOUNT	TYPE_6T TYPE_6U TYPE_6W	$\frac{\left(V_{CANSHRUB} \times V_{SPPCOUNT}\right) + \left(V_{CANGRASS} \times V_{INDICATGR}\right) + \left(V_{CANFORB} \times V_{INDICATFB}\right) + \left(V_{CANSEDGE} \times V_{NATIVESDG}\right)}{4}$
Spatial Integrity and Disturbance (RIP-SPATIAL)	PATCHSIZE TYPDISTURB DISTPATCH	ALL	$\frac{\left[2 \times \left(V_{PATCHSIZE} \times V_{DISTPATCH}\right)^{1/2}\right] + V_{TYPDISTURB}}{3}$
Overall Habitat Suitability Index (HSI):			$\frac{V_{BBIOTA} + V_{BWATER} + V_{BLANDSCPAPE}}{3}$

It is important to note that the community-based model developed herein does not subscribe to the "limiting-factor" species-based modeling paradigm of the past, but rather attempts to capture the community's integrity based on a series of component indicators (i.e., ***Hydrology***, ***Spatial Integrity/Disturbance***, and ***Biotic Integrity***) that together characterize the functioning of the system. This new function-based approach does not rely on a geometric mean, but rather takes into account the compensatory nature of the system's components. In other words, a degraded bosque might be considered "unsuitable" for a given species, but could potentially have value for others, and therefore would still be considered "functional" (although minimally so). Thus, the hydrologic connection to a bosque could be altered (possibly through channelization or tiling), and would therefore score very low (<0.2) on the Hydrology Component of the model, yet still retain some functionality – it might still provide structure or niches for disturbance-tolerant species. This approach is not new, but is a common strategy for habitat suitability modeling in the scientific literature of late (Brook and Bowman 2006 and references therein, Schluter et al. 2006; Store and Jokimaki 2003; Store and Kangas 2001; Ruger et al. 2005).

Algorithms were only the first step in the model development process. The second step was to calibrate the individual variables that together characterize the model's components using a process that normalizes the individual variable inputs to capture ecosystem integrity on a scale of 0 to 1. Refer to *Chapter 4* of this document for details surrounding the individual variables described above in these algorithms, and to garner details surrounding the sampling and calibration efforts that led to the finalization of this model for the MRGBER study.

4 HSI Model Sampling and Calibration Protocols

This chapter describes the variables employed within the bosque riparian community index model. In an effort to support the future use of the model, we have included detailed sampling protocols, as well as rationale for the incorporation of each variable into the model, and offer scientific literature to support their inclusion therein. In order to use these parameters within a traditional HEP context, each variable must be normalized or scaled on a 0 to 1 range. Here we describe the normalization process in some detail, and have also included *Appendix E* at the end of this report to fully document the final index curves.

HSI Model Variables Selection Rationale

As mentioned previously, ERDC-EL used a systematic, scientifically-based, statistical protocol to develop and calibrate the community model for the study using an iterative approach that involved the selection of reference sites from across the watershed and a sampling scheme that obtained numbers to assure model precision. Below, the variables associated with the bosque riparian community model (and justifications for their inclusion in the model) have been provided in tabular format (Table 4).

Table 4. Variables and rationales for association in the bosque riparian community index model.

Code	Variable Description	Rationale
CANFORB CANGRASS CANHERB CANSEDGE CANSHRUB CANTREE COVGRND CTGRNDCOV DISTBIGTR	Canopy Cover of Forb Species (%) Canopy Cover of Grass Species (%) Canopy Cover of Herbaceous Vegetation (%) Canopy Cover of Sedge Species (%) Canopy Cover of Shrubs (%) Canopy Cover of Overstory Trees (%) Ground Cover Present (%) Count of Ground Cover Categories Present Distance to Biggest Tree from Sample Point (m)	Three distinct layers can be described in any terrestrial ecosystem (including wetlands): groundcover, understory (i.e., mid-canopy) and overstory (i.e., upper canopy). The presence of each layer offers a niche for community associations. High structural complexity promotes diversity in ecosystems. Species rarely occupy area – they occupy three-dimensional space (Giles 1978). The abundance of vegetative structure greatly influences the abundance and diversity of animals in both wetland and terrestrial ecosystems - complex habitats accommodate more species because they create more ways for species to survive (Norse 1990). Furthermore, studies indicate that physical structure may prevent generalist foragers from fully exploiting resources and thus promoting the coexistence of more species (Werner 1984). In particular, vertical stratification diversification of forests produces stratification of light and temperature, as well as providing intricate spaces for shelter and food sources for species. Thus, structural complexity plays a critical role in the presence of microclimate, food abundance, and cover that affect organism fitness (Cody 1985). The predominance of woody vegetation in riparian ecosystems provides an important habitat value, especially near grasslands, deserts, and farmlands where extensive forests are lacking (Brinson et al. 1981). Riparian forest habitats have considerable vertical structure, foliage height diversity, and foliage density which contribute to wildlife diversity and abundance. By definition, forested wetlands contain tree species in their upper and lower canopies, and tree canopy in particular exceeds 50% coverage in healthy, functioning forested wetlands (Cowardin et al. 1979; Chicago Region Biodiversity Council. 1999; Moulton, Dahl and Dall 1997; Wagner 2004; Jacob, Moulton and López 2004; and Texas Parks and Wildlife Department 2007). **These variables were designed to capture the multiple layers of a healthy bosque ecosystem capturing not only future successional changes in the community, but offering target thresholds for restoration activities.**
DEPTHGW	Depth to Groundwater (ft)	All riparian cottonwoods are dependent on shallow alluvial groundwater that is linked to stream water, particularly in semi-arid regions (Rood et al. 2003). When alluvial groundwater is depleted as a result of river dewatering or groundwater pumping, riparian cottonwoods exhibit drought-stress responses including stomatal closure and reduced transpiration and photosynthesis, altered 13C composition, reduced predawn and midday water potentials, and xylem cavitation. These physiological responses are accompanied by morphological responses including reduced shoot growth, altered root growth, branch sacrifice and crown die-back. As stream flows become more intermittent, diversity and cover of herbaceous species along the low-flow channel also decline (Stromberg et al. 2007). As groundwater deepens, diversity of riparian plant species (particularly perennial species) and landscape patches are reduced and species composition in the floodplain shifts from wetland pioneer trees (*Populus, Salix*) to more drought-tolerant shrub species including Tamarix (introduced). **The conservation and restoration of cottonwoods will rely on the provision of river flow regimes that satisfy the ecophysiological requirements for survival, growth and reproduction – this variable was included in the model to capture the critical linkage between the bosque and the riparian zone's groundwater table.**

(Continued)

Table 4. (Continued).

Code	Variable Description	Rationale
DEPTHOM	Depth of Organic Matter (cm)	Soil is mainly composed of minerals and organic matter, like decaying plants and animals, as well as living organisms. The minerals are derived from the weathering of "parent material" - bedrock and overlying sub-soil. The organic matter in soil derives from plants and animals. In a forest, for example, leaf litter and woody material falls to the forest floor. This is sometimes referred to as organic material (http://www.epa.gov/epawaste/conserve/materials/organics/index.htm). When it decays to the point it is no longer recognizable it is called soil organic matter. When the organic matter has broken down into a stable humic substances that resist further decomposition it is called humus. Thus soil organic matter comprises all of the organic matter in the soil exclusive of the undecayed material (http://soils.usda.gov/sqi/concepts/glossary.html). Because primary production in riparian zones is extremely complex and variable, organic matter (detritus) processing becomes a key component in maintaining the trophic dynamics of these aquatic ecosystems. In general, primary energy sources for rivers are organic material from riparian vegetation (allochthonous) and organic material generated within the river (Crawford et al 1993 and numerous references therein). Rivers with high sediment load, such as the Rio Grande, generally have a paucity of aquatic vegetation and thus minimal autochthonous input. Autochthonous input from upstream is a critical source of organic carbon for these systems. Allochthonous input in the Middle Rio Grande supports bacteria and algae that assimilate carbon and thus are vital to the food chain. Course organic matter is initially attacked by microbial organisms and converted to organic matter either by natural degradation or shredder macroinvertebrates. Consumer invertebrates, such as detritivores and collectors, use the free organic matter as an energy source and are subsequently consumed by both vertebrate and invertebrate predators. **This variable was included in the model as an indicator of the level of primary production within the bosque.**
DISTPATCH	Distance to Nearest Patch (aka Nearest Neighbor of Forest or Meadow) (m)	Too often, ecologists perceive habitats as lone entities, when in reality they are interacting, functional components of the landscape (Noss 1991). Landscape connectivity, therefore, involves the linkage of habitats, species, communities and ecological processes at multiple spatial and temporal scales (Noss 1991). Many of the most significant human effects on biodiversity involve changes in the connectivity of habitat (Noss 1991). Human activities can reduce connectivity by creating artificial barriers to species dispersal, leading to isolated populations that become vulnerable to extinction due to reduced access to resources, genetic deterioration, increased susceptibility to environmental catastrophes and demographic accidents, and other problems (Harris 1984; Soule 1987). Connectivity of the landscape mosaic is absolutely necessary for species to survive (Noss 1991). Disturbances periodically make portions of the landscape uninhabitable. Corridors fulfill a “fire escape” function b permitting animals to flee disturbance. Corridors also aid in recolonization of the recovering site by plants and animals. Habitat patches that are isolated from similar habitat patches by great distances or inhospitable terrain are likely to have fewer species than less isolated patches because relatively few individuals of a given species will immigrate into the isolated patch, and fewer mobile species will visit isolated patches because it is inefficient to do so (Hunter 1996). **This variable has been included to capture the connectivity of the habitats in the region – indicating species “source” availability.**

(Continued)

Table 4. (Continued).

Code	Variable Description	Rationale
DURATION FLOODFREQ WETTEDAREA	Average Duration of Flooding Events (days) Frequency of Flooding (#/yr) Percent of Polygon that is Wet (%)	Riparian vegetation in dry regions is influenced by low-flow and high-flow components of the surface and groundwater flow regimes. The duration of no-flow periods in the surface stream controls vegetation structure along the low-flow channel, while depth, magnitude and rate of groundwater decline influence phreatophytic vegetation in the floodplain (Stromberg et al. 2007 and references therein). Flood flows influence vegetation along channels and floodplains by increasing water availability and by creating ecosystem disturbance. Floods influence riparian biota by creating ecosystem disturbance, driving geomorphic change, and altering availability of resources including water, light and nutrients (Stromberg et al. 2007 and references therein). In arid regions, floods tend to have high magnitude but short duration. The rapidly peaking and receding waters of small floods create minor disturbance and provide a transitory water source. Floods of greater magnitude and longer duration can shape vegetation structure for decades, and mediate water availability both through short-term hydrologic processes (overbank soil wetting, groundwater recharge) and longer-term geomorphic processes (channel incision, floodplain aggradation and degradation, deposition of course versus fine sediments) (Stromberg et al. 2007 and references therein). On impounded rivers, changes in flood timing can simplify landscape patch structure and shift species composition from mixed forests composed of Populus and Salix, which have narrow regeneration windows, to the more reproductively opportunistic Tamarix. If flows are not diverted, suppression of flooding can result in increased density of riparian vegetation, leading in some cases to very high abundance of Tamarix patches (Stromberg et al. 2007 and references therein). Cottonwood and willow seedlings are small and particularly vulnerable to drought stress and consequently altered flow regimes often severely suppress seedling recruitment and this provides a predominant factor impacting riparian cottonwood forests (Braatne et al. 2007 and references therein). Since cottonwoods are relatively short-lived trees, typically dying within a century and seldom surviving beyond two centuries ongoing reproduction is essential to provide continuity of riparian cottonwood forests (Braatne et al. 2007 and references therein). The recruitment of cottonwood seedlings is dependent on dynamic fluvial and geomorphic processes (Braatne et al. 2007 and references therein). Seasonal flow patterns including periodic spring flooding produce moist and barren substrates that are required for seedling recruitment (Braatne et al. 2007 and references therein). After germination, the roots of young seedlings must keep pace with the receding soil moisture that is closely coordinated with the declining river stage (Braatne et al. 2007 and references therein). Thus, if river levels decline abruptly, young seedlings succumb to drought stress. Older cottonwoods also benefit from periodic flooding that recharges the alluvial groundwater table (Braatne et al. 2007 and references therein). **These variables were included in the model to capture and the critical hydrologic pulsing necessary to support riparian bosque recruitment and maintenance.**

(Continued)

Table 4. (Continued).

Code	Variable Description	Rationale
INDICATFB INDICATGR INDICATHB	Percent of Forb Canopy that is an Undesirable Indicator Species (%) Percent of Grass Canopy that is an Undesirable Indicator Species (%) Percent of Herbaceous Canopy that is an Undesirable Indicator Species (%)	Many of the most dramatic examples of population fluctuations affecting ecological processes involve the invasion of non-native (exotic) species (USEPA 1999). Through direct biotic interactions (predation and competition) and indirect interactions (ecological engineering and habitat modification), invasive species can disrupt the natural population dynamics of native species (USEPA 1999). Invasives can include noxious plants (i.e., plants that are listed by a state because of their unfavorable economic or ecological impacts), non-native, and native plants. Invasive plants may impact an ecosystem's type and abundance of species, their interrelationships, and the processes by which energy and nutrients move through the ecosystem. These impacts can influence both biological organisms and physical properties of the site (Olson 1999). The affects range from slight to catastrophic responses depending on the species involved and their degree of dominance. Invasive species may adversely affect a site by increased water usage (e.g., salt cedar (tamarisk) in riparian areas) or rapid nutrient depletion (e.g., high nitrogen use by cheatgrass). Some invasive plants (e.g., knapweeds) are capable of invading undisturbed climax bunchgrass communities (Lacey et al. 1990) further emphasizing their use as an indicator of new ecosystem stress. Even highly diverse, species-rich plant communities are susceptible to exotic species invasion (Stohlgren et al. 1999). **These variables then were included to capture the presence/absence of invasives indicating a level of functionality (when compared to the reference setting) indicative of disturbance and competition both now and in the future.**
NATIVESDG NATIVETREE SPPCOUNT	Percent of Sedge Canopy that is a Desirable Indicator Species (%) Percent of Tall Overstory Tree Canopy that is a Native Species (%) Number of Native Tree and Shrub Species (presence/absence)	The assessment of ecosystem integrity based on a single index will be insufficient to account for all relevant aspects (Herman, et al. 2001). Species richness (number of species) by itself can also be an insensitive indicator of habitat quality since it is possible for a degraded site to support a similar or greater number of taxa than an intact, high quality site. Six measures of biological integrity for wetlands have been suggested by Keddy et al. 1993. These include species diversity, indicator guilds, exotic species, rare species, plant biomass, and amphibian biomass. Keddy et al. (1993) views diversity as an essential indicator of integrity, but also recommends assessing guild diversity. **These variable were included to capture the number of "native" species at the site in an attempt to capture several of these key measures, namely species diversity (richness and eveness), presence specifically of "indicators," and presence of these species tied to a specific community or guild (namely ground vegetation) - the assumption being that higher numbers of native species present signifies ecosystem health and integrity.**

(Continued)

Table 4. (Continued).

Code	Variable Description	Rationale
PATCHSIZE	Size of Patch (ac)	The size of habitat patches has important implications for ecological integrity (USEPA 1999). Fragmentation of habitats has been implicated in the decline of biological diversity and the ability of ecosystems to recover from disturbances (Flather et al. 1992). Large patches have more species because they provide a greater number and variety of niches. Large patches are more likely to have both common and rare species, while small patches are more likely to have only common species (i.e., area-sensitive species will be excluded in smaller patches) (Hunter 1996). Small habitat patches (e.g., habitat islands) have fewer species than large patches, and are more susceptible to extinction. Area-sensitive species that cannot maintain populations in limited areas of otherwise high quality habitat will avoid patches purely on the basis of size (USEPA 1999). Species with small home ranges, such as songbirds, may also avoid small fragments if they prefer the interior of large habitat patches (Robbins, et al. 1989) or select patches large enough to support other members of their species (Stamps 1991). Larger tracts/patches of habitat containing larger populations of targeted species have better functionality and suitability than smaller tracts/patches of habitat with small numbers of species (USEPA 1999). Larger patch fragments have a higher core to edge ratio. The greater the distance between larger and smaller patches, the more inefficient it becomes for mobile species to visit the smaller patches, affecting the number and diversity of species (Hunter 1996). **This variable was included to characterize both the patch size of the various habitats as well as to capture the future urbanization threat to these ecosystems if preventative measures are not taken in the recommended plans.**

(Continued)

Table 4. (Continued).

Code	Variable Description	Rationale
TYPDISTURB	Type of Human Disturbance (aka Adjacent Landuse Within 2 km)	Ecosystems do not exist in a steady-state; they are dynamic, each possessing a characteristic composition structure and function that have adapted to natural disturbances over long periods of time. At the landscape level, natural disturbances destroy patches of vegetation and restart plant succession. Human activities (both onsite and offsite) that deviate from these patterns affect individual species (and through biotic interactions many other species and ecological processes) by direct exploitation, habitat elimination, and modification of ecological processes (USEPA 1999). By changing the access of species to their food, shelter, and reproduction, human activities initiate a cascade of biotic interactions that can affect entire ecosystems (USEPA 1999). Impervious surfaces prevent infiltration and direct water away from subsurface pathways to overland flow, increasing the flashiness of streams. Urbanization and suburbanization commonly exceed the threshold of approximately 10 to 20 percent impermeable surface that is known to cause rapid runoff throughout the watershed (Center for Watershed Protection 1994). In heavily urbanized watershed, stream channelization and large amount of impervious surface result in rapid changes in flow, particularly during storm events. These artificially high runoff events increase flood frequency (Beven 1986), cause bank erosion and channel widening (Hammer 1972), and reduce baseflow during dry periods. Agricultural practices also greatly affect hydrologic patterns (USEPA 1999). Clearing forest and prairie environments generally decreases interception of rainfall by natural plant cover and reduces soil infiltration resulting in increased overland flow, channel incision, floodplain isolation, and headward erosion of stream channels (Prestegaard 1988). Draining and channelizing wetlands directs flow more quickly downstream, increasing the size and frequency of floods, and reducing baseflow (USEPA 1999). Such activities can actually increase the magnitude of extreme floods by decreasing upstream storage capacity and accelerating water delivery. Human activities, such as land clearing and erosion, can cause the loss of nutrients (e.g., phosphorus), disrupt natural cycling of nutrients, and limit ecosystem productivity (USEPA 1999). At the same time, agriculture and industry can discharge excessive amounts of nutrients (e.g., nitrogen) into natural ecosystems and drastically change their trophic structure, and degrade water quality. **This variable was added to the model to capture the effects of human activities immediately outside of the habitat area, and can be used as an indication of urban pressures on the remaining relictual ecosystems in the future.**

(Continued)

Baseline ecosystem characterization for this study included gathering data on water quality, hydrology, substrate conditions, flora, and fauna, and to the greatest extent possible, identifications of underlying stressors in the region. In particular, land-use activities, physical habitat alterations, and native species were identified. In addition to the physical and chemical characteristics of the study area, land ownership and regulatory jurisdictions played an important role in determining opportunities for restoration. Some of this information was geographically-based and was assessed using documented protocols in an ArcGIS environment (see below). The field data was collected from the reference sites between May and July of 2005. The landscape-level data and historical data were subsequently generated over the course of the next several years (2005-2007). These datasets, in turn, were used to characterize the baseline conditions of the study area.

To assure adequate sampling size, the District was asked to locate at least three sites per cover type spanning the range of reference conditions and representing the relative variation found across the system (described earlier in the reference-based section above). Again, an attempt was made to evenly distribute these sites across the entire watershed. To reduce data collection variability, a single three-person sampling team (a recorder and two data collectors) was used to collect all field data. To the greatest extent possible, underlying stressors in the region were described in the notes section of the field data collection sheets. In particular, land-use activities, physical habitat alterations, and indicator species were described in detail.

A Reference-Based Modeling Approach

To begin, the E-Team developed hypothetical mathematical algorithms to relate the various components to the ecosystem processes occurring throughout the watershed in this community. To test these concepts, a

series of reference sites[1] were used to provide relevant feedback and verification of the model's conceptual architecture.

Background on Reference-based approaches

The following information was provided to the authors in a workshop hosted by ERDC-EL in the summer of 2008 under the Ecosystem Management and Restoration Research Program's Environmental Benefits Analysis initiative by Drs. Ronald (Dan) Smith and John Nestler. In that workshop, a draft manuscript was circulated to the participants for review and comment. Here we provide excerpts from that paper, and inject local knowledge of the bosque system's reference conditions where relevant.

Reference sites in this instance refer to multiple sites in a defined geographic area (the reference domain) that were selected to represent a specific type of ecosystem (i.e., arid riparian forests and wetlands or bosques). Reference sites are most commonly described as natural settings with minimal human disturbances (Hughes 1994, Bailey et al. 2004a, Chessman and Royal 2004, Intergovernmental Task Force on Water Quality Monitoring 2005). Reference-based conditions are therefore the range of physical, chemical, and biological values exhibited within the reference sites. When reference sites are characterized as undisturbed ecosystems, reference conditions exhibit at a range of values that reflect the spatial and temporal variability that commonly occur in natural ecosystems (Swanson et al. 1993; Morgan et al. 1994; White and Walker 1997; Landres et al. 1999). When reference sites include altered or disturbed ecosystems (as is the case in most urban-based ecosystem restoration efforts such as the MRGBER), the reference conditions exhibit a wider range of values that reflect both natural variability and variability due to human activities. In these instances, optimal conditions or "virtual" references can be established using a variety of techniques including literature values, historical data, paleoecological data, and expert opinion (Society for Ecological Restoration International 2004; Ecological

[1] Choosing the relevant reference conditions in a region is a matter of judgment (Andreasen et al. 2001). In some instances, the natural state might be reconstructed from historic records or based on scientific knowledge such as reconstruction of potential vegetation. ERDC-EL assisted the Albuquerque District in locating a series of 27 sample sites across the entire study area that were considered both reference standard (optimal) or degraded (sub-optimal) that represented the range of conditions existing within the reference domain.

Restoration Institute 2008). Regardless of how reference conditions are established, ecosystem restoration evaluations can use the reference-based approach as a template for model development, restoration planning, and alternative analysis.

Various types of reference-based approaches have been developed for a variety of ecosystems including streams (Barbour et al. 1999, Karr and Chu 1999, Bailey et al. 2004b), large rivers (Angradi 2006, and Flotemersch et al. 2006), wetlands (Smith et al. 1995, Brinson and Rheinhardt 1996, Smith 2001, USEPA 2002), grasslands (Prober et al. 2002), forests (Fule et al. 1997, Moore et al. 1999, Tinker et al. 2003, Ecological Restoration Institute 2008), tidal marshes/estuaries (Findlay et al. 2002, Merkey 2003), and coral reefs (Jameson 1998). Reference-based approaches have also been used to evaluate ecosystems in a landscape or watershed context (Warne et al. 2000, Andreasen et al. 2001, Reinhardt et al. 2007, Wardrop et al. 2007, Whigham et al. 2007, Smith 2008).

Reference Site Selection Strategy

A one-page handout was provided to the Albuquerque District early-on in the planning process to assist in the selection of reference sites for the bosque model. Here we synopsize the directives given to the team:

A. Definitions

1) ***Reference*** sites serve several purposes in HEP. First, they function as the physical representation of the communities from the region that can be observed and measured repeatedly. Second, they make it possible to establish the range of variability exhibited by the measures of the model variables, which make it possible for calibration of variables and indices. Third, they serve as a template for restoration by providing design specifications.

2) ***Reference standard*** areas are those optimum conditions in the region that are then used to establish the highest standard of comparison for calibrating assessment model variables and indices. In HEP, the least altered areas in the least altered landscapes are selected as *reference standard* wetlands. This is based on the

assumption that these areas sustain the highest level of function across the suite of habitats within the community that are inherent to the system.

B. General Selection Strategy

1) ***Conduct field reconnaissance*** to screen potential candidate reference sites. The objective is to identify sites that represent the range of conditions that exist in the reference area from highly altered sites in highly altered landscapes to unaltered (pristine) sites in unaltered landscapes.

2) ***Determine the number*** of reference sites to be included. A variety of factors influence the number of reference sites to be included in the process. Large projects will require more reference sites. Reference areas with a wide variety of alteration scenarios will require more sites. Detail of resolution to detect the types of impacts that typically affect riparian areas in the region is another factor. Lastly, the ideal number of sites dictated by the foregoing considerations must be balanced against the realities of budgets, time and personnel.

C. Criteria for Defining Reference Conditions

1) Must be politically palatable and reasonable;

2) Must include a large number of sites from the region;

3) Must represent important aspects of pre-historical conditions;

4) May use minimal disturbance as the surrogate for pre-historical conditions, given the difficulty of establishing pre-historical conditions;

5) Must be uniform across political boundaries and bureaucracies (e.g., Federal, State, and local); and

6) When the areas have experienced extensive alteration, it may be possible to reconstruct a reference standard area using historical accounts and photography.

Desired Reference Standard Conditions

Based on the inventory and reconnaissance efforts completed by the District in early 2005, the reference standard conditions for the Middle Rio Grande bosque community can be characterized by the following in the following manner:

Hydrology - Channel characteristics (channel pattern, sinuosity, and width) are not altered by human disturbances that cause changes in hydroregime (flood frequency, duration, or magnitude) or sediment transport. The sediment transport, channel morphology, width, and sinuosity patterns are natural. The river channel should exhibit deposition and erosion of soils creating a wide flood plain characteristic of the area. The flood flow should mimic the climatic/natural regime. Vegetation is present to resist flow downstream, and together with topographic relief and subsurface water flow, they promote surface water storage. The flood prone area is undisturbed by humans. Surface hydraulic connections exist between the bankfull channel and the flood prone area. Surface water ponds for more than one day. Side channels are unmodified and connected to the main reach. If the river system has been altered in the past, the system has attained a stable condition for those characteristics and is no longer undergoing degradation. The depth of saturated sediment is near the surface of the wetland. Groundwater and the managed water supply must be appropriate to establish and maintain a diverse cover type.

Biogeochemical - A range of vegetation types and sediment combined with suitable topographic relief support detention of particulates. Sufficient water flow through the riparian zone (surface and subsurface) must be evident as well as substrates with enough silt to adsorb elements, promote propagule recruitment, and supply organic materials. In addition, presence of organic mater indicates nutrient cycling occurring within the bosque.

Vegetation - There must be an abundance of native trees, shrubs, and herbaceous vegetation. Invasive plant species are absent. Guild representatives (i.e., indicators) must include a wide variety of growth

forms (trees, shrubs, vines, grasses, forbs, algae, and lichens). Plant vertical configuration and foliage profile (canopy cover) must represent a variety of layers. Vegetation provides vertical and horizontal connectivity the length of the system. All age classes of trees (seedlings, saplings, and trees) must be represented. Biotic legacies from preceding bosque forests, propagules from adjacent cottonwood stands, forest structuring processes and the generation of spatial heterogeneic complexes combined to produce both overall compositional diversity and patch diversity (habitat breadth).

Spatial Configuration – Spatially-explicit landscape characteristics within the bosque setting associated with patch geometry and distribution are maximized. Landscape simplification is absent – a mosaic or heterogeneic suite of habitat types are present in sufficient in both size and numbers to promote both core area stability and edge diffusion (a blurring of the edge contrast). Habitat connectivity is evident and supports the persistence of both plant and animal populations. Distances between high quality patches are minimized, and a mixture of age classes are present within a reasonable distance of one another to promote niche diversification and offer escape routes during stochastic disturbances. Land adjacent to the project is undeveloped and unperturbed by human disturbances such as agricultural activities.

Reference Site Selection

Once the inventory and reconnaissance was completed, the E-Team used the strategy outlined above to filter and screen the potential sites down to a manageable number. To assure adequate sampling size, the District was asked to locate at least three sites per cover type spanning the range of reference conditions and representing the relative variation found across the system (described earlier in the reference-based section above). Again, an attempt was made to evenly distribute these sites across the entire watershed. To reduce data collection variability, a single three-person sampling team (a recorder and two data collectors) was used to collect all field data. To the greatest extent possible, underlying stressors in the region were described in the notes section of the field data collection sheets. In particular, land-use activities, physical habitat alterations, and indicator species were described in detail. Their goal was to identify, prioritize, and then select sites across the study area that were considered either “high (**H**),” “medium (**M**),” or “low quality (**L**)” based on expert opinion (Table 5).

Table 5. Middle Rio Grande Reference Sites.

Reach	Reference Site	Site No.	Cover Type	Expected Value (E-Team Estimated)
Reach 1	Corrales	28	TYPE_2U	High
	Corrales	29	TYPE_6W	High
	Corrales	30	TYPE_6W	High
	Corrales	33	TYPE_4U	Low
	Alameda	34	TYPE_4U	Medium
	Alameda NE	36	TYPE_6U	Medium
Reach 2	Paseo NE	1	TYPE_1	High
	Paseo NE	2	TYPE_3	High
	Paseo NE	3	TYPE_6T	Low
	Paseo SE	4	TYPE_4T	Medium
	Paseo SE	5	TYPE_3	Medium
	Paseo SW	6	TYPE_2T	Medium
	La Orilla N	7	TYPE_6T	Medium
	La Orilla S	8	TYPE_6T	Medium
Reach 3	Oxbow N	9	TYPE_5	Low
	Oxbow M	10	TYPE_6W	Medium
	Oxbow S	11	TYPE_2U	Medium
	RGNC N	12	TYPE_2U	Medium
	RGNC S	13	TYPE_4T	Medium
	RGNC W	14	TYPE_1	Low
	Montano SW	15	TYPE_2T	Medium
Reach 4	Bridge SW	16	TYPE_4T	Medium
	AOP	17	TYPE_2U	Medium
	Rio Bravo NE	18	TYPE_4U	Medium
	Tingley Bar	35	TYPE_6U	High
Reach 5	Harrison levee	20	TYPE_1	Medium
	Harrison bar	21	TYPE_6U	High
	SDC North levee	22	TYPE_2T	Low
	SDC North river	23	TYPE_5	High
	SDC South	24	TYPE_5	Low
	Price's Dairy	26	TYPE_3	Medium

These initial rankings were based upon the consensus of the "on-the-ground" resource managers that had actual knowledge of each site's level of disturbance, species composition, land ownership, and the presence or absence of hydrologic alterations. An attempt was made to evenly distribute the site selection across the study area. All told, **31** sites were considered either reference standard (optimal) or sub-optimal and were chosen to represent the range of conditions existing within the reference domain (Figure 39).

Figure 39. Bosque reference sites in the MRGBER study area used to calibrate the Bosque community index model.

Sampling Protocol – Site Preparations

A standardized approach was developed to collect all field data. Using a somewhat subjective protocol (taking random numbers of footsteps in a random direction into each reference site) a central sample point in the field was established by the team, and a rebar stake was placed there in the ground. This point served as both a permanent plot marker and as the center point for two, perpendicularly aligned 50-m sampling transects which formed a "cross" configuration (Figure 40).

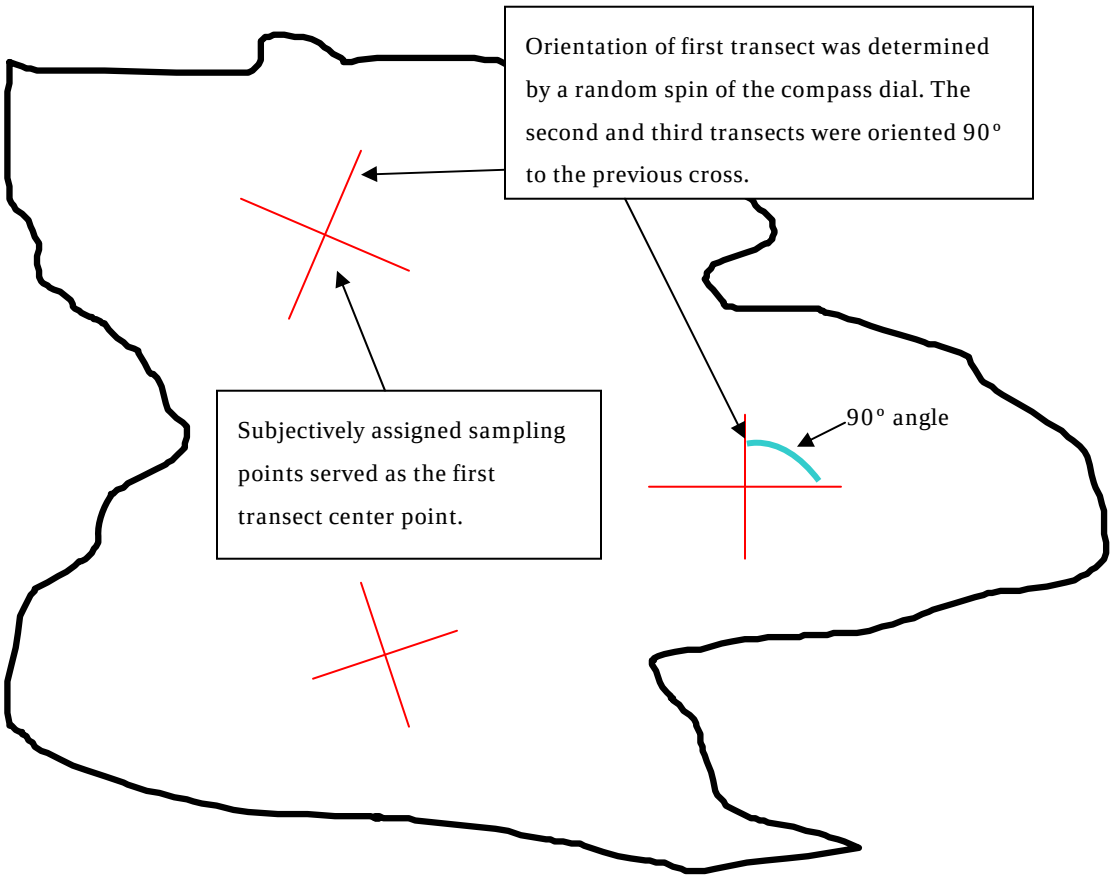


Figure 40. Illustration of the MRGBER baseline sampling design for the Bosque Riparian HSI model components. Up to three 120-m plots (crosses) were established in a single vegetation polygon.

The orientation of the first 50-m tape in the first "cross" was determined randomly by standing over the central point and making an unobserved spin of a compass dial. The next cross was oriented a random distance away (again through the use of random steps and random compass bearings) at a 90° angle to the previous cross. Three crosses were established per polygon (up to 300-m sampling transect length per

polygon) in this manner when polygon size/shape permitted. As each cross was established, a GPS was used to document the coordinates (northing/easting) of the central sample point and entered into a GIS upon returning to the office.[1]

On a technical note, while the sampling distance along each transect was 50-m, each transect was actually extended to 60-m because the 5-m circumference around the center rebar was avoided to restrict measurement overlap (refer to the green square in Figure 41 below), and because this area was trampled to some extent during plot setup.

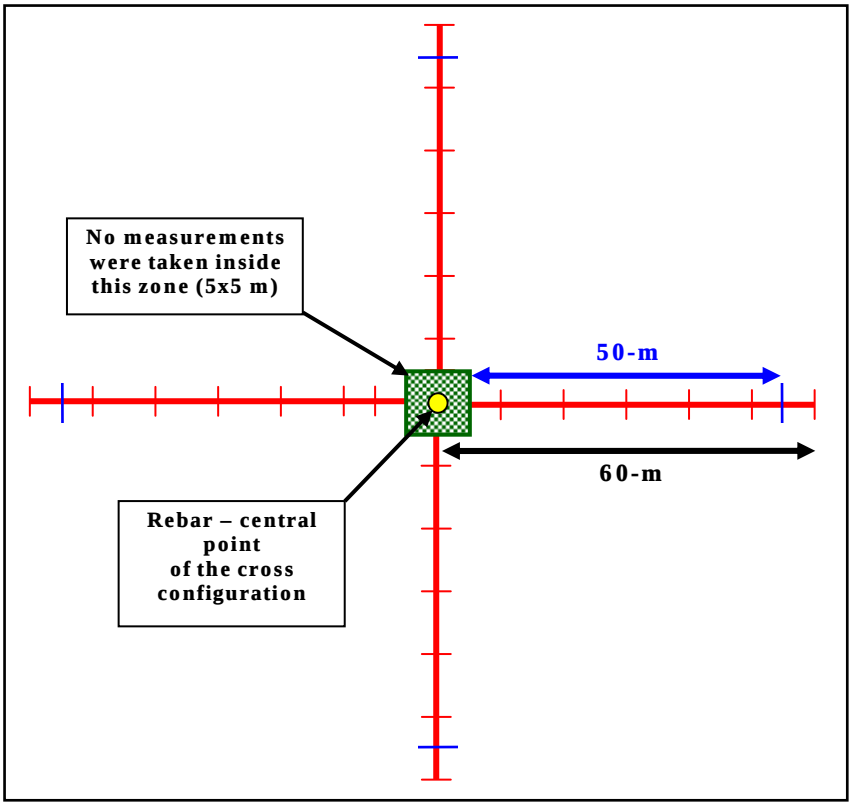


Figure 41. Details of the "cross" configuration used to sample the vegetative variables in the MRGBER study.

[1] This procedure will allow researchers and managers to return to these points in the future to facilitate monitoring activities.

Vegetative Data Collection

Table 6 below identifies the sampling techniques used to measure the individual HSI variables in the 2005 field effort. For more details regarding these protocols refer to *Appendix F*.

Table 6. Field sampling protocols summarized for the variables associated with the Bosque Riparian community index model.

Code	Variable Description	Sampling Methodology and Data Management	Cover Type Applicability
CANFORB	Canopy Cover of Forb Species (%)	Point-intercept was used to measure the numerous herbaceous canopy cover parameters (percent grass, sedge, forbs, and overall herbaceous canopy cover). To increase efficiency and considering the project goals, the field team only recorded canopy "hits" according to plant life-form (i.e., grass, forb, sedge, or rush). The only exception to this rule will be if the pin made contact with a highly desirable or undesirable plant species ("indicator species") (refer to INDICATFB, INDICATGR, INDICATHB, and NATIVESDG below). Canopy "hits" per life-form (for Type 6's) or for herbaceous canopy in general (for Types 1-5) were converted to a value of 100 and "misses" were converted to zeroes. The average of these values was then calculated per cross (100-m sample point) and the three crosses were averaged to generate a mean score per cover type.	TYPE_6T TYPE_6U TYPE_6W
CANGRASS	Canopy Cover of Grass Species (%)	Same as CANFORB above	TYPE_6T TYPE_6U TYPE_6W
CANHERB	Canopy Cover of Herbaceous Vegetation (%)	Same as CANFORB above	TYPE_1 TYPE_2T TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5
CANSEDGE	Canopy Cover of Sedge Species (%)	Same as CANFORB above	TYPE_6T TYPE_6U TYPE_6W
CANSHRUB	Canopy Cover of Shrubs (%)	Aerial cover of shrubs was recorded using a line-intercept technique. Canopy cover was measured (cm) along the line intercept transect by noting the point along the tape where the canopy began and point at which it ended based on a technique described by Elzinga et al. (1998). For this study, a minimum continuous distance along the tape for recording a shrub was set at 0.5-meters. After all line-intercept data was recorded for a plot (plot = two 50-m transects), the intercepts for each shrub species were divided by the total line length sampled (100-m) to get the percent shrub cover for each cross. The three crosses were averaged to generate a mean score per cover type.	ALL TYPES

(Continued)

Table 6. (Continued).

Code	Variable Description	Sampling Methodology and Data Management	Cover Type Applicability
CANTREE	Canopy Cover of Overstory Trees (%)	Aerial cover of trees was recorded at 2-meter intervals along each transect using a vertical densitometer. A vertical densitometer (a.k.a. "moosehorn") provided a point measure of canopy cover using a crosshairs and a bubble level that allowed the observer to determine whether canopy is present directly over a position along the transect. Species identity was noted, and used to generate the NATIVETREE values as well (see below). Canopy "hits" were converted to a value of 100 and "misses" were converted to zeroes. The average of these values was then calculated per cross (100-m sample point) and the three crosses were averaged to generate a mean score per cover type.	TYPE_1 TYPE_2T TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5
COVGRND	Ground Cover Present (%)	As with aerial herbaceous plant cover (*CANHERB* above), ground cover was measured at 2-m intervals along each transect using the point-intercept method. Ground cover was reported as one of six general categories: 1) bare soil, 2) litter (leaves or other non-living plant tissue, accept for "woody" plant material) 3) mulch (shredded woody debris created by mulching tractors), 4) live basal vegetation (the pin rests on the basal portion of a live plant), 5) downed woody vegetation <3-in. diameter (shrub or tree stem), or 6) downed woody vegetation >3-in. diameter (shrub or tree stem/log). Ground cover "hits" were converted to a value of 100 and "misses" were converted to zeroes. The average of these values was then calculated per cross (100-m sample point) and the three crosses were averaged to generate a mean score per cover type.	TYPE_1 TYPE_2T TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5
CTGRNDCOV	Count of Ground Cover Categories Present	Refer to COVGRND above, but in this instance, counts of ground cover categories were recorded. The average of these values was then calculated per cross (100-m sample point) and the three crosses were averaged to generate a mean score per cover type.	TYPE_1 TYPE_2T TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5
DEPTHOM	Depth of Organic Matter (cm)	Depth of organic matter (O-horizon) will be measured to the nearest 0.25 cm recorded at 2-m intervals along each transect. The average of these values was then calculated per cross (100-m sample point) and the three crosses were averaged to generate a mean score per cover type.	ALL TYPES

(Continued)

Table 6. (Continued).

Code	Variable Description	Sampling Methodology and Data Management	Cover Type Applicability
DISTBIGTR	Distance to Biggest Tree from Sample Point (m)	The point-centered quarter method was known to be a frequently used distance methods to sample forest communities (Bonham 1989; Cottam & Curtis 1956; Elzinga et al. 1998; Krebs 1999). After a sampling point along a transect was located (in this case, at the end of each cross arm), the area around those points was split into four 90° quadrants (quarters) and the distance to the nearest tree and root-sprout in each quarter was estimated with an optical rangefinder. The average distance for all four quadrats (cross-terminus') were calculated per cross (100-m sampling point) and the three crosses were averaged to generate a mean score per cover type.	TYPE_1 TYPE_2T TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5
INDICATFB	Percent of Forb Canopy that is an Undesirable Indicator Species (%)	The point-intercept approach was used to measure these more particular herbaceous canopy cover parameters, but the sampling team was required to record species identity when undesirable indicators or desirable species were encountered. For a list of undesirable and desirable (native) species per life-form, refer to *Appendix F*. Canopy "hits" per life-form (for Type 6's) or for herbaceous canopy in general (for Types 1-5) were converted to a value of 100 and "misses" were converted to zeroes. The average of these values was then calculated per cross (100-m sample point) and the three crosses were averaged to generate a mean score per cover type.	TYPE_6T TYPE_6U TYPE_6W
INDICATGR	Percent of Grass Canopy that is an Undesirable Indicator Species (%)	Same as INDICATFB above	TYPE_6T TYPE_6U TYPE_6W
INDICATHB	Percent of Herbaceous Canopy that is an Undesirable Indicator Species (%)	Same as INDICATFB above	TYPE_1 TYPE_2T TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5
NATIVESDG	Percent of Sedge Canopy that is a Desirable Indicator Species (%)	Same as INDICATFB above	TYPE_6T TYPE_6U TYPE_6W

(Continued)

Table 6. (Concluded).

Code	Variable Description	Sampling Methodology and Data Management	Cover Type Applicability
NATIVETREE	Percent of Tall Overstory Tree Canopy that is a Native Species (%)	The percent of the "hits" recorded as desirable (native) species under the aerial canopy protocol for trees above (CANTREE) was used to generate an average for each of the 100-m sample points (i.e., crosses), and the three crosses were averaged to generate a mean score per cover type.	TYPE_1 TYPE_2T TYPE_2U TYPE_3 TYPE_4T TYPE_4U TYPE_5
SPPCOUNT	Number of Native Tree and Shrub Species (presence/absence)	Same as NATIVETREE	ALL TYPES

Spatially Explicit Data Collection

Landscape variables were determined based on a combination of onsite reconnaissance, interpretation of maps and aerial photos, and analysis of GIS data layers using ArcGIS 9.2. The GIS information (e.g., vegetative cover, access points along the river, bike trails, kiosks, etc.) was collected by ERDC-EL from various sources including the District itself, Bernalillo County, New Mexico Resource Geographic Information System (http://rgis.unm.edu/) and the U.S. Census Bureau (http://www.census.gov/) between 2005 and 2008 (JUNE 2008). A personal geodatabase was developed to organize and house the data for quick retrieval.

June, 2005 QuickBird aerial imagery in NAD83, U.S. Survey Feet, New Mexico State Plane Central was used to complete the baseline cover type mapping exercises. The Albuquerque District was responsible for the development of *Hink and Ohmart* classification vegetation mapping (with ground-truthing) from this imagery in 2006. These maps were then digitized and converted into shapefiles with attributes including H&O Codes (C/CW,MH5 , etc.) and acreage. Any questions surrounding this information should be addressed to the Albuquerque District's Ondrea Hummel (refer to *Appendix D* for point of contact information). ERDC-EL developed expression files to crosswalk the H&O codes to the HSI cover type classifications associated with the model (TYPE_1, TYPE_2T, etc.) (*Appendix F*). Gaps and overlaps were cleaned, and cover type acreages were generated and exported to spreadsheets at the reach level for the entire study area for use in the HSI model.

The spatially-explicit landscape metrics in the Bosque Riparian HSI model is directly dependent on the cover type mapping results. ERDC-EL developed a series of protocols to calculate these parameters and incorporated their resultant shapefiles into the study's geodatabase (Table 7).[1]

[1] Contact Ondrea Hummel in the USACE Albuquerque District Office to obtain copies of the geodatabase.

Table 7. GIS sampling protocols summarized for the variables associated with the Bosque Riparian community index model.

Code	Variable Description	Sampling Methodology	Cover Type Applicability
DISTPATCH	Distance to Nearest Patch (aka Nearest Neighbor of Forest or Meadow) (m)	To calculate the distance between like patches (NEIGHBOR), a tool developed by Jeff Lin at ERDC-EL was employed (http://el.erdc.usace.army.mil/emrrp/gis.html). Step 1: Build Base files using the Individual Cover Type (dissolved) *PATCHSIZE* files developed earlier - merge these to make 1 Cover Type file containing all the like polygons across the 5 reaches. . . these will be used to calculated nearest neighbor for the baseline condition in Step 4 below. Step 2: Create 10 template files (1 per Cover Type) for each reach, by systematically clipping out each reach from the Base files (i.e., Template for Reach 1's Type_1 has all Type_1 polygons for Reach 2-5, but lacks Reach 1's). Step 3: For each alternative, merge the WP Type files from the Dissolved *PATCHSIZE* files with the Template files (10 files per alternative - 1 for each TYPE will all Reach polygons included). Step 4: Run the NearestNeighbor.py script to on each file. Step 5: Export the data from this analysis into Excel using Xtools Pro (or from the table view). Step 6: Clip out non-applicable reaches (i.e., for Plan 1-A, only use the nearest neighbor calculations for Reach 1 polygons). Step 7: Convert the nearest neighbor values from feet to meters, and average the values across the Reach for each Cover Type. To characterize/quantify changes in WOP and WP conditions based on successional trends, a "factor" was applied to the *PATCHSIZE* variables over the course of the remaining TYs to show change over time. The variable was calculated at the Landscape scale (i.e., Type 1 and New Type 1 cover types were combined as a single class for this exercise).	ALL TYPES

(Continued)

Table 7. (Continued).

Code	Variable Description	Sampling Methodology	Cover Type Applicability
PATCHSIZE	Size of Patch (ac)	Step 1: Select by attribute the target cover type and export it as separate shape file for that cover type. Step 2: Using the Dissolve tool, edit the file, and select all target features (this must be done at the Reach level - i.e., dissolve on Reach ID). Step 3: Explode these (using the explode multipart feature tool) to ensure that multiple, separate polygons aren't being misrepresented by what appears as a single feature in the attribute table which is in reality a merged multipart feature. Step 4: Recalculate the acres after this step (using Xtools pro or the VBA code for calculating area while in editor). Step 5: Export the data as a database file from the attribute table view or into Excel using Xtools Pro. Step 6: Patch size for bosque cover types were calculated by reach by dividing the total area of these cover types by the number of patches (polygons) within each reach. To characterize/quantify changes in WOP and WP conditions based on successional trends, a "factor" was applied to the *PATCHSIZE* variables over the course of the remaining TYs to show change over time. The variable was calculated at the Landscape scale (i.e., Type 1 and New Type 1 covertypes were combined as a single class for this exercise). All polygons smaller than 0.05 acres were merged with the nearest polygon using ArcGIS's "Eliminate" tool.	ALL TYPES

(Continued)

Table 7. (Concluded).

Code	Variable Description	Sampling Methodology	Cover Type Applicability
TYPDISTURB	Type of Human Disturbance (aka Adjacent Landuse Within 2 km)	Step 1: Open the individual Reach shapefiles and use the ArcGIS Buffer Wizard to draw 2-km buffers around each Reach Step 2: Merge these buffer files, and clip the Land Use/Land Cover (LULC) file (to reduce processing) Step 3: Reclassified the Clipped LULC file based on the 5 Disturbance Types (1 Commercial/Industrial, 2 Residential, 3 Right of Ways and Railroads, 4 Agricultural Crops and Pastures, 5 Pristine, uninhabited areas) Step 4: Add 2 fields, 1 for the HEP Code and the HEP Description of these Disturbance types Step 5: X-walk the LULC descriptions and the HEP descriptions/codes (either in *.xls or using expression files and attribute selection) Step 6: Eliminate any "unknown" polygons, and recalculate the area of the shapefile (using XTools) Step 7: Open the 10-1-7 Reach Map, select the area under the reach, use the calculator to reclassify all these areas as "natural" category 5 Step 8: Erase file from Step 6 with file from Step 7 Step 9: Merge file from Step 8 with file from Step 7, Add a field called "Reach" Step 10: Clip the Step 9 file with the individual reach buffer files in Step 1, and fill in the Reach number with the Calculator Step 11: Recalculate the area and export to excel (using XTools) Step 12: Sum the acres by category and determine the category with the most acres (proportionately) To characterize/quantify changes in WOP and WP conditions, assumed that residential/commercial would remain, and that 10% of the agricultural croplands would be lost to development each target year. The variable was calculated at the Landscape scale at the Reach level (i.e., all types in the reach are assigned the same value).	ALL TYPES

Hydrologic Data

The hydrological information presented in (Table 8) below was generated by the Steve Boberg and Ondrea Hummel in the Albuquerque District and provided to ERDC-EL in response to a request for assessment methodology and documentation. Any questions surrounding this information should be addressed to her (refer to *Appendix D* for point of contact information.

Table 8. Hydrologic data sampling protocols summarized for the variables associated with the Bosque Riparian community index model.

Code	Variable Description	Sampling Methodology	Cover Type Applicability
DEPTHGW	Depth To Groundwater (ft)	Depth to groundwater was taken at each reference site if a well was within that patch. If a well was not within that patch, the nearest known well was used. Data was obtained for the date closest to the field sampling date from wells being monitored by the Corps, U.S. Forest Service, and BEMP (Bosque Ecosystem Monitoring Program).	ALL TYPES
DURATION	Average Duration Of Flooding Events (days)	Flood duration defines the amount of time that a specific flood frequency will meet or exceed a given discharge or flow rate. Flood duration is typically defined in either hours or days. For this study the flood duration is defined as the number of days a specific flood frequency exceeds 3,000 cfs. The flood durations for the three flood frequencies considered for this study are as follows: Discharge Flood Frequency # days > 3,000 cfs 21 day duration flow** 3,770 cfs 70% 30 days 3500, cfs 6,500 cfs 31% 51 days 5460 cfs 10,000 cfs 4% 65 days 8230 cfs	ALL TYPES
FLOODFREQ	Frequency Of Flooding (#/yr)	Flood Frequency relates the magnitude of discharge to the probability of occurrence or exceedance. Discharge or flow rate is typically given in cubic feet per second (cfs). Probability is given as the likelihood of a particular event occurring in a given year. Therefore, the event commonly called "the 100 year storm" is given a flood frequency of 0.01 or 1% since that is the likelihood that it will occur in any given year. The flood frequencies being considered for this study are as follows: Discharge Flood Frequency Return Period Comment 3,770 cfs 70% 1.42 years Average Annual Hydrograph 6,500 cfs 31% 3.25 years Bank Full Hydrograph 10,000 cfs 4% 23.6 years Future Target Release	ALL TYPES
WETTEDAREA	Percent Of Polygon That Is Wet (%)	The wetted area is defined as that area in the Bosque located between the active channel bank-line and the levee that is inundated during flooding events. This area is known as the over-bank and is the area where the inventoried sites are located. For any given reach of the Rio Grande there are two over-bank areas, the left over-bank (LOB) and the right over-bank (ROB) defined from looking downstream. For this project the LOB is on east side of the Rio Grande and the ROB is on the west side of the Rio Grande. The wetted area is that area of the over-bank that would be flooded from "over-banking" of active channel flows in the Rio Grande during a given Flood Frequency. The Wetted Area for the individual inventoried sites will be given in percent of area within the site that is inundated or wetted. The wetted areas were determined primarily by the use of the FLO-2D hydraulic model and verified by the HEC-RAS hydraulic model. In some areas of the Corrales reach the HEC-RAS hydraulic model only was used since this area was outside of the FLO-2D analysis limits.	ALL TYPES

HSI Statistical Analysis and Curve Calibrations

The reference condition described earlier defined the measurement scale and the state toward which the E-Team desired to move the system. In the case of the MRGBER project, the reference-based approach employed "reference standard ecosystems" to establish optimal conditions (HSI = 1.0) that served as benchmarks or standards of comparison for the existing and future conditions. Locating "degraded" reference sites was essential to calibrating the model. These "degraded" reference conditions represented the other end of the measurement scale and represented the ecological systems that were clearly degraded and socially unacceptable (HSI – 0.0). We refer to this process as "calibration," which we define here loosely as the use of known (reference) data on the observed relationship between a dependent variable and an independent variable to make estimates of other values of the independent variable from new observations of the dependent variable.

To calibrate the models, we used the average values across the watershed and their associated standard deviations to generate a curve for each variable in each model. We calculated these statistics on both a "cover type-by-cover type" basis, as well as at the broader reach and watershed scales. To develop curves for each variable, ERDC used a straightforward assignment process. The watershed mean was assigned a **0.75** SI value in every case. The standard deviation of the mean was added to the average, and this total was assigned a **1.0** SI on the curve (Figure 42).

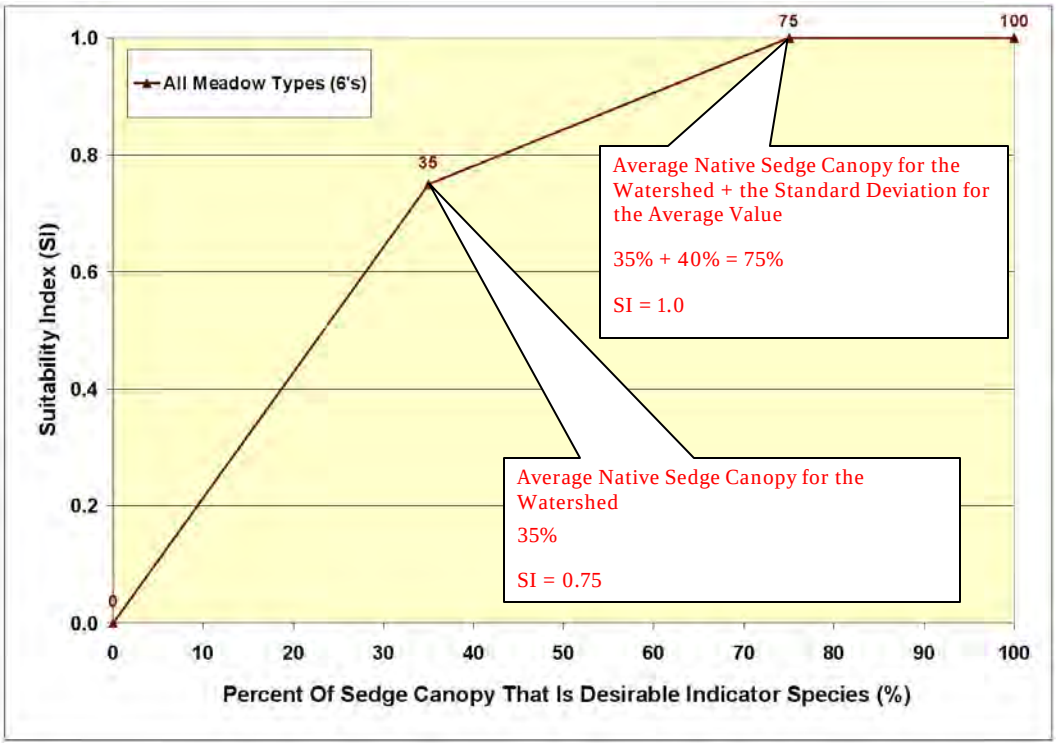


Figure 42. Example of curve calibration method using the reference mean and its standard deviation.

In most instances, the E-Team made the decision to calibrate the curve on the basis of cover type distinctions. For example, the E-Team reviewed the individual cover type means and made the decision that TYPE 1 and TYPE 3 cover types have significantly lower levels of herbaceous canopy cover than rest of the watershed's cover types. As a result, they chose to create two curves - one for each unique setting (Figure 43).

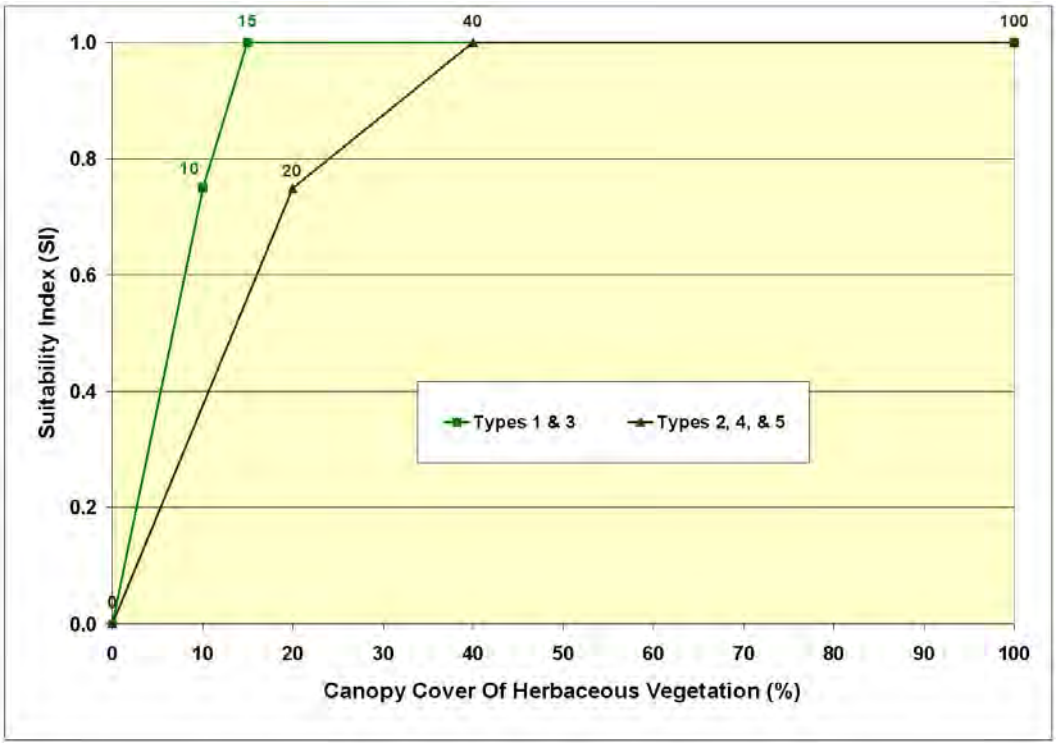


Figure 43. The model calibration approach was flexible enough to encourage and incorporate professional expertise into the methodology. Here, the reference data support the separation of cover types based on mean data. Type 1 and 3 classes have significantly higher tree canopy cover, shading out the herbaceous layers closer to the ground. As a result, the HSI model was calibrated to capture this unique feature.

Ultimately, the curves developed for the watershed were the result of an iterative process where the E-Team directed ERDC-EL to gradually modify the curves to better reflect reality as they perceived it "in-the-field." ERDC-EL made a conscious effort to fully document these changes, and curves that have been altered from the means and standard deviations as a result of "expert judgment" are presented as "red" curves in the graphs and supporting text (Figure 44).

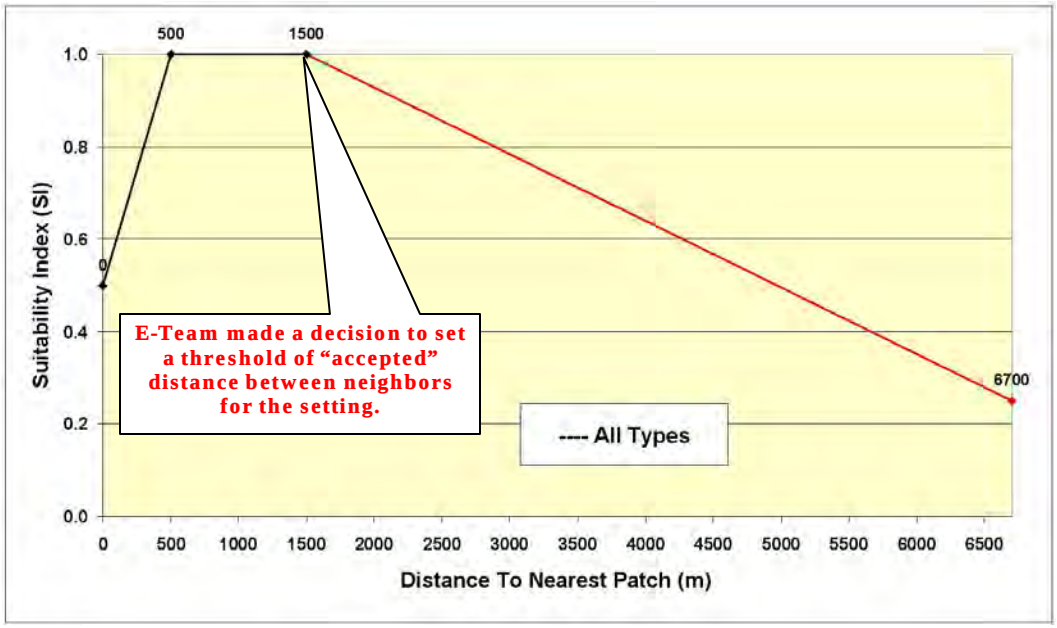


Figure 44. Example of curve calibration method using a combination of watershed means, standard deviations and expert opinion.

To review the final curves for the Bosque Riparian HSI model, refer to *Appendix E*.

Model Results

Because the community-based index model for Middle Rio Grande bosque was developed to operate on a larger, watershed scale, it was important to test their veracity of the tool at the reach level[1] (Figure 45).

[1] Testing here refers to model verification or "the act of reviewing, inspecting, testing, etc. to establish and document that a product, service, or system meets the regulatory, standard, or specification requirements."

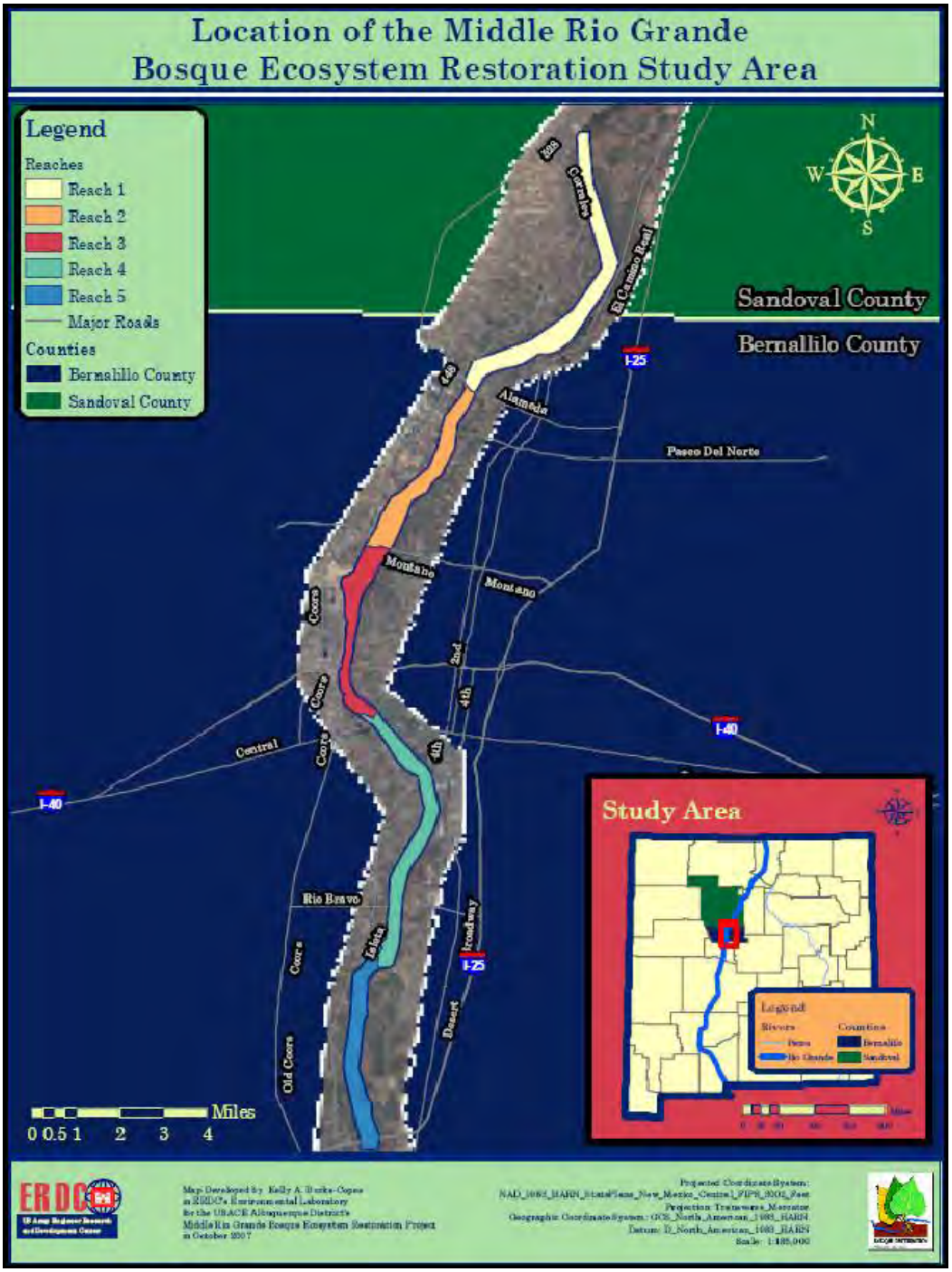


Figure 45. Reaches delineated for the baseline HSI assessment of the MRGBER study

To do this, the individual reference site field data collected between 2005 and 2008 was compiled on a reach-by-reach basis. Data for each variable

per cover type within the community were recorded and the variable means/modes were calculated to generate watershed baseline HSIs at the reach level.[1] Twenty three variables were measured according to the sampling protocols described above at the reference sites for the bosque community. The means for each variable are summarized in Table 9 below.

[1] GIS shapefiles and associated datasets are available upon request - contact the District POC (Ondrea Hummel, contact information can be found in *Appendix D*).

Table 9. Baseline data for the five reaches used to verify the bosque riparian HSI model.

Reach	Cover Type	BASALAREA	CANFORB	CANGRASS	CANHERB	CANSEDGE	CANSHRUB	CANTREE	COVGRND	CTGRNDCOV	DEPTHGW	DEPTHOM	DISTBIGTR	DISTPATCH	DURATION	FLOODFREQ	INDICATFB	INDICATGR	INDICATHB	NATIVESDG	NATIVETREE	PATCHSIZE	SPPCOUNT	TYPDISTURB	TYPEPATCH	WETTEDAREA
1	1	45			15		10	90	95	1	6.0	4.5	6.5	190	0	0			15		80	20.5	5	6	2	0
	2T	20			25		0	90	95	1	3.5	3.5	8.5	15	0	0			40		95	18.0	7	2	2	0
	2U	20			50		0	90	100	1	6.0	2.5	5.0	0	0	0			20		70	24.5	5	7	2	0
	3	45			20		10	65	100	1	5.5	7.0	11.0	555	0	0			15		35	11.5	3	4	2	0
	4T	20			40		0	65	80	1	7.0	2.0	14.0	75	0	0			10		90	17.0	7	6	2	0
	4U	25			15		10	35	65	1	7.5	1.5	8.5	770	0	0			0		60	5.0	3	6	2	0
	5	35			30		15	30	90	1	4.5	2.5	14.0	25	0	0			40		15	3.5	5	6	2	0
	6T		15	20		0	5				5.0			150	0	0	20	35		0		10.0	5	5	2	0
	6U		0	10		0	30				6.0			105	0	0	0	0		0		8.0	5	4	2	0
	6W		25	15		20	50				6.5			315	20	1	0	0		60		5.0	4	8	2	100
2	1	65			0		35	85	80	1	8.0	3.5	7.5	535	0	0			0		100	6.0	3	4	2	0
	2T	30			55		0	100	95	1	3.5	3.5	8.0	50	0	0			45		95	19.0	12	2	2	0
	2U	35			20		0	90	95	1	4.5	3.5	6.5	115	0	0			5		65	18.0	4	6	2	0
	3	65			10		5	80	95	1	8.5	3.5	8.5	345	0	0			30		40	5.0	3	4	2	0
	4T	20			35		0	50	60	1	9.0	2.0	16.5	60	0	0			5		95	16.0	7	5	2	0
	4U	30			20		5	35	70	1	6.0	1.5	9.0	545	0	0			0		60	10.0	3	6	2	0
	5	35			30		15	30	90	1	4.5	2.5	14.0	25	0	0			40		15	3.5	5	6	2	0
	6T		15	20		0	5				5.0			150	0	0	20	35		0		10.0	5	5	2	0
	6U		5	15		5	45				4.5			135	0	0	0	0		60		5.5	5	5	2	0
	6W		20	10		20	35				6.0			210	15	0	0	0		40		11.5	3	8	2	65

Note: Blank cells indicate the variable was not associated with the particular cover type and therefore were not sampled therein.

(Continued)

Table 9. (Continued).

Reach	Cover Type	BASALAREA	CANFORB	CANGRASS	CANHERB	CANSEDGE	CANSHRUB	CANTREE	COVGRND	CTGRNDCOV	DEPTHGW	DEPTHOM	DISTBIGTR	DISTPATCH	DURATION	FLOODFREQ	INDICATFB	INDICATGR	INDICATHB	NATIVESDG	NATIVETREE	PATCHSIZE	SPPCOUNT	TYPDISTURB	TYPEPATCH	WETTEDAREA
3	1	35			30		0	95	100	1	5.5	3.5	6.0	0	0	0			0		45	30.5	5	8	2	0
	2T	10			0		0	90	100	1	2.0	5.0	8.5	0	0	0			0		85	23.5	5	1	2	0
	2U	35			15		0	85	90	1	3.5	3.5	6.0	235	0	0			0		50	15.0	4	6	2	0
	3	50			10		10	65	100	1	5.5	7.0	11.0	555	0	0			15		35	11.5	3	4	2	0
	4T	15			65		0	75	90	1	5.5	2.0	11.0	165	0	0			10		100	16.5	5	8	2	0
	4U	30			20		5	35	70	1	6.0	1.5	9.0	545	0	0			0		60	10.0	3	6	2	0
	5	25			30		10	10	100	1	2.5	5.0	16.5	0	0	0			65		0	3.0	8	6	2	0
	6T		15	20		0	5				5.0			150	0	0	20	35		0		10.0	5	5	2	0
	6U		5	15		5	45				4.5			135	0	0	0	0		60		5.5	5	5	2	0
	6W		15	5		25	5				5.0			0	0	0	0	0		0		23.5	2	7	2	0
4	1	45			15		10	90	95	1	6.0	4.5	6.5	190	0	0			15		80	20.5	5	6	2	0
	2T	20			25		0	90	95	1	3.5	3.5	8.5	15	0	0			40		95	18.0	7	2	2	0
	2U	50			0		0	100	100	1	4.0	4.0	8.0	0	0	0			0		90	19.5	5	4	2	0
	3	45			10		10	65	100	1	5.5	7.0	11.0	555	0	0			15		35	11.5	3	4	2	0
	4T	25			25		0	65	90	1	7.0	2.0	14.5	0	0	0			15		80	18.5	8	4	2	0
	4U	45			30		0	40	85	1	6.0	1.5	9.0	545	0	0			5		70	18.5	3	7	2	0
	5	35			30		15	30	90	1	4.5	2.5	14.0	25	0	0			40		15	3.5	5	6	2	0
	6T		15	20		0	5				5.0			150	0	0	20	35		0		10.0	5	5	2	0
	6U		15	35		10	70				6.0			105	0	0	0	5		85		4.0	4	4	2	0
	6W		20	10		20	35				6.0			210	15	0	0	0		40		11.5	3	8	2	65

Note: Blank cells indicate the variable was not associated with the particular cover type and therefore were not sampled therein.

(Continued)

Table 9. (Concluded).

Reach	Cover Type	BASALAREA	CANFORB	CANGRASS	CANHERB	CANSEDGE	CANSHRUB	CANTREE	COVGRND	CTGRNDCOV	DEPTHGW	DEPTHOM	DISTBIGTR	DISTPATCH	DURATION	FLOODFREQ	INDICATFB	INDICATGR	INDICATHB	NATIVESDG	NATIVETREE	PATCHSIZE	SPPCOUNT	TYPDISTURB	TYPEPATCH	WETTEDAREA
5	1	40			10		0	95	100	1	5.0	6.5	5.5	35	0	0			50		90	25.5	8	7	2	0
	2T	15			20		0	80	95	1	5.5	2.5	9.5	0	0	0			80		100	11.5	3	4	2	0
	2U	35			20		0	90	95	1	4.5	3.5	6.5	115	0	0			5		65	18.0	4	6	2	0
	3	30			0		0	100	100	1	5.5	14.5	7.5	1530	0	0			0		60	30.5	3	7	2	0
	4T	20			40		0	65	80	1	7.0	2.0	14.0	75	0	0			10		90	17.0	7	6	2	0
	4U	30			20		5	35	70	1	6.0	1.5	9.0	545	0	0			0		60	10.0	3	6	2	0
	5	40			30		20	45	90	1	5.5	1.5	13.0	40	0	0			25		25	5.0	4	6	2	0
	6T		15	20		0	5				5.0			150	0	0	20	35		0		10.0	5	5	2	0
	6U		0	0		0	35				1.5			190	0	0	0	0		100		4.5	5	8	2	0
	6W		20	10		20	35				6.0			210	15	0	0	0		40		11.5	3	8	2	65

Note: Blank cells indicate the variable was not associated with the particular cover type and therefore were not sampled therein.

The results of the baseline HEP assessment for the reaches are summarized below. HSIs capture the quality of the acreage within the reach. Units (i.e., HUs) take this quality and apply it to the governing area through multiplication (Quality X Quantity = Units). Both HSIs and HUs are reported for each reach. Interpretations of these findings can be generalized in the following manner (Table 10).

Table 10. Interpretation of HSI scores resulting from HEP assessments.

HSI 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) - 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

In most instances, the individual component indices (aka Life Requisite Suitability Indices or LRSIs) and composite HSIs scored in the mid-range of values (<0.5) indicating only a moderate level of functionality in the study area (Table 11 and Figure 46).[1] The highest functioning reach was Reach 1 (HSI = 0.50). This was to be expected – the last vestiges of undisturbed bosque are found in this area. Not surprisingly, 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. These areas were also targeted for moderate to heavy fire prevention, and as such, their understorys had incurred significant impacts.

[1] Data are available upon request - contact the District POC (Ondrea Hummel, contact information can be found in *Appendix D*).

Table 11. Baseline tabular results for the bosque riparian community.

Reach Name	LRSI Code	LRSI Score	Habitat Suitability Index (HSI)	Applicable Acres	Baseline Habitat Units (HUs)
Reach 1	RIP-BIOINTEG	0.41	0.50	1090	541
	RIP-SPATIAL	0.76			
	RIP-HYDRO	0.32			
Reach 2	RIP-BIOINTEG	0.39	0.40	561	225
	RIP-SPATIAL	0.54			
	RIP-HYDRO	0.28			
Reach 3	RIP-BIOINTEG	0.38	0.41	502	206
	RIP-SPATIAL	0.59			
	RIP-HYDRO	0.26			
Reach 4	RIP-BIOINTEG	0.41	0.42	726	307
	RIP-SPATIAL	0.53			
	RIP-HYDRO	0.33			
Reach 5	RIP-BIOINTEG	0.37	0.48	616	296
	RIP-SPATIAL	0.75			
	RIP-HYDRO	0.33			

If we compare the proposed restoration initiatives to a “virtual” reference conditions (HSI = 1.0), we find that the reaches are functioning at approximately 40 to 50 percent of the maximum potential. Clearly, there are opportunities for improvements – in other words, all the reaches are prime candidates for restoration/rehabilitation activities in terms of the bosque community’s structure and functionality.

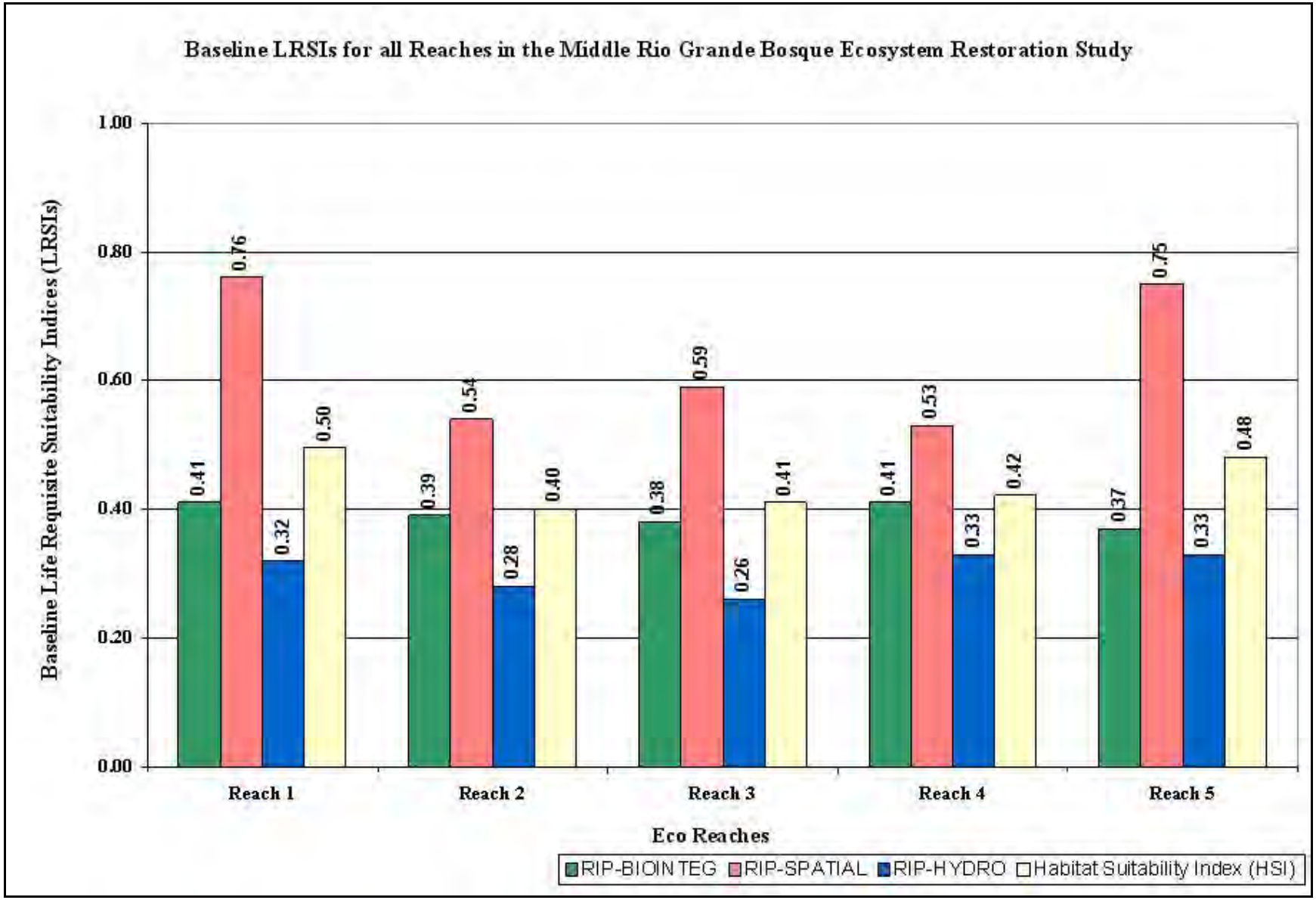


Figure 46. Baseline graphical results for the bosque community.

Model Verification

The first test of the model was to assess the various references sites (both optimal and sub-optimal) with the formulas and curves and determine whether the model "relating to reality" with respect to the E-Team's expectations. We consider this step to be model verification:

> ***Verification*** *(aka Confirmation) is the comparison of the model output to data from well-known, published test cases to confirm that the algorithms and computer code accurately represent system dynamics.*[1]

For purposes of this effort, *verification* asks whether the model is responding as they experts believe it should. Sites deemed to be highly functional wetlands according to experts, should produce high HSI scores. Sites deemed dysfunctional (by the experts) should produce low HSI scores. Again, the model calibration effort described above was an iterative process, and as such, changes to the model's curves and algorithms were made in an attempt to bring these results as close to the expected outcome as possible. Admittedly, this process was somewhat subjective. But the experts working on the process were the best in the region, and where possible, actual reference conditions and/or historical data sets and literature-based studies were used to refine the model throughout the process. Below, we provide both the E-Team's expectation of reference site condition (i.e., **High**, **Medium**, or **Low**), and provide the results of the final iteration of model calibration (Table 12 and Table 13).

[1] Personal communication regarding American Society of Civil Engineers' definitions with Dr. John Nestler, ERDC-EL, August 2009

Table 12. Baseline results for the Bosque Riparian HSI assessment of the reference sites.

Reach	Reference Site	Site No.	Cover Type	Model Components			Habitat Suitability Index (HSI)
				RIP-BIOINTEG	RIP-SPATIAL	RIP-HYDRO	
Reach 1	Corrales	28	TYPE_2U	0.32	0.00	0.00	0.11
	Corrales	29	TYPE_6W	0.64	0.68	0.91	0.74
	Corrales	30	TYPE_6W	0.48	0.00	0.75	0.41
	Corrales	33	TYPE_4U	0.34	0.30	0.00	0.21
	Alameda	34	TYPE_4U	0.41	0.29	0.00	0.23
	Alameda NE	36	TYPE_6U	0.24	0.21	0.00	0.15
Reach 2	Paseo NE	1	TYPE_1	0.48	0.23	0.00	0.24
	Paseo NE	2	TYPE_3	0.41	0.23	0.00	0.21
	Paseo NE	3	TYPE_6T	0.19	0.12	0.00	0.10
	Paseo SE	4	TYPE_4T	0.29	0.31	0.00	0.20
	Paseo SE	5	TYPE_3	0.23	0.28	0.00	0.17
	Paseo SW	6	TYPE_2T	0.34	0.19	0.00	0.18
	La Orilla N	7	TYPE_6T	0.34	0.45	0.00	0.26
	La Orilla S	8	TYPE_6T	0.19	0.00	0.00	0.06
Reach 3	Oxbow N	9	TYPE_5	0.43	0.00	0.00	0.14
	Oxbow M	10	TYPE_6W	0.21	0.00	0.00	0.07
	Oxbow S	11	TYPE_2U	0.26	0.16	0.00	0.14
	RGNC N	12	TYPE_2U	0.41	0.00	0.00	0.14
	RGNC S	13	TYPE_4T	0.47	0.75	0.00	0.40
	RGNC W	14	TYPE_1	0.36	0.00	0.00	0.12
	Montano SW	15	TYPE_2T	0.31	0.00	0.00	0.10
Reach 4	Bridge SW	16	TYPE_4T	0.44	0.00	0.00	0.15
	AOP	17	TYPE_2U	0.32	0.00	0.00	0.11
	Rio Bravo NE	18	TYPE_4U	0.45	0.52	0.00	0.32
	Tingley Bar	35	TYPE_6U	0.66	0.15	0.00	0.27
Reach 5	Harrison levee	20	TYPE_1	0.37	0.00	0.00	0.12
	Harrison bar	21	TYPE_6U	0.18	0.47	0.00	0.22
	SDC North levee	22	TYPE_2T	0.23	0.00	0.00	0.08
	SDC North river	23	TYPE_5	0.45	0.00	0.00	0.15
	SDC South	24	TYPE_5	0.35	0.25	0.00	0.20
	Price's Dairy	26	TYPE_3	0.36	0.71	0.00	0.36

Table 13. Comparison of the baseline reference results to the E-Team's expectation of reference conditions.

Reach	Reference Site	Site No.	Cover Type	Model Components			Habitat Suitability Index (HSI)	Expected Value (E-Team Estimated)
				RIP-BIOINTEG	RIP-SPATIAL	RIP-HYDRO		
Reach 1	Corrales	28	TYPE_2U	Low	Low	Low	Low	High
	Corrales	29	TYPE_6W	High	High	High	High	High
	Corrales	30	TYPE_6W	Medium	Low	High	Medium	High
	Corrales	33	TYPE_4U	Medium	Medium	Low	Low	Low
	Alameda	34	TYPE_4U	Medium	Medium	Low	Low	Medium
	Alameda NE	36	TYPE_6U	Low	Medium	Low	Low	Medium
Reach 2	Paseo NE	1	TYPE_1	Medium	Medium	Low	Low	High
	Paseo NE	2	TYPE_3	Medium	Medium	Low	Low	High
	Paseo NE	3	TYPE_6T	Low	Medium	Low	Low	Low
	Paseo SE	4	TYPE_4T	Low	Medium	Low	Low	Medium
	Paseo SE	5	TYPE_3	Low	Medium	Low	Low	Medium
	Paseo SW	6	TYPE_2T	Medium	Medium	Low	Low	Medium
	La Orilla N	7	TYPE_6T	Medium	Medium	Low	Low	Medium
	La Orilla S	8	TYPE_6T	Low	Low	Low	Low	Medium
Reach 3	Oxbow N	9	TYPE_5	Medium	Low	Low	Low	Low
	Oxbow M	10	TYPE_6W	Low	Low	Low	Low	Medium
	Oxbow S	11	TYPE_2U	Low	Medium	Low	Low	Medium
	RGNC N	12	TYPE_2U	Medium	Low	Low	Low	Medium
	RGNC S	13	TYPE_4T	Medium	High	Low	Medium	Medium
	RGNC W	14	TYPE_1	Medium	Low	Low	Low	Low
	Montano SW	15	TYPE_2T	Low	Low	Low	Low	Medium
Reach 4	Bridge SW	16	TYPE_4T	Medium	Low	Low	Low	Medium
	AOP	17	TYPE_2U	Low	Low	Low	Low	Medium
	Rio Bravo NE	18	TYPE_4U	Medium	Medium	Low	Low	Medium
	Tingley Bar	35	TYPE_6U	High	Medium	Low	Low	High
Reach 5	Harrison levee	20	TYPE_1	Medium	Low	Low	Low	Medium
	Harrison bar	21	TYPE_6U	Low	Medium	Low	Low	High
	SDC North levee	22	TYPE_2T	Low	Low	Low	Low	Low
	SDC North river	23	TYPE_5	Medium	Low	Low	Low	High
	SDC South	24	TYPE_5	Medium	Medium	Low	Low	Low
	Price's Dairy	26	TYPE_3	Medium	High	Low	Low	Medium

As a simple test of the veracity of the models and the expert's opinions of the reference site conditions was performed using a correlation analysis. (Figure 47).

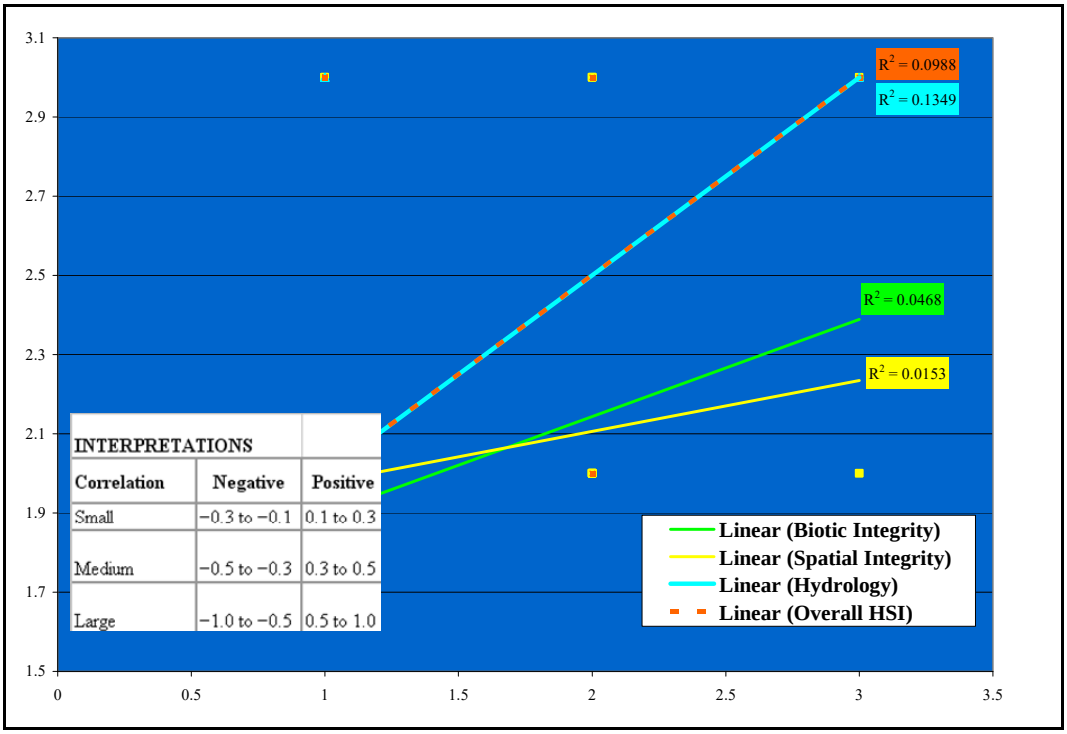


Figure 47. A Pearson's correlation of expert team's opinion of site functionality and the HEP results indicate that they are positively related to some degree.

The most common measure of correlation is the Pearson Product Moment Correlation (aka Pearson's correlation).[1] The Pearson correlation values range from +1 to -1. A rule-of-thumb interpretation of the Pearson's correlation is found in the corner of Figure 47 above. Based on this analysis, we can demonstrate that the model is moderately correlated to expert opinion regarding site conditions, and therefore can be said to pass the test of "verification" (Pearson correlation value = 0.31). Because the area is suffering from severe alterations of the natural hydrologic regime, there are no sites within the reference domain functioning at the expected optimal levels, the E-Team felt it was still reasonable to assume that the

[1] Background information was retrieved from http://en.wikipedia.org/wiki/Pearson_product-moment_correlation_coefficient and http://davidmlane.com/hyperstat/A34739.html (SEPTEMBER 2008).

model offered a solid, scientifically driven means to characterizing conditions and assessing alternative plans. So for now, the E-Team has agreed that the reference sites were functioning at a reasonable level of expectation and as such the model calibrations were deemed acceptable.

Model Validation

To date the Bosque (Riparian) community index model has not been validated. We define model validation here as:

> ***Validation*** *is accomplished by establishing an objective yet independent line of evidence that the model specifications conform to the user's needs and intended use(s). The validation process questions whether the model is an accurate representation of the system based on independent data not used to develop the model in the first place. Validation can encompass all of the information that can be verified, as well as all of the things that cannot -- i.e., all of the information that the model designers might never have anticipated the user might want or expect the product to do.* [1]

For purposes of this effort, *validation* refers to independent data collections (bird surveys, water quality surveys, etc.) that can be compared to the model outcomes to determine whether the model is capturing the essence of the ecosystem's functionality. As independent measures of function for the model herein, we propose three options or directions to consider as future research opportunities:

1. A few "relevant" HSI Blue Book (species) models could be used to assess the baseline conditions of the area comparing their outputs to the community models' outputs. As these are already "approved" for use under the USACE model certification program, their outputs should provide relevant cross-validation. However, as most of the HSI Blue Books lack validation, this approach may not be appropriate either. And again, as the

[1] Personal communication regarding American Society of Civil Engineers' definitions with Dr. John Nestler, ERDC-EL, August 2009

Blue Book models are designed to measure only limiting "life requisites" of these key species, they might not be inclusive enough to capture community function and processes.

2. An extremely expensive and time consuming approach could be undertaken to assess biodiversity (both species richness and diversity) in an attempt to identify an "independent measure of function." However, to validate the communities modeled herein, a majority of the faunal groups present would need to be surveyed (mammals, birds, fish, reptiles, amphibians, plants, and possibly even insects). This in turn leads to the question, if we had time and funds to do this level of inventory, why use models at all?
3. Alternatively, validation of the models could potentially be accomplished by assessing patch dynamics using transition model at a landscape scale (Acevedo et al. 1995). Again, this would be validating models with models which might not be considered a true validation exercise.

5 Summary and Conclusions

The implications of this report's findings are rather straightforward. First, the results support the conceptual premise surrounding the HSI model and indicate its representative capabilities. In other words, scientific literature characterizing the state of the bosque ecosystems along the middle Rio Grande point to an overall decline in ecosystem integrity (i.e., health, biodiversity, stability, sustainability, naturalness, wildness, and beauty) – a finding the model can now verify and quantify (we found less than optimal HSI scores in all reaches). Furthermore, the results indicate an opportunity to redress ongoing losses. There is great potential to restore sustainable bosque communities therein, offering a significant positive return on investment to both the stakeholders and the federal government.

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Appendix A: Notation

AAHU	Average Annual Habitat Unit
AOSD	City of Albuquerque Open Space Division
BOR	Bureau of Reclamation
CT	Cover Type
EA	Environmental Assessment
EC	Engineering Circular
ERDC-EL	Engineer Research and Development Center, Environmental Laboratory
ESM	Ecological Service Manual
E-Team	Ecosystem Assessment Team
EXHEP	EXpert Habitat Evaluation Procedures Module
EXHGM	EXpert Hydrogeomorphic Approach to Wetland Assessments Module
GIS	Geographic Information System
HEAT	Habitat Evaluation and Assessment Tools
HEP	Habitat Evaluation Procedures
HGM	Hydrogeomorphic Wetland Assessment
HSI	Habitat Suitability Index
HU	Habitat Unit
ISC	Interstate Stream Commission
IWR	Institute for Water Resources
LRSI	Life Requisite Suitability Index
LPDT	Laboratory-based Project Delivery Team
LTR	Laboratory-based Technical Review
LTRT	Laboratory-based Technical Review Team
LULC	Land Use/Land Cover
MCDA	Multi Criteria Decision Analysis
MRGBER	Middle Rio Grande Bosque Ecosystem Restoration Feasibility Study
MRGCD	Middle Rio Grande Conservancy District
NER	National Ecosystem Restoration Plan
NEPA	National Environmental Policy Act
NHNM	Natural Heritage New Mexico

NMDGF	New Mexico Department of Game and Fish
NMSFD	New Mexico State Forestry Division
NRC	National Research Council
PMIP	USACE Planning Models Improvement Program
RMRS	Rocky Mountain Research Station
RA	Relative Area
SI	Suitability Index
SWCD	Ciudad Soil and Water Conservation District
TY	Target Year
UNM	University of New Mexico
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WOP	Without-project Condition
WP	With-project Condition

Appendix B: Glossary

Activity

The smallest component of a management measure that is typically a nonstructural, ongoing (continuing or periodic) action in USACE planning studies (Robinson, Hansen, and Orth 1995).

Alternative (aka Alternative Plan, Plan, or Solution)

An alternative can be composed of numerous management measures that in turn are comprised of multiple features or activities. Alternatives are mutually exclusive, but management measures may or may not be combinable with other management measures or alternatives (Robinson, Hansen, and Orth 1995).

In HEP analyses, this is the "With-project" condition commonly used in restoration studies. Some examples of Alternatives include:

Alternative 1: Plant food plots, increase wetland acreage by 10 percent, install 10 goose nest boxes, and build a fence around the entire site.

Alternative 2: Build a dam, inundate 10 acres of riparian corridor, build 50 miles of supporting levee, and remove all wetlands in the levee zone.

Alternative (cont)	*Alternative 3: Reduce the grazing activities on the site by 50 percent, replant grasslands (10 acres), install a passive irrigation system, build 10 escape cover stands, use 5 miles of willow fascines along the stream bank for stabilization purposes.*
Assessment Model	A simple mathematical tool that defines the relationship between ecosystem/landscape scale variables and either functional capacity of a wetland or suitability of habitat for species and communities. Habitat Suitability Indices are examples of assessment models that the **HEAT** software can be used to assess impacts/benefits of alternatives.

Average Annual Habitat Units (AAHUs)

A quantitative result of annualizing Habitat Unit (HU) gains or losses across all years in the period of analysis.

AAHUs = Cumulative HUs ÷ Number of years in the life of the project (aka period of analysis), where:

Cumulative HUs =

$$\sum (T2 - T1)[\{((A1\ H1 + A2\ H2) / 3)\} + \{((A2\ H1 + A1\ H2) / 6)\}]$$

and where:

T1 = First Target Year time interval
T2 = Second Target Year time interval
A1 = Area of available wetland assessment area at beginning of T1
2 = Area of available wetland assessment area at end of T2
H1 = HSI at beginning of T1
H2 = HSI at end of T2.

Baseline Condition (aka Existing Conditions)

The point in time before proposed changes are implemented in habitat assessment and planning analyses. Baseline is synonymous with Target Year (TY = 0).

Blue Book In the past, the USFWS was responsible for publishing documents identifying and describing HSI models for numerous species across the nation. Referred to as "Blue Books" in the field, due primarily to the light blue tint of their covers, these references fully illustrate and define habitat relationships and limiting factor criteria for individual species nationwide. Blue Books provide: HSI Models, life history characteristics, SI curves, methods of variable collection, and referential material that can be used in the application of the HSI model in the field. For copies of Blue Books, or a list of available Blue Books, contact your local USFWS office.

Calibration The use of known (reference) data on the observed relationship between a dependent variable and an independent variable to make estimates of other values of the independent variable from new observations of the dependent variable.

Combined NED/NER Plan (Combined Plan) Plans that produce both types of benefits such that no alternative plan or scale has a higher excess of NED plus NER benefits over total project costs (USACE 2003).

Cover Type (CT) Homogenous zones of similar vegetative species, geographic similarities and physical conditions that make the area unique. In general, cover types are defined on the basis of species recognition and dependence.

Ecosystem A biotic community, together with its physical environment, considered as an integrated unit. Implied within this definition is the concept of a structural and functional whole, unified through life processes. Ecosystems are hierarchical, and can be viewed as nested sets of open systems in which physical, chemical and biological processes form interactive subsystems. Some ecosystems are microscopic, and the largest comprises the biosphere. Ecosystem restoration can be directed at different-sized ecosystems within the nested set, and many encompass multi-states, more localized watersheds or a smaller complex of aquatic habitat.

Ecosystem Assessment Team (E-Team) An interdisciplinary group of regional and local scientists responsible for determining significant resources, identification of reference sites, construction of assessment models, definition of reference standards, and calibration of assessment models. In some instances the E-Team is also referred to as the Environmental Assessment Team or simply the Assessment Team.

Ecosystem Function

Ecosystem functions are the dynamic attributes of ecosystems, including interactions among organisms and interactions between organisms and their environment (SERI 2001). Some restoration ecologists limit the use of the term "ecosystem functions" to those dynamic attributes which most directly affect metabolism, principally the sequestering and transformation of energy, nutrients, and moisture. Examples are carbon fixation by photosynthesis, trophic interactions, decomposition, and mineral nutrient cycling. When ecosystem functions are strictly defined in this manner, other dynamic attributes are distinguished as "ecosystem processes" such as substrate stabilization, microclimatic control, differentiation of habitat for specialized species, pollination and seed dispersal. Functioning at larger spatial scales is generally conceived in more general terms, such as the long-term retention of nutrients and moisture and overall ecosystem sustainability.

Ecosystem Integrity

The state or condition of an ecosystem that displays the biodiversity characteristic of the reference, such as species composition and community structure, and is fully capable of sustaining normal ecosystem functioning (SERI 2001). These characteristics are often defined in terms such as health, biodiversity, stability, sustainability, naturalness, wildness, and beauty.

Ecosystem Services	The capacity of natural processes and components to provide goods and services that satisfy human needs directly or indirectly (de Groot et al. 2002). The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits (Millennium Ecosystem Assessment 2005).
Equivalent Optimal Area (EOA)	The concept of equivalent optimal area (EOA) is used in HEP applications where the composition of the landscape, in relation to providing life requisite habitat, is an important consideration. An EOA is used to weight the value of the LRSI score to compensate for this inter-relationship. For example, for optimal wood duck habitat conditions, at least 20 percent of an area should be composed of cover types providing brood-cover habitat (a life requisite). If an area has less than 20 percent in this habitat, the suitability is adjusted downward.
Existing Condition	Also referred to as the baseline condition, the existing condition is the point in time before proposed changes, and is designated as Target Year (TY = 0) in the analysis.

Feature A feature is the smallest component of a management measure that is typically a structural element requiring construction in USACE planning studies (Robinson, Hansen, and Orth 1995).

Field Data This information is collected on various parameters (i.e., variables) in the field, and from aerial photos, following defined, well-documented methodology in typical HEP applications. An example is the measurement of percent herbaceous cover, over ten quadrats, within a cover type. The values recorded are each considered "field data." Means of variables are applied to derive suitability indices and/or functional capacity indices.

Goal A goal is defined as the end or final purpose. Goals provide the reason for a study rather than a reason to formulate alternative plans in USACE planning studies (Yoe and Orth 1996).

Guild A group of functionally similar species with comparable habitat requirements whose members interact strongly with one another, but weakly with the remainder of the community. Often a species HSI model is selected to represent changes (impacts) to a guild.

Habitat Assessment The process by which the suitability of a site to provide habitat for a community or species is measured. This approach measures habitat suitability using an assessment model to determine an HSI.

Habitat Suitability Index Model (HSI)

A quantitative estimate of suitability habitat for a site. The ideal goal of an HSI model is to quantify and produce an index that reflects functional capacity at the site. The results of an HSI analysis can be quantified on the basis of a standard 0-1.0 scale, where 0.00 represents low functional capacity for the wetland, and 1.0 represents high functional capacity for the wetland. An HSI model can be defined in words, or mathematical equations, that clearly describe the rules and assumptions necessary to combine functional capacity indices in a meaningful manner for the wetland.

Habitat Suitability Index Model (HSI) (cont)

For example:

$HSI = (SI\ V_1 * SI\ V_2) / 4,$

where:
$SI\ V_1$ is the Variable Subindex for variable 1;
$SI\ V_2$ is the SI for variable 2

Habitat Unit (HU)

A quantitative environmental assessment value, considered the biological currency in HEP. Habitat Units (HUs) are calculated by multiplying the area of available habitat (quantity) by the quality of the habitat for each species or community. Quality is determined by measuring limiting factors for the species (or community), and is represented by values derived from Habitat Suitability Indices (HSIs).

HU = AREA (acres) X HSI.

Changes in HUs represent potential impacts or improvements of proposed actions.

Life Requisite Suitability Index (LRSI)

A mathematical equation that reflects a species' or community's sensitivity to a change in a limiting life requisite component within the habitat type in HEP applications. LRSIs are depicted using scatter plots and bar charts (i.e., life requisite suitability curves). The LRSI value (Y axis) ranges on a scale from 0.0 to 1.0, where an LRSI = 0.0 means the factor is extremely limiting and an LRSI = 1.0 means the factor is in abundance (not limiting) in most instances.

Limiting Factor

A variable whose presence/absence directly restrains the existence of a species or community in a habitat in HEP applications. A deficiency of the limiting factor can reduce the quality of the habitat for the species or community, while an abundance of the limiting factor can indicate an optimum quality of habitat for the same species or community.

Locally Preferred Plan (LPP)	The name frequently given to a plan that is preferred by the non-Federal sponsor over the National Economic Development (NED) plan (USACE 2000).
Management Measure	The components of a plan that may or may not be separable actions that can be taken to affect environmental variables and produce environmental outputs. A management measure is typically made up of one or more features or activities at a particular site in USACE Planning studies (Robinson, Hansen, and Orth 1995).
Measure	The act of physically sampling variables such as height, distance, percent, etc., and the methodology followed to gather variable information in HEP applications (i.e., see "Sampling Method" below).

Multiple Formula Model (MM) (aka Life Requisite Model)	In HEP applications, there are two types of HSI models, the Single Formula Model (SM) (refer to the definition below) and the Multiple Formula Model (MM). In this case a multiple formula model is, as one would expect, a model that uses more than one formula to assess the suitability of the habitat for a species or a community. If a species/community is limited by the existence of more than one life requisite (food, cover, water, etc.), and the quality of the site is dependent on a minimal level of each life requisite, then the model is considered an MM model. In order to calculate the HSI for any MM, one must derive the value of a Life Requisite Suitability Index (LRSI) (see definition below) for each life requisite in the model – a process requiring the user to calculate multiple LRSI formulas. This Multiple Formula processing has led to the name "Multiple Formula Model" in HEP.
Multi-Criteria Decision Analysis (MCDA)	The study of methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the management planning process", as defined by the International Society on Multiple Criteria Decision Making (http://www.terry.uga.edu/mcdm/ MAY 2008). MCDA is also referred as Multi-Criteria Decision Making (MCDM), Multi-Dimensions Decision-Making (MDDM), and Multi-Attributes Decision Making (MADM)

National Economic Development (NED) Plan	For all project purposes except ecosystem restoration, the alternative plan that reasonably maximizes net economics benefits consistent with protecting the Nation's environment, the NED plan, shall be selected. The Assistant Secretary of the Army for Civil Works (ASACW) may grant an exception when there are overriding reasons for selecting another plan based upon other Federal, State, local and international concerns (USACE 2000).
National Ecosystem Restoration (NER) Plan	For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective, shall be selected. The selected plan must be shown to be cost effective and justified to achieve the desired level of output. This plan shall be identified as the National Ecosystem Restoration (NER) Plan. (USACE 2000).
No Action Plan (aka No Action Alternative or Without-project Condition)	Also referred to as the Without-project condition, the No Action Plan describes the project area's future if there is no Federal action taken to solve the problem(s) at hand. Every alternative is compared to the same Without-project condition (Yoe and Orth 1996).

Objective	A statement of the intended purposes of the planning process; it is a statement of what an alternative plan should try to achieve. More specific than goals, a set of objectives will effectively constitute the mission statement of the Federal/non-Federal planning partnership. A planning objective is developed to capture the desired changes between the without- and With-project conditions that when developed correctly identify effect, subject, location, timing, and duration (Yoe and Orth 1996).
Plan (aka Alternative, Alternative Plan, or Solution)	A set of one or more management measures functioning together to address one or more planning objectives (Yoe and Orth 1996). Plans are evaluated at the site level with HEP or other assessment techniques and cost analyses in restoration studies (Robinson, Hansen, and Orth 1995).
Program	Combinations of recommended plans from different sites make up a program. Where the recommended plan at each such site within a program is measured in the same units, a cost analyses can be applied in a programmatic evaluation (Robinson, Hansen, and Orth 1995).
Project Area	The area that encompasses all activities related to an ongoing or proposed project.
Project Manager	Any biologist, economist, hydrologist, engineer, decision- maker, resource project manager, planner, environmental resource specialist, limnologist, etc., who is responsible for managing a study, program, or facility.

Reference Domain The geographic area from which reference communities or wetland are selected in HEP applications. A reference domain may, or may not, include the entire geographic area in which a community or wetland occurs.

Reference Ecosystems All the sites that encompass the variability of all conditions within the region in HEP applications. Reference ecosystems are used to establish the range of conditions for construction and calibration of HSIs and establish reference standards.

Reference Standard Ecosystems The ecosystems that represent the highest level of habitat suitability or function found within the region for a given species or community in HEP applications.

Relative Area (RA) The relative area is a mathematical process used to "weight" the various applicable cover types on the basis of quantity in HEP applications. To derive the relative area of a model's CTs, the following equation can be utilized:

$$\text{Relative Area} = \frac{\text{Acres of Cover Type}}{\text{Total Applicable Area}}$$

where:

Acres of Cover Type = only those acres assigned to the cover type of interest within the site
Total Applicable Area = the sum of the acres associated with the model at the site.

Relative Preferences	The rank of ecosystem services in order of importance. Relative preferences for various services are much easier to determine than differences in dollar measures of service values. Although less common than dollar measures of value, individual and community indices of ranked preferences can be used to aggregate service values and compare plans using a single measure (King et al. 2000).
Risk	The volatility of potential outcomes. In the case of ecosystem values, the important risk factors are those that affect the possibility of service flow disruptions and the reversibility of service flow disruptions. These are associated with controllable and uncontrollable on-site risk factors (e.g., invasive plants, overuse, or restoration failure) and landscape risk factors (e.g., changes in adjacent land uses, water diversions) (King et al. 2000).

Sampling Method

The protocol followed to collect and gather field data in HEP and HGM applications. It is important to document the relevant criteria limiting the collection methodology. For example, the time of data collection, the type of techniques used, and the details of gathering this data should be documented as much as possible. An example of a sampling method would be:

Between March and April, run five random 50-m transects through the relevant cover types. Every 10-m along the transect, place a 10-m^2 quadrat on the right side of the transect tape and record the percent herbaceous cover within the quadrat. Average the results per transect.

Scale

In some geographical methodologies, the scale is the defined size of the image in terms of miles per inch, feet per inch, or pixels per acres. Scale can also refer to different "sizes" of plans (Yoe and Orth 1996) or variations of a management measure in cost analyses. Scales are mutually exclusive, and therefore a plan or alternative may only contain one scale of a given management measure (Robinson, Hansen, and Orth 1995).

Single Formula Model (SM)	In habitat assessments, there are two potential types of models selected to assess change at a site – the Single Formula Model and the Multiple Formula Model (refer to the definition above). In this instance, an HSI model is based on the existence of a single life requisite requirement, and a single formula is used to depict the relationship between quality and carrying capacity for the site.
Site	The location upon which the project manager will take action, evaluate alternatives and focus cost analysis (Robinson, Hansen, and Orth 1995).
Solutions (aka Alternative, Alternative Plan, or Plan)	A solution is a way to achieve all or part of one or more planning objectives (Yoe and Orth 1996). In cost analysis, this is the alternative (see definition above).
Spreadsheet	A type of computer file or page that allows the organization of data (alpha-numeric information) in a tabular format. Spreadsheets are often used to complete accounting/economic exercises.
Suitability Index (SI)	A mathematical equation that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type in HEP applications. These indices are depicted using scatter plots and bar charts (i.e., suitability curves). The SI value (Y-axis) ranges on a scale from 0.0 to 1.0, where an SI = 0.0 means the factor is extremely limiting, and an SI = 1.0 means the factor is in abundance (not limiting) for the species/community (in most instances).

Target Year (TY) A unit of time measurement used in HEP that allows the project manager to anticipate and direct significant changes (in area or quality) within the project (or site). As a rule, the baseline TY is always TY = 0, where the baseline year is defined as a point in time before proposed changes would be implemented. As a second rule, there must always be a TY = 1, and a TY = X_2. TY_1 is the first year land- and water-use conditions are expected to deviate from baseline conditions. TY_{X2} designates the ending target year. A new target year must be assigned for each year the project manager intends to develop or evaluate change within the site or project. The habitat conditions (quality and quantity) described for each TY are the expected conditions at the end of that year. It is important to maintain the same target years in both the environmental and economic analyses.

Trade-Offs(TOs) Used to adjust the model outputs by considering human values. There are no right or proper answers, only acceptable ones. If trade-offs are used, outputs are no longer directly related to optimum habitat or wetland function (Robinson, Hansen, and Orth 1995).

Validation Establishing by objective yet independent evidence that the model specifications conform to the user's needs and intended use(s). The validation process questions whether the model is an accurate representation of the system based on independent data not used to develop the model in the first place. Validation can encompass all of the information that can be verified, as well as all of the things that cannot -- i.e., all of the information that the model designers might never have anticipated the user might want or expect the product to do.

For purposes of this effort, *validation* refers to independent data collections (bird surveys, water quality surveys, etc.) that can be compared to the model outcomes to determine whether the model is capturing the essence of the ecosystem's functionality.

Variable A measurable parameter that can be quantitatively described, with some degree of repeatability, using standard field sampling and mapping techniques. Often, the variable is a limiting factor for a wetland's functional capacity used in the development of SI curves and measured in the field (or from aerial photos) by personnel, to fulfill the requirements of field data collection in an HEP application. Some examples of variables include: height of grass, percent canopy cover, distance to water, number of snags, and average annual water temperature.

Verification	Model verification refers to a process by which the development team confirms by examination and/or provision of objective evidence that specified requirements of the model have been fulfilled with the intention of assuring that the model performs (0r behaves) as it was intended. Sites deemed to be highly functional wetlands according to experts, should produce high HSI scores. Sites deemed dysfunctional (by the experts) should produce low HSI scores.
Without-project Condition(WOP) (aka No Action Plan or No Action Alternative)	Often confused with the terms "Baseline Condition" and "Existing Condition," the Without-Project Condition is the expected condition of the site without implementation of an alternative over the life of the project (aka period of analysis), and is also referred to as the "No Action Plan" in traditional planning studies (Yoe and Orth 1996; USACE 2000).
With-project Condition (WP)	In planning studies, this term is used to characterize the condition of the site after an alternative is implemented (Yoe and Orth 1996; USACE 2000).

Appendix C: Model Certification Crosswalk

Information necessary to address model certification/one-time-use approval under EC 1105-2-407 is presented in *Table 2* of the *USACE Protocols for Certification of Planning Models* report (USACE 2007c, pages 9-11)[1]. In an effort to streamline the review of the Bosque Riparian community-based (HSI) index model, the authors have provided a table to crosswalk the EC requirements and the information contained in this report (Table C - 1). One-time-use approval was granted by the Eco-PCX in April 2009, and the memo documenting this approval has been included below the table.

Table C - 1. Crosswalk between EC 1105-2-407 model certification requirements and information contained in this report.

Cover Sheet		
	a.	**Model Name(s):** Bosque Riparian Community Index Model for the Middle Rio Grande, Albuquerque, New Mexico
	b.	**Functional Area:** Ecosystem Restoration; Impact Assessment /Mitigation
	c.	**Model Proponent:** Albuquerque District
	d.	**Model Developers** ERDC-EL and Albuquerque District (with support from interagency and stakeholder participants)
1. Background		
	a.	**Purpose of Model:** The model was developed in an effort to quantify the value of diverse biological resources in this study area with the intent of capturing complex biotic patterns of the landscape. Refer to *Chapter 1*, "Purpose of the Models" for more detail.
	b.	**Model Description and Depiction:** The model was rendered in a HEP-compatible format. Model components were comprised of combinations of relevant parameters to characterize the hydrology, soils, biotic integrity, structure, spatial complexity, and disturbance regimes of the unique bosque riparian ecosystem occurring along the Middle Rio Grande Reach in central New Mexico. Model components (and their underlying variables) were normalized (scaled from 0.0 to 1.0) as required by traditional HEP procedures. Both flow charts ("ecosystem puzzles") and mathematical algorithms were used to depict the model herein. Refer to *Chapter 3* (*Model Flow Diagram*), *Chapter 4* (*Model Formulas*), and *Chapter 5* (*Model Concept* and *Steps 1-5)* for details relating to the individual model components and format.
	c.	**Contribution to Planning Effort:** The model helped to characterize the baseline conditions

[1] http://www.usace.army.mil/cw/cecw-cp/models/protocols_cert_7-02-07.pdf

		(in a quantitative manner) of the unique and significant ecological resources along the Middle Rio Grande Reach in central New Mexico. When applied within the HEP assessment paradigm, the study team will be able to evaluate and compare the benefits of proposed ecosystem restoration initiatives. Future applications in the watershed could also use the model to evaluate and compare flood risk management measures and determine the ability of the proposed mitigation measures to offset these losses.
	d.	**Description of Input Data:** Both field and spatially-explicit (GIS) data are necessary to calculate the outputs. Refer to *Chapter 4* for a list of variables and appropriate sampling protocols and statistical data management activities.
	e.	**Description of Output Data:** Habitat Suitability Indices are output on a normalized scale of 0-1 in compliance with the traditional HEP paradigm. Within a standard HEP application, these indices can be multiplied by area to produce Habitat Units (HUs), and can be assessed over time under both With- and Without-project scenarios to generate Average Annual Habitat Units (AAHUs) (Refer to *Chapter 2 HEP Overview*).
	f.	**Statement on the capabilities and limitations of the model:** The model has been tested using reference data and conditions along the Middle Rio Grande Reach. It can be used to assess baseline conditions as well as assess both a No Action condition and proposed alternative designs in either an Impact/Mitigation study or within an Ecosystem Restoration context. The model should not be applied outside of the Rio Grande-Albuquerque watershed without review and recalibration.
	g.	**Description of model development process including documentation on testing conducted (Alpha and Beta tests):** A series of workshops were convened and experts contributed to the development of both the conceptual framework and the final index model presented here. The model was calibrated using reference data from across the model domain (Middle Rio Grande Reach – refer to Figure 9). Internal (ERDC-EL) peer review has commenced, and the authors are drafting several peer-reviewed journal articles for publication. *Appendix G* discusses the internal/external peer review process standard for ERDC-EL publications and model building efforts. *Chapter 3* discusses the model building process. *Chapter 4* discusses the model calibration process as well as the alpha/beta tests of the model to quantify baseline conditions for the study area.
2. Technical Quality		
	a.	**Theory:** In theory, the quantification of ecosystem function in these communities can be obtained by using indicators of ecosystem integrity and applying these in the well documented, and accepted HEP-based framework. The U.S. Fish and Wildlife Service (USFWS) published quantifiable procedures in 1980 to assess planning initiatives as they relate to change of fish and wildlife habitats (USFWS 1980a,b,and c). These procedures, referred to collectively as Habitat Evaluation Procedures and known widely as 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. Habitat Suitability Indices (HSIs) are simple mathematical algorithms that generate a unitless index derived as a function of one or more environmental variables that characterize or typify the site conditions (i.e., vegetative cover and composition, hydrologic regime, disturbance, etc.) and are deployed in the HEP framework to quantify the outcomes of restoration or impact scenarios. These tools have been applied many times over the course of the last 30 years (Williams 1988, VanHorne and Wiens 1991, Brooks 1997, Brown et al. 2000, Store and Jokimaki 2003, Shifley et al. 2006, Van der Lee et al. 2006). Virtually all attempts to use HSI models have been heavily criticized, and many criticisms are well deserved. In most instances, these criticisms have focused on the lack of: (a) identification of the appropriate context (spatial and temporal) for the model parameters, (b) a conceptual framework for what the model is indicating, (c) integration of science and values, and (d) validation of the models (Kapustka 2005, Barry et al. 2006, Hirzel et al.

2006, Inglis et al. 2006, Ray and Burgman 2006, Van der Lee et al. 2006). A fundamental problem with these approaches continues to be the inability to link species presence or relative abundance with significant aspects of habitat quality (VanHorne and Wiens 1991) such as productivity.

Despite such criticisms, 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). These modeling approaches emphasize usability. Efforts are made during model development to ensure that they are biologically valid and operationally robust. Most HSI models are constructed largely as working versions rather than as final, definitive models (VanHorne and Wiens 1991). Simplicity is implicitly valued over comprehensiveness, perhaps because the models need to be useful to field managers with little training or experience in this arena. The model structure is therefore simple, and the functions incorporated in the models are relatively easy to understand. The functions included in models are often based on published and unpublished information that indicates they are responsive to species density through direct or indirect effects on life requisites. The general approach of HSI modeling is valid, in that the suitability of habitat to a species is likely to exhibit strong thresholds below which the habitat is usually unsuitable and above which further changes in habitat features make little difference. And as such, most HSI models should be seen as quantitative expressions of the best understanding of the relations between easily measured environmental variables and habitat quality. Habitat suitability models then, are a compromise between ecological realism and limited data and time (Radeloff et al. 1999, Vospernik et al. 2007).

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	b.	**Description of system being represented by the model:** The Middle Rio Grande bosque riparian ecosystem has been modeled here. *Chapter 3* offers community (ecosystem) characterization garnered from peer reviewed literature and gray literature generated by federal/local resource management agencies.
	c.	**Analytical requirements and assumptions:** Adequate sample sizes (30+ per variable) must be obtained to assure some level of precision (reduction of uncertainty). It is assumed that the user will adopt and follow the suggested sampling protocols detailed herein. Follow-on data management (calculation of means per variable) is straightforward

		and should not be difficult to emulate.
	d.	**Conformance with Corps policies and procedures:** As indicated in the PMIP, HEP is an accepted and approved approach to quantifying benefits/impacts for these types of studies (Refer to *Chapter 1 Planning Model Certification*). The protocol described herein was fully vetted through the ERDC review process, and participants in the workshops, as well as external reviewers have been included in the process (Refer to *Chapter 2 – Model Review Process*). Outputs conform to Corps policies and procedures.
	e.	**Identification of formulas used in the model and proof that the computations are appropriate and done correctly:** Formulas can be found in *Chapter 3*. All spreadsheets used to organize data and the datafiles used to calculate outputs can be obtained from the District upon request (contact Ondrea Hummel – see *Appendix D* for contact information). ERDC-EL performed QA/QC on all spreadsheet and datafile operations and can describe these to the reviewers upon request.
3. System Quality		
	a.	**Description and rationale for selection of supporting software tool/programming language and hardware platform:** The **HEAT** software is a fully vetted software package currently undergoing model certification. The model described here is not software per se (Refer to *Chapter 1 – Planning Model Certification*), and as such do not contain any programming. ArcMap, ArcToolbox, and Spatial Analyst are all commercially developed off-the-shelf software programs readily available to the user base.
	b.	**Proof that the programming was done correctly:** NA
	c.	**Description of process used to test and validate model:** Verification of the model can be found in *Chapter 4– Model Verification*.
	d.	**Discussion of the ability to import data into other software analysis tools (interoperability issue):** NA
4. Usability		
	a.	**Availability of input data necessary to support the model:** All data (presented in spreadsheet and database format) can be obtained from the District upon request (contact Ondrea Hummel – see *Appendix D* for contact information).
	b.	**Formatting of output in an understandable manner:** Outputs of the model are standard indices (HSI) - compatible with traditional HEP applications (scaled 0-1).
	c.	**Usefulness of results to support project analysis:** Model results have been successfully utilized in plan formulation and alternative comparison analyses for the Middle Rio Grande Bosque Ecosystem Restoration (MRGBER) Study.
	d.	**Ability to export results into project management documentation:** All outputs are MS Office-compatible and easily imported into MS Word and MS PowerPoint for documentation and distribution.
	e.	**Training availability:** **HEAT** software training was been provided to the Albuquerque District (and the MRGBER E-Team will receive a 5-day workshop in FY09) in 2006-2007. ERDC-EL also provides model building workshops at the local, regional and national level through PROSPECT and/or on a reimbursable basis. The District was also required to perform 1/3 of all calculations and 1/3 of all spreadsheet management activities to assure successful technology transfer ("ownership") of the model and the evaluations thereafter.
	f.	**Users documentation availability and whether it is user friendly and complete:** This document serves as the model "manual." There is a draft manual for the **HEAT** software currently undergoing certification (Burks-Copes et al. 2008). And there are Ecological Service Manuals (ESMs) to support HEP

		applications (USFWS 1980a-c).
	g.	**Technical support availability:** ERDC-EL provides technical support on all products upon request and on a reimbursable basis.
	h.	**Software/hardware platform availability to all or most users:** The model was provided in both MS Word and MS Excel format and in HEAT datafiles to all study participants (including contractors and stakeholders). All data (presented in spreadsheet and database format) can be obtained from the District upon request (contact Ondrea Hummel – see *Appendix D* for contact information). The GIS data utilized herein is available upon request from the Albuquerque District.
	i.	**Accessibility of the model:** The model is accessible now, and will be posted on the System-wide Water Resources Program's (SWWRP) Water Resources Depot website upon completion of ERDC-EL technical review (https://swwrp.usace.army.mil/DesktopDefault.aspx).
	j.	**Transparency of model and how it allows for easy verification of calculations and outputs:** The mathematical operations in the model have been clearly documented herein and can be easily transferred into any spreadsheet program for verification (a step ERDC-EL uses to QA/QC every model development activity). The outputs are scaled from 0-1 (1 = optimal functionality and 0 = not functioning). An interpretative table has been provided in *Chapter 4* to assist the user in conclusions.
	k.	**Accessibility (where is model physically located?:** Both the Albuquerque District and ERDC-EL will maintain separate and relatively permanent copies of all model information (NTE 7 years). The model will also be posted on the SWWRP website.

DEPARTMENT OF THE ARMY
MISSISSIPPI VALLEY DIVISION, CORPS OF ENGINEERS
P.O. BOX 80
VICKSBURG, MISSISSIPPI 39181-0080

REPLY TO
ATTENTION OF:

CEMVD-RB-T 23 April 2009

MEMORANDUM FOR Commander, South Pacific Division
ATTN: (Paul Bowers, CESPD-PDC)

SUBJECT: Middle Rio Grande Bosque Feasibility, New Mexico General Investigation Detailed Feasibility Study, Ecosystem Restoration Planning Center of Expertise Endorsement of Review Plan

1. References:
a. EC 1105-2-410, Review of Decision Documents, 22 August 2008.

2. The enclosed Review Plan (RP) complies with all applicable policy and provides an adequate peer review of the plan formulation, engineering, and environmental analyses, and other aspects of the plan development. The Ecosystem Restoration Planning Center of Expertise (ECO-PCX) has reviewed the RP and documentation of the review is attached.

3. The ECO-PCX concurs with the conclusion that Independent External Peer Review of this project is not necessary. Documentation and review of the Bosque Community Habitat Suitability Index Model is sufficient to demonstrate technical and system quality of the model for single-use on this project. Non-substantive changes to this RP do not require further approval.

3. The ECO-PCX recommends the RP for approval by the MSC Commander. Upon approval of the RP, please provide a copy of the approved RP, a copy of the MSC Commander approval memorandum, and the link to where the RP is posted on the District to Jodi Staebell and Valerie Ringold.

4. Thank you for the opportunity to assist in the preparation of the Review Plan. Please continue to coordinate the Agency Technical Review efforts outlined in the RP with the ECO-PCX.

Enclosure

Jodi Staebell
Operational Director,
National Ecosystem Planning
Center of Expertise

CF:
CEMVD-RB-T (D. Vigh, J. Staebell)
CEMVD-PD-N (Smith, Wilbanks)
CEPOA-EN-CW-PF (V. Ringold)
CESPD-PDC (P. Bowers, P. Devitt)
CESPD-PDS-P (F. Tabatai)
CESPA-PM-C (A. Austin-Johnson)
CESPA-PM-L (K. Schaeffer, M. Mann)

Appendix D: E-Team Participants

As described in the main report, a series of workshops were used to facilitate the development of the community-based index model compatible with the HEP application paradigm for the MRGBER feasibility study. Formal minutes were developed for each workshop and can be provided upon request from the Albuquerque District (contact Ondrea Hummel – refer to contact information below). 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. A complete list of participants can be found in Table D - 1 below. It is important to note that attrition over the course of the study led to many changes in this original roster. We have attempted to include both the names of original participants as well as replacements and additions here as well.

Table D - 1. Model development workshop(s) participants.

E-Team Members	Agency	Phone	Email Address
Abeyta, Cyndie	USFWS	(505) 761-4738	cyndie_abeyta@fws.gov
Anderson, Steve	NMDGF	(505) 841-8881	scanderson@state.nm.us
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Boberg, Steve	USACE	(505) 342-3336	Steve.A.Boberg@usace.army.mil
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Buntjer, Mike	USFWS	(505) 761-4733	Mike_Buntjer@fws.gov
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Crawford, Cliff	UNM	(505) 242-7081	ccbosque@juno.com
DelloRusso, Gina	USFWS	(505) 835-1828	Gina_DelloRusso@fws.gov
Doles, Mark	USACE	(505) 342-3364	Mark.W.Doles@usace.army.mil
Finch, Debbie	USFS, RMRS	(505) 856-0153	dfinch@fs.fed.us
Giesen, Lynette	USACE	(505) 342-3322	Lynette.M.Giesen@usace.army.mil
Gonzales, Santiago	USFWS	(505) 761-4720	Santiago_Gonzales@fws.gov

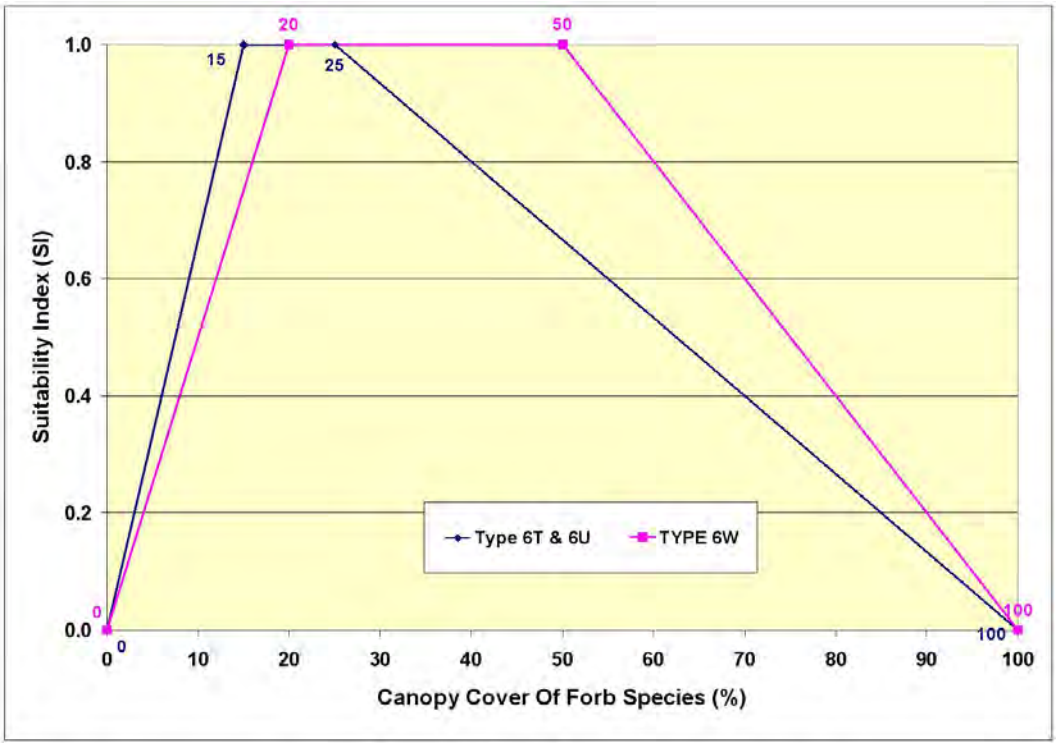
(Continued)

Table D - 1. (Concluded).

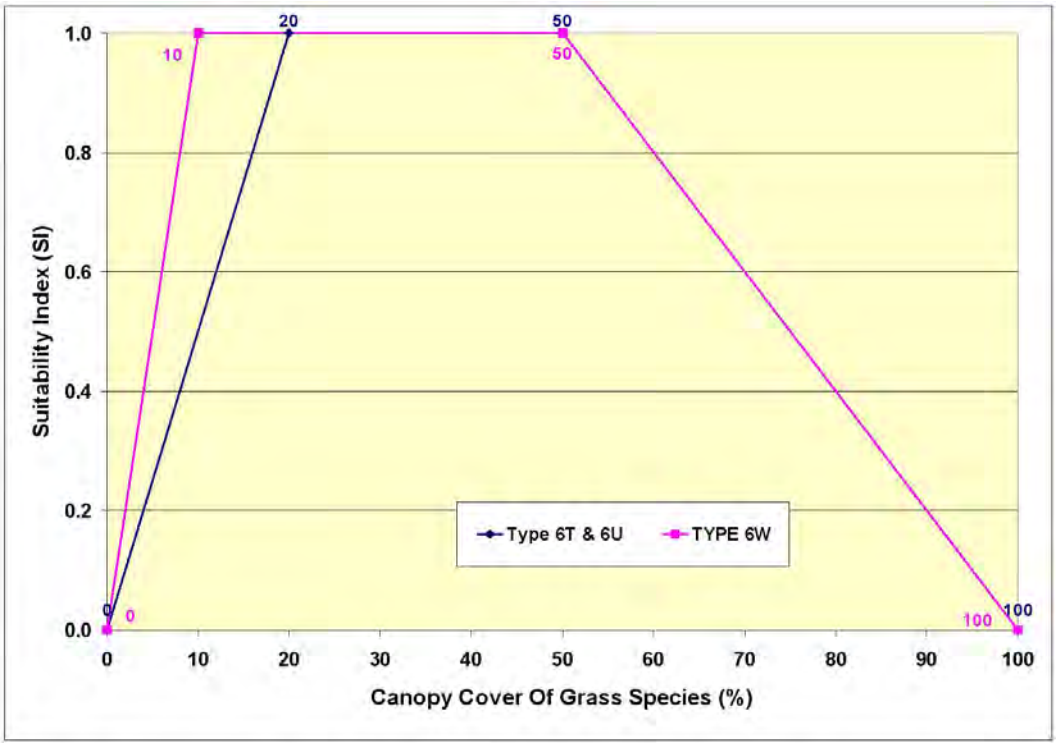
E-Team Members	Agency	Phone	Email Address
Grogan, Sterling	MRGCD	(505) 247-0235	grogan@mrgcd.com
Hummel, Ondrea	USACE	(505) 342-3375	Ondrea.C.Linderoth-Hummel@usace.army.mil
Jones, Seth	USACE - Galveston District (Remote Team Member)	(409) 766-3068	Seth.W.Jones@usace.army.mil
Najmi, Yasmeen	MRGCD	(505) 247-0234	yasmeen@mrgcd.dst.nm.us
Pegram, Page	ISC	(505) 764-3890	ppegram@ose.state.nm.us
Schmader, Matt	City of Albuquerque Open Space	(505) 452-5200	Mschmader@cabq.gov
Stretch, Doug	MRGCD	(505) 247-0234	doug@mrgcd.us
Umbreit, Nancy	BOR	(505) 462-3599	numbreit@uc.usbr.gov
Wicklund, Charles	NMSFD	(505) 865-2776	cwicklund@state.nm.us

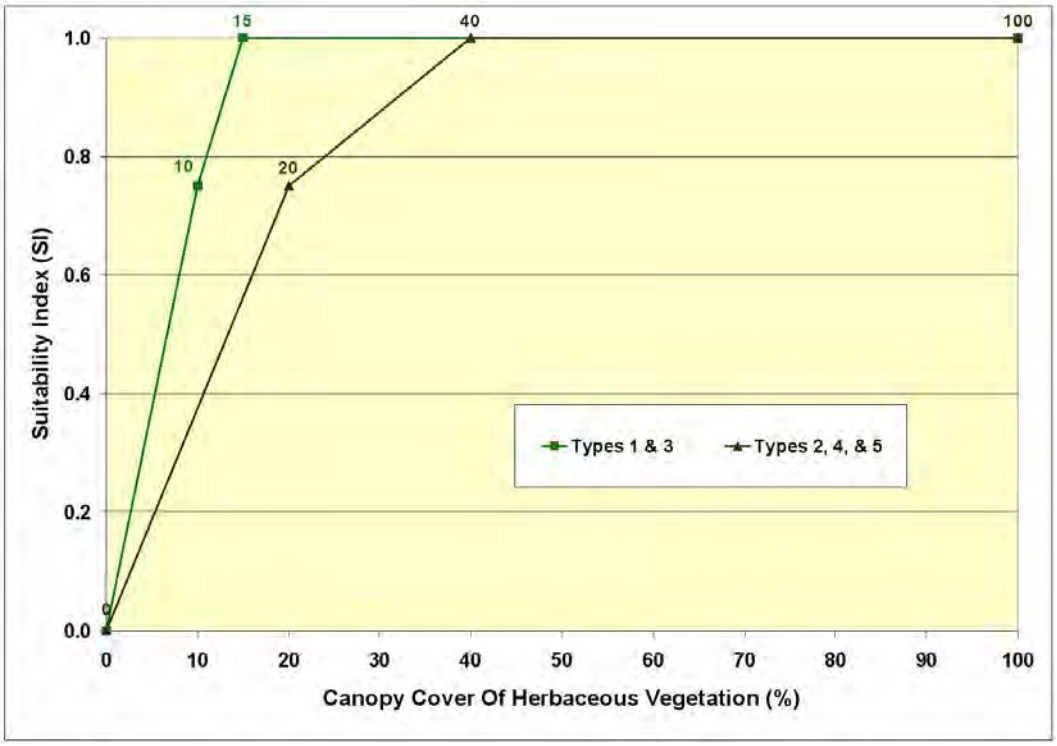
Appendix E:
HSI Curves for the Bosque Riparian Model

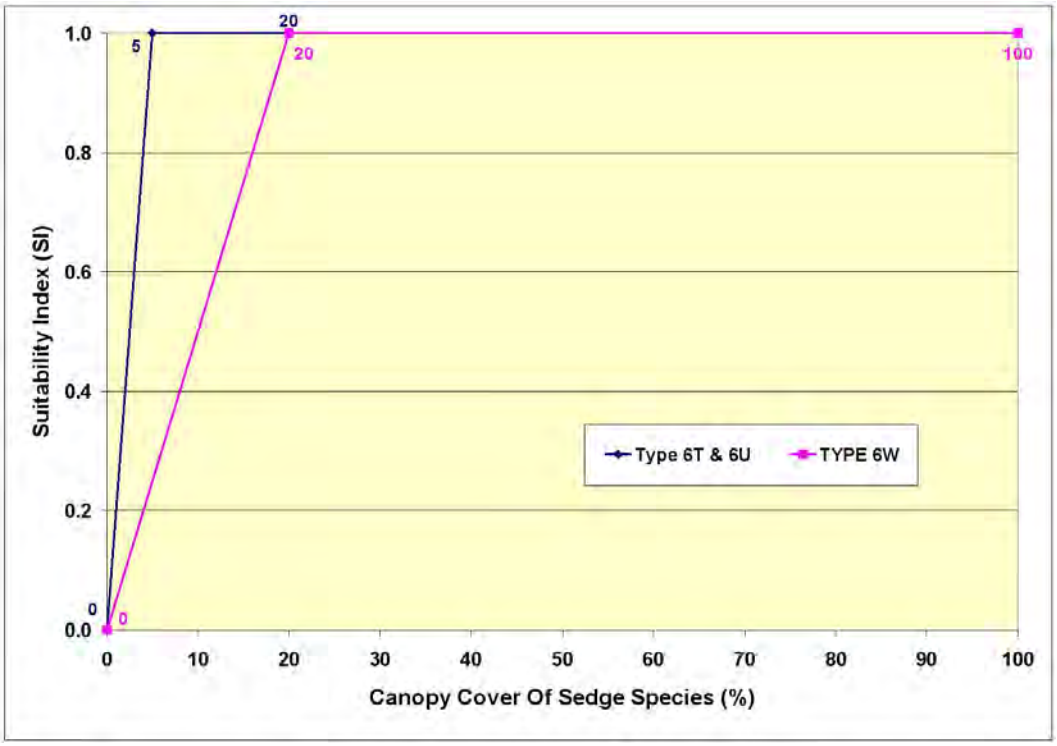
The following curves were developed by the E-Team to measure ecosystem function in the bosque communities found along the Middle Rio Grande Reach running through Albuquerque, New Mexico.[1]

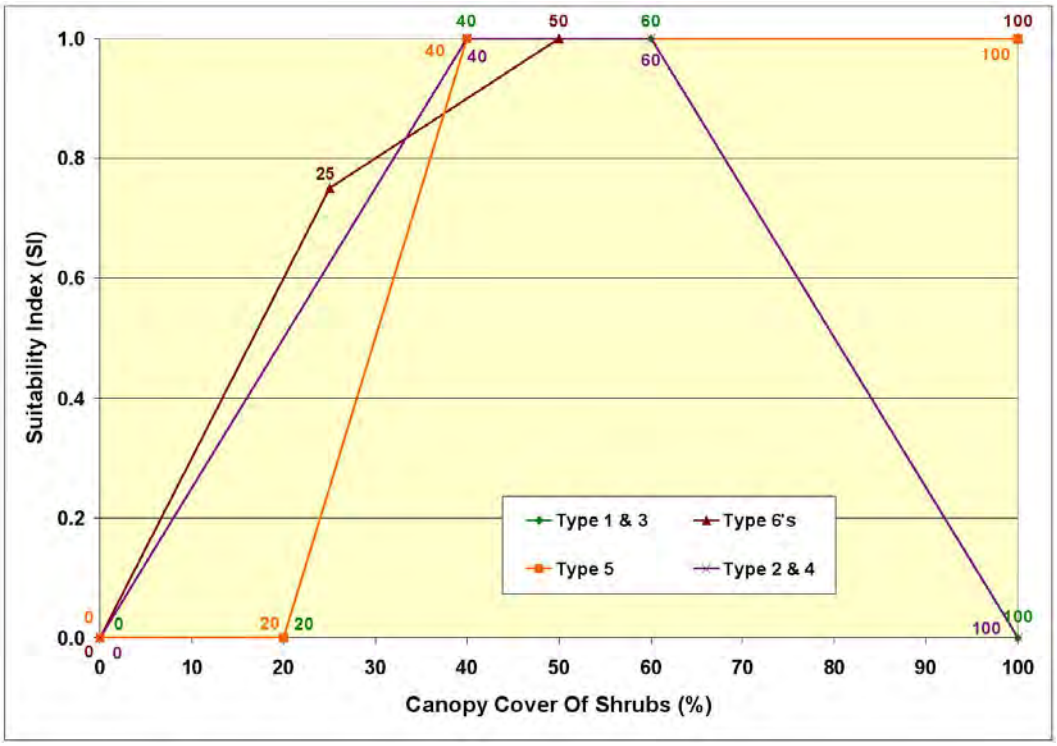


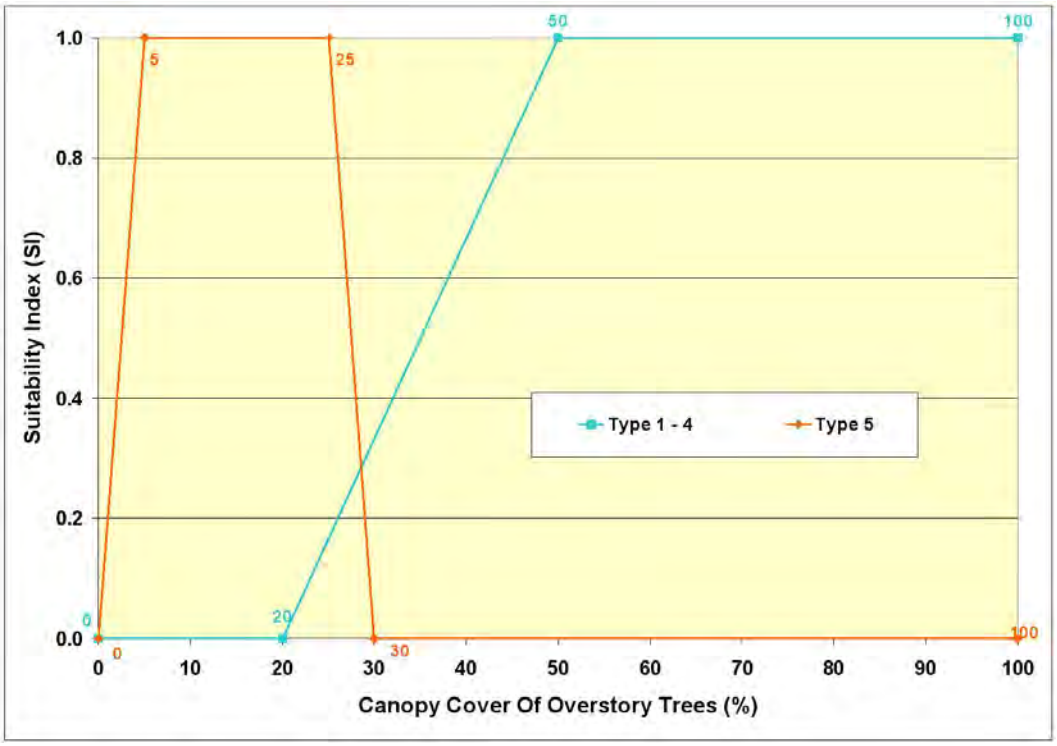
[1] Data are available upon request - contact the District POC (Ondrea Hummel, contact information can be found in *Appendix D*).

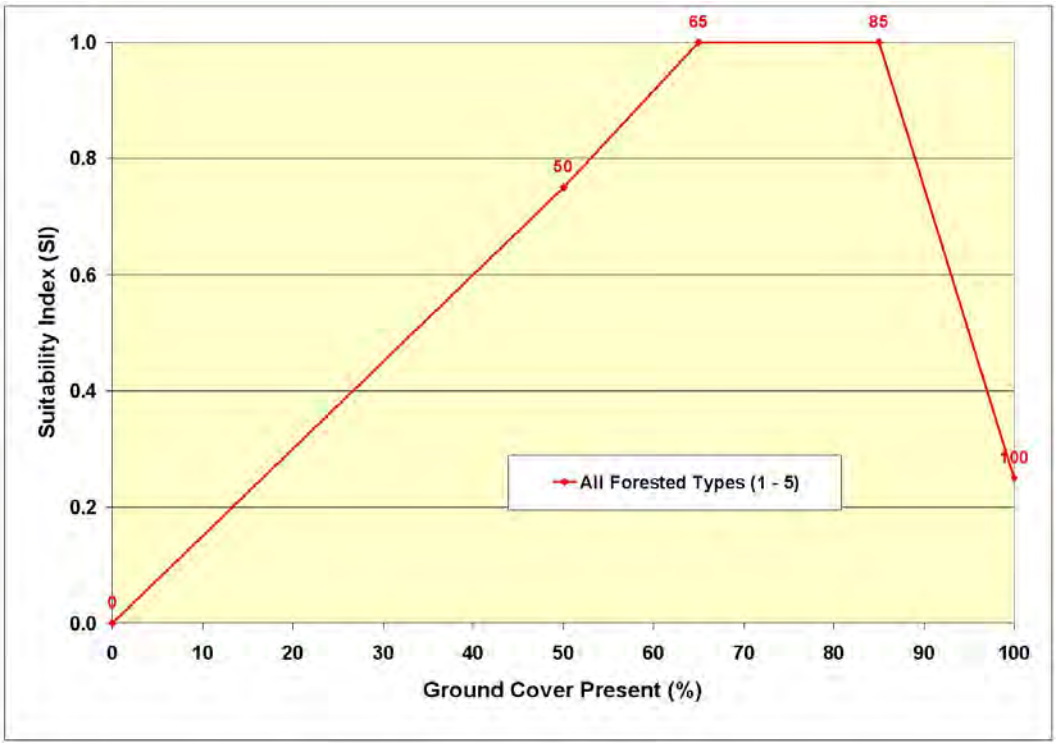

Suitability Index (SI)
Canopy Cover Of Grass Species (%)
Type 6T & 6U
TYPE 6W
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
20
50
10
50
0
0
100
100

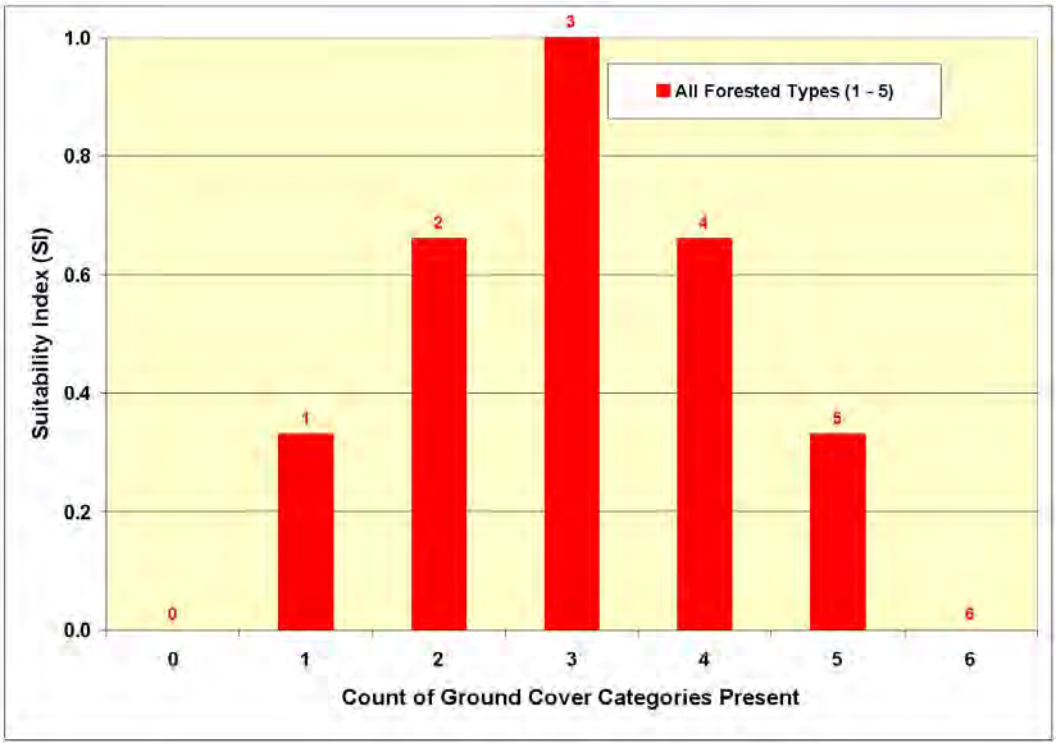

Suitability Index (SI)
Canopy Cover Of Herbaceous Vegetation (%)
Types 1 & 3
Types 2, 4, & 5
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
15
40
100
10
20
0

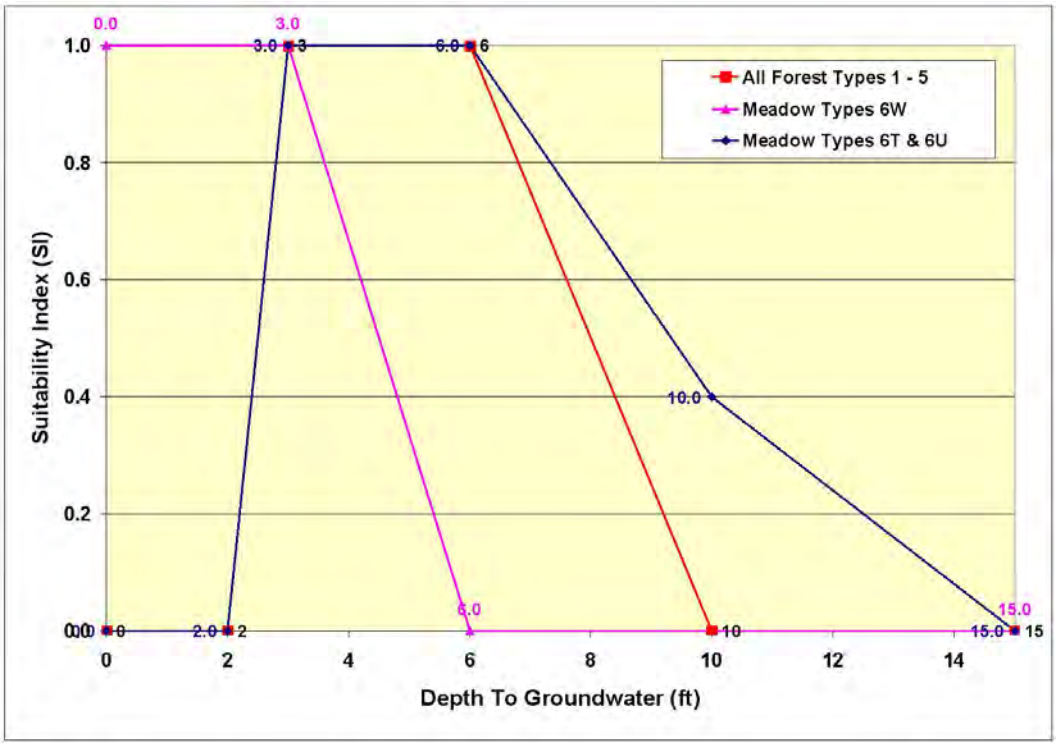

Suitability Index (SI)
Canopy Cover Of Sedge Species (%)
Type 6T & 6U
TYPE 6W
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
5
20
100
0

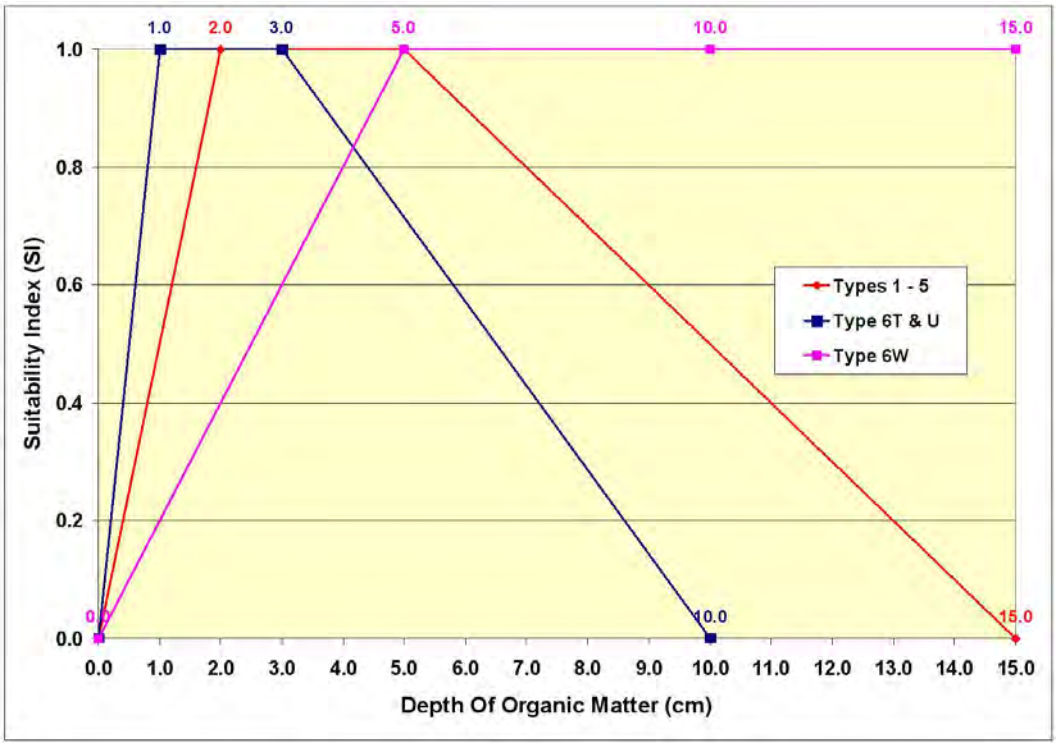

Suitability Index (SI)
Canopy Cover Of Shrubs (%)
Type 1 & 3
Type 6's
Type 5
Type 2 & 4
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
25
40
50
60
100
20

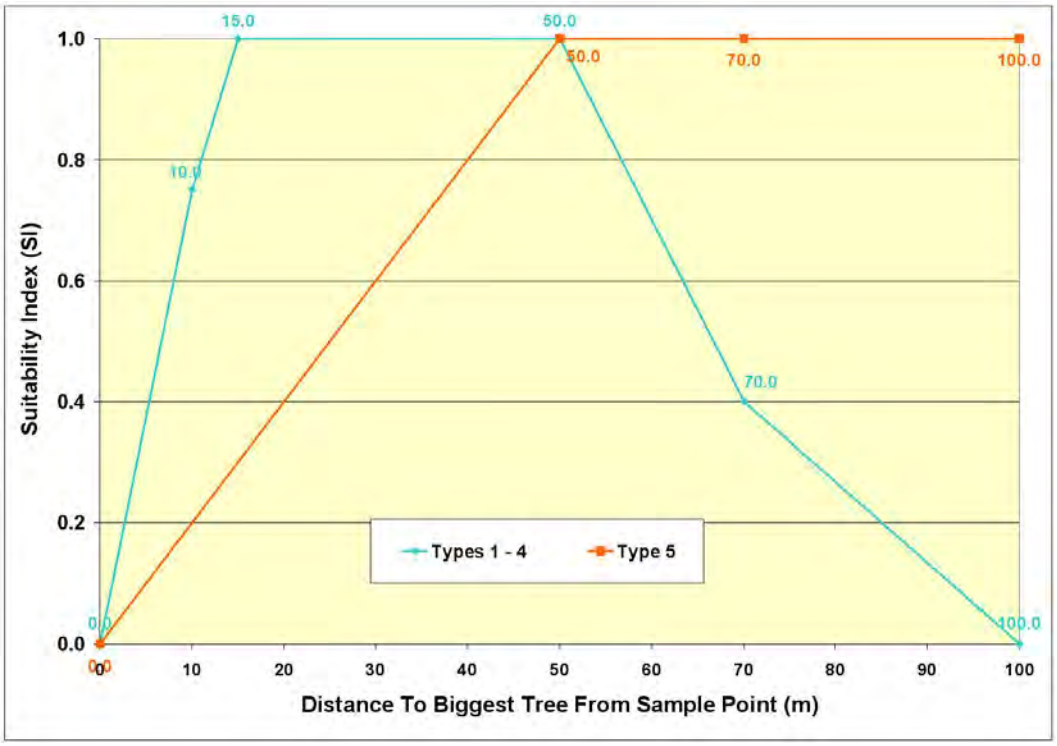

Suitability Index (SI)
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
Canopy Cover Of Overstory Trees (%)
Type 1 - 4
Type 5
0
20
50
100
0
5
25
30
100

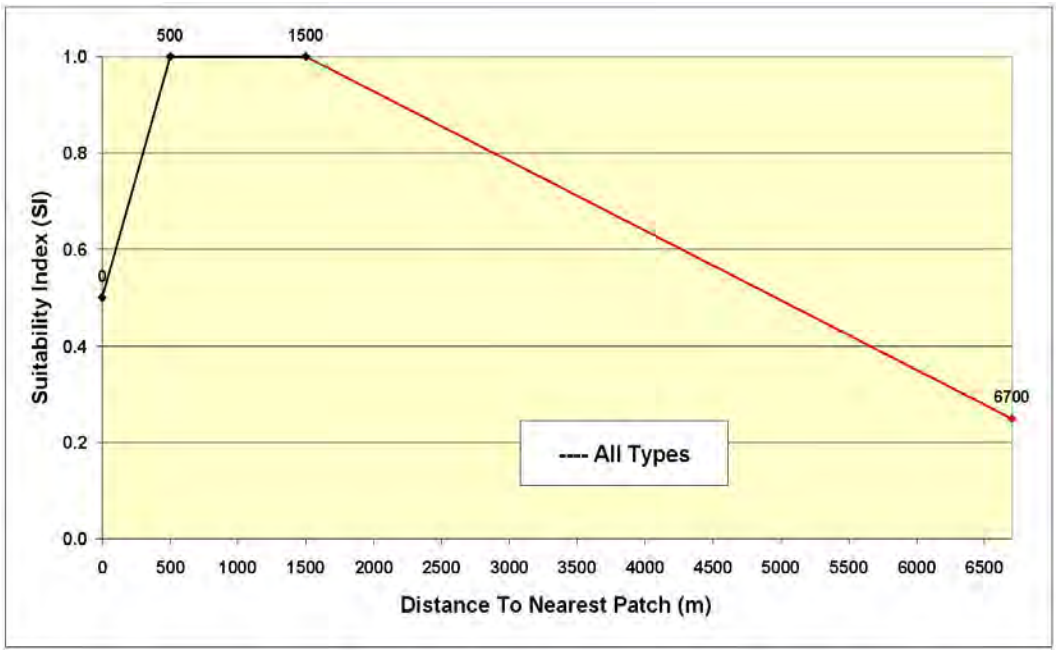

Suitability Index (SI)
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
Ground Cover Present (%)
All Forested Types (1 - 5)
0
50
65
85
100

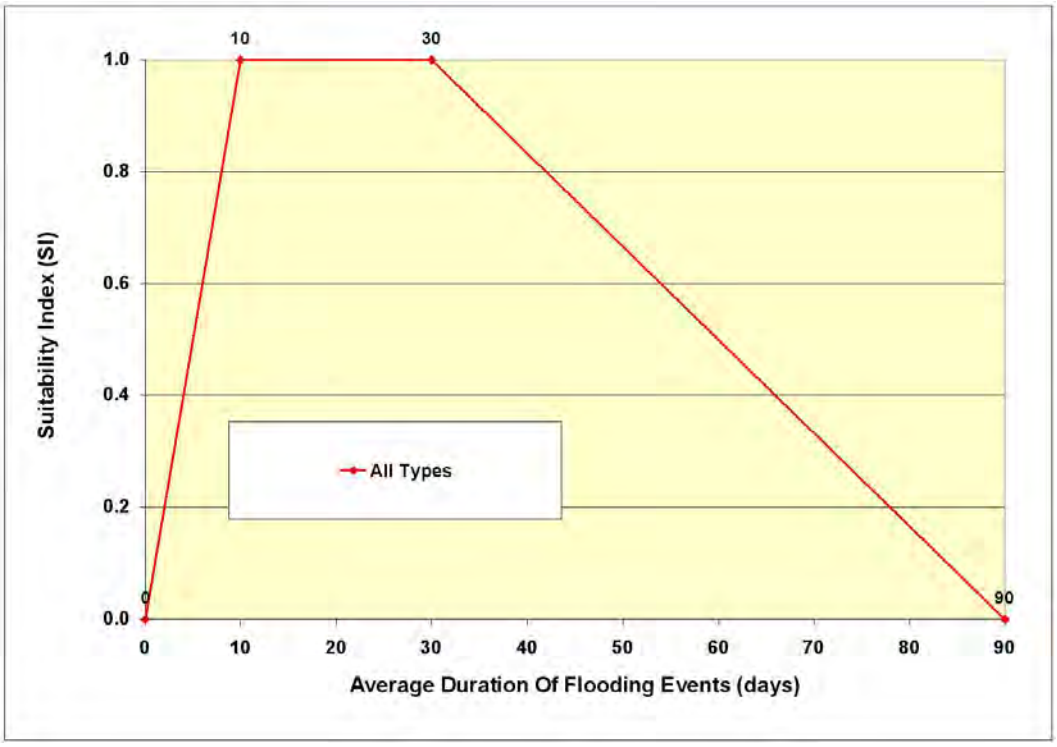

All Forested Types (1 - 5)
Suitability Index (SI)
Count of Ground Cover Categories Present
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6

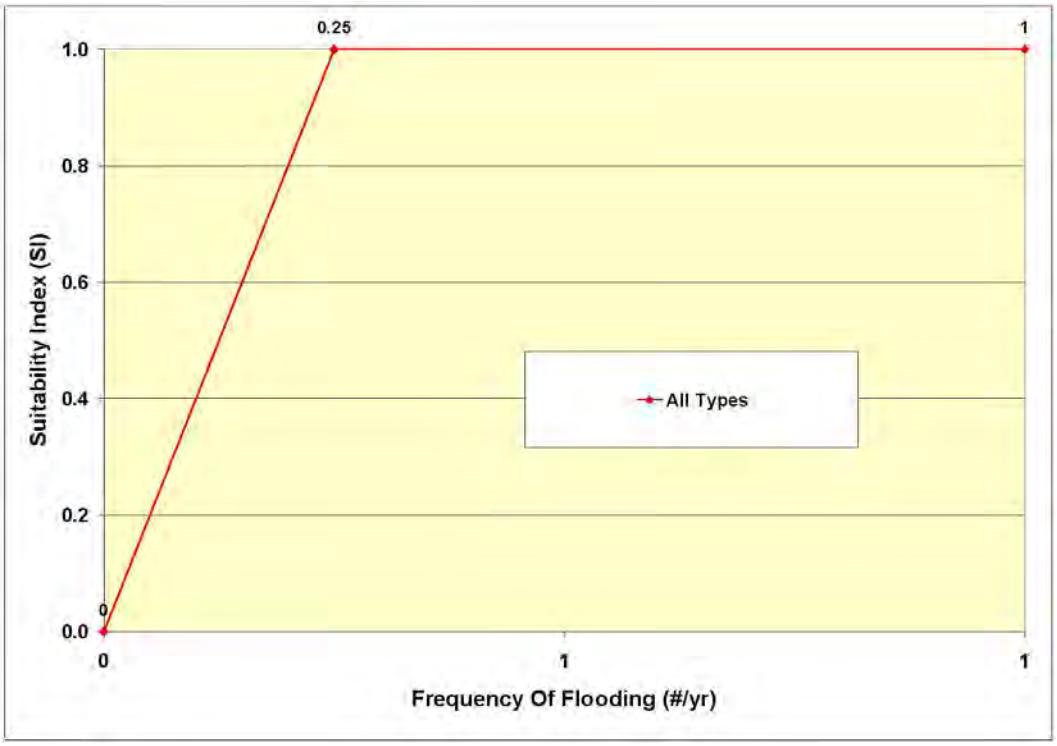

All Forest Types 1 - 5
Meadow Types 6W
Meadow Types 6T & 6U
Suitability Index (SI)
Depth To Groundwater (ft)
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
14
0.0
3.0
6.0
10.0
15.0

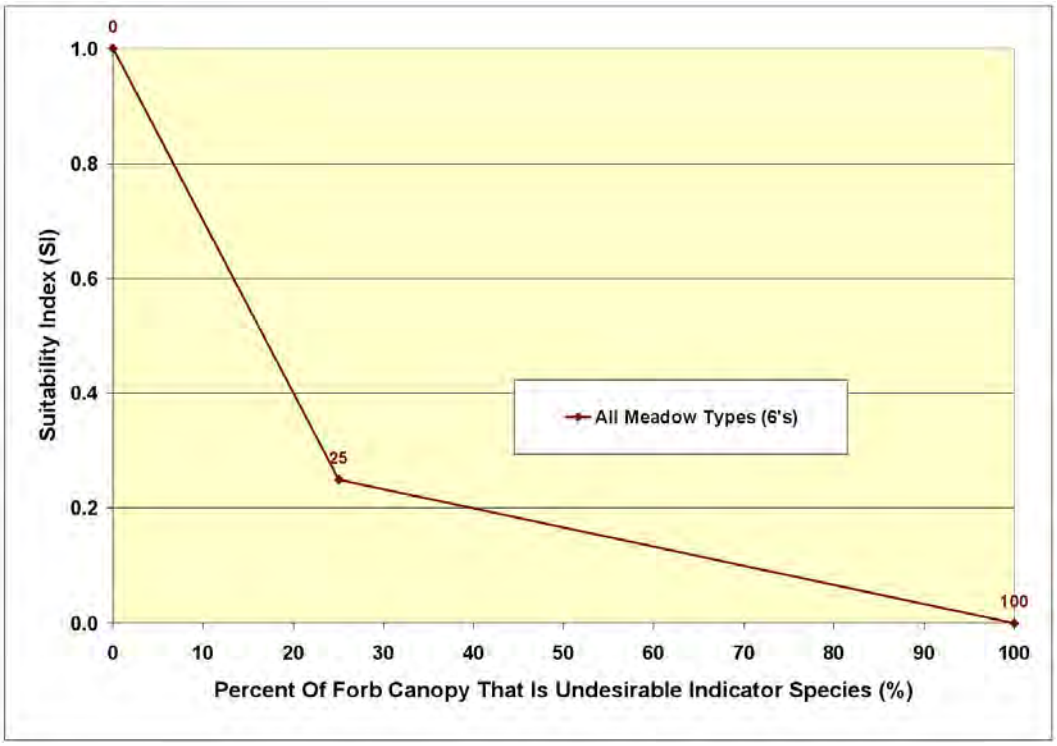

Suitability Index (SI)
Depth Of Organic Matter (cm)
Types 1 - 5
Type 6T & U
Type 6W
1.0
2.0
3.0
5.0
10.0
15.0
0.0
0.2
0.4
0.6
0.8
1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0

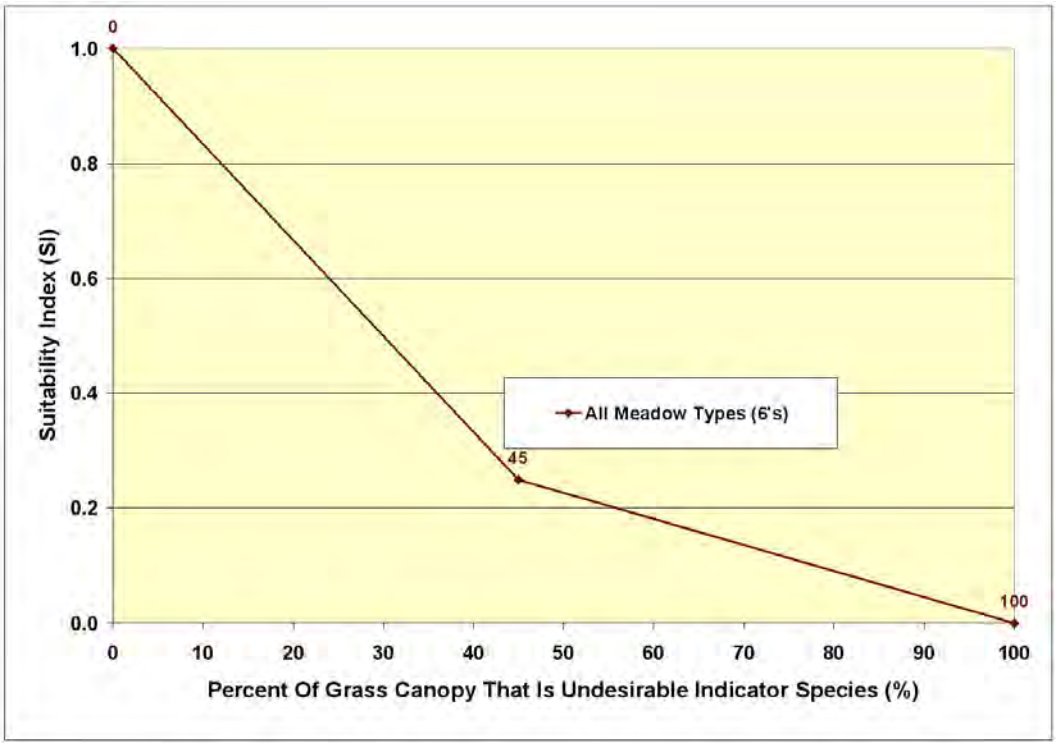

Suitability Index (SI)
Distance To Biggest Tree From Sample Point (m)
Types 1 - 4
Type 5
15.0
50.0
70.0
100.0
10.0
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50
60
70
80
90
100

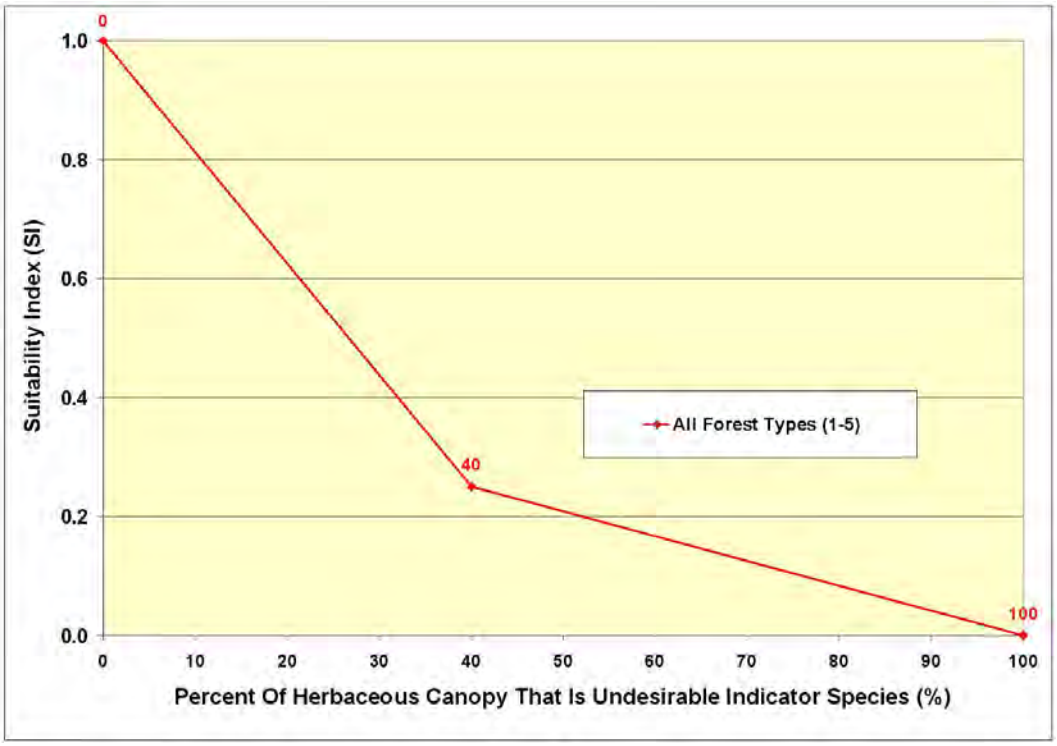

500
1500
0
6700
1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
---- All Types
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
Distance To Nearest Patch (m)

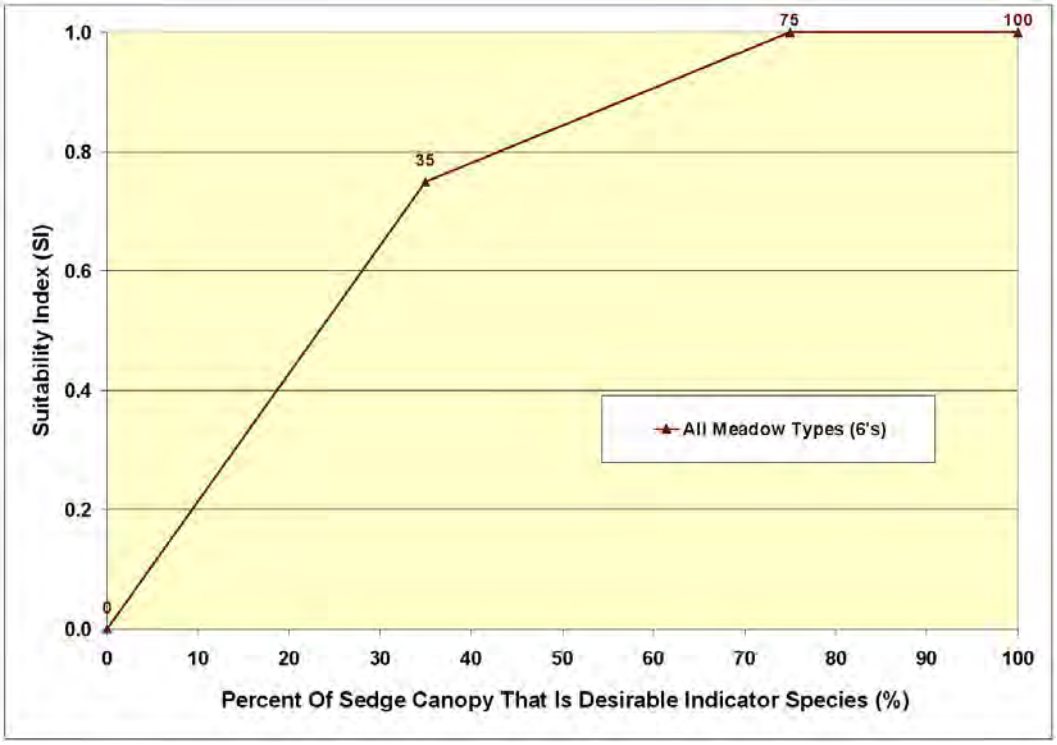

10
30
0
90
1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
All Types
0
10
20
30
40
50
60
70
80
90
Average Duration Of Flooding Events (days)

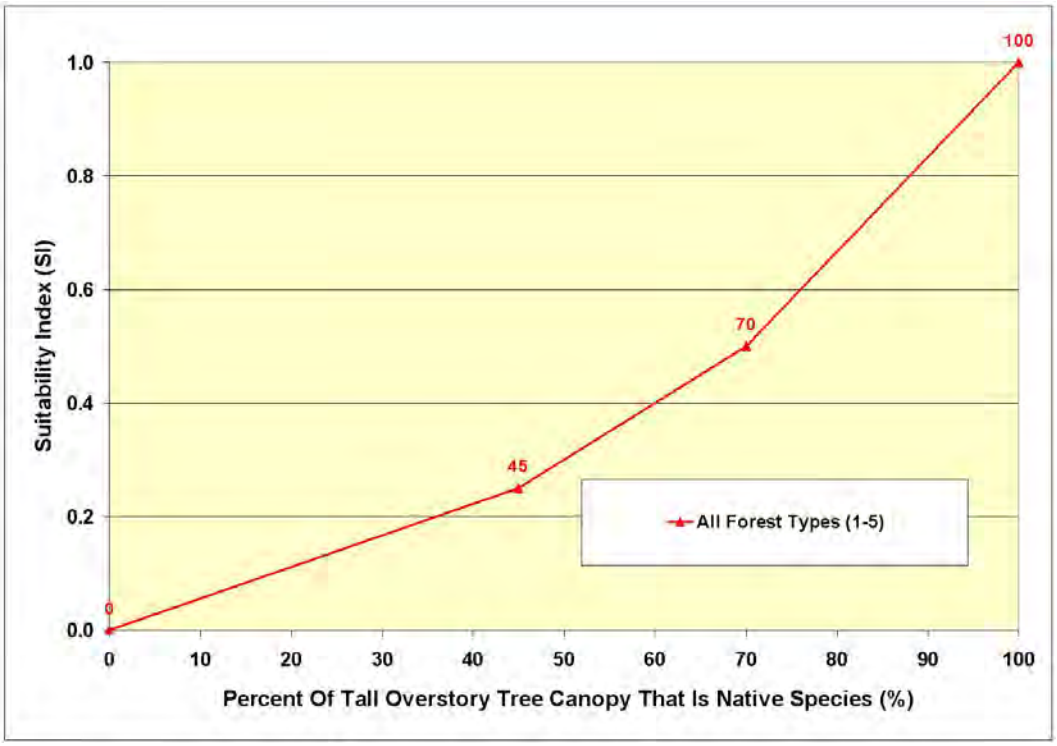

0.25
1
1.0
0.8
0.6
0.4
0.2
0
0.0
Suitability Index (SI)
All Types
0
1
1
Frequency Of Flooding (#/yr)

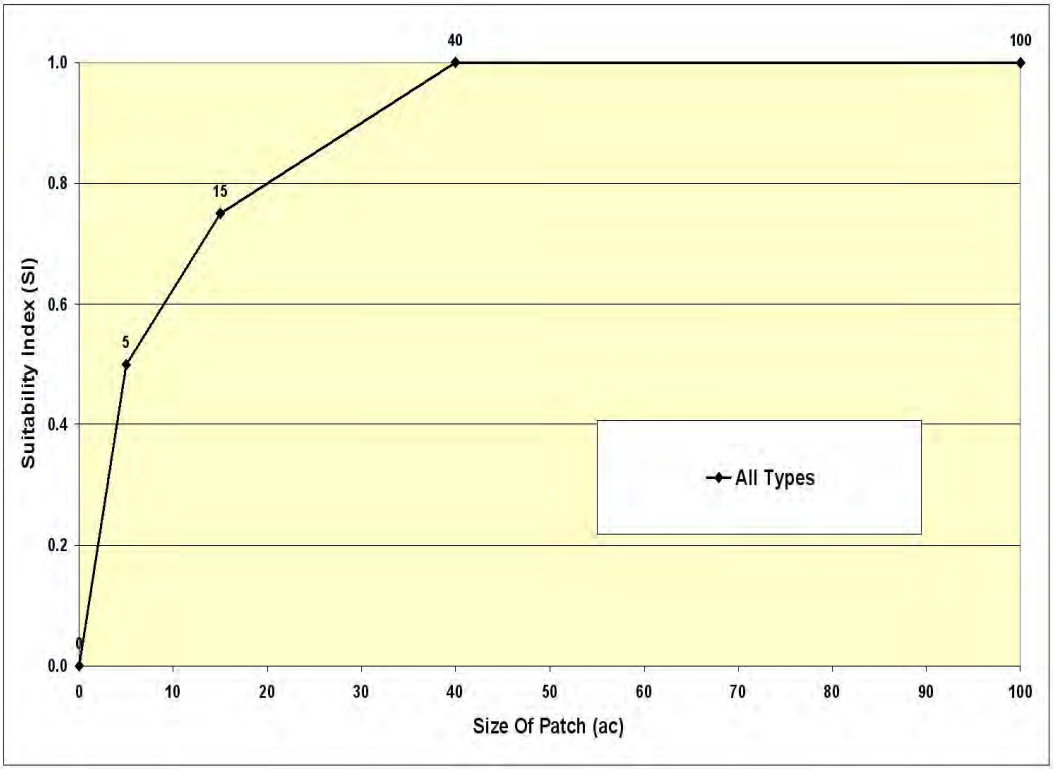

0
1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
All Meadow Types (6's)
25
100
0
10
20
30
40
50
60
70
80
90
100
Percent Of Forb Canopy That Is Undesirable Indicator Species (%)

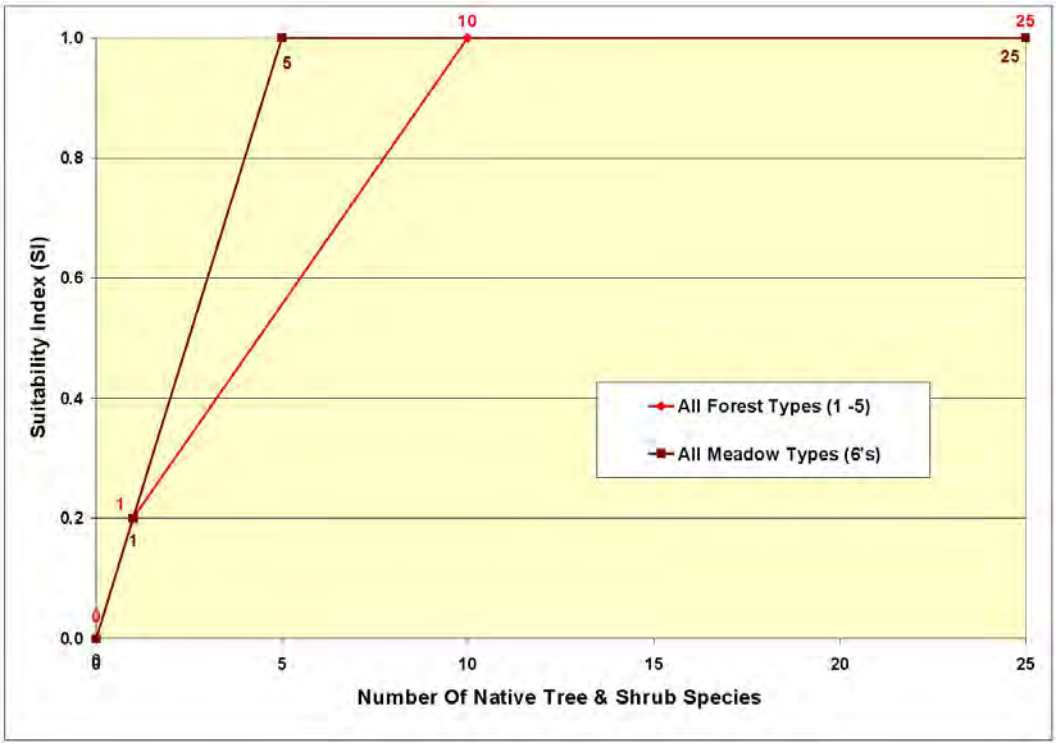

0
45
100
1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
All Meadow Types (6's)
0
10
20
30
40
50
60
70
80
90
100
Percent Of Grass Canopy That Is Undesirable Indicator Species (%)

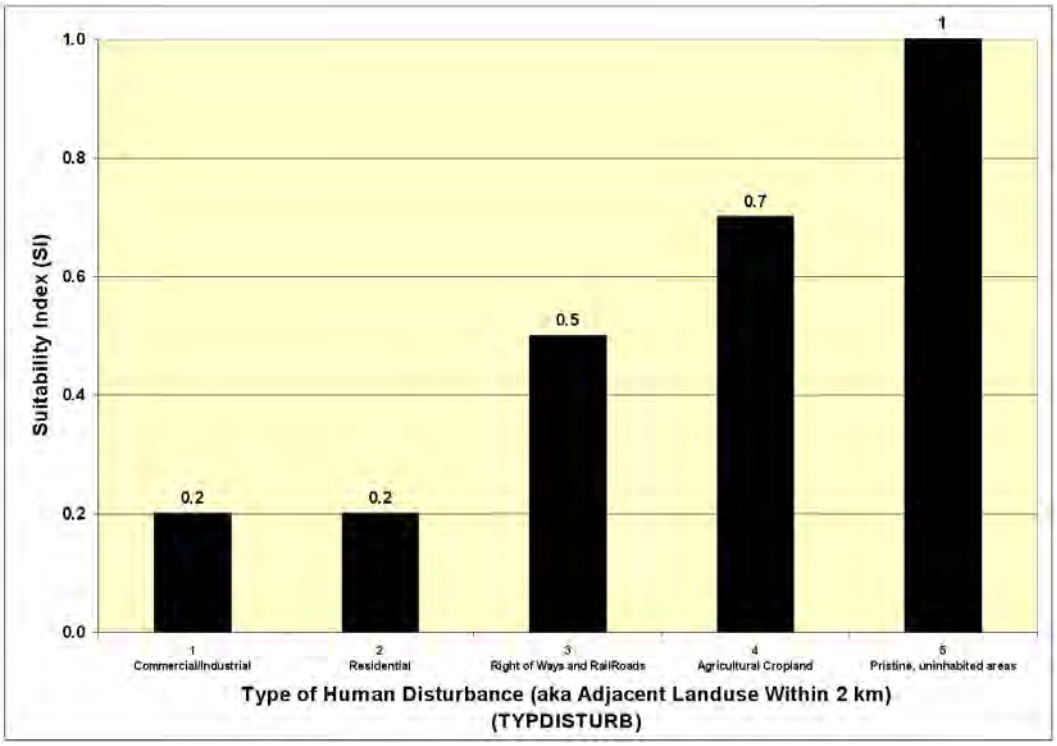

0
40
100
1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
All Forest Types (1-5)
0
10
20
30
40
50
60
70
80
90
100
Percent Of Herbaceous Canopy That Is Undesirable Indicator Species (%)

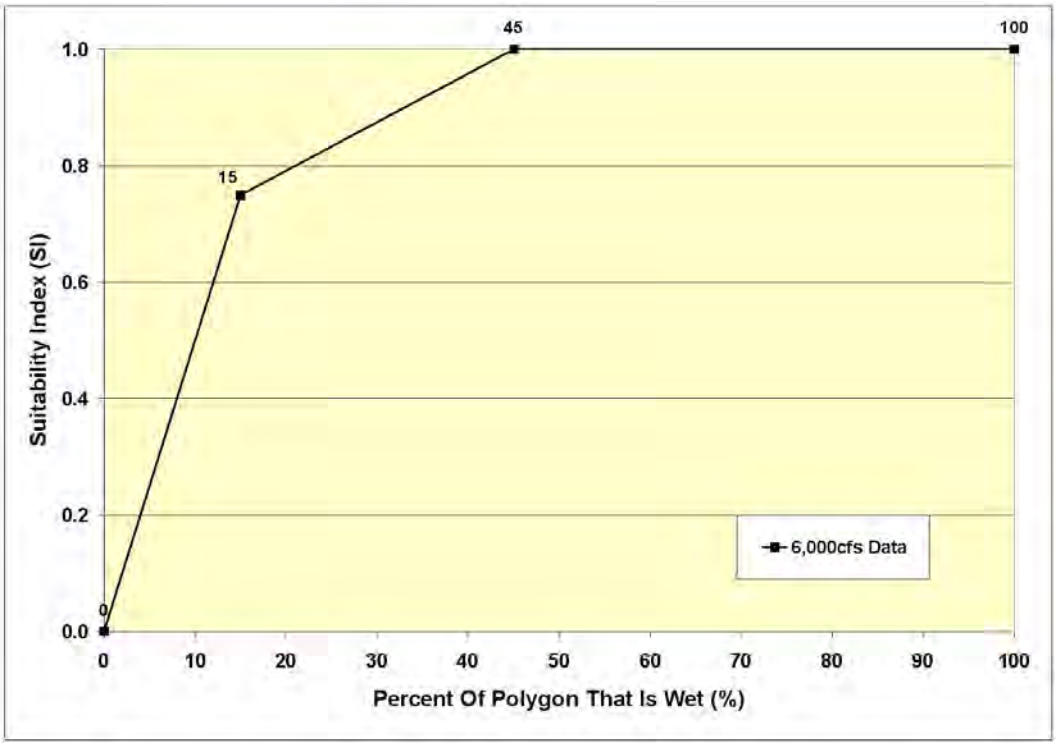

1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
0
35
75
100
All Meadow Types (6's)
0
10
20
30
40
50
60
70
80
90
100
Percent Of Sedge Canopy That Is Desirable Indicator Species (%)


1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
0
45
70
100
All Forest Types (1-5)
0
10
20
30
40
50
60
70
80
90
100
Percent Of Tall Overstory Tree Canopy That Is Native Species (%)


Suitability Index (SI)
Size Of Patch (ac)
All Types
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50
60
70
80
90
100
0
5
15
40
100


Suitability Index (SI)
Number Of Native Tree & Shrub Species
All Forest Types (1 -5)
All Meadow Types (6's)
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
0
1
1
5
10
25
25


1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
0.2
0.2
0.5
0.7
1
1 Commercial/Industrial
2 Residential
3 Right of Ways and RailRoads
4 Agricultural Cropland
5 Pristine, uninhabited areas
Type of Human Disturbance (aka Adjacent Landuse Within 2 km)
(TYPDISTURB)


1.0
0.8
0.6
0.4
0.2
0.0
Suitability Index (SI)
0
15
45
100
6,000cfs Data
0
10
20
30
40
50
60
70
80
90
100
Percent Of Polygon That Is Wet (%)

Appendix F
Useful Field Protocols and Checklists for the Bosque Riparian Model

Several checklists or crosswalks have been included in this appendix to assist the field in the application of the HSI model.

1. For those readers accustomed to the Hink and Omart (1984) vegetative classification system (H&O system), we offer a crosswalk in this appendix between it and the cover typing classification system used in the HSI model (Table F - 2).

2. We provide a list of "desirable" and "undesirable" species that will be needed to record both the indicator and native variables (Table F - 3 and Table F - 4).

3. And finally, we provide direction and diagrams to assist in the measurement of the various vegetative variables for the HSI model (i.e., point-intercept, line-intercept, point-centered quarter).

H&O Classification System

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 (Table F - 1.).

Table F - 1. Vegetation structure categories using modified Hink & Ohmart classification.

Structure Type	Dominant Overstory Height (ft)	Overstory Cover (%)	Understory Cover (%)	General Description
1s	>40	>25	25-50	Tall trees with well developed understory
1f	>40	>25	>50	Tall trees with very dense understory
2	>40	>25	<25	Tall trees with little of not understory
3s	20-40	>25	25-50	Intermediate-sized trees with medium understory density
3f	20-40	>25	>50	Intermediate-sized trees with dense understory
4	20-40	>25	<25	Scattered woodlands of intermediate-sized trees
5s	<20	>25	25-50	Shrubs with medium density
5f	<20	>25	>50	Dense shrubby growth
6	<20	<25	<25	Sparse and/or very young shrubs

Six general plant vegetation categories were developed by Hink and Ohmart (1984), based on the height of the vegetation and the make-up of the understory or lower layers:

- Forest Types I & III (untreated only)
- Forest Types II & IV (untreated and treated)
- Shrub Type V (untreated only)
- Dry Meadow Type VI (untreated and treated)
- Wet Meadow Type VI (untreated only)

Armed with this information, Table F - 2 offers a crosswalk between the H&O classification system and the cover type mapping performed for the HSI modeling efforts.

Table F - 2. Crosswalk between the commonly used Hink and Omart vegetative classification system and the Bosque Riparian HSI Model's cover type classification naming conventions

H&O Code	Hink & Omart Description	Scientific Name (*Genus species*)	HSI Cover Type
ATX-SS5	Four-wing salt bush-Sand sage, Type 5	*Atriplex canescens-Oligosporus filifolius*	TYPE 5
ATX-SS6	Four-wing salt bush-Sand sage, Type 6	*Atriplex canescens-Oligosporus filifolius*	TYPE 6U
B-CW5	Bulrush-Coyoto Willow, Type 5	*Scirpus spp.-Salix exigua*	TYPE 5
BD6	Broom dalea, Type 6	*Dalea scoparia*	TYPE 6U
C/A2t	Cottonwood overstory/Atriplex understory, Type 2, treated	*Populus fremontii var. wislizenii/Atriplex canescens*	TYPE 2T
C/B-A3	Cottonwood/Bulrush-Atriplex, Type 3	*Populus fremontii var. wislizenii/Scirpus-Atriplex canescens*	TYPE 3
C/C5pt	Cottonwood/Cottonwood, planted and treated	*Populus fremontii var. wislizenii*	TYPE 5
C/C6bpt	Cottonwood/Cottonwood, burned, planted and treated	*Populus fremontii var. wislizenii*	TYPE 6T
C/CW1	Cottonwood/Coyote Willow, Type 1	*Populus fremontii var. wislizenii/Salix exigua*	TYPE 1
C/CW1t	Cottonwood/Coyote Willow, Type 1, treated	*Populus fremontii var. wislizenii/Salix exigua*	TYPE 2T
C/CW3	Cottonwood/Coyote Willow, Type 3	*Populus fremontii var. wislizenii/Salix exigua*	TYPE 3
C/CW3S	Cottonwood/Coyote Willow, Type 3, sparse	*Populus fremontii var. wislizenii/Salix exigua*	TYPE 3
C/CW3t	Cottonwood/Coyote Willow, Type 3, treated	*Populus fremontii var. wislizenii/Salix exigua*	TYPE 3
C/CW4	Cottonwood/Coyote Willow, Type 4	*Populus fremontii var. wislizenii/Salix exigua*	TYPE 4U
C/CW-RO1	Cottonwood/Coyote Willow-Russian olive, Type 1	*Populus fremontii var. wislizenii/Salix exigua-Elaeagnus angustifolia*	TYPE 1
C/LC3bpt	Cottonwood overstory/(wolfberry) understory, Type 3	*Populus fremontii var. wislizenii/Lycium*	TYPE 3
C/MB2t	Cottonwood/Mulberry, Type 2, treated	*Populus fremontii var. wislizenii/Morus*	TYPE 2T
C/MB2t	Cottonwood/Mulberry, Type 2, treated	*Populus fremontii var. wislizenii/Morus*	TYPE 2T
C/MB-TW1t	Cottonwood/Mulberry-Tree Willow (Peach-leaf willow or Goodding willow), Type 1, treated	*Populus fremontii var. wislizenii/Morus/Salix*	TYPE 1
C/NMO1	Cottonwood/New Mexico olive, Type 1	*Populus fremontii var. wislizenii/Forestiera neomexicana*	TYPE 1
C/NMO1S	Cottonwood/New Mexico olive, Type 1, sparse	*Populus fremontii var. wislizenii/Forestiera neomexicana*	TYPE 1
C/NMO2t	Cottonwood/New Mexico olive, Type 2, treated	*Populus fremontii var. wislizenii/Forestiera neomexicana*	TYPE 2T
C/NMO3	Cottonwood/New Mexico olive, Type 3,	*Populus fremontii var. wislizenii/Forestiera neomexicana*	TYPE 3
C/NMO3t	Cottonwood/New Mexico olive, Type 3, treated	*Populus fremontii var. wislizenii/Forestiera neomexicana*	TYPE 3

(Continued)

Table F - 2. (Continued).

H&O Code	Hink & Omart Description	Scientific Name (*Genus species*)	HSI Cover Type
C/NMO-RO1	Cottonwood/New Mexico olive-Russian olive, Type 1	*Populus fremontii var. wislizenii/Forestiera neomexicana-Elaeagnus angustifolia*	TYPE 1
C/NMO-SC-RO1	Cottonwood/New Mexico olive-Salt cedar-Russian olive, Type 1	*Populus fremontii var. wislizenii/Forestiera neomexicana-Tamarix chinensis-Elaeagnus angustifolia*	TYPE 1
C/RO1	Cottonwood/Russian olive, Type 1	*Populus fremontii var. wislizenii/Elaeagnus angustifolia*	TYPE 1
C/RO15	Cottonwood/Russian olive, Type 15	*Populus fremontii var. wislizenii/Elaeagnus angustifolia*	TYPE 5
C/RO1F	Cottonwood/Russian olive, Type 1, Flycatcher	*Populus fremontii var. wislizenii/Elaeagnus angustifolia*	TYPE 1
C/RO1S	Cottonwood/Russian olive, Type 1, sparse	*Populus fremontii var. wislizenii/Elaeagnus angustifolia*	TYPE 1
C/RO2	Cottonwood/Russian olive, Type 2	*Populus fremontii var. wislizenii/Elaeagnus angustifolia*	TYPE 2U
C/RO2t	Cottonwood/Russian olive, Type 2, treated	*Populus fremontii var. wislizenii/Elaeagnus angustifolia*	TYPE 2T
C/RO3	Cottonwood/Russian olive, Type 3	*Populus fremontii var. wislizenii/Elaeagnus angustifolia*	TYPE 3
C/RO-CW1	Cottonwood/Russian olive-Coyote Willow, Type 1	*Populus fremontii var. wislizenii/Elaeagnus angustifolia-Salix exigua*	TYPE 1
C/RO-CW3	Cottonwood/Russian olive-Coyote Willow, Type 3	*Populus fremontii var. wislizenii/Elaeagnus angustifolia-Salix exigua*	TYPE 3
C/RO-NMO-SC1	Cottonwood/Russian olive-New Mexico olive-Salt cedar, Type 1	*Populus fremontii var. wislizenii/Elaeagnus angustifolia-Forestiera neomexicana-Tamarix chinensis*	TYPE 1
C/RO-SC1	Cottonwood/Russian olive-Salt cedar, Type 1	*Populus fremontii var. wislizenii/Elaeagnus angustifolia-Tamarix chinensis*	TYPE 1
C/RO-SC3	Cottonwood/Russian olive-Salt cedar, Type 3	*Populus fremontii var. wislizenii/Elaeagnus angustifolia-Tamarix chinensis*	TYPE 3
C/SC1	Cottonwood/Salt cedar, Type 1	*Populus fremontii var. wislizenii/Tamerix chinensis*	TYPE 1
C/SC2pt	Cottonwood/Salt cedar, Type 2, planted, treated	*Populus fremontii var. wislizenii/Tamerix chinensis*	TYPE 2T
C/SC3S	Cottonwood/Salt cedar, Type 3, sparse	*Populus fremontii var. wislizenii/Tamerix chinensis*	TYPE 3
C/SC4	Cottonwood/Salt cedar, Type 4	*Populus fremontii var. wislizenii/Tamerix chinensis*	TYPE 4U
C/SC-CW5	Cottonwood/Salt cedar-Coyote Willow, Type 5	*Populus fremontii var. wislizenii/Tamerix chinensis-Salix exigua*	TYPE 5
C/SC-RO1	Cottonwood/Salt cedar-Russian olive, Type 1	*Populus fremontii var. wislizenii/Tamerix chinensis-Elaeagnus angustifolia*	TYPE 1
C/SE1	Cottonwood/Siberian elm, Type 1	*Populus fremontii var. wislizenii/Ulmus pumila*	TYPE 1
C/SE2t	Cottonwood/Siberian elm, Type2, treated	*Populus fremontii var. wislizenii/Ulmus pumila*	TYPE 2T
C/TH1	Cottonwood/Tree of Heaven, Type 1	*Populus fremontii var. wislizenii/Ailanthus altissima*	TYPE 1
C/TH-SE2t	Cottonwood/Tree of Heaven-Siberian elm, Type 2, treated	*Populus fremontii var. wislizenil/Ailanthus altissima-Ulmus pumila*	TYPE 2T

(Continued)

Table F - 2. (Continued).

H&O Code	Hink & Omart Description	Scientific Name (*Genus species*)	HSI Cover Type
C/TH-SE4t	Cottonwood/Tree of Heaven-Siberian elm, Type 4, treated	*Populus fremontii var. wislizenii/Ailanthus altissima-Ulmus pumila*	TYPE 4T
C/TW1t	Cottonwood/Peach-leaf willow or Goodding willow, Type 1, treated	*Populus fremontii var. wislizenii/Salix gooddingii*	TYPE 1
C/TW2t	Cottonwood/Peach-leaf willow or Goodding willow, Type 2, treated	*Populus fremontii var. wislizenii/Salix gooddingii*	TYPE 2T
C2	Cottonwood, Type 2	*Populus fremontii var. wislizenii*	TYPE 2U
C2bpt	Cottonwood, Type 2, burned, planted and treated	*Populus fremontii var. wislizenii*	TYPE 2T
C2p	Cottonwood, Type 2, planted	*Populus fremontii var. wislizenii*	TYPE 2U
C2pt	Cottonwood, Type 2, planted, treated	*Populus fremontii var. wislizenii*	TYPE 2T
C2t	Cottonwood, Type 2, treated	*Populus fremontii var. wislizenii*	TYPE 2T
C4	Cottonwood, Type 4	*Populus fremontii var. wislizenii*	TYPE 4U
C4bpt	Cottonwood, Type 4, burned, planted and treated	*Populus fremontii var. wislizenii*	TYPE 4T
C4pt	Cottonwood, Type 4, planted and treated	*Populus fremontii var. wislizenii*	TYPE 4T
C4t	Cottonwood, Type 4, treated	*Populus fremontii var. wislizenii*	TYPE 4T
C5Sbpt	Cottonwood, Type 5, sparse, burned, planted and treated	*Populus fremontii var. wislizenii*	TYPE 5
C5Spt	Cottonwood, Type 5, sparse, planted and treated	*Populus fremontii var. wislizenii*	TYPE 5
C5St	Cottonwood, Type 5, sparse, treated	*Populus fremontii var. wislizenii*	TYPE 5
C5t	Cottonwood, Type 5, treated	*Populus fremontii var. wislizenii*	TYPE 5
C6bpt	Cottonwood, Type 6, burned, planted and treated	*Populus fremontii var. wislizenii*	TYPE 6T
C-CW5p	Cottonwood-Coyote Willow, Type 5, planted	*Populus fremontii var. wislizenii-Salix exigua*	TYPE 5
C-MB/MB1t	Cottonwood-Mulberry/Mulberry, type 1, treated	*Populus fremontii var. wislizenii-Morus/Morus*	TYPE 1
C-RO4	Cottonwood-Russian olive, Type 4	*Populus fremontii var. wislizenii-Elaeagnus angustifolia*	TYPE 4U
C-RO	Cottonwood-Russian olive	*Populus fremontii var. wislizenii-Elaeagnus angustifolia*	TYPE 5
C-RO/RO3	Cottonwood-Russian olive/Russian olive, Type 3	*Populus fremontii var. wislizenii-Elaeagnus angustifolia/Elaeagnus angustifolia*	TYPE 3
C-RO4pt	Cottonwood-Russian olive, Type 4, planted, treated	*Populus fremontii var. wislizenii-Elaeagnus angustifolia*	TYPE 4T

(Continued)

Table F - 2. (Continued).

H&O Code	Hink & Omart Description	Scientific Name (*Genus species*)	HSI Cover Type
C-RO-TW5	Cottonwood-Russian olive-Tree Willow (Peach-leaf willow or Goodding willow), Type 5	*Populus fremontii var. wislizenii-Elaeagnus angustifolia/Salix gooddingii*	TYPE 5
C-SC/SC1	Cottonwood-Salt cedar/Salt cedar, Type 1	*Populus fremontii var. wislizenii-Tamarix L/Tamerix chinensis*	TYPE 1
C-SC2	Cottonwood-Salt cedar, Type 2	*Populus fremontii var. wislizenii-Tamerix chinensis*	TYPE 2U
C-SE/CW3	Cottonwood-Siberian elm/Coyote Willow, Type 3	*Populus fremontii var. wislizenii-Ulmus pumila L./Salix exigua*	TYPE 3
C-SE/RO1	Cottonwood-Siberian elm/Russian olive, Type 1	*Populus fremontii var. wislizenii-Ulmus pumila L./Elaeagnus angustifolia*	TYPE 1
C-SE/SC1	Cottonwood-Siberian elm/Salt cedar, Type 1	*Populus fremontii var. wislizenii-Ulmus pumila L./Tamerix chinensis*	TYPE 1
C-SE/SC2	Cottonwood-Siberian elm/Salt cedar, Type 2	*Populus fremontii var. wislizenii-Ulmus pumila L./Tamerix chinensis*	TYPE 2U
C-SE/SE2t	Cottonwood-Siberian elm/Siberian elm, Type 2, treated	*Populus fremontii var. wislizenii-Ulmus pumila L./Ulmus pumila L.*	TYPE 2T
C-SE-TW/SC1	Cottonwood-Siberian elm/Tree Willow (Peach-leaf willow or Goodding willow)/Salt cedar, Type 1	*Populus fremontii var. wislizenii-Ulmus pumila L./Salix gooddingii/Tamerix chinensis*	TYPE 1
C-TH3	Cottonwood-Tree of Heaven, Type 3	*Populus fremontii var. wislizenii-Ailanthus altissima*	TYPE 3
C-TW/CW3	Cottonwood-Tree Willow (Peach-leaf willow or Goodding willow)/Coyote Willow, Type 3	*Populus fremontii var. wislizenii-Salix gooddingii/Salix exigua*	TYPE 3
C-TW/TH2pt	Cottonwood-Tree Willow (Peach-leaf willow or Goodding willow)/Tree of Heaven, Type 2, planted and treated	*Populus fremontii var. wislizenii-Salix gooddingii/Ailanthus altissima*	TYPE 2T
C-TW4t	Cottonwood-Tree Willow (Peach-leaf willow or Goodding willow), Type 4, treated	*Populus fremontii var. wislizenii-Salix gooddingii*	TYPE 4T
C-TW5pt	Cottonwood-Tree Willow (Peach-leaf willow or Goodding willow), Type 5, planted and treated	*Populus fremontii var. wislizenii-Salix gooddingii*	TYPE 5
C-TW6bpt	Cottonwood-Tree Willow (Peach-leaf willow or Goodding willow), Type 6, burned, planted and treated	*Populus fremontii var. wislizenii-Salix gooddingii*	TYPE 6T
C-TW-SC5bpt	Cottonwood-Tree Willow (Peach-leaf willow or Goodding willow)-Salt cedar, Type 5, burned, planted and treated	*Populus fremontii var. wislizenii-Salix gooddingii-Tamerix chinensis*	TYPE 5
C-TW-SE2t	Cottonwood-Tree Willow (Peach-leaf willow or Goodding willow)-Siberian elm, Type 2, treated	*Populus fremontii var. wislizenii-Salix gooddingii-Populus fremontii var. wislizenii*	TYPE 2T
CW5	Coyote Willow, Type 5	*Salix exigua*	TYPE 5
CW5	Coyote Willow, Type 5	*Salix exigua*	TYPE 5
CW5bt	Coyote Willow, Type 5, burned, treated	*Salix exigua*	TYPE 5

(Continued)

Table F - 2. (Continued).

H&O Code	Hink & Omart Description	Scientific Name (*Genus species*)	HSI Cover Type
CW5F	Coyote Willow, Type 5, Flycatcher	*Salix exigua*	TYPE 5
CW5t	Coyote Willow, Type 5, treated	*Salix exigua*	TYPE 5
CW6	Coyote Willow, Type 6	*Salix exigua*	TYPE 6U
CW6C-RO/CW6	Coyote Willow, Type 6, Cottonwood-Russian olive/Coyote Willow, Type 6	*Salix exigua, Populus fremontii var. wislizenii-Elaeagnus angustifolia/Salix exigua*	TYPE 6U
CW6pt	Coyote Willow, Type 6, planted, treated	*Salix exigua*	TYPE 6T
CW6S	Coyote Willow, Type 6, sparse	*Salix exigua*	TYPE 6U
CW6t	Coyote Willow, Type 6, treated	*Salix exigua*	TYPE 6T
CW-B-CAT6	Coyote Willow-Bulrush-Cattail, Type 6	*Salix exigua-Scirpus-Typha*	TYPE 6U
CW-C5	Coyote Willow-Cottonwood, Type 5	*Salix exigua-Elaeagnus angustifolia*	TYPE 5
CW-C6	Coyote Willow-Cottonwood, Type 6	*Salix exigua-Elaeagnus angustifolia*	TYPE 6U
CW-CAT6	Coyote Willow-Cattail, Type 6	*Salix exigua-Typha*	TYPE 6U
CW-RO5	Coyote Willow-Russian olive, Type 5	*Salix exigua-Elaeagnus angustifolia*	TYPE 5
CW-RO5F	Coyote Willow-Russian olive, Type 5, Flycatcher	*Salix exigua-Elaeagnus angustifolia*	TYPE 5
CW-RO6	Coyote Willow-Russian olive, Type 6	*Salix exigua-Elaeagnus angustifolia*	TYPE 6U
CW-RO-SC5	Coyote Willow-Russian olive-Salt cedar, Type 5	*Salix exigua-Elaeagnus angustifolia-Tamerix chinensis*	TYPE 5
CW-SC6	Coyote Willow-Salt cedar, Type 6	*Salix exigua-Tamerix chinensis*	TYPE 6U
CW-TW5	Coyote Willow-Tree Willow (Peach-leaf willow or Goodding willow), Type 5	*Salix exigua-Salix gooddingii*	TYPE 5
MB6t	Mulberry, Type 6, treated	*Morus*	TYPE 6T
MB-SE6t	Mulberry-Siberian elm, Type 6, treated	*Morus-Ulmus pumila L*	TYPE 6T
MH5	Marsh, Type 5	*Morass*	TYPE 5
MH5-OW	Marsh, Type 5-Open Water	*Morass*	TYPE 5
MH6	Marsh, Type 6	*Morass*	TYPE 6W
NMO-CW5	New Mexico olive-Coyote Willow, Type 5	*Forestiera neomexicana-Salix exigua*	TYPE 5
NMO-SB5	New Mexico olive-Sandbar, Type 5	*Forestiera neomexicana-Salix interior*	TYPE 5
OP	Open land		OPENLAND

(Continued)

Table F - 2. (Continued).

H&O Code	Hink & Omart Description	Scientific Name (*Genus species*)	HSI Cover Type
OPbpt	Open land, burned, planted and treated		OPENLAND
OPpt	Open land, planted and treated		OPENLAND
OPt	Open land, treated		OPENLAND
OW	Open water		OPENWATER
OWb	Open water, burned		OPENWATER
OW-MH5	Open water-Marsh, Type 5		TYPE 5
RO/CW3	Russian olive/Coyote Willow, Type 3	*Elaeagnus angustifolia/Salix exigua*	TYPE 3
RO3	Russian olive, Type 3	*Elaeagnus angustifolia*	TYPE 3
RO5	Russian olive, Type 5	*Elaeagnus angustifolia*	TYPE 5
RO5b	Russian olive, Type 5, burned	*Elaeagnus angustifolia*	TYPE 5
RO6	Russian olive, Type 6	*Elaeagnus angustifolia*	TYPE 6U
RO-C4	Russian olive-Cottonwood, Type 4	*Elaeagnus angustifolia-Populus fremontii var. wislizenii*	TYPE 4U
RO-C6	Russian olive-Cottonwood, Type 6	*Elaeagnus angustifolia-Populus fremontii var. wislizenii*	TYPE 6U
RO-CW5	Russian olive-Coyote Willow, Type 5	*Elaeagnus angustifolia-Salix exigua*	TYPE 5
RO-CW5F	Russian olive-Coyote Willow, Type 5, Flycatcher	*Elaeagnus angustifolia-Salix exigua*	TYPE 5
RO-CW6	Russian olive-Coyote Willow, Type 6	*Elaeagnus angustifolia-Salix exigua*	TYPE 6U
RO-SC3	Russian olive-Salt cedar, Type 3	*Elaeagnus angustifolia-Tamerix chinensis*	TYPE 3
RO-SC5	Russian olive-Salt cedar, Type 5	*Elaeagnus angustifolia-Tamerix chinensis*	TYPE 5
RO-SE-SC5S	Russian olive-Siberian elm, Salt cedar, Type 5, sparse	*Elaeagnus angustifolia-Ulmus pumila-Tamerix chinensis*	TYPE 5
SC3	Salt cedar, Type 3	*Tamerix chinensis*	TYPE 3
SC5	Salt cedar, Type 5	*Tamerix chinensis*	TYPE 5
SC5F	Salt cedar, Type 5. Flycatcher	*Tamerix chinensis*	TYPE 5
SC5S	Salt cedar, Type 5, sparse	*Tamerix chinensis*	TYPE 5
SC5t	Salt cedar, Type 5, treated	*Tamerix chinensis*	TYPE 5
SC6	Salt cedar, Type 6	*Tamerix chinensis*	TYPE 6U
SC6S	Salt cedar, Type 6, sparse	*Tamerix chinensis*	TYPE 6U

(Continued)

Table F - 2. (Continued).

H&O Code	Hink & Omart Description	Scientific Name (*Genus species*)	HSI Cover Type
SC-C5	Salt cedar-Cottonwood, Type 5	*Tamerix chinensis-Populus fremontii var. wislizenii*	TYPE 5
SC-C6S	Salt cedar-Cottonwood, Type 6, sparse	*Tamerix chinensis-Populus fremontii var. wislizenii*	TYPE 6U
SC-CW5	Salt cedar-Coyote Willow, Type 5	*Tamerix chinensis-Salix exigua*	TYPE 5
SC-CW5pt	Salt cedar-Coyote Willow, Type 5, plant, treated	*Tamerix chinensis-Salix exigua*	TYPE 5
SC-RO/SC3	Salt cedar-Russian olive/Salt cedar, Type 3	*Tamerix chinensis-Elaeagnus angustifolia/Tamerix chinensis*	TYPE 3
SC-RO/SC-RO3	Salt cedar-Russian olive/Salt cedar-Russian olive, Type 3	*Tamerix chinensis-Elaeagnus angustifolia/Tamerix chinensis-Elaeagnus angustifolia*	TYPE 3
SC-RO/TW-SE3	Salt cedar/Russian olive-Tree Willow (Peach-leaf willow or Goodding willow)-Siberian elm, Type 3	*Tamerix chinensis-Elaeagnus angustifolia/Salix gooddingii-Ulmus pumila*	TYPE 3
SC-RO5	Salt cedar-Russian olive, Type 5	*Tamerix chinensis-Elaeagnus angustifolia*	TYPE 5
SC-SE5pt	Salt cedar-Siberian elm, Type 5, plant, treated	*Tamerix chinensis-Ulmus pumila*	TYPE 5
SE/MB-TH3	Siberian elm/Mulberry-Tree of Heaven, Type 3	*Ulmus pumila/Morus-Ailanthus altissima*	TYPE 3
SE/SC3	Siberian elm/Salt cedar, Type 3	*Ulmus pumila/Tamerix chinensis*	TYPE 3
SE1	Siberian elm, Type 1	*Ulmus pumila*	TYPE 1
SE5bt	Siberian elm, Type 5, burned, treated	*Ulmus pumila*	TYPE 5
SE-C/SC1	Siberian elm-Cottonwood/Salt cedar, Type 1	*Ulmus pumila-Populus fremontii var. wislizenii/Tamerix chinensis*	TYPE 1
SE-C1	Siberian elm-Cottonwood, Type 1	*Ulmus pumila-Populus fremontii var. wislizenii*	TYPE 1
SE-RO/SC-CW5	Siberian elm-Russian olive/Salt cedar-Coyote Willow, Type 5	*Ulmus pumila-Elaeagnus angustifolia/Tamerix chinensis-Salix exigua*	TYPE 5
SS6t	Sand sage, Type 6, treated	*Artemisia filifolia*	TYPE 6T
TW5Sbpt	Tree Willow (Peach-leaf willow Goodding willow), Type 5, sparse, burned, planted and treated		TYPE 5
TW-C4	Tree Willow (Peach-leaf willow Goodding willow)-Cottonwood, Type 4		TYPE 4U
TW-SE/CW3	Tree Willow (Peach-leaf willow Goodding willow)-Siberian elm/Coyote Willow, Type 3		TYPE 3
WM	Utility areas not considered “habitat”		UTILITY

Undesirable vs. Desirable Species Lists

In addition, the E-Team developed a list of "indicator" species to serve as proxies to capture the desired vegetative composition and diversity in a restored bosque ecosystem. Here we offer the list of the undesirable "indicator" species (Table F - 3) as well as the native species of concern (Table F - 4) for Bosque Riparian HSI model applications (variable codes include INDICATFB, INDICATGR, INDICATHB, SPPCOUNT, NATIVETREE, and NATIVESDG).

Table F - 3. List of undesirable indicator species when applying the model.

Life Form	Scientific Name	Common Name	Kartez Symbol	NHNM-ACRO1
Trees	*Ailanthus altissima*	tree of heaven	AIAL	AILALT
	Elaeagnus angustifolia	Russian olive	ELAN	ELAANG
	Ulmus pumila	Siberian elm	ULPU	ULMPUM
	Tamarix ramosissima	saltcedar	TARA	TAMRAM
Graminoids	*Agrostis gigantea*	redtop	AGGI2	AGRGIG
	Bromus catharticus	rescuegrass	BRCA6	BROCAT
	Bromus japonicus	Japanese brome	BRJA	BROJAP
	Bromus tectorum	cheatgrass	BRTE	BROTEC
	Cynodon dactylon	bermudagrass	CYDA	CYNDAC
	Hordeum murinum	mouse barley	HOMU	HORMUR
	Saccharum ravennae	ravennagrass	SARA3	SACRAV
	Sorghum halepense	johnsongrass	SOHA	SORHAL
Forbs	*Kochia scoparia*	common kochia	KOSC	KOCSCO
	Lepidium latifolium	perennial pepperweed	LELA2	LEPLAT
	Salsola tragus	prickly Russian thistle	SATR12	SALTRA
	Aster spp.	dandelion		
	Solidago spp.	Solidago		
	Salsola kalii	tumbleweed	SAKA	SALKAL
	Cardaria draba (L.) Desv.	Hoary cress		
	Alhagi pseudalhagi (Bieb) Desv.	camelthorn		
	Euphorbia esula L.	leafy spurge		
	Peganum harmala L.	African rue		
	Centaurea maculosa Lam.	spotted knapweed		
	Centaurea solstitialis L.	yellow starthistle		
	Carduus natuans L.	musk thistle		

Table F - 4. List of native indicator species when applying the model.

Life Form	Scientific Name	Common Name	Kartez Symbol	NHNM-ACRO1
Trees	*Populus deltoides ssp. wislizeni*	Rio Grande cottonwood	PODEW	POPDELW
	Salix gooddingii	Goodding's willow	SAGO	SALGOO
Shrubs	*Amorpha fruticosa*	desert indigobush	AMFR	AMOFRU
	Forestiera pubescens	New Mexico olive	FOPU2	FORPUB
	Salix exigua	coyote willow	SAEX	SALEXI
	Baccharis spp	baccharis		
	Ribes aureum	golden currant		
	Rhus sp	sumac		
	Lycium torii	wolfberry		
	Shepherdia argentea	silver buffalo berry		
Graminoids	*Carex spp.*	sedge	CAREX	CAREX
	Cyperus spp.	flatsedge	CYPER	CYPERU
	Juncus spp.	Rush	JUNCU	JUNCUS
	Muhlenbergia asperifolia	alkali muhly	MUAS	MUHASP
	Oryzopsis hymenoides	Indian ricegrass	ORHY	ORYHYM
	Panicum spp.	panicgrass	PANIC	PANICU
	Sorghastrum nutans	Indiangrass	SONU2	SORNUT
Forbs	*Anemopsis californica*	yerba mansa	ANCA10	ANECAL

Field Sampling Protocols and Diagrams

Three specific protocols were used to measure the vegetative conditions on the references sites for the MRGBER study: 1) point-intercept, 2) line-intercept, and 3) point-centered quarter. Below we illustrate their methodology with the hope that our techniques can be repeated by future users for various reasons (i.e., to perform validation of the model; facilitate a monitoring program using the HSI model; apply the model elsewhere, etc.).

Point-Intercept

Point-intercept[1] was used to measure the numerous herbaceous canopy cover parameters (CANFORB, CANGRASS, CANHERB, CANSEDGE), and was calculated by dividing the number of "hits" on a plant by the total number of sample points taken along the transect. Narrow points (e.g. a nail on the bottom of a wooden dowel) were vertically lowered through a frame (e.g. a camera tripod) at pre-determined intervals along the transects (in this case, every 2-meters). As the pin moved towards the ground, every plant that made contact with the pin was recorded as a "canopy hit" (as opposed to a "basal hit", described below in the ground cover section above). A canopy "hit" included any pin contact with a plant leaf, stem or flower (Figure F - 1).

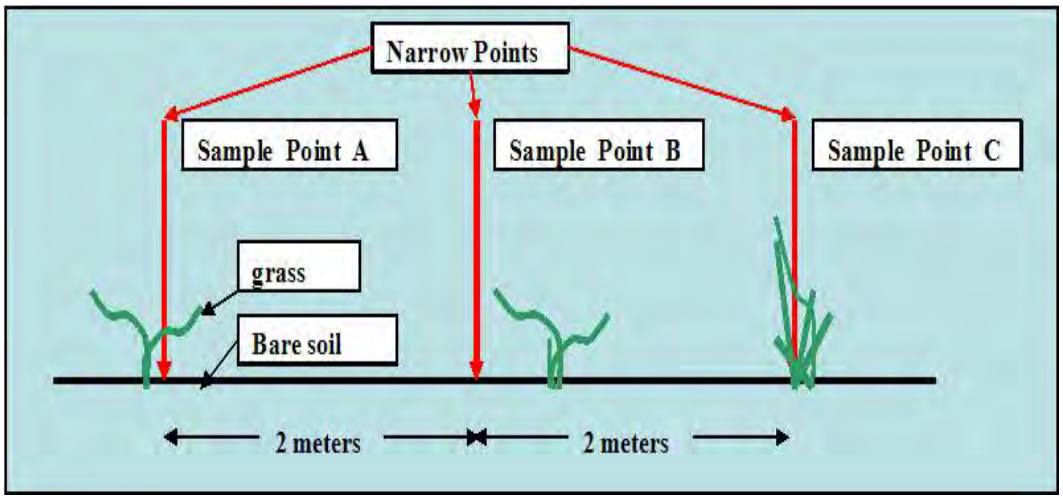


Figure F - 1. Illustration of the point-intercept method used to record aerial herbaceous plant cover for the MRGBER study.

In the example, the observer would record "grass" as a canopy "hit" and "soil" as a ground cover "hit" (*COVGRND* and *CTGRNDCOV)* at **Sample Point A**. For **Sample Point B**, the there would be no aerial "hit" recorded, but the ground cover "hit" would be recorded as "litter." For **Sample Point C**, both the aerial and the ground cover "hits" would be

1 While all methods for estimating plant cover have their advantages and disadvantages, points were considered the most objective way to estimate plant cover (Bonham 1989) and for herbaceous plants, is considered more precise and efficient than estimating aerial cover with quadrats (Bonham 1989; Chambers & Brown 1983; Elzinga et. al. 1998; Floyd and Anderson 1987).

recorded as "grass." To increase efficiency and considering the project goals, the field team only recorded canopy hits according to plant life-form (i.e., grass, forb, sedge, or rush). The only exception to this rule will be if the pin made contact with a highly desirable or undesirable plant species ("indicator species") (i.e., *INDICATFB*, *INDICATGR*, *INDICATHB*, and *NATIVESDG*). In those instances, the species must be identified along with the "hit".

Line-Intercept

The line-intercept method proved to be a fast and efficient way to estimate shrub canopy cover (*CANSHRUB*) over large areas of the study. The line-intercept method run using the existing cross transects. Any shrub crowns that overlapped or intercepted the transect line was recorded (by species) (Figure F - 2).

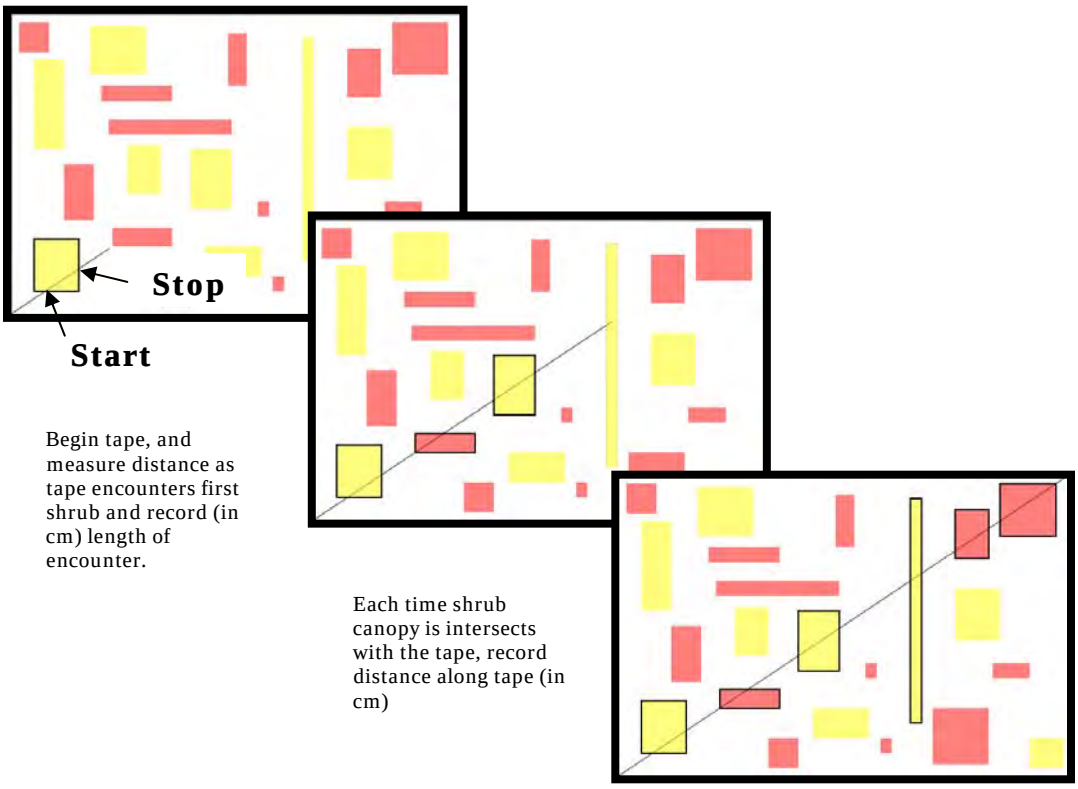


Figure F - 2. Illustration of the line-intercept method used to record shrub cover for the MRGBER study.

The beginning and end of where the canopy overhung the tape was recorded and later converted to percent cover. A pole with a level/optical sighting device was used, when necessary, to reduce observer bias for

determining if a shrub was "in", and for determining the starting and ending points along the tape.[1]

Point-Centered Quarter

The pint-centered quarter method was known to be a frequently used distance methods to sample forest communities (Bonham 1989; Cottam & Curtis 1956; Elzinga et al. 1998; Krebs 1999). After a sampling point along a transect was located (in this case, at the end of each cross arm), the area around those points was split into four 90° quadrants (quarters) and the distance to the nearest tree and root-sprout in each quarter was estimated with an optical rangefinder (*DISTBIGTR*) (Figure F - 3).

[1] Information taken from http://ag.arizona.edu/AREC/pubs/rmg/1%20rangelandmanagement/5%20monitorrangebrowseveg93.pdf (SEPTEMBER 2008) and diagram taken from http://en.wikipedia.org/wiki/Image:LiTrSa42008Geelhoed.svg (SEPTEMBER 2008).

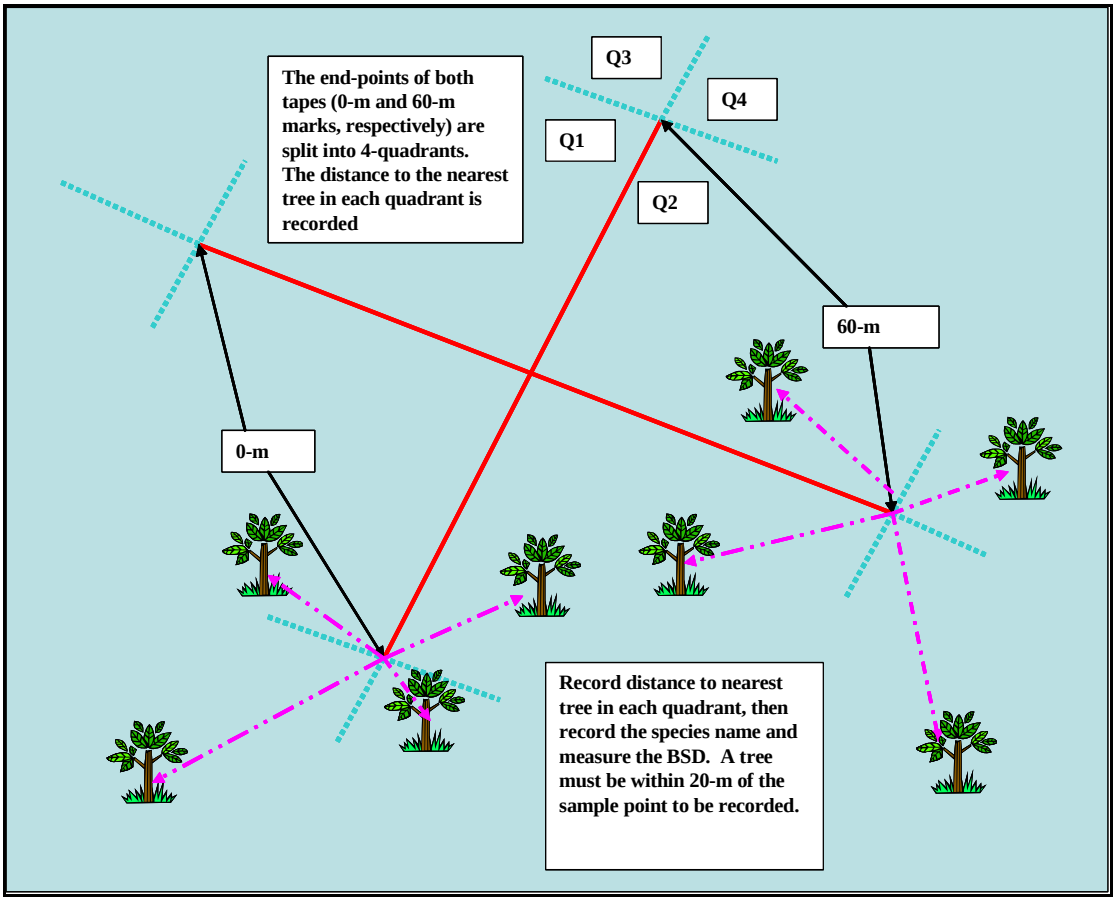


Figure F - 3. Illustration of point-centered quarter method used to record tree and root-sprout density and size.

The tree species was recorded and basal stem diameter of trees (not root-sprouts) was measured with calipers or a dbh tape and recorded on the data sheet as well. Double counting was not allowed. To avoid the potential problem of double counting, the measurements were only recorded at the terminus of each cross arm, and a maximum distance of 20-m was applied for recording a tree in any PCQ quadrant. Krebs (1999) stressed the importance of accurately dividing each sampling point into four even quadrants. We used a compass with the optical rangefinder while standing at the sample point to ensure that a tree or root-sprout was actually in the quadrant of interest before recording it on the data sheet. In those instances where no tree within 20-m in a particular quadrant was found, the team recorded a “>20-m” value on the data sheet. Equations for calculating density and basal area using PCQ are described in Krebs (1999).

Appendix G: Model Review Forms and Comments

ERDC-EL used technical experts both within the laboratory itself, and outside the facility (but still within the USACE planning community) to perform a review of both the model development process and the model itself. To assure fair and impartial review of the products, members of the Laboratory-based Technical Review Team (LTRT) were chosen on the basis of expertise, seniority in the laboratory chain of command, and USACE planning experience.

The following were members of the LTRT:

1. Dr. Andrew Casper (ERDC-EL) – technical (peer) reviewer,
2. Ms. Kristine Nemec (Kansas City District) – technical (peer) reviewer,
3. Janean Shirley – editorial review (Technical Editor),
4. Ms. Antisa Webb - management review (Branch Chief),
5. Dr. Edmond J. Russo – management review (Division Chief),
6. Dr. Steve Ashby – program review (System-wide Water Resources Research Program, Program Manager),
7. Dr. Al Cofrancesco – program review (Technical Director), and
8. Dr. Mike Passmore – executive office review (Environmental Laboratory Deputy Director).

No peer review members of the LTRT were directly associated with the development or application of the model(s) for this study, thus assuring independent technical peer review.[1] Referred to as the in-house Laboratory-based Technical Review (LTR), these experts were asked to consider the following issues when reviewing this document:

1. Whether the concepts, assumptions, features, methods, analyses, and details were appropriate and fully coordinated;

[1] Resumes for Dr. Casper and Ms. Nemec (i.e., the technical peer reviewers) can be found immediately following the comment/response tables at the end of this appendix.

2. Whether the analytic methods used were environmentally sound, appropriate, reasonable, fall within policy guidelines, and yielded reliable results;
3. Whether any deviations from USACE policy and guidance were identified, documented, and approved;
4. Whether the products met the Environmental Laboratory's standards based on format and presentation; and
5. Whether the products met the customer's needs and expectations.

Review comments were submitted to the Laboratory-based Project Delivery Team (LPDT) in written format and the LPDT responded in kind (Table G - 1). In the EL Electronic Manuscript Review System (ELEMRS) 2.0, both reviewers indicated that the document was "Acceptable" with grammatical/formatting modifications needed, and when asked to offer their opinion as to the production of the report they stated that it was a, "quality study, well designed and presented [with] important new information."

Table G - 1. Review comments.

Review Comments				
Project:	A Bosque Riparian Community Index Model for the Middle Rio Grande, Albuquerque, New Mexico		**Review Focus:** Model Documentation – Completeness, Scientific Basis (Editorial comments accepted as well)	
Reviewer	**Page/ Para**	**Chapter**	**Reviewer Comments**	**Response**
Kristine Nemec	Pg. 76 Table 4	4	(Wagner 2004), Jacob, Moulton and Lopez 2004) missing reference	Concur and rectified.
	Pg. 80 Table 4	4	Stamps 1991 missing reference	Concur and rectified
	Pg. 104	Table 10	Explain why some cells are shaded black	Concur and explanation incorporated into table footnote.
		References	Missing or references included that were not cited in text.	Concur and rectified
	Throughout doc	NA	Grammar and spelling suggestions made in track changes format	Concur and incorporated.
	Pg. 6	1	The Middle Rio Grande study documentation identified and recommended effective, affordable and environmentally sensitive ecosystem restoration features throughout the middle reach of the Rio Grande system. Should you add the 905(b) or quote the problem statement?	Do not concur – the reader must turn to the feasibility documentation to investigate study goals and objectives. The purpose of this report is to document the model – not it's use.
	Pg. 7 Para 1		Do you think a definition of function is necessary	Concur – a definition of function has been incorporated into the text and added to the glossary.
	Pg. 7 Para 2		baseline - Should you use planner speak - inventory or FWOP?	Do not concur – the syntax in the model documentation follows standard USACE planning paradigm. As such, baseline is not the future without-project condition, nor is it wholly equal to the term inventory. An inventory can include more than the baseline condition per the model. The Without project-condition describes changes into the future from the baseline condition under a "No Action" scenario.

(Continued)

Table G - 1. (Continued).

Review Comments				
Project:	A Bosque Riparian Community Index Model for the Middle Rio Grande, Albuquerque, New Mexico		**Review Focus:** Model Documentation – Completeness, Scientific Basis (Editorial comments accepted as well)	
Reviewer	Page/ Para	Chapter	Reviewer Comments	Response
Kristine Nemec	Pg. 8 Para 2		In May of 2005, the PMIP developed Engineering Circular (EC) 1105-2-407, Planning Models Improvement Program: Model Certification (USACE 2005).	No – documents cited in this section are current.
	Pg. 9 Para 4	1	developed - And certified? Or state that certification is not needed	The HEAT software has been recommended for certification, but has not been certified as of December 2009. ERDC-EL is incorporating reviewer changes to the User Guide, and will be submitting the software for certification to USACE-Headquarters soon.
	Pg. 15 # 5	2	Conduct field sampling - Can it also be done with pre-existing GIS files	Although it could be done with pre-existing GIS data to some extent, it was not handled in this manner, and any change from this protocol would necessitate an external peer review (i.e., review via model certification protocols). As such, this issue was not addressed in the document.
	Pg. 21 Figure 1	3	**Figure 1** I can't tell what the right figure # is this should be 5? (the next is Figure 6	Concur and rectified.
	Pg. 23 Para 1	3	Subsequent iterative refinement of these models led to the identification of contributing ecosystem components, and a description of associated variables (with suggested sampling protocols) that can be used to measure ecosystem restoration benefits. Citation? Is his sentence needed	Do not concur – this sentence if absolutely necessary, and original. Therefore no citations are necessary.

(Continued)

Table G - 1. (Continued).

Review Comments				
Project:	A Bosque Riparian Community Index Model for the Middle Rio Grande, Albuquerque, New Mexico		**Review Focus:** Model Documentation – Completeness, Scientific Basis (Editorial comments accepted as well)	
Reviewer	Page/ Para	Chapter	Reviewer Comments	Response
Andy Casper	Pg. 28 Para 1 (heading)	3	Climatic Characterization - Citations? Maybe 'Dahm, C.M., Edwards, R.J. and F.P. Gelwick. 2005. The Gulf Coast Rivers of the Southwestern United States. Chapter 5. In: The Rivers of North America . Benke, A.C. and C. E. Cushing (eds.). Academic Press, Inc.	Do not concur - Citations unnecessary as this information was taken from the internet and weather citations provided therein.
	Pg. 37 Para 2	3	It should be noted, - It is unclear what the significance is? Does this add/subtract one of the categories? Affect them some other way?	Do not concur – significance is provided at the end of the paragraph.
	Pg. 39 Para 1	3	Clearing activities have greatly reduced the acreage of Type I, III, and V woodlands. Recently-created Type II stands are largely devoid of understory vegetation - Significance to the model is not clear	Do not concur – significance is provided at the end of the paragraph.

(Continued)

Table G - 1. (Concluded).

Review Comments				
Project:	A Bosque Riparian Community Index Model for the Middle Rio Grande, Albuquerque, New Mexico		**Review Focus:** Model Documentation – Completeness, Scientific Basis (Editorial comments accepted as well)	
Reviewer	Page/ Para	Chapter	Reviewer Comments	Response
Andy Casper	Pg. 39 & 40 Last & first para	3	Because the "treated" habitats were significantly different in terms of vegetative cover, infiltration, etc., from the "untreated" cover types in the region, the E-Team made a decision to capture these differences by dividing several of the Hink and Omart categories (namely Types II, IV, and VI) into "Treated" and "Untreated" classifications (designated by "U's") to better capture the degraded habitat conditions in "fire managed" areas within the study boundary . . . " – Ah here it is! Maybe add an intro sentence to the first paragraph in this section that says something like 'The prevalence of fire in the riparian community can have a strong impact on the six categories.' So the reader knows why they are reading about fire in a water project	Do not concur – significance is provided at the end of the paragraph.
	Pg. 40 Para 2	3	Open areas not associated with the model have been mapped, and offer potential areas of restoration and rehabilitation within the study area. I am confused , if it is not part of the accounting the model, it is per force not part of the restoration – why even bring it up if it doesn't affect the project somehow.	Do not concur - Although this is an application question, the point of this statement is that unassociated habitats CANNOT be assessed with the model, and yet a full accounting of landuse/landcover classifications must be completed in order to balance the books. Unassociated habitat <u>can be</u> enhanced/restored in such a manner that the conversion allows for model assessment.
	Pg. 87 Table 5	4	Need protocol from Ondrea	Concur and rectified.

US Army Corps of Engineers

Professional Experience

Dr. Andrew F. Casper

Research Biologist, Aquatic Ecology and Invasive Species Branch, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS., 2006 to present.

- Specializing in large river science, engineering and ecology spanning the continent from Gulf Coast rivers and estuaries to the Ohio and Mississippi River Valley's to the arctic Mackenzie River Delta and Beaufort Sea in Canada
- Development of conceptual, physical habitat, and watershed models
- Modeling climate change and land use impacts/responses
- Assessment of dam removal and ecological restoration
- Food web and community ecology techniques for fish and invertebrates in large navigable rivers and flood plains
- GIS-based, 2-D water quality mapping in tidal creeks/coastal rivers

Research Biologist - ERDC, Environmental Laboratory
3909 Halls Ferry Rd., Vicksburg, MS 39180
601-634-4681
Andrew.F.Casper@usace.army.mil

Education

- **Ph.D.** Océanography, 2005, Université Laval, Québec City, QC.
- **M.S.** Biological Sciences, 1993 Southern Illinois University Carbondale.
- **B.S.** Natural Sciences, 1990 Southern Illinois University Carbondale

Research & Teaching

- A.F. Casper and C. Fischenich. Framework and Integration of Conceptual Models in the CoE Planning Process (System Wide Water Resource Program Environmental Benefits Analysis Program, USACE HQ).
- Brasfield, S., A.F. Casper and B. S. Payne. Potential Contribution of Climate Change to the Bioassessment of Contaminants on Military Installations: Additive, Synergistic or Antagonistic? (USACE ERDC Basic Research Program).
- K. J. Killgore, J. J. Hoover, D. R. Johnson, and A. F. Casper. Envirofish: A HEC compatible floodplain habitat model for evaluating mitigation scenarios (reimbursable project for D. R. Johnson, Mississippi Valley District).

Other Professional Activities

- Ecosystem restoration/mitigation
- Sensitivity analysis and incorporation of risk/uncertainty
- Forecasting effects of scenarios and plan formulations
- Project/Watershed cumulative impacts assessments
- Coordinate field collections, management, analysis and reporting for river ecology
- SOW proposal and budget writing for multi-year research projects (NSF, EPA, USACE)

Selected Publications & Conference Presentations

- Casper, R. A. Efoymson, S. M. Davis, G. Steyer, and B. Zettle. 2009. Improving Conceptual Model Development: Avoiding Underperformance Due to Project. U.S. Army Engineer Reseawrch and Development Center, Vicksburg, MS.
- Casper A. F., and J. H. Thorp. 2007. Diel and lateral patterns of zooplankton distribution in the St. Lawrence River. Rivers Research and Application 23(1):73-85.
- Casper, A. F., J. H. Thorp, S. P. Davies, and D. L. Courtemanch. 2006. Ecological responses of large river benthos to the removal of the Edwards Dam on Kennebec River, Maine (USA). Archiv fur Hydrobiologie 16(4):541-555 (Large River Supplement 115).
- June 2008 - A surrogate model for future regional climate change: The current affects of the Atlantic Multidecadal Oscillation and its influence on the ecohydrology of Great Lakes and New England rivers. 56th Annual North American Benthological Society International Conference, Salt Lake City, Utah.
- July 2007 - Linking ecological responses to hydrologic characteristics of rivers: Examples from studies of dam removals and PHABSIM modeling for minimum flow standards. US Army Corps of Engineers Waterways Experiment Station, Vicksburg MS.
- A. F. Casper, B. Dixon, E. Steimle, J. Gore, P. Coble, and R. Conmy. Water quality sampling strategies for monitoring coastal rivers & estuaries: Applying technological innovations to Tampa Bay tributaries. Awarded by USEPA (Oct 2006 - Dec 2007).
- Carrabetta, M., A. F. Casper, B. Chernoff, and M. Daniels. The ecological and physical effects of removal of two low-head dams on Eight Mile Creek, a tributary of the Connecticut River. Awarded by TNC/NOAA Community Restoration Program (2005-07).

September 2009

Missouri River Cottonwood Management Plan

Kristine T. Nemec

Professional Experience

Environmental Resources Specialist, U.S. Army Corps of Engineers, Omaha District, December 2002 to present

- Prepare environmental assessments required under the National Environmental Policy Act for shallow water habitat and emergent sandbar habitat projects along the Missouri River
- Designed planting specifications for riparian forest restorations in South Sioux City, Nebraska; Sioux Falls, South Dakota; and Lower Brule Sioux Reservation, South Dakota
- Served on the South Dakota Bald Eagle Management Team, 2003-05
- Developed environmental sections of mater plan updates for Gavins Point and Oahe projects in South Dakota

Education

- **Ph.D.,** In progress
  University of Nebraska at Lincoln, Lincoln, NE
- **M.S.,** Biology, 2003
  University of Nebraska at Omaha, Omaha, NE
- **B.S.,** Environmental Studies, 1999
  University of Nebraska at Omaha, Omaha, NE
  Summa Cum Laude. University Honors Program

Research & Teaching

- Restoration ecology, agroecology, and ecological resilience
- Conducted fieldwork during the summer for research projects in forest, wetland, and grassland ecosystems in Nebraska, 1995 to present
- Taught undergraduate and graduate students in Ecology, Biology I, and Biology II labs at the University of Nebraska at Omaha

Awards/Honors

- J. E. Weaver Competitive Grant. The Nature Conservancy, 2009
- Center for Great Plains Studies Grant. Center for Great Plains Studies, 2008
- Contributed two articles to a newspaper series on Platte River water issues which received the Nebraska Wildlife Federation's Conservation Communicator award, 2006 and the Renewable Natural Resources Foundation's national Excellence in Journalism award, 2007

USACE - Omaha District
1616 Capitol Avenue
Omaha, NE 68102
402-995-2685
Kristine.t.nemec@usace.army.mil

Selected Publications & Conference Presentations

Nemec, K. T., C. R. Allen, A. Alai, G. Clements, A. Kessler, T. Kinsell, A. Major, and B. J. Stephen. Woody invasions of urban parks and trails and the changing face of urban forests in the Great Plains, USA. (Submitted for publication, Biological Invasions).

Invited speaker for cottonwood panel discussion sponsored by the Izaak Walton League, Sioux City, Iowa, 2008.

Presented poster entitled "Lower Brule Shoreline Protection and Cottonwood Habitat Enhancement Project, Lake Sharpe, South Dakota" at the Second National Conference on Ecosystem Restoration, Kansas City, Missouri. 2007.

Delivered presentation entitled "Cottonwood Community Delineation" at the Corps of Engineers Wildlife Workshop, Omaha, Nebraska. 2006.

Presented poster entitled "Cottonwood Management and Regeneration along the Missouri River" at the First National Conference on Ecosystem Restoration, Orlando, Florida. 2004.

Other Professional Activities

- Society for Ecological Restoration
- Ecological Society of America
- Nebraska Native Plant Society
- Association for Women in Science

September 2009

The documentation is now in senior staff and program management review. Two technology transfer forms will be completed when the document has been reviewed approved by both the senior staff and the program managers (Table G - 2 and Table G - 3).

Table G - 2. Internal ERDC-EL Technology Transfer Review Form.

TECHNOLOGY TRANSFER STATUS SHEET

INSTRUCTIONS
The author(s) of a document based on ERDC-EL research and written for publication or presentation should attach one copy of this sheet to the document when the first draft is prepared. Documents include reports, abstracts, journal articles, and selected proposals and progress reports. The sheet will remain with the most recent draft of the document.

JOB NUMBERS:

a. WORD PROCESSING SECTION _____
b. ENVIRONMENTAL INFORMATION ANALYSIS CENTER _____
c. VISUAL PRODUCTION CENTER _____

2. TITLE	3. AUTHOR(S)
4. PRESENTATION (Conference Name & Date)	5. PUBLICATION (TR, IR, MP, Journal Name, etc.)
6. SPONSOR OR PROGRAM WORK UNIT	7. DATE REQUIRED BY SPONSOR

8. DATE DRAFT COMPLETED BY AUTHOR(S) AND AREADY FOR SECURITY OR TECHNICAL REVIEW

9. SECURITY REVIEW (Military Projects)

a. THIS DOCUMENT HAS BEEN REVIEWED FOR SECURITY CLASSIFICATION FOLLOWING GUIDELINES SPECIFIED IN AR 380-5, DEPARTMENT OF THE ARMY INFORMAITON SECURITY PROGRAM, AND FOUND TO BE:

CLASSIFIED _____ CONFIDENTIAL _____ SECRET _____ TOP SECRET _____
UNCLASSIFIED _____ SENSITIVE _____ DISTRIBUTION LIMITED _____

CLASSIFICATION WAS BASED ON THE _____
SECURITY CLASSIFICATION GUIDE DATED _____

10. AUTHOR	11. DATE
12. GROUP/DIVISION CHIEF	13. DATE

14. IN-HOUSE TECHNICAL REVIEW (To be completed by two or more reviewers who are GS-12 or Above, Expert, or Contractor)
a. _____ _____ _____ _____
DATE TO REVIEWER DATE RETURN REQUESTED DATE RETURNED TECHNICAL REVIEWER

____ ACCEPTABLE W/MINOR REVISIONS ____ ACCEPTABLE W/MAJOR REVISIONS ____ UNACCEPTABLE

b. _____ _____ _____ _____
DATE TO REVIEWER DATE RETURN REQUESTED DATE RETURNED TECHNICAL REVIEWER

____ ACCEPTABLE W/MINOR REVISIONS ____ ACCEPTABLE W/MAJOR REVISIONS ____ UNACCEPTABLE

c. _____ _____ _____ _____
DATE TO REVIEWER DATE RETURN REQUESTED DATE RETURNED TECHNICAL REVIEWER

____ ACCEPTABLE W/MINOR REVISIONS ____ ACCEPTABLE W/MAJOR REVISIONS ____ UNACCEPTABLE

NOTE: RETURN TO AUTHOR WHEN TECHNICAL REVIEW IS COMPELTED.

ERDC FORM 2378
R OCT 89 PREVIOUS EDITIONS ARE OBSOLETE. (CONTINUED ON REVERSE)

15. SUPERVISORY REVIEW

THE DOCUMENT IS TECHNICALLY SUITABLE AND REVIEWERS' COMMENTS HAVE BEEN ACKNOWLEDGED. IT IS SUBMITTED FOR EDITORIAL REVIEW AND CLEARANCE FOR PUBLICATION OR PRESENTATION AS INDICATED. THE DOCUMENT CONTAINS NO COPYRIGHTED INFORMATION.* ENG FORM 4329-R OR 4330-R HAS BEEN COMPLETED, IF REQUIRED, AND IS ATTACHED TO THE DOCUMENT.

a. _____ _____ _____ _____
DATE TO GROUP CHIEF DATE RETURN REQUESTED DATE RETURNED GROUP CHIEF

b. _____ _____ _____ _____
DATE TO DIVISION CHIEF DATE RETURN REQUESTED DATE RETURNED DIVISION CHIEF

16. PROGRAM MANAGER REVIEW (If Appropriate)

_____ _____ _____ _____
DATE TO PROGRAM MANAGER DATE RETURN REQUESTED DATE RETURNED PROGRAM MANAGER

17. COMPLETE THE FOLLOWING FOR ALL REPORTS

a. RECOMMEND TYPE OF REPORTS (TR, IR, MP, Or Other):

_____

b. LEVEL OF EDITING (Type 1, 2, 3, Or 4):

_____

c. IF TYPE 1 OR 2 EDITING IS INDICATED, ADD A BRIEF JUSTIFICATION:

_____

_____

_____

_____

_____
SIGNATURE OF DIVISION CHIEF

*IF COPYRIGHTED MATERIAL IS USED, STRIKE WORD NO. SOURCE OF COPYRIGHTED MEATERIAL SHOULD BE ACKNOWLEDGED IN THE TEXT. IT IS THE AUTHOR'S RESPONSIBILITY TO OBTAIN WRITTEN PERMISSION FROM THE PUBLISHER TO USED COPYRIGHTED MATERIAL (SEE CURRENT INSTRUCTION REPORT ON PREPARING TECHNICAL INFORMATION REPORTS FOR FORM LETTER). CORRESPONDENCE ON RELEASE OF THE MATERIAL MST BE SUBMITTED WITH A REPORT WHEN IT GOES TO THE VISUAL PRODUCTION CENTER FOR PUBLICATION.

Reverse of ERDC Form 2378, R OCT 89

Table G - 3. Security Clearance Form for ERDC-EL reports.

REQUEST FOR CLEARANCE OF MATERIAL CONCERNING CIVIL WORKS FUNCTIONS OF THE CORPS (ER 360-1-1)		
THRU	TO CDR, USACE CEPA-ZM WASH, DC 20314-1000	FROM
1. TITLE OF PAPER		
2. AUTHOR (NAME)	3. OFFICIAL TITLE AND/OR MILITARY RANK	
4. THIS PAPER IS SBUMITTED FOR CLEARANCE PRIOR TO PRESENTATION OR PUBLICATION AS IT FALLS INTO THE CATEGORY (OR CATEGORIES) CHECKED BELOW:		
☐ MATERIAL THAT AFFECTS THE NATIONAL MISSION OF THE CORPS. ☐ RELATES TO CONTROVERSIAL ISSUES.	☐ MATERIAL IS SIGNIFICANTLY WITHIN THE PURVIEW OF OTHER AGNECIES OF THE FEDERAL GOVERNMENT. ☐ PERTAINS TO MATTERS IN LITIGATION.	
5. CHECK APPLICABLE STATEMENT: ☐ COPYRIGHTED MATERIAL USED.	☐ COPYRIGHTED MATERIAL USED HAS BEEN PREVIOUSLY CLEARED IN ACCORDANCE WITH AR 25-30 AND A COPY OF THE CLEARANC ATTACHED.	
6. FOR PRESENTATION TO: ORGANIZATION: CITY AND STATE:		
7. DATE OF FUNCTION	8. DATE CLEARED PAPER IS REQUIRED	
9. FOR PUBLICATION (Name of Publication Media)	10. DATE CLEARED PAPER IS REQUIRED	
THIS PAPER CONTAINS NO CLASSIFIED ORIGINAL OR DERIVATIVE MATERIAL.		
DATE	NAME AND TITLE (Approving Authority)	SIGANTURE (Approving Authority)
THRU	TO	FROM CDR, USACE CEPA-ZM WASH, DC 20314-1000
1. SUBJECT MANUSCRIPT IS CLEARED FOR PRESENTATION AND PUBLICATION: ☐ WITHOUT CHANGE	☐ WITH CHANGES ANNOTATED ON THE MANUSCRIPT	☐ WITH SUGGESTED CHANGES AND/OR COMMENTS ATTACHED
2. RETURNED WITHOUT CLEARANCE FOR THE FOLLOWING REASON(S):		
DATE	NAME AND TITLE (Approving Authority)	SIGNATURE (Approving Authority)

ENG FORM 4329-R, APR 91 EDITION OF JAN 82 IS OBSOLETE. (Proponent; CEPA-I)

INSTRUCTIONS FOR SUBMISSION OF MATERIAL FOR CLEARANCE (ENG Form 4239-R)

1. An original and two copies of papers or material on civil works functions or other non-military matters requiring HQUSACE approval, will be forwarded to reach HQUSACE at least 15 days before clearance is required. Including any maps, pictures and drawings, etc., referred to in the text.

2. Technical papers containing unpublished data and information obtained by the author in connection with his/her official duties will contain the following acknowledgement when released for publication outside the US Army Corps of Engineers. The acknowledgement will identify the research program which provided resources for the paper, the agency directing the program and a statement that publication is by permission of the Chief of Engineers.

The tests described and the resulting data presented herein, unless otherwise noted, were obtained from research conducted under the _____ of (Program) the United States Army Corps of Engineers by the _____. Permission was granted by (Agency) the Chief of Engineers to publish this information.

3. When manuscripts are submitted for publication in THE MILITARY ENGINEER, a brief biographical sketch (100 to 150 words) of the author is required, indicating his/her background in the subject matter.

Certificate of Product Check

This certifies that adequate review was provided by all appropriate disciplines to verify the following:

1. Correct application of methods;
2. Adequacy of basic data and assumptions;
3. Completeness of documentation;
4. Compliance with guidance, standards, regulations, and laws; and
5. Correct study approach.

_____

Kelly A. Burks-Copes Date
Principal Investigator
Environmental Laboratory
U.S. Army Engineer Research and Development Center
Vicksburg, MS

Albuquerque Bernalillo County
Water Utility Authority

PO Box 568
Albuquerque, NM 87103-0568
505-289-3000
www.abcwua.org

January 29, 2018

Mrs. Danielle Galloway
U.S. Army Corps of Engineers, Albuquerque District
4101 Jefferson Plaza NE
Albuquerque, NM 87109-4335

Dear Mrs. Galloway:

The Albuquerque Bernalillo County Water Utility Authority (Water Authority) generally supports a Feasibility Study Report / Environmental Assessment for the Rio Grande, Sandia to Isleta Pueblo reach, which has been proposed by the U.S. Army Corps of Engineers (Corps). However, after reviewing maps of proposed measures within the Sandia to Isleta reach of the Rio Grande, the Water Authority has some concern that the proposed project areas have not been properly reviewed by the Corps and duplication of restoration efforts may occur. Both the City of Albuquerque Open Space and the Water Authority have several sites where restoration has already been completed and regular monitoring of the sites is ongoing (see attached maps). For example, the Water Authority completed work in 2015 south of the Paseo del Norte bridge on the east and west riverbanks, which included vegetation treatments and construction of swales and high-flow channels, both areas which have been identified for Corps restoration work. In order to achieve the Corps goal of improving the Bosque ecosystem structure and function in the most cost-effective way, the Water Authority recommends that the Corps coordinates with signatories of the Middle Rio Grande Endangered Species Collaborative Program to identify ecosystem restoration projects that have already been completed and have active monitoring occurring to avoid duplication of restoration efforts. The Water Authority also recommends that long-term monitoring be implemented for all restoration work completed to ensure restored sites are properly maintained and will continue to enhance wildlife habitat into the future.

If you have any questions or would like to further discuss habitat restoration projects completed by the Water Authority, please contact Mr. Rick Billings at rbillings@abcwua.org or (505) 289-3022.

Sincerely,

Rick Billings
Environmental Scientist
Albuquerque Bernalillo County Water Utility Authority

Paseo del Norte Blvd.
↑

Montaño Rd. ↓

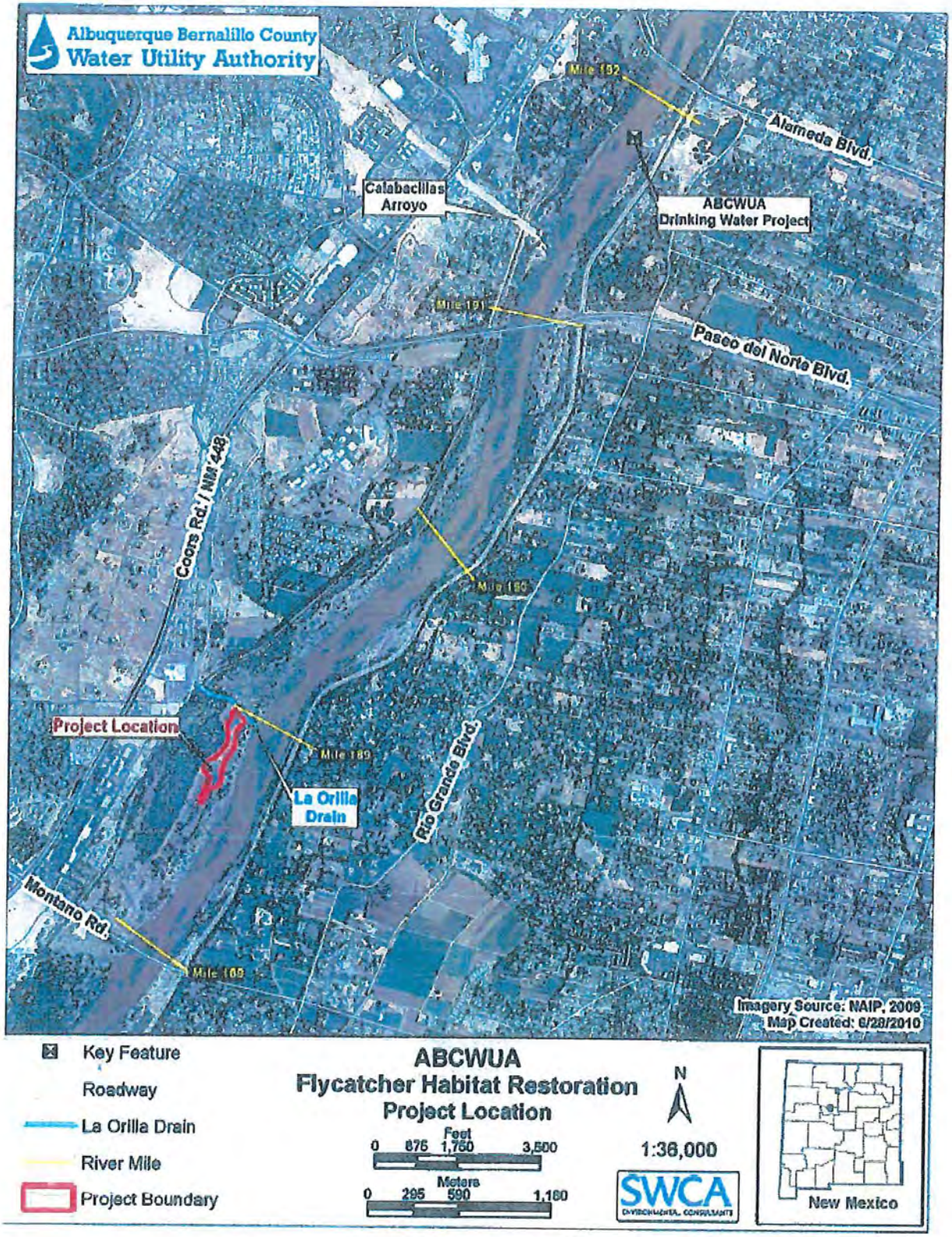


Figure 1. Project location.

From: Bennett, Nolan
To: Galloway, Danielle A CIV USARMY CESPA (US)
Subject: [Non-DoD Source] Feasibility Study Report/EA from Rio Grande
Date: Sunday, February 04, 2018 9:15:03 AM

Ms. Galloway,

Thanks you for your invitation to participate in the Feasibility Study Report. AMAFCA would like to participate in the discussions regarding equipment and maintenance activity at irrigation and Stormwater outfalls into the Rio Grande in the project area. Thanks again and I look forward to hearing from you soon.

–

Nolan Bennett, P.E.

Field Engineer

Albuquerque Metropolitan Arroyo Flood Control Authority

2600 Prospect Ave NE

Albuquerque, NM 87107

Direct Office: (505) 878-8943

Cell: (505) 301-6941

Main Office: (505) 884-2215

Fax: (505) 884-0214

nbennett@amafca.org <mailto:nbennett@amafca.org>

From: Garcia, Hector
To: Galloway, Danielle A CIV USARMY CESPA (US)
Subject: [Non-DoD Source] Comments on Feasibility Study Report
Date: Wednesday, January 31, 2018 2:06:55 PM

Reclamation received a letter dated January 4,2018, requesting comments for the Feasibility Study Report/Environmental Assessment for the "Rio Grande, Sandia to Isleta Pueblos Ecosystem Restoration Feasibility Study". Since there is no document to review, the comments provided are general in nature.

The key comment is that there are on that reach of the river many existing habitat restoration projects. These projects have been done by Reclamation, City of Albuquerque Open Space, Interstate Stream Commission, AMAFCA, Corps, and the Pueblos. We expect the Corps to work around existing projects along the river and use existing data to assess and validate new projects.

There are also other projects in that reach being planned by those same entities and others. Isleta Pueblo has its own environmental study ongoing for their reach of the river.

A key resource will be the Collaborative Program and all their ongoing work to meet ESA obligations.

This section of the river has many floodplain and river owners, so be aware of many interested parties.

Reclamation will review the Corps"s feasibility study report and environmental assessment when available.

Hector Garcia
Senior Environmental Protection Specialist

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202-2733

February 16, 2018

U.S. Army Corps of Engineers, Albuquerque District
Attn: Ms. Danielle Galloway, Biologist
Environmental Resources Section
4101 Jefferson Plaza NE
Albuquerque, NM 87109-4335

Subject: Detailed Scoping Comments in Preparing a Feasibility Study Report/ Environmental Assessment for the Rio Grande, Sandia to Isleta Pueblo, CO, NM, TX Restoration Feasibility Study

Dear Ms. Galloway:

The Region 6 office of the U.S. Environmental Protection Agency (EPA) has reviewed the January 4, 2018, letter stating the U.S. Army Corps of Engineers intention to prepare a Feasibility Study Report/ Environmental Assessment (EA) for the Rio Grande, Sandia to Isleta Pueblo, CO, NM, TX Restoration. The study is designed to restore the Middle Rio Grande (MRG) bosque. The study area covers the Albuquerque reach of the MRG and extends north to the Pueblo of Sandia and south to the Pueblo of Isleta.

To assist in the scoping process for this project, EPA has identified several areas for your attention in the preparation of the EA and enclosed detailed scoping comments for your consideration. Our comments are provided pursuant to the National Environmental Policy Act (NEPA), Council on Environmental Quality (CEQ) regulations (40 CFR Parts 1500-1508) and Section 309 of the Clean Air Act.

EPA is most interested in the following areas: mitigation, alternative development, impacts to water and biological resources, endangered species, invasive species management, habitat protection, air quality, cumulative impacts, cultural/historic resource impacts and environmental justice.

We appreciate the opportunity to review the Feasibility Study Report/ Environmental Assessment and are available to discuss our comments. Please send one hard copy of the EA and several digital copies to this office when completed and submitted for public comment. If you have any further questions, comments, or concerns, please contact Gabe Gruta of my staff at (214) 665-2174 or gruta.gabriel@epa.gov.

Sincerely,

signing for

Robert Houston, Chief
Special Projects Section

Enclosure

DETAILED SCOPING COMMENTS
ON THE
ECOSYSTEM RESTORATION FEASABILITY STUDY REPORT
FOR THE U.S. ARMY CORPS OF ENGINEERS (ACE)
TO PREPARE AN
ENVIRONMENTAL ASSESSMENT (EA)
FOR THE MIDDLE RIO GRANDE BOSQUE
SANDIA, NM TO ISLETA PUEBLO, CO

Proposed Action

In compliance with the National Environmental Policy Act of 1969 (NEPA), as amended, the U.S. Army Corps of Engineers (ACE), hereafter called the Applicant, intends to prepare an Environmental Assessment (EA) to evaluate the potential impacts of the implementation project to restore the Middle Rio Grande (MRG) bosque. The proposed project will improve the Bosque ecosystem structure and function. The project area lies within the Albuquerque reach of the MRG and extends north to the Pueblo of Sandia and south to the Pueblo of Isleta. The project would restore the native vegetation and habitat, thin exotic species, and revegetation of native riparian species.

DETAILED COMMENTS

Statement of Purpose and Need

The EA should clearly identify the underlying purpose and need to which the Applicant responds to with proposed actions and alternatives (40 CFR 1502.13). It should be a clear, objective statement of the rationale for the proposed project.

Alternatives Analysis

NEPA requires an evaluation of reasonable alternatives, including those not within the jurisdiction of the lead agency (40 CFR 1502.14(c)). These alternatives should be presented in a comparative form that will sharply define and discuss the issues, reasons for elimination of alternatives, significant environmental impacts and means to avoid them. This discussion should provide a clear basis for the choice among the options by the decision maker and the public (40 CFR 1502.14) and environmental impacts of each alternative should be quantified to the greatest extent possible. Development, addressment of project objective, implementation, and rational of significance should be discussed for each alternative.

Water Supply and Quality

The 1996 amendments to the Safe Drinking Water Act require federal agencies to protect sources of drinking water for communities. The potential effects of project discharges, if any, on surface water quality should be addressed. Discharges should be specifically identified and their potential effects on source water areas and subsequent water quality analyzed. The water

reliability for the proposed project and the effect of environmental change on existing and proposed sources should be discussed.

- *Groundwater:* Current groundwater conditions should be discussed and a full assessment of impacts to its quality and quantity due to the proposed project's construction and operational activities should be provided. Mitigation measures and their effectiveness to prevent or reduce such adverse impacts should be included in the discussion.
- *Stormwater:* Under the Federal Clean Water Act, any construction project disturbing a land area of one or more acres requires a construction stormwater discharge permit. The original, or natural, drainage patterns in the project area as well as the expected drainage patterns during project operation should be discussed. A stormwater pollution prevention plan should be appropriately reflected as per permitting requirements. Whether or not the project area lies within a 50 or 100 year floodplain should be addressed.
- *Geographic Extent of Waters of the United States:* Project applicant should coordinate with the U.S. Army Corps of Engineers to determine if the proposed project requires a Section 404 permit under the Clean Water Act (CWA) which regulates the discharge of dredged or fill material into waters of the United States (WOUS), including wetlands, streams, and other special aquatic sites. A jurisdictional delineation for all WOUS should be included in discussion and will confirm the presence or absence of such areas and help determine the need for a permit. If a permit is required, the EPA will review the project for compliance with Federal Guidelines for Specification of Disposal Sites for Dredged or Fill Materials (40 CFR 230), promulgated pursuant to Section 404(b)(1) of the CWA. Subsequent requirement of Section 404(b)(1) of CWA compliance should also be discussed.
- *Clean Water Act Section 303(d):* Any CWA Section 303(d) impaired waters present in the project area should be located and any existing restoration and enhancement efforts for those waters identified. A discussion of how the proposed project will coordinate with current protection efforts as well as any mitigation measures implemented to avoid further degradation should be included.

Biological Resources, Habitat, and Wildlife

The EPA recommends the Applicant consult with the U. S. Fish and Wildlife Services (USFWS), National Marine Fisheries Service (NMFS), and New Mexico Department of Game and Fish (NMDGF) under Section 7 of the Endangered Species Act in order to identify all petitioned and listed threatened and endangered species and critical habitat found in the project area. Any species or critical habitat that might be directly, indirectly, or cumulatively affected by each alternative's construction and regular operation must be identified and possible mitigation for each discussed. Should the Applicant acquire lands for compensation and mitigation, detailed location and management plans must be addressed.

Invasive Species

Executive Order 13112, *Invasive Species* (February 3, 1999), mandates that federal agencies take actions to prevent the introduction of invasive species and to take restorative actions for the native plants and tree species. A discussion on how the Applicant will meet the requirements of the executive order should be included. The EPA encourages alternative management practices limiting herbicide use to control invasive species introduction.

Air Quality

Existing, or baseline, ambient air conditions, National Ambient Air Quality Standards (NAAQS), non-NAAQS pollutants, criteria pollutant nonattainment areas, and cumulative and indirect air quality impacts should be discussed in detail. An evaluation of the potential impacts from temporary, long-term, or cumulative degradation of air quality which includes existing conditions, quantification of emissions, and identification of specific sources should be discussed. Such discussions should include a description and estimate of air emissions from potential construction and maintenance activities, proposed mitigation to limit them, and a construction emissions mitigation plan.

Hazardous Materials – Hazardous Waste – Solid Waste

The potential direct, indirect and cumulative impacts of hazardous waste from construction and operation of the proposed pipeline and other facilities should be addressed. The projected hazardous waste types should be identified along with their volumes, and expected storage, disposal, and management plans should be discussed.

Cumulative and Indirect Impacts

An analysis should be provided which identifies how resources, ecosystems, and communities in the project area and surround areas have or will be affected by past, present, and future activities in the mentioned areas. Resources should be characterized in terms of their response to change and capacity to withstand stressors. Trends data should be included to establish baseline conditions of affected resources, evaluate the significance of historical degradation, and predict the environmental effects of all project alternatives. The EPA recommends a focus on resources of concern or resources that are considered at risk or are significantly impacted by the alternatives before mitigation. A thorough assessment should be provided of cumulative impacts in the context of future developments within the project area, including pending and proposed projects for which EPA may issue permits.

Coordination with Tribal Governments

As per Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments* (November 6, 2000), the Applicant should have regular and meaningful consultation and collaboration with tribal officials and related government-to-government consultation between all tribal governments within or affected by the project area. These interactions should be discussed, and any issues clearly defined and addressed in the selection of an alternative.

National Historic Preservation Act and Executive Order 13007

The Applicant must develop and discuss a Cultural Resource Management Plan, in which compliance with Executive Order 13007 and Section 106 of the National Historic Preservation Act (NHPA) is addressed. Under Section 106 of the NHPA, the appropriate parties must be consulted regarding any historic or cultural properties, as defined in NHPA, which could be affected by the proposed project. Additionally, under Executive Order 13007 a discussion of any affect to the physical integrity, accessibility, or used of sacred sites within or affected by the project area should be included. Each alternative should identify and discuss any impacts to tribal, cultural, or other treaty resources and address mitigation and all possibilities of avoiding such impacts for each event. A summary of all coordination with the appropriate parties should be included.

Environmental Justice and Impacted Communities

As per Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (February 11, 1994) and the Interagency Memorandum of Understanding of Understanding on Environmental Justice (August 4, 2011), the Applicant must identify and address disproportionately high and adverse human health or environmental effects on minority and low-income populations. An evaluation of the environmental justice populations within or affected by the project area which assesses each alternative's impact on such communities should be discussed, specifically any factors which may cause them disproportionately high and adverse human health effects. A summary of outreach conducted to all communities should be included.

Coordination with Land Use Planning Activities

How the proposed action would support or conflict with the objectives of federal, state, tribal or local lands use plans, policies, and controls in or around the project area should be addressed. "Land use plans" includes all types of formally adopted documents for land use planning, conservation, zoning and related regulatory requirements. Formally and appropriately proposed plans have not yet developed should also be addressed.

Eminent Domain

Any eminent domain issues should be addressed and discussed along with their resolution. The EPA suggests referencing the necessary domain laws for the project area during planning and construction.

From:	Volke, Malia, DGF
To:	Galloway, Danielle A CIV USARMY CESPA (US)
Cc:	Schultz, Charles, DGF; DGF-EEP-TG; nmesfo@fws.gov
Subject:	[EXTERNAL] 18242 Rio Grande Ecosystem Restoration Feasibility Study
Date:	Thursday, January 25, 2018 9:37:43 AM
Attachments:	Restoration_and_Management_of_Native_and_Non-native_Trees_in_SW_Riparian_Ecosystems.pdf

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Dear Danielle,

In response to your letter dated 4 January 2018 regarding the Rio Grande Ecosystem Restoration Feasibility Study, the New Mexico Department of Game and Fish recommends incorporating the guidelines provided in the attached document, Restoration and Management of Native and Non-native Trees in Southwestern Riparian Ecosystems.

Thank you for consulting with us. Let me know if you have any questions.

Malia

Malia Volke, Ph.D.

Aquatic & Riparian Habitat Specialist

Ecological and Environmental Planning Division

New Mexico Department of Game & Fish

505-476-8160 | malia.volke@state.nm.us <mailto:malia.volke@state.nm.us>

CONSERVING NEW MEXICO'S WILDLIFE FOR FUTURE GENERATIONS

State of New Mexico
ENVIRONMENT DEPARTMENT

Office of the Secretary

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Lieutenant Governor

BUTCH TONGATE
Cabinet Secretary

J. C. BORREGO
Deputy Secretary

February 16, 2018

Danielle A. Galloway
USACE
Environmental Resource Section
4101 Jefferson Plaza NE
Albuquerque, NM 87109-4335
By email to: danielle.a.galloway@usace.army.mil

Dear Ms. Galloway,

The New Mexico Environment Department (NMED) has reviewed the January 11, 2018 scoping letter for the proposed USACE Rio Grande, Sandia to Isleta Projects and offers the following comments:

NMED Air Quality Bureau Comments

Most of this project lies outside of NMED jurisdiction (Bernalillo County plus Sandia Pueblo). However, for a small portion north of Bernalillo County and west of Sandia Pueblo, AQB offers the following comments.

This area is currently in attainment with all National Ambient Air Quality Standards. However, parts of the project are within 50 miles of a Class I Area (Bandelier National Monument) where states are required to protect against visibility impairment. As such, extra care must be taken to protect air quality during restoration activities.

Construction activities, tree cutting, chipping and shredding, prescribed fires and other activities that may be considered will create increases in pollutant emissions from combustion-related construction equipment usage, and earth excavation and movement.

To ensure air quality standards are met – including visibility at Bandelier National Monument – applicable local, tribal or county regulations requiring noise or dust control must be followed for the duration of this project. If none are in effect, dust control measures should be considered to minimize the release of particulates due to construction equipment and significant ground disturbances. Extra care should be taken during high wind events. Re-vegetation should be prioritized to minimize blowing dust problems once the project is completed.

Of particular concern is the impact due to smoke if prescribed fires will be considered for thinning activities. State smoke management rules, 20.2.60, 20.2.61 and 20.2.65 NMAC must be followed at all times.

Any asphalt, concrete, quarrying, crushing or screening, tree-cutting, chipping and shredding, and tilling equipment or facilities contracted in conjunction with the proposed project must have current and proper air quality permits, as required for the final recommended alternative. For more information on air quality permitting and modeling requirements, please refer to 20.2.72 NMAC.

Negative impacts associated with construction and restoration activities will be minimized if regulations and guidelines identified here are followed. It is not likely that the project would negatively affect air quality on a long-term basis.

NMED Department of Energy Oversight Bureau

Sedimentation downstream of any tributaries to the reach of interest should be addressed in the Feasibility Study/Environmental Assessment. DOE-OB has performed a technical review of the Smith Engineering overview of erosion along Tijeras Arroyo and the construction of sedimentation basins on the west side of I-25. Is USACE considering these projects to help prevent sediment from being deposited in the reach? Do they have any mechanisms in their plan to mitigate sediment removal and transport into and from the reach?

Actual Locations
The request did not provide any maps to show the exact location of the study area or the extent of the study area (i.e. distance from main channel of the study area).

NMED Ground Water Quality Bureau

The U.S. Army Corps of Engineers, Albuquerque District, proposes to develop alternatives to restore the Middle Rio Grande (MRG) bosque within the study area. The study area lies within the Albuquerque reach of the MRG and extends north to the Pueblo of Sandia and south to the Pueblo of Isleta. The objectives of the study include: (1) improving hydrologic functions by constructing high-flow channels, willow swales, and wetlands; and (2) restoring native vegetation and habitat by removing jetty jacks, thinning exotic species, and revegetation of native riparian species.

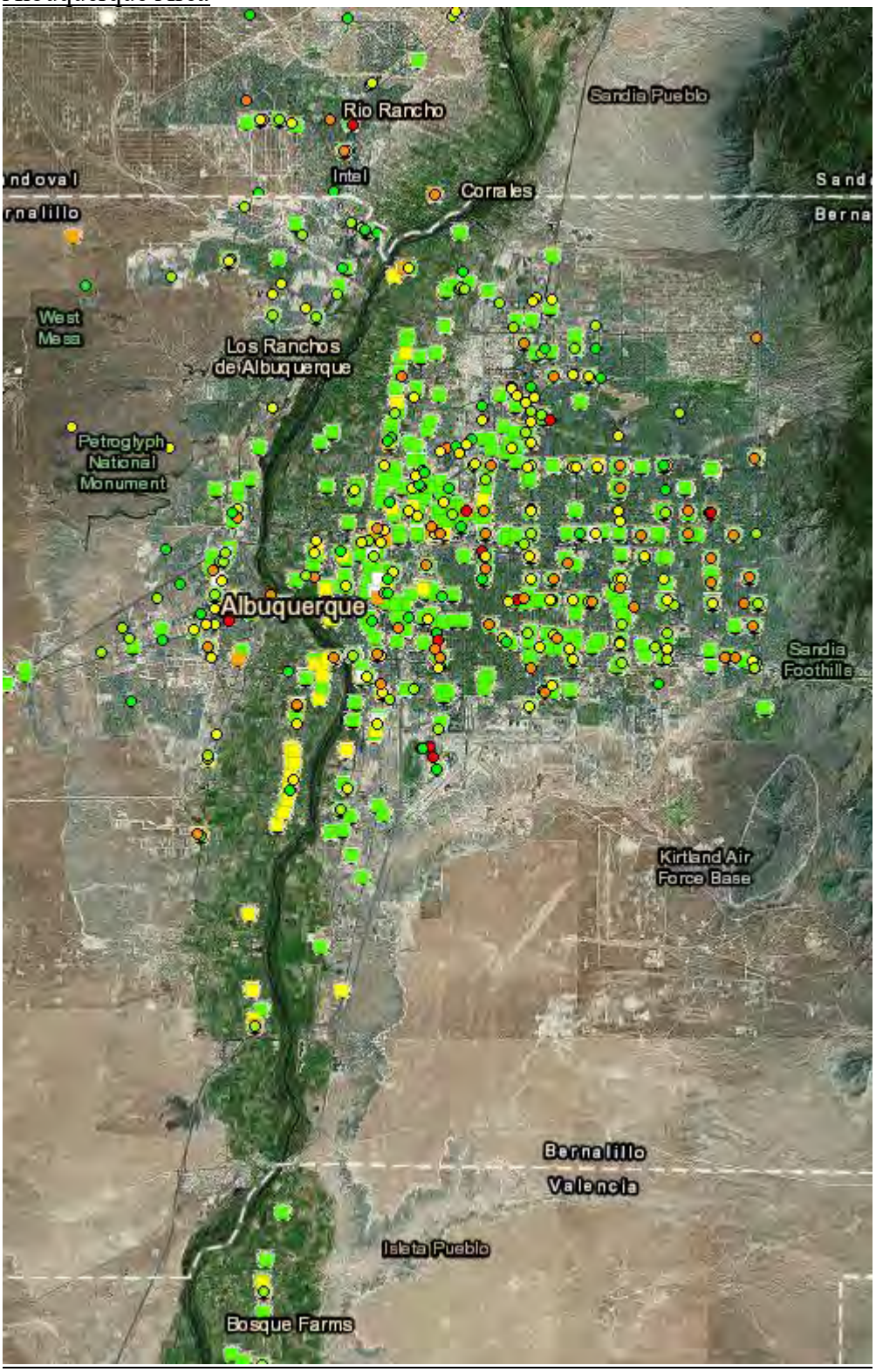
The project is not expected to have any adverse impacts on ground water quality in the area of the potential effect. However, implementation of the project may involve the use of heavy equipment thereby leading to a possibility of contaminant releases (e.g., fuel, hydraulic fluid, etc.) associated with equipment malfunctions. The GWQB advises all parties involved in the project to be aware of accidental discharge notification requirements specified at 20.6.2.1203 NMAC. Compliance with the notification and response requirements will further ensure the protection of ground water quality in the vicinity of the project.

A copy of the Ground and Surface Water Protection Regulations, 20.6.2 NMAC, is available at http://164.64.110.239/nmac/parts/title20/20.006.0002.pdf .

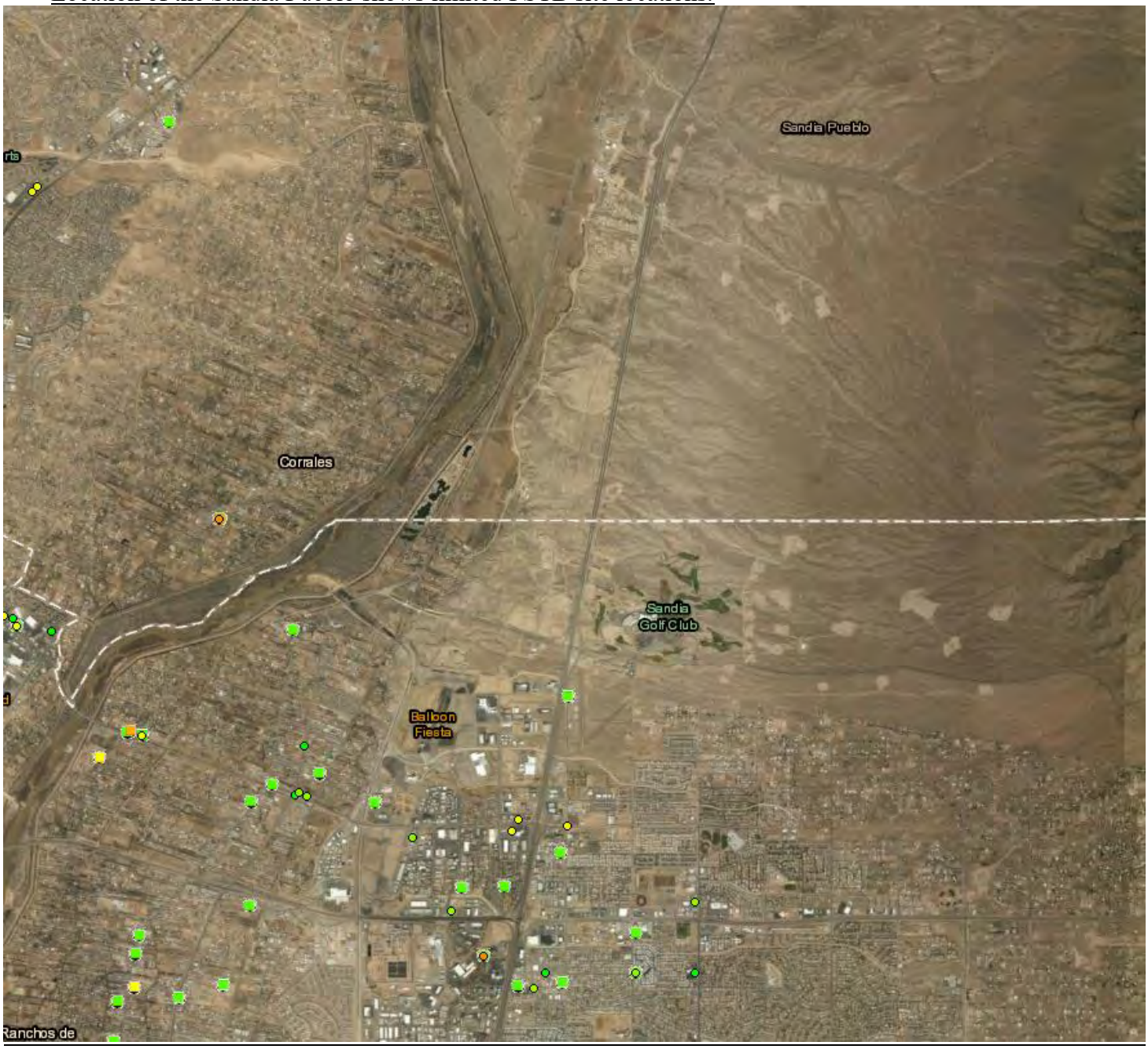

San Ysidro
Kewa Pueblo
550
San Felipe
Pueblo
25
550
Bernalillo
Placitas
Rio Rancho
Cibola
National Forest
40
Albuquerque
South Valley
25
ISLETA PUEBLO
Bosque Farms
Los Lunas
25
Belen
Bosque

There are numerous UST and AST sites throughout the City of Albuquerque and surrounding areas. Information for specific sites can be located by following the link below. See instructions for GoNM and other online resources at the end of the Petroleum Storage Tank bureau response. GoNM map link: https://gis.web.env.nm.gov/oem/?map=gonm. Colored shapes represent sites and facilities with USTs, ASTs, or both. The legend at GoNM explains which sites are known to have had releases of regulated substances (almost always petroleum products) into the environment.

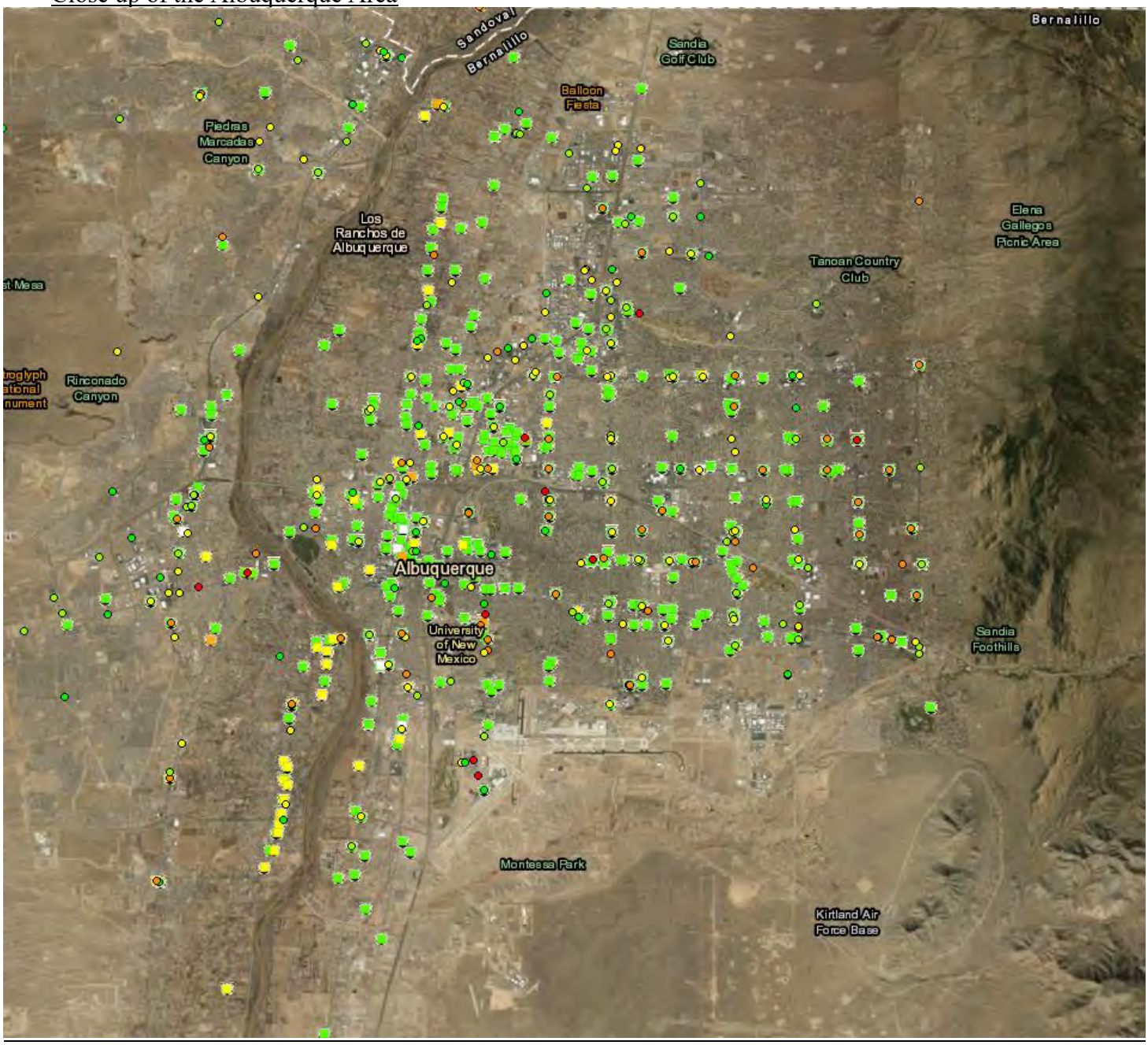
Albuquerque Area



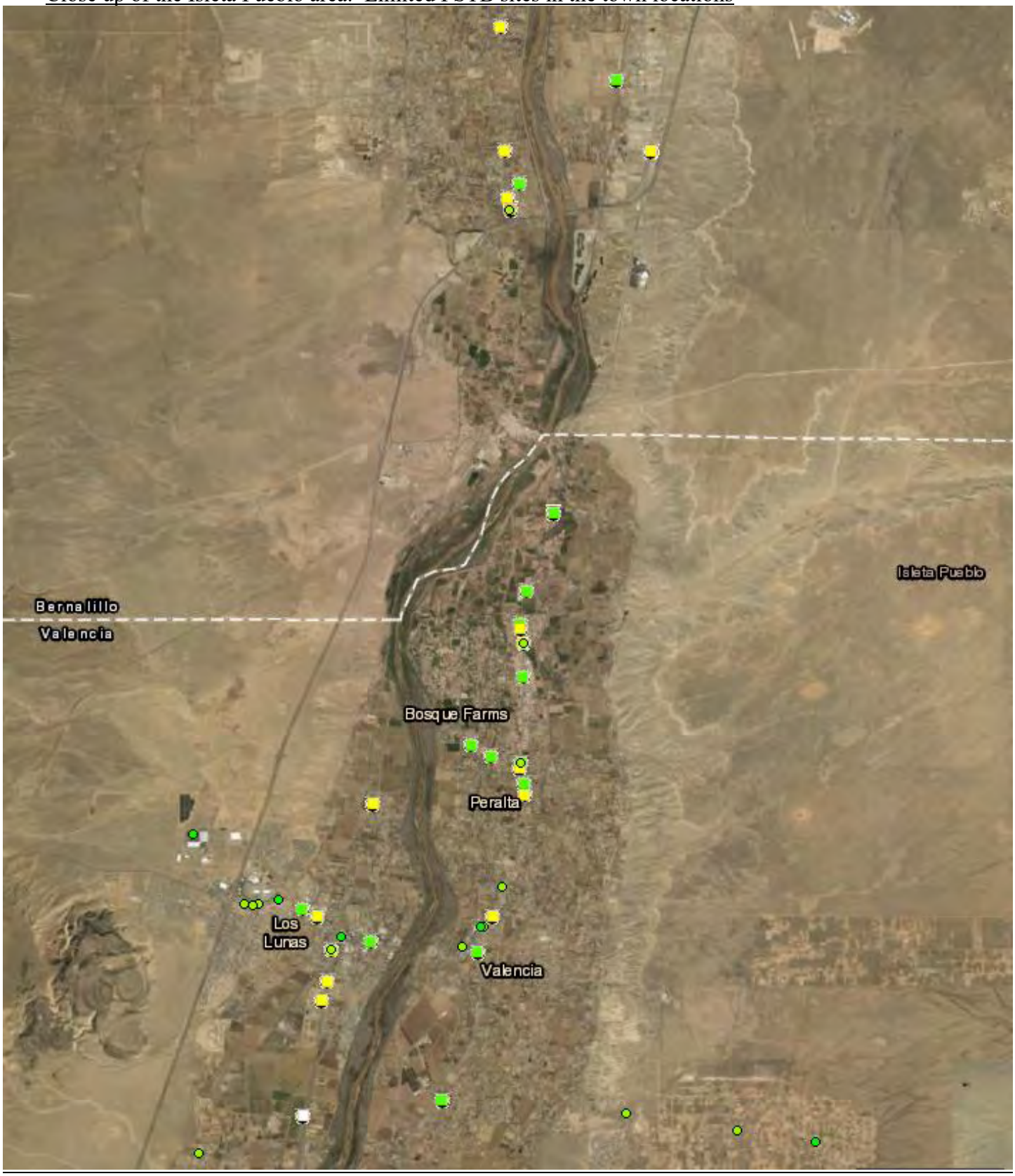
Location of the Sandia Pueblo shows limited PSTB site locations.



Close up of the Albuquerque Area



Close up of the Isleta Pueblo area. Limited PSTB sites in the town locations



Based on the letter provided, the development of wetlands and high-flow channels could impact ground water levels that may impact facilities closest to the project area. Changes to ground water levels could impact corrosion protection systems currently operating at facilities within the impact area. The list below are facilities that are close enough to the possible impact area but the list may not be limited to only these sites. At this point we do not know the size of the impact area or even if there will be an impact.

FID # 28496, Health Science Services Building, 2500 Mable Ave. NE, Albuquerque, NM
FID # 29854, 7 to 11 # 750, 800 Bridge Blvd SW, Albuquerque, NM
FID # 27714, Corner Store #1226, 511 Bridge Blvd SW, Albuquerque, NM

Instructions for using online resources:
Many of the records requested from the Petroleum Storage Tank Bureau are available online, and you can access them quickly by following the directions below. If you need any help using the online resources, please let us know.

The GoNM map link also enables you to locate quite a bit of information that will facilitate your search, including No Further Action required letters. Not all information about each site has been uploaded there, but *recently many site documents have been added*. Instructions for Go NM: Go to https://www.env.nm.gov/ust/lists.html. Click on the GoNM map at the bottom left of the page. Documents may download more easily if you use Internet Explorer. When you are in the GoNM Mapper, you can use the zoom slider at the upper left of the map to zoom in. Colored and white shapes represent facilities that have or had tanks and/or have been involved in a release. To find out more about a facility, click on the white i inside the blue circle at top of the screen and then click on the shape that represents that facility. When the dialog box pops up, you can click on either the Report or any link under Documents. Many No Further Action letters and other documents are accessible and downloadable under Documents. If you click on the icon under Report at the left of the dialogue box, there is also quite a bit of information there.

Please review the lists on the webpage, https://www.env.nm.gov/ust/lists.html. Click on the Active Leaking and NFA Sites link. The first document lists NFA sites (sites for which no further action is currently required) by county and city. The third document lists active sites alphabetically by priority (the second and fourth documents are pdfs). Click on the document you need, then click Download for the option you choose in the window that opens. You can search the Active Leaking or NFA Sites spreadsheets (or any other spreadsheet) by holding down the ctrl key on your keyboard and then hitting the F key, or by going to Find & Select (all the way to the right) on the Home tab of the spreadsheet, selecting Find, and entering an address or part of an address, a name, or any information you'd like to search on and then clicking on Find Next repeatedly to find all records that fit your search. You can download the No Further Action letter for many of these records by clicking the link in the last column of the NFA spreadsheet. If the No Further Action letter is not online and you need it or any other information, let us know.

If you are looking for information about the presence of underground or aboveground storage tanks at an address, please download the All Storage Tank list, also at https://www.env.nm.gov/ust/lists.html. This lists all storage tanks in the state that fall or fell under our regulations and have been registered with us, whether they are still present or not. This spreadsheet can be searched the same way as the above ones. If you only need to know about tanks that are currently in use or temporarily out of use, download the Active Storage Tank list.

After consulting all of these resources, if you need further information, please let us know. If you have a large number of sites, please refine the list of sites for which you need information by

categorizing the sites as NFA sites, Active Leaking sites, or sites that are not indicated to be leaking. Be sure to indicate which information is needed for each site.

In addition to compliance with the NM Water Quality Regulations, 20.6 NMAC, both Pueblos have their own water quality regulations (links below) that may be impacted by the proposed activities and therefor Sandia Pueblo and Isleta Pueblo need to be consulted.
https://www.epa.gov/wqs-tech/water-quality-standards-regulations-pueblo-sandia
https://www.epa.gov/wqs-tech/water-quality-standards-regulations-pueblo-isleta

Thank you for providing NMED with the opportunity to review and comment on this proposed project.

Sincerely,

Michaelene Kyrala
Director of Policy
New Mexico Environment Department
Office: 505.827.2892
E-mail: michaelene.kyrala@state.nm.us

FINAL

Rio Grande, Sandia Pueblo to Isleta Pueblo, CO, NM, TX
Ecosystem Restoration Project
Monitoring and Adaptive Management Plan

June 2018

Table of Contents

1.0 Authority and Purpose

Per Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007), feasibility studies for ecosystem restoration are required to include a plan for monitoring the success of the ecosystem restoration. "Monitoring includes the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be need to attain project benefits." Therefore, Section 2039 also directs that a Contingency Plan (Adaptive Management Plan) be developed for all ecosystem restoration projects.

2.0 Goals of the Project to be measured through monitoring

The first step in designing an evaluation program for the Rio Grande, Sandia to Isleta Restoration Project is to define the goals and objectives of the project. As stated in the U.S. Army Corps of Engineers (Corps) Feasibility Report (June 2018), they are as follows:

1. Improve habitat quality and increase the amount of native bosque communities to a sustainable level.
2. Restore hydrologic connection between the bosque and the river characterized by a more frequent overbank inundation pattern.
3. Protect, extend and enhance areas of potential habitat for listed species within the bosque.

Goals for a Monitoring and Adaptive Management Plan for the project should measure whether these objectives have been met or not. Some general items to keep in mind when developing specific monitoring components to measure include:

- Provide a thorough understanding of the ecosystem with and without restoration.
- Show direct cause-effect relationships between restoration measures and ecological responses.
- Include quantifiable biological responses.
- Document changes that are of social and scientific importance. (USACE, 1992).

There are also some constraints to implementation of the restoration project that should be kept in mind when developing specific monitoring components to measure. Some of these are:

1. The Rio Grande is a multi-jurisdictional, multi-boundary natural resource that is extremely human managed and manipulated due to this multi-jurisdictional setting.
2. There are legal obligations in the form of water rights in the State of New Mexico and especially on the Rio Grande.
3. With the exception of some jetty jacks (not all), river channelization and manipulation structures will remain in place.

These are some of the constraints of not only the evaluation of restoration, but of the restoration components themselves. These are the constraints, challenges, and potential benefits (when trying to approach this optimistically) that must be operated within in this large scale restoration effort.

3.0 Implementation

3.1 Implementation of the Monitoring Plan

Pre-construction, during construction and post construction monitoring shall be conducted by the Corps. After that time, monitoring would continue and be the responsibility of the local sponsor.

Monitoring will be aimed at evaluating project success and guiding adaptive management actions by determining if the project has met 'performance standards'. Validation monitoring will involve various degrees of quantitative monitoring aimed at verifying that restoration objectives have been achieved for both biological and physical resources. Effectiveness monitoring will be implemented to confirm that project construction elements perform as designed. Monitoring will be carried out until the project has been determined to be successful (performance standards have been met), as required by Section 2039 of WRDA 2007, as noted in paragraph 3.c of the implementation guidance. Monitoring objectives have been tied to original baseline measurements that were performed during the Habitat Evaluation Assessment Tool (HEAT) modeling effort and are shown below.

Measurement	**Performance Standard**	**Adaptive Management**
Vegetation – tree density, tree canopy cover, shrub canopy cover, ground cover, species count/composition, % native/non-native; overall percent cover	Overall % cover – overall stand density mosaic per HEAT measurement goals: 50% native tree, 30% native shrub, 20% native herbaceous and/or wet habitat	Any planted material that has died shall be replaced (per one year warranty); After one year, adaptive management should focus on non-native vegetation treatment per below.
	Non-native vegetation % cover: <= 30%	On an annual basis, areas ¼ acre in size or larger that have > 30% areal cover by non-native vegetation shall be treated
	Noxious weeds: <= 30%	On an annual basis, areas ¼ acre in size or larger that have > 30% areal cover by weeds shall be treated
Hydrology – flood frequency, flood duration, depth, velocity, wetted area, groundwater depth	Increase flood frequency and duration into bosque by 10%; increase wetted area in bosque by 15%	As features potentially get filled with sediment, they will need to be cleaned out; Review designs for potential needed change
Avian monitoring -	Increase in species diversity by 10% in areas where wet habitat is constructed; Increase in species diversity by 10% of other areas within	Ensure wet features are functioning (per hydrology Performance Standard and Adaptive Management above); ensure native

	3-5 years (noting that there will be an initial decrease); 10% increase in potential SWFL habitat	riparian vegetation is thriving (per vegetation Performance Standard and Adaptive Management above)

Vegetation: Vegetation measurements listed above were performed during baseline analysis for this project in 2005 and field verified/validated in 2017. All of these measurements (tree density, tree canopy cover, shrub canopy cover, ground cover, species count, % native/non-native) are performed along a transect at the same time and can be completed fairly quickly.

Permanent rebar were placed at the original baseline sampling locations (which are within the recommended plan proposed construction sites) and serve both as the permanent plot marker and as the center point for two, perpendicularly aligned sampling transects (Figure 1). While the sampling distance along each transect will be 50-m, each transect will actually be extended 60-m because the 5-m circumference around the center rebar is not sampled to avoid measurement overlap, and because this area gets trampled during plot set-up. Thus the rebar was located at the 30-m mark for each perpendicular sampling transect, and no data is collected between distance marks 25-m to 35-m on either tape.

The orientation of the first 50-m tape was determined randomly by standing over the rebar and making an unobserved spin of a compass dial. The second transect will be oriented at a 90º angle to the first (Figure 1).

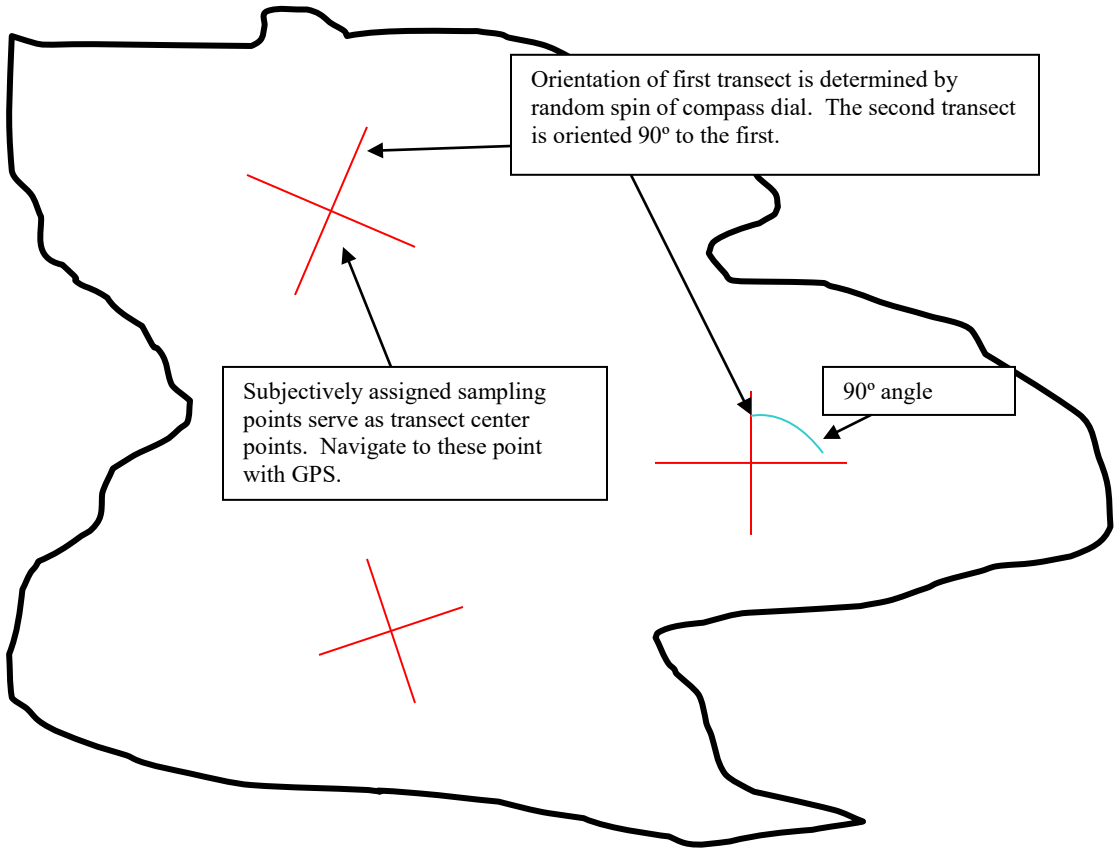


Figure 1. Sampling design. Each transect is 60-m long, although a 5-m circumference around the rebar (meter marks 25m – 35m) is not sampled, so only 50-m along each transect is sampled. Up to three 100-m plots may be established in a single vegetation polygon.

All of these measurements can then be translated into an overall percent cover. Overall percent cover should meet the performance standard for an overall mosaic per HEAT measurement goals: 50% native tree, 30% native shrub, 20% native herbaceous and/or wet habitat. Any planted material that has died shall be replaced (per one year warranty). After one year, adaptive management should focus on non-native vegetation treatment per below.

The measurements would also be used to determine the % of non-native vegetation present. Non-native vegetation % cover should be less than or equal to 30%. On an annual basis, areas ¼ acre in size or larger that have > 30% areal cover by non-native vegetation shall be treated per the Environmental Assessment and Operations and Maintenance Manual for this project. This typically includes treatment using herbicides via cut-stump or foliar application. Noxious weeds shall also be monitored with a performance standard of less than or equal to 30%. On an annual basis, areas ¼ acre in size or larger that have > 30% areal cover by non-native vegetation shall be treated per the Environmental Assessment for this project and Operations and Maintenance Manual for this project. This typically includes treatment using herbicides.

Hydrology: Flood frequency, flood duration, depth, velocity, wetted area and groundwater depth will be evaluated for constructed high-flow channels, bank terracing, willow swales and other wetland features. Results will inform need for adaptive management actions and will inform future restoration designs.

Flood frequency relates the magnitude of discharge to the probability of occurrence or exceedance. Discharge or flow rate is typically given in cubic feet per second (cfs). Flood duration defines the amount of time that a specific flood frequency will meet or exceed a given discharge or flow rate. Flood duration is typically defined in either hours or days.

Flood duration, frequency, depth and velocity would be measured using a FlowTrakker Acoustic Doppler Velocimeter (ADV). This meter samples velocity measurement over a given length of time (seconds) and averages velocity at a given point in the water column. The meter computes discharge, after transects are made, according to USGS standards.

Wetted area can be measured by measuring surface water area. This is done by using the top width of the feature (high flow channel, terrace and/or willow swale) and the duration of flow from the hydrograph. Some areas may be mapped by hand using a GPS to get the overall surface area of wetted area.

Seasonal depth to groundwater will be monitored utilizing existing instrumented shallow groundwater piezometers. Data will be used to evaluate floodplain-channel connectivity and to allow comparisons to vegetation growth parameters.

The overall Performance Standard is to increase flood frequency and duration into bosque by 10% and increase wetted area in bosque by 15%. As features potentially get filled with sediment, they will need to be cleaned out. In order to help reduce the maintenance need, an increase in interconnection between features is proposed. This will also potentially enhance wetted area habitat diversity and function in order to meet the Performance Standard. If this is occurring, adaptive management in form of the maintenance above and/or reviewing the original design would be implemented.

Avian Monitoring – Through other bosque projects, the Corps (via a contractor) has been monitoring transects and project specific locations within the recommended plan project area. This information has been used as baseline information specific to this project and monitoring of these locations prior to, during and after construction is proposed to continue.

Through this monitoring and research, much has been learned about species loss due to increase in non-native vegetation, effects of fuel reduction/exotic removal on bird species, and effects of mid-canopy removal on bird species. These studies have been conducted specifically within the project area (Hawks Aloft, 2003-2018). Therefore, information has been utilized form these studies in order to guide alternative development, project design and construction implementation. One of the main goals of this project is to improve habitat quality and increase the amount of native vegetation.

Monitoring of avian species can aid in understanding whether or not this goal has been met by evaluating the current (and recent past) use of these areas compared to their use during construction (which is hypothesized to decrease initially) and after construction (which is hypothesized to increase over time). Previous work has shown an increase in the diversity of bird species in areas where water features have been added. In areas where thinning of non-native vegetation occurs, there is an initial decrease in species diversity though population sizes remain roughly the same. Over time, species diversity increases again. Therefore, these findings have been used to develop the Performance Standards which include an increase in species diversity by 10% in areas where wet habitat is constructed; and an increase in species diversity by 10% of other areas within 3-5 years (noting that there will be an initial decrease). Through monitoring for Southwestern Willow Flycatcher (SWFL), an increase in potential habitat will be captured. Therefore, the Performance Standard is to also increase potential SWFL habitat by 10%. SWFL surveys would only be performed in areas that are expanding potential habitat (ie: willow swales). Performance Standard and Adaptive Management above); ensure native riparian vegetation is thriving (per vegetation Performance Standard and Adaptive Management above).

Methodologies used by a contractor would continue and include breeding bird point counts and monitoring of existing transects.

3.2 Additional monitoring – It should also be noted that additional endangered species monitoring for Rio Grande silvery minnow (RGSM) would be performed per the Biological Opinion for this project. While it is not listed as a specific Performance Standard above, it would still provide information regarding the use of water features by RGSM.

3.3 General periodic site assessment: In terms of assessing overall effectiveness of the restoration construction, a general annual assessment of each site would be conducted. A site assessment form is included in Appendix A.

3.4 Reporting

The Corps and/or their agents will prepare annual reports that include specific information pertaining to each of the monitoring elements. These reports will include information about all equipment and techniques used for monitoring purposes.

Annual reports will be submitted to the Middle Rio Grande Conservancy District (MRGCD), City of Albuquerque Open Space Division (OSD), U.S. Bureau of Reclamation (Reclamation, U.S. Fish and Wildlife Service (USFWS), New Mexico Department of Game and Fish (NMDGF) and other interested parties by December 31 of each monitoring year.

3.5 Photographic Documentation

Permanent locations for photographic documentation (i.e., photo points) will be established at strategic locations within each project site so that a visual record of habitat development can be provided. A sufficient number of photo points will be established in

order to provide representative photographs of the site as it changes over time. The locations will be identified in the pre-construction monitoring report. Photographs taken from each of these locations will be included in subsequent monitoring reports.

4.0 Integration of project monitoring and adaptive management with other, ongoing restoration and research efforts in the bosque

One of the biggest challenges and potentially another component to this evaluation program is the coordination of monitoring and adaptive management restoration efforts. Current restoration and research efforts are underway and on the ground in the Albuquerque Reach of the Middle Rio Grande by the City of Albuquerque Open Space Division, the Middle Rio Grande Conservancy District (project sponsor), U.S. Bureau of Reclamation, Natural Heritage New Mexico, BEMP, etc. Many of the research efforts are currently being funded by the Corps in relation to other bosque projects and providing information toward pre-construction monitoring information for this project. As mentioned above, the Corps is a member of the Collaborative Program which is monitoring components of the system specifically for SWFL and RGSM. These monitoring methods have been included above (where appropriate) and close coordination of efforts on the ground would occur. The key to a successful restoration program in the Middle Rio Grande will be to collaborate with these efforts in creating a fully integrated and ecosystem-based evaluation program.

There are a large number of monitoring efforts currently being conducted in the Project Area. Many are efforts currently contracted by the Corps Albuquerque District that would continue to be contracted as part of implementing this monitoring and adaptive management plan. Other efforts are conducted by other agencies or Programs that are being coordinated with in order to reduce a duplication of effort.

The Corps has spearheaded a demonstration or 'test' of this effort during implementation of the BioPark Restoration Project and the Ecosystem Restoration @ RT66 Project. The BioPark Restoration project was completed in October 2006 and the RT66 Project is currently under construction to be completed in April 2010. The BioPark Restoration Project is currently being monitored and providing valuable input toward design of this project as well as input toward monitoring efforts. These projects are also crucial components to the analysis for adaptive management. Adaptive management will be the key to the long-term success of the MRG Project as well as the monitoring program.

5.0 Estimated Cost

Per discussion above, annual costs can fluctuate depending upon specific monitoring needs as well as available funding. Potential annual costs based on the potential combination of monitoring elements are below:

Post-construction Year 1:

Monitoring Element	**Estimated Cost**
Vegetation	$ 50,000
Hydrology	$ 25,000
Avian Monitoring	$ 55,000
TOTAL ESTIMATED COST	$130,000

Post-construction Year 2:

Monitoring Element	**Estimated Cost**
Vegetation	$ 50,000
Hydrology	$ 25,000
Avian Monitoring	$ 60,000
TOTAL ESTIMATED COST	$135,000

Post-construction Year 3:

Monitoring Element	**Estimated Cost**
Vegetation	$ 50,000
Hydrology	$ 25,000
Avian Monitoring	$ 65,000
TOTAL ESTIMATED COST	$140,000

Post-construction Year 4:

Monitoring Element	**Estimated Cost**
Vegetation	$ 50,000
Hydrology	$ 25,000
Avian Monitoring	$ 70,000
TOTAL ESTIMATED COST	$145,000

Post-construction Year 5:

Monitoring Element	**Estimated Cost**
Vegetation	$ 50,000
Hydrology	$ 25,000
Avian Monitoring	$ 75,000
Monitoring Report	$ 55,000
TOTAL ESTIMATED COST	$205,000

References

Hawks Aloft, Inc. 2009. Bird and vegetation community relationships in the Middle Rio Grande Bosque: 2008 Interim Report. Submitted to: U.S. Army Corps of Engineers. 105 pp.

U.S. Army Corps of Engineers. 1992. Kissimmee River Restoration Study Report. Communication from the Assistant Secretary of the Army.

APPENDIX A
PERIODIC SITE ASSESSMENT FORM
Sample Format for Periodic Site Assessment Form

Middle Rio Grande Bosque Restoration Project Assessment Report

Site:
Location of site (include map:
Personnel:
Date:

Item No.	Description	Response	
		Yes	No
1	Erosion observed in revegetation areas? If yes, describe location(s) and provide a map of affected area(s).		
2	Erosion control blankets, geotextile mats, and underlying soil on low berm in good condition?		
3	Fire damage to vegetation or other site features?		
4	Flood damage to vegetation or other site features?		
5	Wind damage to vegetation or other site features?		
6	Herbicide damage to desired vegetation?		
7	Wildlife damage to desired vegetation?		
8	Vandalism to desired vegetation?		
9	Vandalism to other site features (e.g., signs)?		
10	Debris or refuse present?		
11	Access roads maintained as specified?		
12	Access gates, barriers and locks in good working order?		
13	Volunteer establishment of desired species observed?		
14	Portions of revegetation areas currently flooded? If yes, describe extent of flooding and provide a map of affected area(s).		
15	Other items?		
Comments:			

United States Department of the Interior

FISH AND WILDLIFE SERVICE

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Albuquerque, New Mexico 87113
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July 20, 2018

Consultation No. 02ENNM00-2018-CPA-0050

George H. MacDonell, Chief
Environmental Resource Section
Planning Branch
Planning, Project, and Program Management Division
U.S. Army Corps of Engineers, Albuquerque District
4101 Jefferson Plaza NE
Albuquerque, New Mexico 87109-3435

Dear Mr. MacDonell:

This is the U.S. Fish and Wildlife Service (Service) response to your request for review of the U.S. Army Corps of Engineers (USACE) Rio Grande, Sandia Pueblo to Isleta Pueblo, CO, NM, TX Ecosystem Restoration Feasibility Study (Project) under the Fish and Wildlife Coordination Act (16 USC 661-667e). Please consider this letter to be our 2(b) report for this Project.

Introduction

As described in your June 4, 2018, request for a Fish and Wildlife Coordination Act 2(b) Report, the purpose of your project is to restore function and increase high value habitat in the Middle Rio Grande (MRG) bosque within the proposed study area. The Rio Grande, Sandia Pueblo to Isleta Pueblo, CO, NM, TX feasibility study (Proposed Action) is being conducted under the authority of Section 5056 of the Water Resources Development Act of 2007, as amended by Section 4009 of the Water Resources Reform and Development Act of 2014. The Act authorizes a program for the planning, construction, and evaluation of measures for fish and wildlife habitat rehabilitation and enhancement as well as implementation of long-term monitoring, computerized data inventory and analysis, applied research, and adaptive management.

Project Description

With local sponsorship, USACE is proposing to restore function and increase high value habitat through the Albuquerque reach at ten locations adjacent to the Rio Grande spanning the area between the Sandia Pueblo to the north and the Isleta Pueblo to the south (Project Area). Upon completion, the project will include approximately 260 acres of improvements within the Rio Grande floodplain in reaches 2, 3, and 4 of the Project Area (Figure 1). Improvements at these

sites will include the construction of 42 willow swales, 5 high-flow channels, the creation or restoration of 3 wetlands, the removal of 3 berms, improvement of 2 connections to the Rio Grande, construction of a wet meadow, enhancement of a ditch for wet habitat, diversion of an outfall flow, bank destabilization, and the removal and treatment of non-native vegetation followed by seeding and planting of natives at 15 locations (USACE 2018).

Figure 1. Reaches 0 through 6 of the Sandia to Isleta, CO, NM, TX Ecosystem Restoration Feasibility Study.

Table 1. Preferred Alternative measures by reach and associated acreage.

Plan Area	Reach	Measures	Area (acres)
D	2	Willow swale, Treat-Retreat-Reveg	7.54
E	2	Willow swale, Treat-Retreat-Reveg, Hi-flow Channel	44.75
F	2	Willow swale, Treat-Retreat-Reveg	42.59
G	2	Willow swale, Treat-Retreat-Reveg, Wetland	9.92
H	3	Willow swale, Treat-Retreat-Reveg, Bank destabilization, Hi-flow Channel, Remove berm	47.7
J	3	Wetland, Willow swale, Treat-Retreat-Reveg	13.68
M	3	Wetland, Willow swale, Treat-Retreat-Reveg	39.48
P	4	Treat-Retreat-Reveg, Hi-flow channel	15.82
Q	4	Wet meadow, Connection to River, Enhance ditch for wet habitat	10.43
T	4	Willow swale, Treat-Retreat-Reveg, Divert outfall flows	28.8

Reach 2

This reach will include construction of 10 swales, the creation of a wetland and a high-flow channel, and 6 locations will undergo the Treat-Retreat-Reveg process. Sites D, E, and F are located on the western side of the channel and Site G is on the east side. These sites are situated at the outlet of the Calabacillas Arroyo.

Reach 3

Measures proposed along this reach include construction of 25 swales, removal of 3 berms, construction of 3 high-flow channels, creation of 2 outfall wetlands, bank destabilization, and 7 locations will receive the Treat-Retreat-Reveg management. Sites H and M are located on the eastern side of the river and are separated by I-40. Site J is a peninsula along the west side.

Reach 4

This reach will include construction of 7 swales, 2 connections to the river, a high-flow channel, a meadow, ditch enhancement, diversion of an outfall flow, and 2 locations will receive the Treat-Retreat-Reveg management. Site Q is located on the eastern edge of the river and Sites P and T are on the west.

Sensitive Species and Habitat

This section of the Middle Rio Grande has a diverse biotic community and some of the best riparian habitat on the Rio Grande (Hink and Ohmart 1984; Finch et al. 1999; Cartron et al. 2008). The Middle Rio Grande harbors the largest cottonwood forest (Bosque) along the Rio Grande (Crawford et al. 1993; Scurlock 1998). In the last 30 years, the Bosque has become aged (Mount et al. 1996) and increasingly dominated by invasive species (Horner 2006). The Bosque provides a riparian corridor that helps maintain regional biodiversity (Naiman et al. 1993).

Federally listed species in the Project Area include the Rio Grande silvery minnow (RGSM), Southwestern Willow Flycatcher (SWFL), and Yellow-billed Cuckoo (YBCU), and their designated and/or proposed critical habitat (Table 2).

Table 2. List of Endangered Species Found Within the Project Area.

Common Name	Scientific Name	Federal Listing	Designated or Proposed Critical Habitat Present	Species Presence in Project Area
Rio Grande silvery minnow	*Hybognathus amarus*	Endangered	Yes, in project area	Yes
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	Endangered	Yes, but not within the project area	As migrant only
Yellow-billed Cuckoo	*Coccyzus americanus*	Threatened	Yes, in project area	Yes, has been detected

Rio Grande Silvery Minnow

Designated critical habitat for the species encompasses nearly the entire proposed Project Area. Work would not take place in the main channel but it would take place along the bank and it may result in erosion or other inputs into the river. When work is to occur close to the bank of the river, BMPs would be enforced to prevent erosional inputs into the river. These BMPs would include, but would not be limited to: the use of silt fences adjacent to the riverbank; fueling of vehicles would not take place inside the levees; and equipment and vehicles would be cleaned prior to entering the Bosque.

The goal of this project is to provide potential habitat for the RGSM through the creation of high-flow channels and ephemeral side channels (embayments) for the RGSM and potential refuge during spawning, egg, and/or juvenile stages.

Southwestern Willow Flycatcher

Based on the surveys conducted within the proposed Project Area and other surveys performed in the past within the Project Area (by other entities), it is highly unlikely that nesting SWFLs would occupy the Project Area during the construction period. 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 are anticipated to continue each year as they have in the past.

The creation of willow swales in the proposed Project Area is anticipated to provide potential habitat for the SWFLs, and over time, these could create willow stands of the preferred density and stature for the species.

Yellow-billed Cuckoo

Habitat potentially suitable for nesting of YBCU is present within the proposed Project Area, primarily in the form of dense saltcedar stands, therefore, it is limited. YBCUs have been known to nest late into October. Surveys for the YBCU have been conducted within the last couple of years. Based on the surveys done by the USACE and other entities within the proposed Project

Area, it is highly unlikely that nesting YBCUs would occupy the Project Area during the construction period mentioned above. It is possible that migrants would be present in the Project Area in spring and fall. Surveys at the locations where migrants have been detected are anticipated to continue each year as they have in the past.

Birds

Birds are one of the most diverse groups of wildlife in the Project Area with over 280 species known from the Middle Rio Grande (Hink and Ohmart 1984; Thompson et al. 1994; Hawks Aloft 2010). The riparian corridor of the Rio Grande is a major migratory route for neotropical birds (Yong et al. 1995; Leal et al. 1996; Yong and Finch 1997; Finch and Yong 2000). About 61 percent of the birds known from the area are neotropical migrants. Loss of riparian habitat in the region is believed to be related to the decline in some bird species (DeSante and George 1994; Askins 2002). The effects of floodplain dysfunction may be first evident in loss of bird species richness and abundance.

Discussion

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. The Proposed Action provides opportunities to restore some Rio Grande ecosystem biological components to benefit fish and wildlife resources.

By constructing swales, high-flow channels, and increasing connection to the river, this would increase opportunity for overbank flows, decreased depth to groundwater, or increase the area with saturated soils. This type of environment could create or enhance wetlands within the Rio Grande riparian zone; and may sustain and enhance existing cottonwood communities as well as create new native cottonwood communities.

The value of riparian habitat is well known to resource managers because of the high diversity and abundance of animal species which rely on the ecosystem for its unique plant community types, hydrologic features, soil, topography, and other environmental features that do not exist in adjacent upland habitat. Many animals species are obligates (depending entirely on the riparian zone) while most are facultative (occurring in riparian habitat as well as in other habitat types). The ecological attributes that contribute to the high value of riparian habitat should be maintained to preserve the value to wildlife include the following:

- Heterogeneity of plant communities and structure
- Predominance of woody plant communities
- Presence of surface water, soil moisture, and high water table
- Continuous, unfragmented corridors of habitat
- Sustainability
- Soil composition
- Geomorphology

The remaining population of the RGSM 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

RGSM 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). Increasing the area that is inundated by overbanking is needed to help restore the remaining floodplain habitat within the spoil banks (Ellis et al. 1996) and restore RGSM populations.

At the end of 2007, 1,299 SWFL breeding territories were estimated to occur throughout southern California, southern Nevada, southern Utah, southern Colorado, Arizona, and New Mexico (Service 2014). Some of the most densely SWFL populated areas are found along the MRG. Creating an environment to accommodate successional age classes of vegetation via increased connection to the river, could increase areas within the MRG that could support SWFL nesting activity.

Roughly fifteen percent of the YBCU population is located within the state of New Mexico (Service 2014a). Similar to that of the SWFL, the MRG currently supports a dense population of YBCU's. By creating an environment to allow for natural recruitment of native vegetation, this would increase potential habitat that may be suitable for nesting activity of the YBCU in future years.

Mitigation for Habitat Loss

The Service mitigation policy states that the degree of mitigation should correspond to the value and scarcity of the fish and wildlife habitat at risk. Consequently, no net loss of in-kind habitat value should be the mitigation goal for this resource category. The Service believes that the proposed project will likely meet the "no net loss of in-kind habitat" mitigation goal for this resource category, though our full understanding of the Project is limited to the two request letters received. Assuming there is truly "no net loss of in-kind habitat" as a result of the Proposed Action, no specific mitigation would be needed.

The Proposed Action would provide fish and wildlife benefits by restoring portions of the Bosque to a condition nearer to natural and productive biotic community via multiple restoration features as identified in Table 1. Therefore, the Service believes the project would improve important migratory bird habitat as well as resident fish and wildlife habitat within the Rio Grande corridor in Albuquerque.

Recommendations

The Service anticipates some minor short-term impacts to fish and wildlife resources associated with project construction. To ensure that federally listed species are not adversely impacted by the project, ESA section 7 consultation will be completed prior to construction. To ensure that the objectives of the project are met, post-construction monitoring of the Project Area should be conducted. The recommendations of Hink and Ohmart (1984) are still relevant and sound today and are incorporated in our recommendations. Recommendations are grouped into three categories; impact avoidance, mitigation and restoration, and monitoring.

Impact Avoidance

To minimize adverse impacts to birds, tree stands (or other adequately vegetated areas)

slated for grubbing or clearing should be surveyed for the presence of nesting birds during the general migratory bird nesting season of March through September. Disturbance to nesting areas is encouraged to be avoided until nesting is completed. Areas occupied by SWFL and YBCU should be avoided from April 15 to September 1.

Construction should be accomplished during periods of least resource impact. Work should be scheduled to avoid disturbance to breeding and nesting birds especially Neotropical migrants (March through September) and to fish, especially native fishes, during the spawning and hatching periods. To minimize disturbance to wildlife, the duration of disturbance activities should be as brief as possible.

Backfill should be uncontaminated earth or alluvium suitable for revegetation with native plant species.

Vegetation clearing and construction related soil disturbances can cause sediment-laden runoff to enter waterways. To minimize impacts associated with erosion, the contractor should employ silt curtains (without lead weights), coffer dams, dikes, straw bales, or other suitable erosion control measures.

Protect mature cottonwood trees adjacent to the construction footprint from damage during clearing of nonnative species or other construction activities using fencing, or other appropriate materials.

Immediately prior to construction of each unit and prior to reinitiation of work following an extended period of no action, conduct surveys to assess the possible presence of Federal and State endangered or threatened species, or Tribal species of concern. If protected species are located, coordinate with Federal, State, and Tribal wildlife agencies to prevent adverse impacts to the species.

There has been substantial restoration planned and completed in the Project Area (Crawford et al. 1993; Robert 2005; Parametrix 2008; SWCA 2008, 2010). Project construction activities should avoid impacts to proposed and existing restoration areas.

Construction related petrochemical spills can also negatively impact fish and wildlife resources. Therefore, measures should be implemented to minimize the likelihood of petrochemical spills. Spill procedures should be in place prior to construction to minimize impacts associated with unexpected spills.

Mitigation and Restoration

Replace topsoil and revegetate all disturbed sites with suitable mixture of native grasses, forbs, and woody shrubs. We recommend working with the Natural Resources Conservation Service Los Lunas Plant Materials Center to select and test suitable native plants for maintaining a diverse vegetative assemblage. Active management of the plant community will be necessary and operations and maintenance plans should include agreements to maintain an appropriate plant community in terms of ground coverage and composition.

Support maintenance of riparian habitat and agricultural lands outside the levees on the historical floodplain (i.e. assist irrigation districts, local open space divisions, or Valle de Oro National Wildlife Refuge via funding opportunities, construction, planting material, etc.).

Wetlands with a variety of water depths, water movement through the wetland, small islands, an irregular water-land interface, and protection of adjacent uplands, are habitat requirements to produce a diverse healthy wetland. To maximize benefits to fish and wildlife resources, the Service recommends further exploration of wetland creation opportunities within the Middle Rio Grande.

Monitoring

Develop an Adaptive Management Plan to monitor and evaluate success of project mitigation, especially water quality, revegetation, and habitat enhancement to determine if the Proposed Action is meeting its objectives.

Continue support and participation in annual bird monitoring especially for SWFL and YBCU in the proposed Project Area.

In coordination with the Service, develop a protocol to monitor presence/absence of silvery minnows in the channels following high flows, and to determine whether channel maintenance is warranted.

We appreciate the opportunity to provide these recommendations and look forward to working with you on this project in the future. If you have any questions about this consultation, please feel free to contact me or Dave Campbell of this office at (505) 761-4745.

Sincerely,

Susan S. Millsap
Field Supervisor

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BIOLOGICAL ASSESSMENT

Rio Grande, Sandia Pueblo to Isleta Pueblo, CO, NM, TX
Ecosystem Restoration Project

Prepared by:

U.S. Army Corps of Engineers

4101 Jefferson Plaza NE

Albuquerque, New Mexico 87109

DRAFT

July 2018

US Army Corps of Engineers ®
Albuquerque District

CONVERSION FACTORS

	From	Multiplier	To
Distance:	inches (in)	25.4	millimeters (mm)
	feet (ft)	0.3048	meters (m)
	miles (mi)	1.6093	kilometers (km)
Area:	acres (ac)	0.0407	hectares (ha)
	square miles (mi^2)	2.590	square kilometers (km^2)
Volume:	cubic yards (CY)	0.7646	cubic meters (m^2)
	acre-feet (ac-ft)	1,233.5	cubic meters (m^2)
	acre-feet (ac-ft)	325,851	gallons (gal)
Discharge:	cubic feet/second (cfs)	0.0283	cubic meters/second (cms)
Mass (weight) :	tons [short]	0.9072	metric tons [long]
Velocity:	feet/second (fps)	0.3048	meters/second (cms)
Salinity:	µSiemens/cm or µmhos/cm	0.32379	parts/million NaCl or mg/liter NaCl
Temperature:	° Fahrenheit (°F)	(°F-32)/1.8	° Celsius (°C)

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1.1 Scope of the Biological Assessment

The U.S. Army Corps of Engineers (Corps) is submitting this Biological Assessment (BA) to the U.S. Fish and Wildlife Service (Service) pursuant to Section 7(a)(2) of the Endangered Species Act (ESA). This BA evaluates the effects of the Rio Grande, Sandia Pueblo to Isleta Pueblo, Ecosystem Restoration Feasibility Study and Environmental Assessment proposed action (Project) on Federally-listed species, and designated and proposed critical habitat within the action area.

When determining the proposed action for this consultation, the Corps carefully considered the water management activities of non-Federal and other Federal entities in the action area. Activities that are interdependent or interrelated (as defined in 50 CFR §402.02) with the Corps' action could be included as a proposed action in this BA. However, none of the water management activities of other entities met these criteria for inclusion. Therefore, the proposed action in this Section 7 consultation focuses only on the construction, operation and maintenance, and monitoring of the Project as described below.

This BA considers the effects of the Project's proposed action (Chapter 2) on Federally-listed species and their designated and proposed critical habitat occurring from Sandia Pueblo to Isleta Pueblo with focus on the endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*) (flycatcher), the threatened Western U.S. Distinct Population Segment (DPS) of the Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*) (cuckoo), and the endangered Rio Grande silvery minnow (*Hybognathus amarus*) (minnow). A detailed description of the action area is provided in Section 2.1 of this document.

The special status species considered for analysis of effects in this document either occur in the action area and/or have critical habitat or proposed critical habitat in the action area (Table 1). Other identified species of interest include the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) and Mexican Spotted Owl (*Strix occidentalis lucida*), however as there is either no critical habitat, a lack of suitable habitat for the species or primary constituent elements (PCEs), or the species are unlikely to occur within the action area, none of these species meet the criteria for further analysis.

Table 1: Special status species with the potential to occur in the study area.

Common Name	Scientific Name	Federal Status	Date of Listing	Critical Habitat	Habitat Type	Presence in Project Area
Southwestern Willow Flycatcher	*Empidonax traillii extimus*	Endangered	1995	Yes, but not within project action area	Dense riparian	As migrant only
Yellow-billed Cuckoo (Western U.S. DPS)	*Coccyzus americanus occidentalis*	Threatened	2014	Yes, proposed in project action area	Multi-layered Riparian	As migrant only
Rio Grande Silvery Minnow	*Hybognathus amarus*	Federal Endangered	1994	Yes, in project action area	Aquatic	Yes

Mexican Spotted Owl	*Strix occidentalis lucida*	Threatened	1993	Yes, but not within project action area	Subalpine coniferous forest	No
New Mexico Meadow Jumping Mouse	*Zapus hudsonius luteus*	Endangered	2014	Yes, but not within project action area	Dense riparian/wetland	No

1.2 History of Consultation

This is the initial consultation for this Project. However, this Project area falls wholly within the Middle Rio Grande Project (MRG Bosque Project) for which planning started in 2002 and was ready for construction by late 2011. On November 10, 2010, the Service submitted to the Corps a final *Coordination Act Report (CAR) for the Middle Rio Grande Feasibility Report, Albuquerque, NM* (USFWS 2010). The CAR concluded that the proposed project would not have any permanent adverse impacts on the biological resources in the project area with implementation of recommendations outlined in the report, stating, too, "The proposed project would enhance and revitalize the Rio Grande bosque in the Middle Rio Grande Reach, in Albuquerque, Bernalillo County, New Mexico."

On April 15, 2011, the Service transmitted to the Corps their Biological Opinion (BO) on the effects of the action described in the 2010 BA for Middle Rio Grande Bosque Restoration Project, Bernalillo and Sandoval counties, New Mexico. The BO analyzed the effects of the action on the minnow and flycatcher (as the cuckoo was not yet listed) and its relationship to the function and conservation role of their critical habitat based on information submitted in the April 2010 BA and November 2010 amended BA. The Service concurred with the Corps' determination that the proposed project "may affect, but not likely to adversely affect," the flycatcher. As per the minnow, it was the Service's biological opinion that the Corps' MRG Bosque Restoration Project was not likely to jeopardize its continued existence.

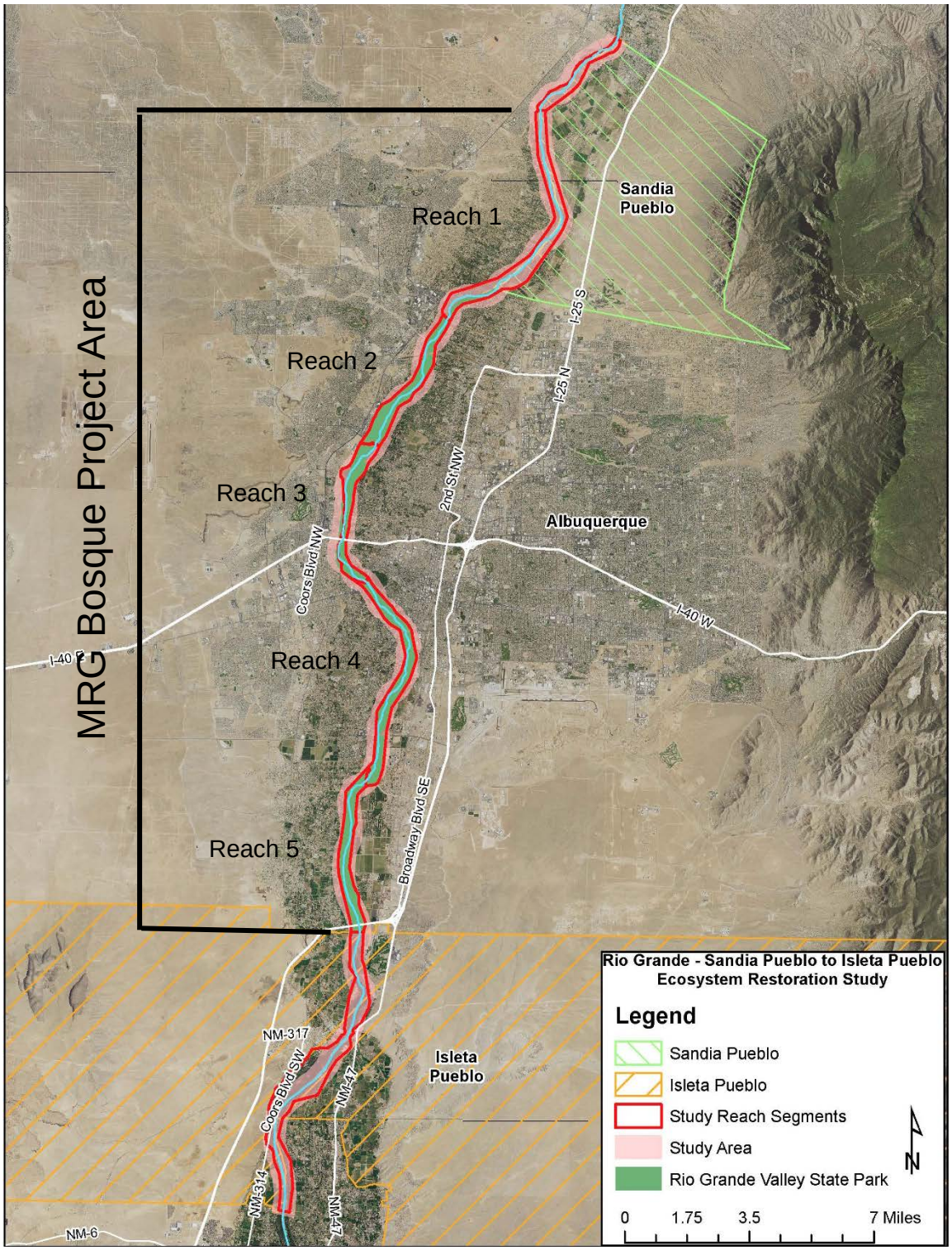

Figure 1: Sandia to Isleta Ecosystem Restoration Study Area with MRG Bosque Project Area.

1.3 General Project Background

The Project stems from the Rio Grande, Sandia Pueblo to Isleta Pueblo, Ecosystem Restoration Feasibility Study (study) which is being conducted as the first such study under the Rio Grande Environmental Management Program (RGEMP) for the Rio Grande basin. The RGEMP has been authorized by Section 5056 of the Water Resources Development Act of 2007 (WRDA 2007), as amended by Section 4006 of the Water Resources Reform Development Act of 2014 (WRRDA 2014). The RGEMP is established for the planning, construction, and evaluation of measures for fish and wildlife habitat rehabilitation and enhancement; and implementation of a long-term monitoring, computerized data inventory and analysis, applied research, and adaptive management program in consultation with the States of Colorado, New Mexico, and Texas, and other appropriate entities.

Prior to dam construction in the early 1900s, the Rio Grande supported substantial areas of cottonwood (*Populus* spp.), willow (*Salix* spp.), New Mexico olive (*Forestiera neomexicana*), and various species of shrubs and wetland plant (Scurlock, 1998). This suite of vegetation is considered to be representative of the natural "climax community" of species that would be found in an undisturbed riparian corridor along the Rio Grande. Stabilization of the channel through rectification and channelization supported development of extensive areas of cottonwood gallery forest in the 1940's through 60's, which is now reaching senescence.

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). About 90 percent of the historic wetland and riparian habitat in the Southwest has been eliminated. Open water or wet soil habitats are 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, and, although highly altered and in a much reduced and degraded state compared to its historic status, the MRG still has one of the highest value riparian ecosystems remaining in the Southwest. It remains a critical travel corridor for many species, especially migratory birds that include neo-tropical songbirds, waterfowl, raptors, and cranes. 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, and, therefore, activities that restore and enhance fish and wildlife habitat within the MRG are timely.

Moreover, the Bosque of the MRG is an ideal location for restoration due to its unique quality and critical resource values making it an area of importance on a local, regional, national, and international scale. Lending to the significance of the Albuquerque reach of the MRG, the Bosque:

- Embodies the largest remaining continuous cottonwood forest found in North America;

- 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;
- 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); and
- Provides breeding and foraging habitat for four 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.

The MRG Bosque Project area was divided into five reaches (Figure 1). Phase 1 of the MRG Project was completed in 2014, followed by Phase 2 which began in 2014 and was completed in 2017. The MRG Project, implemented by the Corps, expanded, created, and improved fish and wildlife habitat along a 22-mile reach of the MRG between the northern-boundary of the Village of Corrales downstream to the Interstate 25 (I-25) bridge near the northern-boundary of Isleta Pueblo. The MRG Project restored a total of 916 acres of the MRG 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 forest restoration. In addition to these projects, a number of MRG Endangered Species Collaborative Program (Collaborative Program) projects have been constructed in the Albuquerque Reach.

The current proposed Project incorporates environmental restoration measures to improve the Rio Grande Bosque ecosystem function in the MRG and includes 261 acres of the Bosque that would be restored 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 exotic species/fuel reduction and riparian gallery forest restoration).

In the Project area, past water management and flood control actions have reduced the total habitat from historic conditions and severely altered habitat conditions for the Federally-listed minnow, flycatcher, and cuckoo, and their designated critical habitat. Narrowing and deepening of the channel, lack of side channels and off-channel pools, and changes in natural flow regimes have all adversely affected these species. The proposed plan would create wetlands within the Rio Grande riparian zone; and would sustain and enhance existing, in addition to creating new, native cottonwood communities.

The Project's action area includes the Bosque within Albuquerque designated as the *Rio Grande Valley State Park* through the Park Act of 1983 and which is cooperatively managed by City of Albuquerque Open Space Division (AOSD) and the Middle Rio Grande Conservancy District (MRGCD).

1.4 Purpose and Need

The purpose of the proposed Project is to:

1. Improve habitat quality and increase the amount of native Bosque communities to a sustainable level,
2. Restore hydraulic processes between the Bosque and the river characterized by a more natural overbank inundation pattern and higher riparian groundwater levels, and
3. Protect, expand, and improve areas of potential habitat for listed species within the Bosque including the minnow, the flycatcher, and the cuckoo.

To develop a set of alternatives that meet the Project purpose, the Corps has identified the following objectives:

- Achieve a moderately high functionality or higher habitat value over 30 percent or more of the areas of consideration. This value will be achieved in 20 years or less after project implementation and will be sustained for the remaining 30 years of the proposed analysis.
- Produce a 25 percent or more increase in the area of inundation during flow events greater than or equal to 3,000 cubic feet per second (cfs) (hydrologic analysis identified a discharge of 3,770 cfs will meet this objective and has a recurrence interval of 1.4 years).
- Provide additional areas for hatching and rearing of the minnow using the increase in inundation areas described above and to provide over-25 percent increase in high quality habitats suitable for breeding by the flycatcher.

Habitat loss, fragmentation, and alteration have resulted in the loss of 12 fish species from the MRG, two of which are now extinct. Habitat restoration within the MRG will provide additional habitat for listed species so that they may 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.

1.5 Consideration of Related Actions

In addition to activities authorized, funded, or carried out by Federal agencies, Section 7 consultation regulations also require agencies to consult on interrelated and interdependent actions. Interdependent actions are those having no independent utility apart from the proposed action (defined in 50 CFR §402.02). Interrelated actions are those actions that are part of a larger action and depend on the larger [proposed] action for their justification (defined in 50 CFR §402.02).

When determining the proposed action for this consultation, the Corps carefully considered the water management activities of non-Federal and other Federal entities in the action area. None of the water management activities of other entities met the statutory criteria for inclusion.

2 - Proposed Action

2.1 Action Area

Per the Rio Grande, Sandia Pueblo to Isleta Pueblo, Ecosystem Restoration Feasibility Study and Environmental Assessment, the action area includes all areas to be affected directly or indirectly by the proposed action (see 50 CFR §402.02). This Project's proposed action will occur along the Rio Grande between the levees, extending approximately 15 miles from the northern end at Alameda Bridge, downstream to the South Diversion Channel.

The study area extends approximately 26 miles (from the Village of Corrales in Sandoval County downstream to the northern boundary of the Pueblo of Isleta in Bernalillo County). The Corps divided the study area into five reaches because the study area is so large, the relative effects of proposed designs are localized to some degree, and to maintain consistency with the MRG Bosque Study (Figure 1). Reach designation supports 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.

The five reaches of the study are area defined as follows:

• Reach 1	North end of Corrales south to Alameda Blvd. – includes lands of Village of Corrales, Pueblo of Sandia, and RGVSP	River miles (RM) ~ 198.4-192.2 (~ 6 mi.)
• Reach 2	Alameda south to Montano	RM ~ 192.2-188 (~ 4 mi.)
• Reach 3	Montano south to Central	RM ~ 188-183.5 (~4.5 mi.)
• Reach 4	Central south to South Diversion Channel	RM ~ 183.5-177 (~6.5 mi.)
• Reach 5	South Diversion Channel south to Pueblo of Isleta boundary	RM ~177-172 (~ 5 mi.)

For this consultation the action area is defined as the entire width of the 100-year floodplain of the Rio Grande from RM 192.2 to RM 177 and only includes reaches 2, 3, and 4 (Figure 2), and includes the Bosque within Albuquerque, designated as the *Rio Grande Valley State Park*.

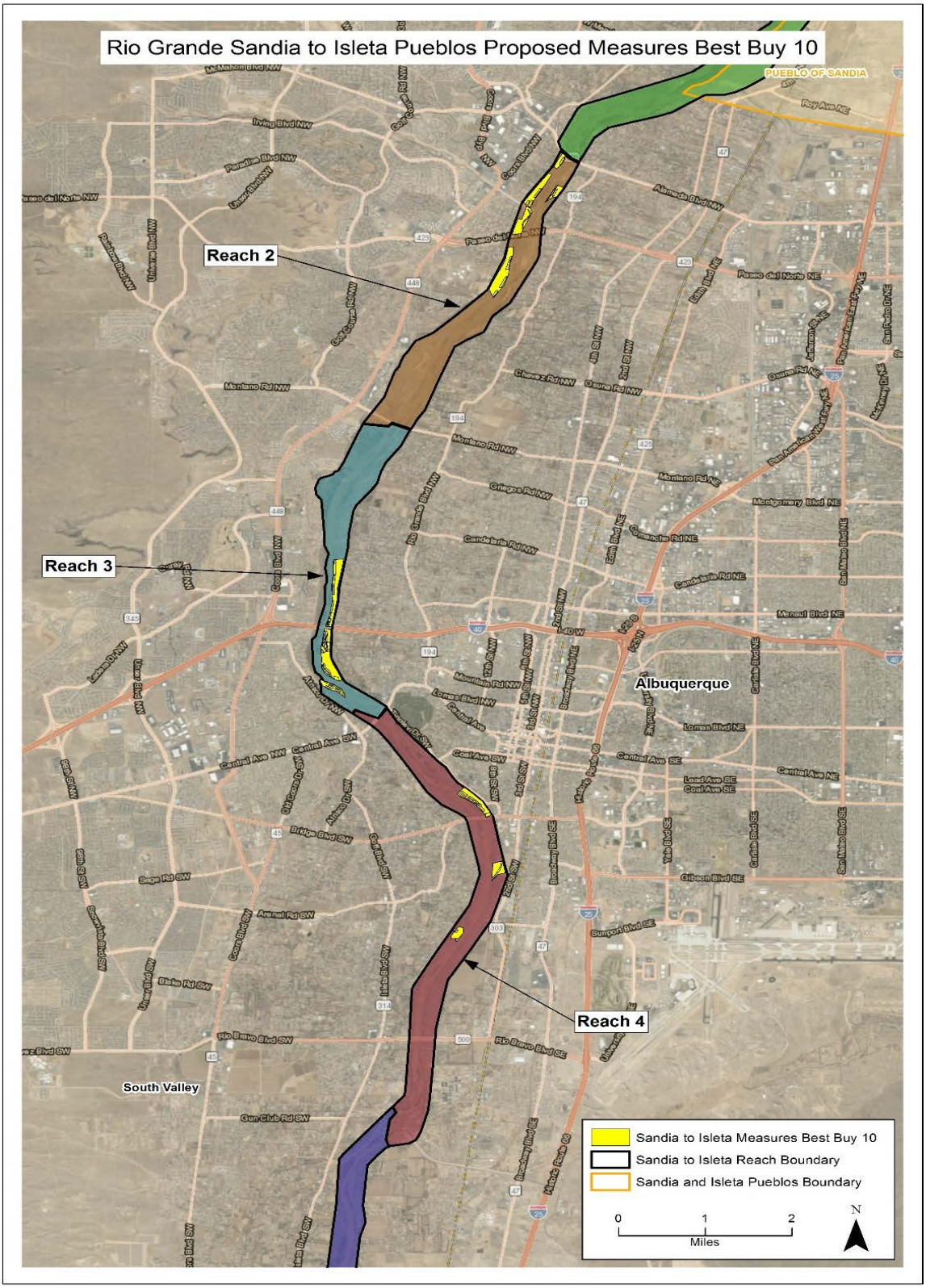

Figure 2: Sandia to Isleta Ecosystem Restoration Project Proposed Action Area.

2.2 Description of the Proposed Action

With local sponsorship, the Corps is proposing to restore function and increase high value habitat through the Albuquerque reach at 10 locations adjacent to the Rio Grande, spanning the area between the Sandia Pueblo to the north and the Isleta Pueblo to the south. Upon completion, the Project would include approximately 261 acres of improvements and an increase of over 1,000 Average Annual Habitat Units within the Rio Grande floodplain in reaches 2, 3, and 4 of the Project area (Figure 2). Improvements at these sites would include the construction of 42 willow swales, five high-flow channels, the creation or restoration of three wetlands, the removal of three berms, construction of a wet meadow, outfall wetland enhancements (improvement of two connections to the Rio Grande, enhancement of a ditch for wet habitat, diversion of an outfall flow), bank destabilization, and fuel reduction/thinning of non-native vegetation followed by seeding and planting of natives at 15 locations (Treat-Retreat-Revegetate) (Table 2).

The proposed project actions include the following feature enhancements on Reaches 2, 3 and 4 (Figure 3):

- Reach 2 would include 10 swales, a wetland, and a high-flow channel, with six locations to undergo the Treat-Retreat-Revegetate process. Sites D, E, and F are located on the west side of the Main channel and Site G is on the east side. These sites are situated at the outlet of the Calabacillas Arroyo.
- Reach 3 would include 25 swales, three high-flow channels, two outfall wetlands, removal of three berms, and bank destabilization, with seven locations to receive the Treat-Retreat-Revegetate process. Sites H and M are located on the east side of the Main channel and are separated by I-40. Site J is a peninsula along the west side.
- Reach 4 would include seven swales, two connections to the river, a high-flow channel, a wet meadow, ditch enhancement, and diversion of an outfall flow, with two locations to receive the Treat-Retreat-Revegetate process. Site Q is located on the eastern edge of the Main channel, and Sites P and T are on the west side.

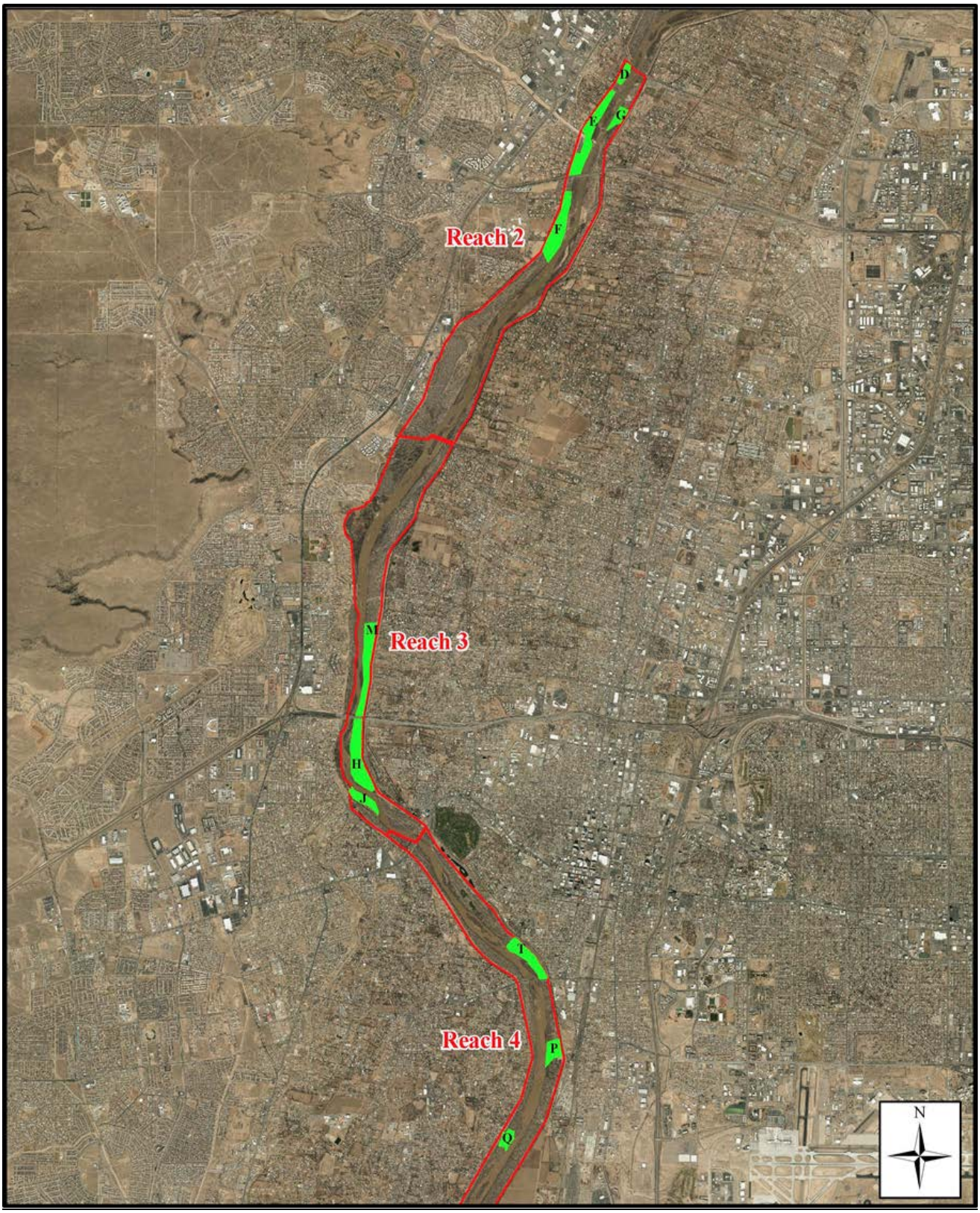

Figure 3: Sandia to Isleta Ecosystem Restoration Project Map of Proposed Measures by Reach.

Table 2: Project proposed measures by reach and associated acreage (correlated with Figure 3).

Site	Reach	Measures	Area (acres)
D	2	Willow swale, Treat-Retreat-Reveg	7.54
E	2	Willow swale, Treat-Retreat-Reveg, High-flow channel	44.75
F	2	Willow swale, Treat-Retreat-Reveg	42.59
G	2	Willow swale, Treat-Retreat-Reveg, Wetland	9.92
H	3	Willow swale, Treat-Retreat-Reveg, Bank destabilization, High-flow channel, Berm removal	47.7
J	3	Wetland, Willow swale, Treat-Retreat-Reveg	13.68
M	3	Wetland, Willow swale, Treat-Retreat-Reveg	39.48
P	4	Treat-Retreat-Reveg, High-flow channel	15.82
Q	4	Wet meadow, Outfall wetland (Connection to River, Enhance ditch for wet habitat)	10.43
T	4	Willow swale, Treat-Retreat-Reveg, Outfall wetland (Divert outfall flows)	28.8

2.2.1 Exotic Species Removal / Fuel Load Reduction and Riparian Gallery Forest Mosaic Restoration

The overall Bosque restoration strategy is to Treat-Retreat-Revegetate: Facilitate restoration efforts by *treating* non-native vegetation species and removing the chief competition to native trees, shrubs, forbs, and grasses; *retreating* those areas, as necessary, for continued maintenance associated with removal of non-native stump sprouts and juvenile volunteer non-natives, and native shrub growth in firebreaks; and *revegetating* existing and previously created open areas of the Bosque forest woodland and thickets with the missing understory component of native shrubs and juvenile trees. At the same time, gaps would 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 identified 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 plantings 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.

These different planting strategies would be combined in order to create the target mosaic of different ecosystem types (Bosque forest, grass meadow, wet features).

2.2.1.1 Exotic Species Removal and Fuel Load Reduction

Non-native plant removal through mowing, cut-stump, and herbicide treatments would facilitate restoration efforts by removing the chief competition to native trees, shrubs, forbs, and grasses, in addition to also

reducing the fire hazard, enhancing aesthetic and recreational aspects of the Bosque, and improving security. Continued maintenance and repeated treatment for stump sprouting and removal of juvenile volunteer non-natives, including subsequent infestations of invasive or noxious species, would be necessary. 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. This is provided for under the Project's operations and maintenance and adaptive management. The initial thinning of non-native vegetation and the reduction of fuel loads would have to occur prior to initiating the remaining measures discussed below.

2.2.1.2 Riparian Gallery Forest Mosaic Revegetation

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

Seeding with native grasses and forbs, such as Indian ricegrass (*Achnatherum hymenoides*), galleta grass (*Pleuraphis 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 saltgrass (*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 Monsoon season is usually optimal.

Bare root container or plug planting with native shrubs, such as peach leaf willow (*Salix amygdaloides*), New Mexico olive, fourwing saltbush (*Atriplex canescens*), Rabbitbrush (*Chrysothamnus nauseosus*), false indigo (*Amorpha fruticosa*), golden currant (*Ribes aureum*), three leaf sumac (*Rhus trilobata*), woodbine (*Parthenocissus* spp.); and in wetter areas, coyote willow (*Salix exigua*), Goodding's willow (*Salix gooddingii*), peachleaf willow (*Salix amygadaloides*), and seep willow (*Baccharis salicifolia*).

- Bare-root planting refers to planting a plant with roots directly in the ground without a root-ball that has soil surrounding it.

- 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 may be planted as bare root with hydro-gel (a.k.a. Dri-Water™), if appropriate.

- 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 2 years).

- Long-stem plantings with deep-rooted native shrub species may also be applied. The deep roots provide a means to get the plant closer to the water table. 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 (100-500 stems per acre as needed).

Pole planting of native trees, such as the Rio Grande cottonwood (*Populus fremontii* var. *wislizenii*), Goodding's willow, coyote willow, and peachleaf willow.

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 to 15 feet in length, are placed into holes augured 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 (10-50 stems per acre). Willows are lacking in some areas of the study area and would be planted at a higher density in those areas (25-75 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 (1-5 gallons), accompanied by a tube to the root zone though which water would be provided by hand from a water truck until the plants are well established.

2.2.2 Water Measures

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 moisture and nutrients. The purpose of the water-related measures 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 measures would be incorporated into the proposed action and would include wetland restoration/construction, bank lowering, 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 (ISC) requires water related measures (wetland, high-flow channel) to be implemented within 300 feet from existing channel centerline.

2.2.2.1 Wetland Restoration/Construction

Wetlands are an integral component of the Bosque ecosystem, not only increasing diversity but also enhancing the value of surrounding plant communities for wildlife. They include marshes, wet meadows, and seasonal ponds that typically support hydrophytic plants such as cattails (*Typha* spp.), sedges (*Carex* spp.), and rushes (*Juncus* spp.). Wetlands have experienced the greatest historical decline of any floodplain plant community. From 1918 to present, wetland-associated habitats have undergone a 93 percent 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).

Wet meadows were the most extensive habitat type in MRG valley prior to the construction of the MRGCD drains and ditches. Wet meadows 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. Moist soil habitat is created, similar to that of the wet meadow at the Albuquerque Biological Park Wetland.

Outfall wetlands may be constructed and enhanced in areas where stormwater outfalls exist but currently do not create or use the potential to create habitat, and simple modifications to existing outfalls could provide several benefits. The conceptual idea is to connect the outfall, via the Bosque, through to the river, providing wetland and/or moist soil habitat. Each area can be designed based depending on the outfall size. The concept is to divert the low flows from the outfall into a reconstructed channel. The conceptual design may include 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. The channel would be planted with wetland plants to promote biological activity, and 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.

2.2.2.2 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 measure 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 (Figures 4 and 7). High-flow channels would deliver much-needed water to Bosque vegetation and increase potential water-based habitats for wildlife.

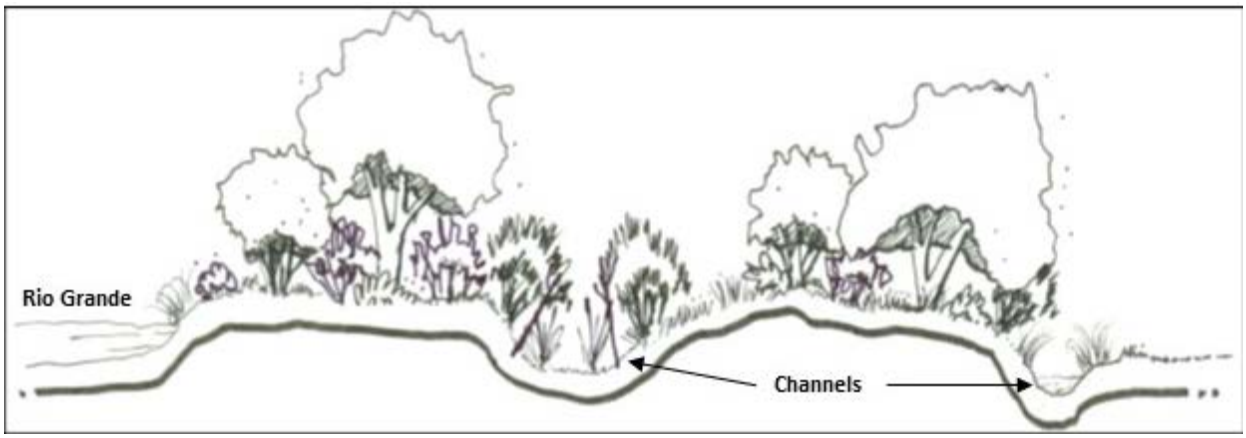

Figure 4: High-flow channel schematic.

2.2.2.3 Swales

In certain areas of the Bosque, the depth-to-water table is minimal, and optimizing these depressions using slight excavations would expose water and provide micro-environments in which native plants, specifically willows for this Project, can thrive due to the decreased distance to the water table and moist soils (Figures 5 and 7). 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 would 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. This measure would create wet meadow and shrub habitat. 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.

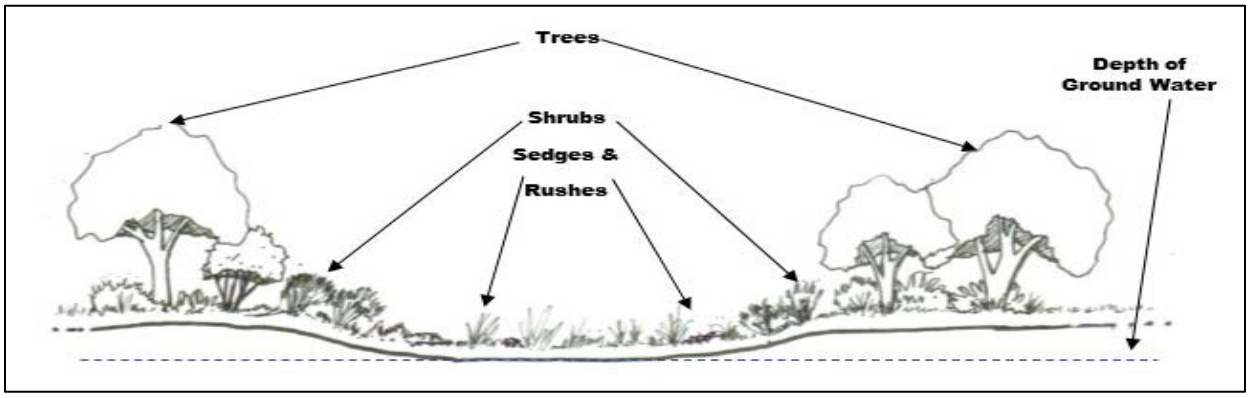

Figure 5: Schematic concept for swale.

2.2.2.4 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 has been used in various locations of the MRG, primarily for creation of potential habitat for the minnow (Figure 7).

2.2.2.5 Bank Lowering

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) (Figure 6). This technique, has been used in various locations of the MRG, primarily for creation of potential habitat for the minnow.

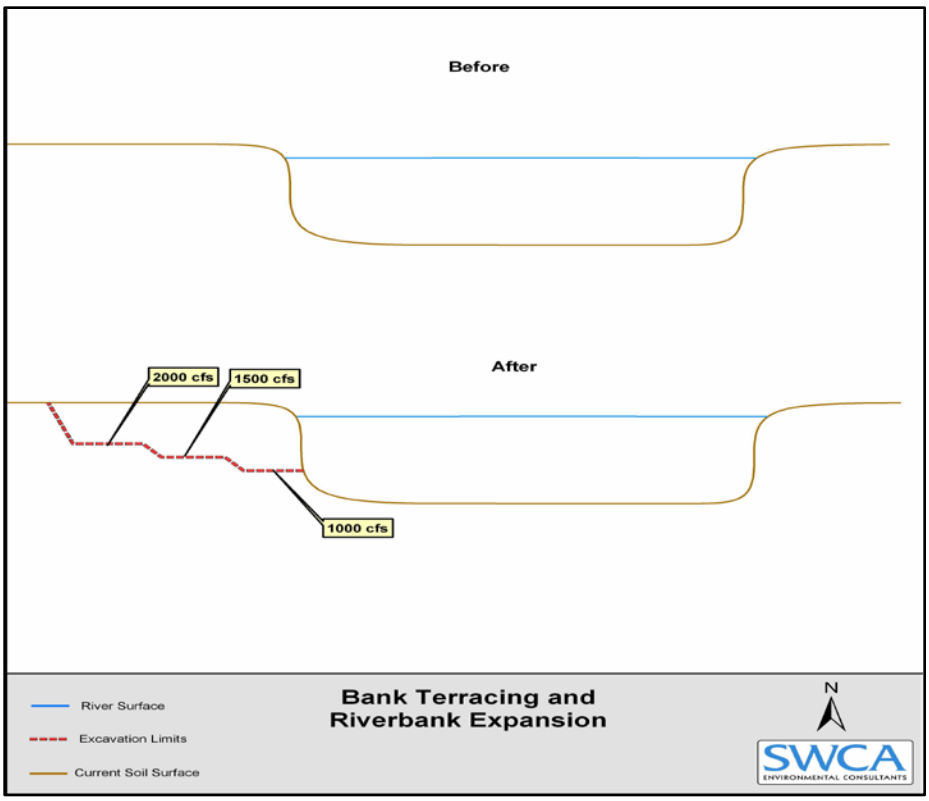

Figure 6: Schematic of bank terracing (lowering) (SWCA, 2006).

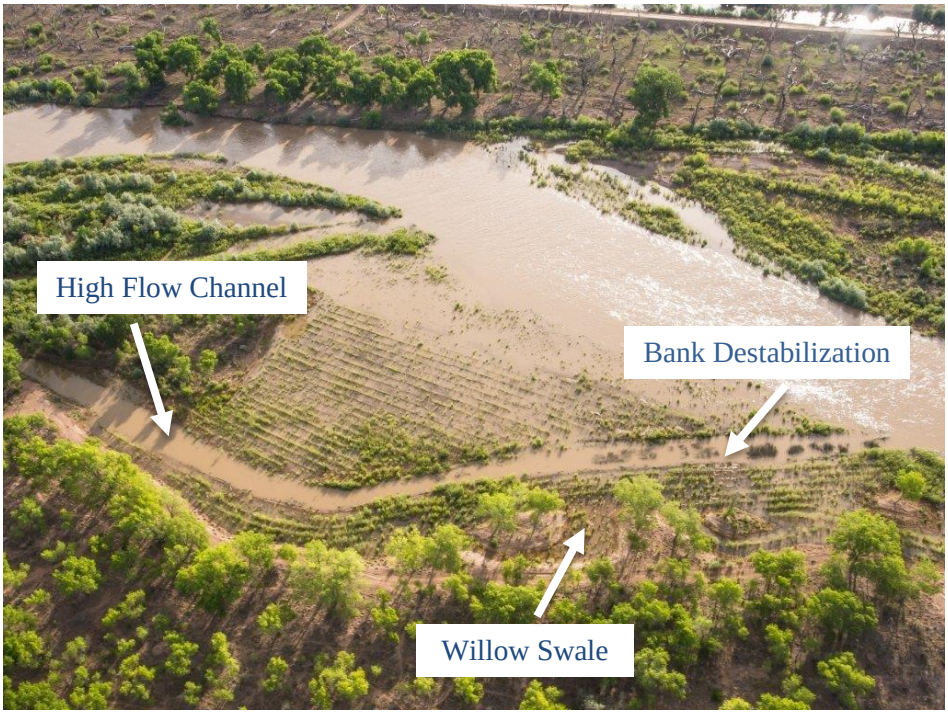

Figure 7: Examples of Proposed Ecosystem Restoration Features.

2.3 Project Implementation

Construction would take place over two to three years to reduce impacts to habitat areas and accommodate funding availability. While removal of non-native species (*treat*), and seeding, planting, and establishment of native species (*revegetate*) would take place over multiple years to minimize impacts to birds nesting in non-native vegetation within the Project area. Once the initial removal takes place, a follow-up treatment is often required six months to a year later to eliminate trees that may re-sprout from roots or stumps (*retreat*). Conservation measures and Best Management Practices (BMPs) would be employed throughout the project to protect natural (water, air, etc) and cultural resources.

2.3.1 Construction Sequence of Ecosystem Restoration Measures

Construction of all features would be scheduled during the typical low-flow seasons on the MRG (fall and winter). However, any work scheduled during the nesting season (April 15 through September 1) would require nesting bird surveys. Fuel reduction, thinning of non-native plant species, and reseeding of native plant species (Treat-Retreat-Revegetate) would take place initially, followed by the construction of water features.

Sequencing of the construction of water feature measures (channel stabilization, high flow channels and/or terrace lowering) is proposed to reduce the amount of potential sediment moving into the river, minimize impacts to water quality, and reduce impacts to the river bank edge.

Water features would be constructed within the Bosque and then connected to the river, and would take place at only one or two areas simultaneously. The high-flow channels would be constructed so that the middle of the channel is excavated first, then the opening at the downstream end, and the opening at the upstream end would be excavated last (similar to previous USACE restoration projects at the Rio Grande Nature Center and Route 66 projects). Flows in the river during construction of these high flow channels are anticipated to be about 400-1000 cfs. Active flows may need to be diverted temporarily with a port-a-dam or similar device during construction. The exact device used to divert the flow of water during construction, if needed, would be at the discretion of the construction contractor and approved by the Corps.

Excess soil generated by the construction of these features would be used for the construction of access ramps and turn-arounds off of the levee. Any remaining material would be made available to local management agencies (MRGCD, USBR, and AOSD) for their use. Material would be hauled to local areas for use, or stockpiled at their facilities for future use.

2.3.2 Access and Staging

Access to all work areas would occur along the levee roads, and staging would occur in adjacent open areas made available by the sponsor, MRGCD. Staging could also take place within the Bosque if other areas are not available. Additional access and subsidiary staging areas required to facilitate construction activities would be coordinated with local land managers. Associated disturbed sites will be prepped and revegetated with native species.

2.3.3 Conservation Measures

The following is a list of conservation measures that would be complied with during construction of the proposed action to protect endangered species and their habitat.

1. Beginning with the breeding season prior to the initiation of construction in each segment, the Corps would perform or fund annual flycatcher and cuckoo protocol surveys throughout the Project area. Annual surveys would continue until the completion of construction and would continue for three years following Project completion.
2. No construction would be performed within 0.25 mile of an occupied flycatcher breeding territory, and within 0.25 mile of a cuckoo nest (generally, late May through September 1).
3. Vegetation removal and clearing-and-grubbing activities would only be performed between September 1 and April 15.
4. The proposed work would occur during the winter, which is when Bald Eagles may be in or near the Proposed Action Area. In order to minimize the potential for disturbing Bald Eagles utilizing 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; or
   - A Corps biologist, in consultation with the Service, would determine that the potential for harassment is minimal.
   - However, if a Bald Eagle arrives during construction activities or if a Bald Eagle is greater than 0.25 mile away, construction need not be interrupted.
5. All construction equipment and large trucks would limit engine noise levels to 60 dB or less to minimize disturbance for piscine and avian species.
6. Monitor minnow (larval, juvenile, adult) use of the inundated floodplain during spring runoff to document habitat use at the river-floodplain interface for comparison with the maximum extent of inundation.

2.3.4 Best Management Practices

The following is a list of best management practices and stipulations that would be complied with during construction of the proposed action to protect water resources and endangered species habitat from degradation.

Equipment and Operations

- Work would be performed below the elevation of the ordinary high water mark only during low-flow periods. No erodible fill materials would be placed below the elevation of the ordinary high water mark.
- Fuels, lubricants, hydraulic fluids and other petrochemicals would be stored outside the 1-percent chance floodplain, if practical. Staging and fueling areas would be located outside of the floodway, landward of the existing spoil bank alignment, and at least 100 feet from any

surface water or channel. All storage areas would include spill prevention and containment features. Park construction equipment outside the one-percent chance floodplain during periods of inactivity.

- All construction equipment, prior to mobilization on-site, would be washed so are clean and free of any petrochemicals or noxious/invasive weed seed/plant remnants and will not contaminate the Project area.
- Construction equipment would be inspected daily to ensure that no leaks or discharges of lubricants, hydraulic fluids or fuels occur in the aquatic or riparian ecosystem. Any petroleum or chemical spills would be contained and removed, including any contaminated soil.
- Ensure equipment operators carry an oil spill kit or spill blanket at all times and are knowledgeable in the use of spill contamination equipment. A spill contingency plan would be developed prior to initiation of construction. Proper Federal and state authorities would be notified in the event of a spill.
- Wattles, silt curtains, cofferdams, dikes, straw bales and other suitable erosion control measures would be employed to prevent sediment-laden runoff or contaminants from entering any watercourse.
- If a disposal site is needed (other than on site outside of the river), a site that has been previously used for dredged material would be utilized.
- Protect mature cottonwood trees from damage during clearing of non-native species or other construction activities using fencing, flagging or other appropriate methods.
- Scarify compacted soils or replace topsoil, and backfill with only uncontaminated (free of petrochemicals and weeds) earth or crushed rock suitable for re-vegetation with native plant species.
- Use of herbaceous nitrogen-fixing groundcover to reduce erosion, support re-vegetation, and suppress woody vegetation.
- Re-vegetate all disturbed sites (e.g. access and staging areas) with suitable mixture of native grasses, forbs, and woody shrubs.

Staging and Access

- All work and staging areas would be limited to the minimum amount of area required. Existing roads and rights-of-ways and staging areas would be used to the greatest extent practicable to transport equipment and construction materials to the project site, and as described in the Project description. Designated vehicle turn-around and maneuvering areas would be used to protect riparian areas from unnecessary damage.

Permitting

- All conditions for Nationwide 33 and 27 would be adhered to during construction (USACE 2018).
- Stormwater Pollution Prevention Plan (SWPPP) for construction sites will be adhered to.
- The Corps would provide an annual report on progress to the Service during the construction

period of the proposed action. Copies of the report would be furnished to the project sponsors, and pertinent Federal and local resource agencies (USACE 2018).

Herbicide Treatments

- Herbicides will not be applied when winds exceed 15 miles per hour or when rain is forecasted for the local area within 48 hours of application. Herbicides will be applied no later than two months before the normal spring runoff and high water tables, or by March 15th. Garlon-4 will be used, but not within a 20-ft buffer zone from areas where standing or flowing water is present; Renovate 3® (triclopyr) will be applied as needed within the 20-ft buffer zone.
- All required permitting and licensure would be obtained by the contractor. Prior to application, all chemicals would be specifically approved per manufacturer's instructions.
- Herbicide label requirements will be followed. Mixing and application of these herbicides would be done so in accordance with all manufacturer instructions and proper personal protective equipment would be worn. Storage and mixing would also be performed following manufacturer's instructions. Storage would not be allowed on site within the Bosque.
- Follow-up inspections and monitoring post-herbicide application would be performed at all locations. All excess herbicide would be disposed of off-site.

Water Quality Monitoring

- If required by the Section 401 Water Quality Certification, water quality would be monitored during construction to ensure compliance with state water quality standards for turbidity, pH, temperature, and dissolved solids.
- Water quality would be monitored before, during and after construction in order to determine any major changes in water chemistry.

2.3.5 Monitoring, Adaptive Management, Operations and Maintenance

2.3.5.1 Authority and Purpose

Per Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007), feasibility studies for ecosystem restoration are required to include a plan for monitoring the success of the ecosystem restoration, and that a Contingency Plan (Adaptive Management Plan) be developed for all ecosystem restoration projects. “Monitoring includes the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be need to attain project benefits.”

Recent Corps guidance, “*Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 – Monitoring Ecosystem Restoration,*” requires that a plan be developed for monitoring the success of the ecosystem restoration. This monitoring plan shall include “1) 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.”

In addition, the relatively recent emergence of restoration science and inherent uncertainty in some aspects of ecosystem restoration theory, planning and methods, success can vary based on a variety of technical and site-specific factors. Recognizing this uncertainty, it is prudent to allow for contingencies to address potential problems in meeting restoration goals that may arise during or after project implementation.

Post-project monitoring is a crucial requisite of the adaptive management process, as performance feedback may generate new insights on ecosystem response and provides 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, Albuquerque Biological Park Wetlands, Rt. 66 Ecosystem Restoration, and Middle Rio Grande Restoration projects have provided information that has been useful in developing goals and alternatives for this Project. Monitoring of this Project would be essential to the success of not only this study, but for other Corps studies as well. Therefore, baseline data will be collected so that results can be quantified and compared.

2.3.5.2 Goals of the Project to be Measured through Monitoring

As stated in Rio Grande, Sandia Pueblo to Isleta Pueblo, Ecosystem Restoration Feasibility Study and EA the Project's Feasibility Report (June 2018), the Project's goals and objectives are as follows:

1. Improve habitat quality and increase the amount of native Bosque communities to a sustainable level.
2. Restore hydrologic connection between the Bosque and the river characterized by a more frequent overbank inundation pattern.
3. Protect, extend and enhance areas of potential habitat for listed species within the Bosque.

Constraints to the Project implementation of monitoring components may include:

1. The Rio Grande is an extremely human-managed and manipulated multi-jurisdictional, multi-boundary natural resource.
2. There are specific legal obligations in the form of water rights in the State of New Mexico especially associated with the Rio Grande.
3. River channelization and manipulation structures will remain in place.

2.3.5.3 Monitoring Implementation

Monitoring of Project measures for performance and success would be conducted for at least five consecutive years following construction. Monitoring of vegetation mortality, wildlife and vegetation species, groundwater and other environmental indicators would be included for that of wetlands and the Bosque. Project monitoring would be coordinated with the sponsor and incorporated with ongoing efforts to reduce duplicate effort. These efforts would continue post-construction to show project benefits and changes in use before and after construction. Monitoring of wildlife use by ecosystem measures may also be performed. All data would be shared and necessary adjustments to restoration activities would be made by consensus of the habitat team.

Monitoring would be aimed at evaluating project success and guiding adaptive management actions by determining if the project has met 'performance standards'. Validation monitoring would involve various degrees of quantitative monitoring aimed at verifying that restoration objectives have been achieved for both biological and physical resources. Effectiveness monitoring would be implemented to confirm that project construction elements perform as designed.

Pre-construction, during construction, and post-construction monitoring would be conducted by the Corps. After that time, monitoring would continue under the responsibility of the local sponsor (MRGCD). Monitoring would continue until the project has been determined to be successful (performance standards have been met), as required by Section 2039 of WRDA 2007, as noted in paragraph 3.c of the implementation guidance. Monitoring objectives have been tied to original baseline measurements that were performed during the Habitat Evaluation Assessment Tool (HEAT) modeling effort and are shown in Table 3.

Table 3: Monitoring Objectives.

Measurement	Performance Standard	Adaptive Management
	Vegetation	
Tree density, tree canopy cover, shrub canopy cover, ground cover, species count/composition, % native/ non-native; overall % cover.	Overall % cover – overall stand density mosaic per HEAT measurement goals: 50% native tree, 30% native shrub, 20% native herbaceous and/or wet habitat.	Any planted material that has died shall be replaced (per one year warranty); After one year, adaptive management should focus on non-native vegetation treatment..
	Non-native vegetation % cover: </= 30%	On an annual basis, areas ¼ acre in size or larger that have > 30% aerial cover by non-native vegetation shall be treated.
	Noxious weeds: </= 30%	On an annual basis, areas ¼ acre in size or larger that have > 30% aerial cover by weeds shall be treated.
	Hydrology	
Flood frequency, flood duration, depth, velocity, wetted area, groundwater depth	Increase flood frequency and duration into bosque by 10%; increase wetted area in bosque by 15%.	As features potentially get filled with sediment, they will need to be cleaned out; Review designs or potential needed change.
	Birds	
	Increase in species diversity by 10% in areas where wet habitat is constructed; Increase in species diversity by 10% of other areas within 3-5 years (noting that there will be an initial decrease); 10% increase in potential flycatcher habitat.	Ensure wet features are functioning (per hydrology Performance Standard and Adaptive Management above); ensure native riparian vegetation is thriving (per vegetation Performance Standard and Adaptive Management above)

(a) Vegetation

Vegetation measurements (Table 3) listed above were performed during baseline analysis for this project in 2005 and field verified/validated in 2017. All of these measurements would be performed along a transect at the same time and can be completed fairly quickly. All of these measurements may then be translated into an overall percent cover. Overall percent cover should meet the performance standard for an overall mosaic per HEAT measurement goals (50% native tree, 30% native shrub, 20% native herbaceous and/or wet habitat). Any planted material that has died would be replaced (per one year warranty).

After one year, adaptive management would focus on non-native vegetation treatments. The measurements would also be used to determine the percent of non-native vegetation present. Non-native vegetation percent cover should be less than or equal to 30 percent. On an annual basis, areas ¼ acre in size or larger that have greater than 30 percent aerial cover by non-native vegetation would be treated per the EA and Operations and Maintenance Manual for this project. This typically includes treatment using herbicides via cut-stump or foliar application. Noxious weeds would also be monitored with a performance standard of less than or equal to 30 percent. On an annual basis, areas ¼ acre in size or larger that have greater than 30 percent aerial cover by non-native vegetation would be treated per the EA for this project and Operations and Maintenance Manual for this project. This typically includes treatment using herbicides.

(b) Hydrology

Hydrology measurements (Table 3) would be evaluated for constructed high-flow channels, bank terracing, willow swales and other wetland features. Results would inform need for adaptive management actions and would inform future restoration designs. Flood duration, frequency, depth and velocity would be measured using a FlowTrakker Acoustic Doppler Velocimeter (ADV). This meter samples velocity measurement over a given length of time (seconds) and averages velocity at a given point in the water column. The meter computes discharge, after transects are made, according to USGS standards. Wetted area can be measured by measuring surface water area. This would be done by using the top width of the feature (high flow channel, terrace and/or willow swale) and the duration of flow from the hydrograph. Some areas may be mapped by hand using a GPS to get the overall surface area of wetted area. Seasonal depth to groundwater would be monitored utilizing existing instrumented shallow groundwater piezometers. Data would be used to evaluate floodplain-channel connectivity and to allow comparisons to vegetation growth parameters. The overall Performance Standard is to increase flood frequency and duration into bosque by 10 percent and increase wetted area in bosque by 15 percent. As features potentially get filled with sediment, they may need to be cleaned out. In order to help reduce the maintenance need, an increase in interconnection between features is proposed. This would also potentially enhance wetted area habitat diversity and function in order to meet the Performance Standard. If this is occurring, adaptive management in form of the maintenance above and/or reviewing the original design would be implemented.

(c) Avian

Through other Bosque projects, the Corps has monitored transects and project specific locations within both the study and Project areas. This information has been used as baseline information specific to this project and monitoring of these locations prior to, during and after construction is proposed to continue.

Through this monitoring and research, much has been learned about species loss due to increase in non-native vegetation, effects of fuel reduction/exotic removal on bird species, and effects of mid-canopy removal on bird species. These studies have been conducted specifically within the Project Area (Hawks

Aloft, 2003-2018). Therefore, information has been utilized form these studies in order to guide alternative development, project design and construction implementation.

One of the main goals of this project is to improve habitat quality and increase the amount of native Bosque community to a stable level. Monitoring of avian species can aid in understanding whether or not this goal has been met by evaluating the current (and recent past) use of these areas compared to their use during construction (which is hypothesized to decrease initially) and after construction (which is hypothesized to increase over time).

Previous work has shown an increase in the diversity of bird species in areas where water features have been added. In areas where thinning of non-native vegetation occurs, there is an initial decrease in species diversity though population sizes remain roughly the same. Over time, species diversity increases again. Therefore, these findings have been used to develop the Performance Standards which include an increase in species diversity by 10 percent in areas where wet habitat is constructed; and an increase in species diversity by 10 percent of other areas within three to five years (noting that there will be an initial decrease). Through monitoring for both flycatcher and cuckoo, an increase in potential habitat would be captured. Therefore, the Performance Standard is to also increase potential flycatcher and cuckoo habitat by 10 percent. Flycatcher and cuckoo surveys would only be performed in areas that are expanding potential habitat (ie: willow swales). Performance Standard and Adaptive Management above ensure native riparian vegetation is thriving. Methodologies used by a contractor would continue and include breeding bird point counts and monitoring of existing transects.

(d) General periodic site assessment

In terms of assessing overall effectiveness of the restoration construction, a general annual assessment of each site would be conducted.

(e) Reporting

The Corps will provide annual reports that include specific information pertaining to each of the monitoring elements. These reports would include information about all equipment and techniques used for monitoring purposes.

Annual reports would be submitted to the MRGCD, AOSD, Reclamation, Service, NMDGF, and other interested parties by December 31 of each monitoring year.

(f) Photographic Documentation

Permanent locations for photographic documentation (i.e., photo points) would be established at strategic locations within each project site so that a visual record of habitat development may be provided. A sufficient number of photo points would be established in order to provide representative photographs of the site as it changes over time. The locations would be identified in the pre-construction monitoring report. Photographs taken from each of these locations would be included in subsequent monitoring reports.

2.3.5.4 Integration of Project Monitoring and Adaptive Management with other, Ongoing Restoration and Research Efforts in the Bosque

One of the biggest challenges and potentially another component to this evaluation program is the coordination of monitoring and adaptive management restoration efforts. Current restoration and research efforts are underway and on the ground in the MRG by AOSD, MRGCD, Reclamation, Natural Heritage New Mexico, BEMP, and other qualified technical research entities. Many of the research efforts are currently being funded by the Corps in relation to other bosque projects and providing information toward pre-construction monitoring information for this project.

As mentioned above, the Corps is a member of the Collaborative Program which is monitoring components of the system specifically for flycatcher, cuckoo, and minnow. These monitoring methods have been included above (where appropriate) and close coordination of efforts on the ground would occur. The key to a successful restoration program in the MRG involves collaboration on these efforts in creating a fully integrated and ecosystem-based evaluation program.

There are a large number of monitoring efforts currently being conducted in the Project Area. Many are efforts currently contracted by the Corps that would continue to be contracted as part of implementing this monitoring and adaptive management plan. Other efforts are conducted by other agencies or programs that are being coordinated with in order to reduce a duplication of effort.

The Corps has spearheaded a demonstration or 'test' of this effort during implementation of the BioPark Restoration Project and the Ecosystem Restoration @ RT66 Project. The BioPark Restoration project was completed in October 2006 and the RT66 Project is currently under construction to be completed in April 2010. The BioPark Restoration Project is currently being monitored and providing valuable input toward design of this project as well as input toward monitoring efforts. These projects are also crucial components to the analysis for adaptive management. Adaptive management will be the key to the long-term success of this Project, the MRG Bosque Project, as well as the monitoring program.

2.3.5.5 Operations and Maintenance

Upon completion, the Corps will complete an Operations and Maintenance manual for the project that summarizes all Operations, Maintenance, Repair, Rebuild, and Rehabilitate (OMRR&R) requirements for which the local sponsor will assume responsibility. Currently, the annual costs for OMRR&R are estimated to be approximately $15,000. This amount includes the following:

- Treatment of non-native plant re-sprouts and seedlings. With approximately 261 acres of treat/retreat of vegetation, the cost is broken down by square mile of spraying and removal for re-sprouts. Treatment of 261acres/640acres/square mile x $10,000 = Annual Cost of $4,078.
- Replacement of native plants that fail to establish. Based on previous experience with the Rio Grande Nature Center, this activity is not expected to experience many native plant failures per acre = Annual cost of $5,000.
- Maintenance of water features (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. 500 cubic yards of sediment would be removed annually at a cost of $10 per cubic yard = Annual Cost of $5,000.

3 - Environmental Baseline

3.1 Law and Regulation

Under Section 7(a)(2) of the ESA, agencies are required to consult with the Service to ensure a proposed action is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat. Defining the effects of an agency's action first requires consideration of the environmental baseline. As defined in 50 CFR §402.02, environmental baseline includes the past and present impacts of all Federal, State, Tribal, or private actions and other human activities in the action area; the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early Section 7 consultation; and the impacts of State and private actions that are contemporaneous with the consultation in progress. This regulation further states that effects of the agency's action only includes those effects which will be *added* to the environmental baseline. In addition, under the provisions of Section 7(c) of the ESA, a federal agency is not required to assess the effects of projects constructed prior to November 10, 1978, the date of the enactment of the ESA. Finally, for each species, the environmental baseline describes its current status and its habitat in the action area as a point of comparison to assess the effects of the action now under consultation. Therefore, by regulation, an accurate assessment of the agency's action must include an accurate definition of environmental baseline, and *exclude* those baseline effects.

3.2 Application of Regulatory Criteria

3.2.1 Description of Habitat in the Action 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. The MRG Bosque is a riparian area located in the middle reach of the Rio Grande, in the vicinity of the City of Albuquerque. 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 RGVSP through the Park Act of 1983 and is cooperatively managed by AOSD and the MRGCD.

The Project's action area baseline habitat consists of the floodplain and river channel within the floodway bordered by the levees on both sides of the Rio Grande from the Alameda Bridge downstream to the South Diversion Channel, approximately 15 river miles in length. It lies within the MRG, a 219-mile-long reach of the river in New Mexico extending from Velarde to Elephant Butte Reservoir. In this reach, the historical floodplain is entrenched in an alluvium-filled rift valley that ranges from less than one mile to about 12 miles wide. The Rio Grande floodway has been delineated by the existing spoil banks constructed by MRGCD as early as the 1930s and subsequent levees. Due to the fact that this infrastructure has been in place in most cases for over three-quarters of a century, the environmental baseline correctly excludes ongoing effects of the existing spoil banks and levees.

The current floodplain area bounded by the spoil banks constructed during the 1930s by MRGCD is the baseline area for species and habitat analysis. The riparian ecosystem consists of a cottonwood gallery

forest, with invasive saltcedar (*Tamarix ramosissima*), Russian olive (*Elaeagnus angustifolia*), and Siberian elm (*Ulmus pumila*). The riparian habitat was classified based on Hink and Ohmart (1984) with the most recent coverage mapped in 2012 (Siegle *et al.* 2013). Scurlock (1998) has summarized trends for historic Rio Grande riparian communities over the last 150 years.

The ecology of the valley is conditioned by the Great Basin Grassland, Semi-desert Grassland, and Chihuahuan Desert Scrub biotic communities through which the river flows (Crawford et al. 1993). The major plant communities in the active floodplain of the MRG Valley include woodlands, shrublands, grasslands, and emergent wetlands (Tetra Tech 2004). The Project action area has an arid to semi-arid continental climate characterized by light precipitation, abundant sunshine, low relative humidity, and wide diurnal and annual range of temperature (Crawford et al. 1993). Summer daytime temperatures can exceed 100 degrees Fahrenheit (°F). Average maximum temperatures in January range from the upper 30°F range to the upper 40°F range. Temperatures below freezing are common during the winter. Relative humidity is usually low, mitigating considerably the effects of the temperature extremes in both winter and summer. Humidity during the warmer months is below 20 percent much of the time. Wind speeds are usually moderate; however, relatively strong winds often accompany frontal activity in late winter and spring, and may exceed 30 miles per hour for several hours. Sources of these moisture-laden air masses are the Pacific Ocean and the Gulf of Mexico.

Average annual precipitation is less than 10 inches throughout the proposed action area. Approximately 50 percent of the annual precipitation occurs during the three-month period of July through October, usually as brief, intense thunderstorms. Winter precipitation, most of which comes from the Pacific Ocean, falls primarily in connection with frontal activity associated with the general movement of storms from west to east. In winter and spring, moisture transported from the Pacific by westerly winds can be amplified by the El Niño/La Niña phenomenon, which ties regional precipitation to global climate (Crawford et al. 1993).

3.2.2 Past and Present Impacts of All Federal, State, Tribal, Private or Other Human Actions

The Rio Grande in the study area is currently characterized by setback spoil banks and levees that contain the floodway that have been in place for more than 75 years. Prior to the formation of the MRGCD in 1925, site-specific irrigation and flood protection structures, mainly community specific acequias, were already in place. However, the first formal, organized attempt at flood risk management began with the MRGCD. From 1930 to 1935, the MRGCD constructed 190 miles of spoil banks (non-engineered levees) in the middle Rio Grande valley as part of their district wide plan to drain the valley farmlands and to provide flood protection. The spoil banks from Bernalillo to San Acacia, New Mexico, date to this time.

The Rio Grande is culturally important to the pueblos for their history, religion, and way of life. Pueblo (tribal) communities were established from 400 to 1600 AD prior to Spanish exploration in the region, and Native American occupation and use of the Rio dates back some 10,000 years. For centuries, the pueblos have used the floodplain and uplands in the MRG for their residences, farming (both on the floodplain and in the uplands), hunting and gathering, religious practices and ritual purposes.

All past and current effects of the confinement of the Rio Grande channel due to construction of the spoil banks and levees associated with the irrigation infrastructure and river canalization are accurately attributable to the environmental baseline.

3.2.3 Recent and Contemporary Actions

3.2.3.1 U .S. Army Corps of Engineers

Within the Project action area, the Corps has consulted on 74 habitat restoration projects covering 514 acres, including the overlapping MRG Bosque Restoration Project in Bernalillo and Sandoval Counties (USACE 2010; USFWS 2011a). The Corps also consulted on the effects of levee construction in the San Acacia reach downstream of the project area (USACE 2013a; USFWS 2013c). The consultation evaluated the effects of levee construction actions on Federally-listed species and designated critical habitat within the middle Rio Grande valley of New Mexico. Consultation was reinitiated in 2015 when the Corps supplemented its Programmatic BA to include newly-listed species (USACE 2015). Consultation concluded with the Service's issuance of its Programmatic Biological and Conference Opinion (USFWS 2016). Construction of Phase I and II was completed February 2017, Phase IIB construction was completed January 2017 and Phase IIC construction was completed November 2017. Following completion of certifying the levees, developing the operations and maintenance manual, and preparing the as-built engineering drawings, the Corps will hand over operations and maintenance to the MRGCD.

3.2.3.2 U. S. Bureau of Reclamation

The Bureau of Reclamation (Reclamation) completed one habitat restoration project on 8.6 acres within the Project action area. Maintenance of the current channel alignment and repairs to threatened portions of the existing spoil banks are conducted by Reclamation through its River Maintenance Program. This program has been consulted upon in 2001 and 2003 (USFWS 2001, 2003b). In 2015, Reclamation (USBOR 2015) submitted a new BA that addressed its water management operations, including spoil bank maintenance, in the MRG. Reclamation's 2015 BA also assessed the actions of its non-federal partners, including MRGCD. A description of MRGCD's maintenance program for the existing spoil banks is also included in Reclamation's 2015 BA. Conservation measures were proposed by Reclamation, MRGCD, the State of New Mexico and other non-federal partners, such as the Albuquerque-Bernalillo County Water Utility Authority. Offsetting actions taken by participants of the MRGESCP are also described. Subsequently, the Service issued Reclamation and its non-Federal partners a BO for their water management operations (USFWS 2016) (Reclamation's 2016 BO).

As part of the requirements of Reclamation's 2016 BO, Reclamation is working on its Lower Reach Plan to provide to the Service by June, 2018. This will include multiple projects that are intended to improve habitat and enhance flows in the Isleta and San Acacia reaches, while managing sediment and increasing safe channel capacity.

Reclamation conducted surveys and nest monitoring for the flycatcher during the summer of 2017 along about 250 miles of the Rio Grande between Isleta Pueblo and Elephant Butte Reservoir. Other areas surveyed included above Cochiti Lake and select 20 locations between Caballo Reservoir and El Paso, Texas. In 2017, a small decrease was noted with 370 flycatcher territories detected along the Rio Grande and the majority of them in the San Marcial/Elephant Butte Reservoir area (257 territories and 85% of New Mexico Rio Grande detections). The number of territories in the Lower Rio Grande increased from 50 to 68, a 36 percent increase.

3.2.3.3 Rio Grande Compact

Water uses on the MRG must be conducted in conformance with the Compact administered by the Rio Grande Compact Commission. The four-member Commission is composed of commissioners from Colorado, New Mexico, and Texas, as well as a Federal representative who chairs the Commission meetings. Colorado is prohibited from accruing a debit, or under-delivery to the downstream States, of more than 100,000 ac-ft, while New Mexico's accrued debit to Texas is limited to 200,000 ac-ft. These limits may be exceeded if caused by holdover storage in certain reservoirs, but water must be retained in the reservoirs to the extent of the accrued debit. Any deviation from the terms of the Compact requires unanimous approval from the three state Commissioners.

In order to meet delivery obligations under the Compact, depletions within New Mexico are carefully controlled. Allowable depletions above Otowi gage (located outside of Santa Fe, near the Pueblo of San Ildefonso) are confined to levels defined in the Compact. Allowable depletions below Otowi gage and above the headwaters of Elephant Butte Reservoir are calculated based on the flows passing through Otowi gage. The maximum allowable depletions below Otowi gage are limited to 405,000 ac-ft in addition to tributary inflows. In an average year, when 1,100,000 ac-ft of water passes the gage, approximately 393,000 ac-ft of water is allowed to be depleted below Otowi gage, in addition to tributary inflows. Depletion volumes are lower in dry years. For instance, in 1977, allowable depletions were 264,600 ac-ft in addition to tributary inflows. No Indian water rights may be impaired by the State's Compact management activities.

3.2.3.4 State of New Mexico

The State of New Mexico has a wide range of agencies that actively represent different aspects of the State's interest in water management:

(a) New Mexico Office of the State Engineer

The New Mexico State Engineer has general supervision of the waters of the State and of the measurement, appropriation, and distribution thereof (N.M. Stat. Ann. 72-2-1 Repl. Pamp. 1994). The Office of the State Engineer (OSE) grants state water rights permits, ensures that applicants meet state permit requirements, and enforces the water laws of the State. The OSE is responsible for administering water rights, including changing points of diversion and places or purposes of use. The OSE uses the "Middle Rio Grande Administrative Area Guidelines for Review of Water Right Applications" to assess the validity and transfer of pre-1907 water rights.

(b) New Mexico Interstate Stream Commission

The NMISC is authorized to develop, conserve, protect and to do any and all things necessary to protect, conserve, and develop the waters and stream systems of the State. It is responsible for representing New Mexico's interests in making interstate stream deliveries, as well as for investigating, planning, and developing the State's water supplies. Thirty four habitat restoration projects have been done be NMISC over 56.5 acres within the Project action area. It also continues to track habitat restoration projects implemented by various federal and state agencies and accounts and reports depletions related to them in the middle Rio Grande. It coordinates with NMOSE to determine if a permit is needed and to ensure the depletions are offset by the project sponsors. The NMISC also coordinates with Reclamation in using the State's Strategic Water Reserve for ESA related water management.

The State cooperates with Reclamation to perform annual construction and maintenance work under the State of New Mexico Cooperative Program. In the past, this work has included some river maintenance on the Rio Chama, maintenance of Drain Unit 7, drain and canal maintenance within the BDANWR, similar work at the state refuges, and temporary pilot channels into Elephant Butte Reservoir. In January 2017, NMISC updated The Middle Rio Grande Regional Water Plan (2000-2050) which includes most of Sandoval and Bernalillo counties, all of Valencia County, and a very small portion of Torrance County; it covers one of 16 water planning regions in the State of New Mexico. Regional water planning was initiated in New Mexico in 1987, its primary purpose being to protect New Mexico water resources and to ensure that each region is prepared to meet future water demands. Between 1987 and 2008, each of the 16 planning regions, with funding and oversight from NMISC, developed a plan to meet regional water needs over the ensuing 40 years. The Middle Rio Grande Regional Water Plan was completed and accepted by the NMISC in 2004. The purpose of the document was to provide new and changed information related to water planning in the MRG region and to evaluate projections of future water supply and demand for the region using a common technical approach applied to all 16 planning regions statewide. Accordingly, this regional water plan update summarizes key information in the 2004 plan and provides updated information regarding changed conditions and additional data that have become available.

(c) New Mexico Department of Game and Fish

The NMDGF administers programs concerned with conservation of endangered species and of game and fish resources. It also manages the La Joya Wildlife Management Area and Bernardo Wildlife Area.

(d) New Mexico Environment Department

The New Mexico Environment Department (NMED) administers the State's water quality program including compliance with various sections of the Clean Water Act. Section 303 of the Clean Water Act allows NMED to establish water quality standards for water bodies and total maximum daily loads for each pollutant. Section 402 of the Clean Water Act includes the National Pollutant Discharge Elimination System Storm Water Permit Program.

3.2.3.5 Counties

All counties that border the Rio Grande and Rio Chama and their respective tributaries perform actions or can perform actions that may at least indirectly affect these rivers. The primary area in which county actions may influence water management is providing for general development and infrastructure of these counties, and activities may include pumping of wells or land-use regulations within the immediate MRG watershed. The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) has done two habitat treatment projects on approximately 14.4 acres within the Project action area.

3.2.3.6 Villages, Towns, and Cities

Citizens in a multitude of villages, towns, and cities are served with municipal and industrial water systems. While most use groundwater exclusively, Santa Fe also uses surface water supplies, and both the cities of Albuquerque and Santa Fe use San Juan-Chama surface water in addition to groundwater. To the extent that future groundwater pumping or use of surface water depletes the river, the NMOSE requires that these depletions be offset, either by acquiring other water rights or with San Juan-Chama Project water. Many of these contractors have voluntarily entered into annual lease programs with Reclamation to enhance MRG valley water management. Municipalities also manage wastewater treatment systems that are point source

discharges into the Rio Grande. Municipalities also release storm water discharge into the Rio Grande. Within the Project action area, three projects covering 58 acres of habitat treatments have been done by the City of Albuquerque.

3.2.3.7 Irrigation Interests

Irrigation interests include a variety of the acequias, pueblos, individual irrigators, and ditch associations, as well as the MRGCD, which have water rights to divert the natural flow of the Rio Grande for beneficial use and then return unused water to the Rio Grande. Many of these irrigation interests have existed for hundreds of years. The MRGCD was established under state law in 1928, to address issues such as valley drainage and flooding, and currently operates the diversion dams of the MRG Project to deliver irrigation water to lands in the middle valley, including areas on six pueblos.

3.2.4 Recent and Contemporary Plans and Reports

Overall, many studies have been conducted pertaining to water and related land resources within the Study area. 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:

- *Rio Grande Floodway, Albuquerque Unit Evaluation Report, Albuquerque, New Mexico,* October 2009.
- *Detailed Project Report and Environmental Assessment, Ecosystem Restoration at Route 66 Habitat Restoration Project,* September 2008.
- *Upper Rio Grande Basin Water Operations Review Environmental Impact Statement,* June 2007.
- *Rio Grande Nature Center Habitat Restoration Project Environmental Assessment,* December 2006.
- *Middle Rio Grande Flow Frequency Study,* June 2006.
- *Detailed Project Report and Environmental Assessment for Albuquerque Biological Park Wetland Restoration Project, Albuquerque, New Mexico,* January 2004.
- *Environmental Assessment for the Bosque Wildfire Project, Bernalillo and Sandoval Counties, New Mexico,* September 2004.
- *Middle Rio Grande Bosque Restoration Supplemental Planning Document,* July 2003.
- *Method & Cost Evaluation Report for the Middle Rio Grande Bosque Jetty Jack Removal Evaluation Study,* January 2003.
- *Middle Rio Grande Bosque Reconnaissance Study, Section 905(b) Analysis,* July 2002.
- *Environmental Assessment and Finding of No Significant Impact for Middle Rio Grande Bosque Jetty Jack Removal Evaluation Study,* July 2002.

- *Historical Documentation of Middle Rio Grande Flood Protection Projects (Corrales to San Marcial)*, 1997.
- *Middle Rio Grande Biological Survey*, 1989.

Other Agency Reports

- *Corrales Bosque Preserve Habitat Management Plan*, Corrales Bosque Advisory Commission, April 2009.
- *Middle Rio Grande Ecosystem Bosque Biological Management Plan - The First Decade: A Review & Update*, Lisa Robert et al., June 2005.
- *Bosque Landscape Alteration Strategy, Objectives, Basic Requirements and Guidelines*, Yasmeen Najmi, Sterling Grogan, and Cliff Crawford, June 2005.
- *Habitat Restoration Plan for the Middle Rio Grande, September 2004.*
- *Effects of Fuels-Reduction and Exotic Plant Removal on Vertebrates, Vegetation and Water Resources in the Middle Grand Bosque: Final Environmental Assessment*, Service and MRGCD, 2001.
- *Middle Rio Grande Conservancy District Interim Progress Report for the Bosque Improvement Group*, Service and MRGCD, 2001.
- *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.
- *Albuquerque Open Space Facilities Plan*, AOSD, 1999.
- *San Antonio Oxbow Management Plan*, ASOD, 1996.
- *Bosque Protection Master Plan Scoping Report*, MRGCD, 1995.
- *The Middle Rio Grande Ecosystem: Bosque Biological Management Plan*, Cliff Crawford, Anne Culley, Rob Leutheuser, Mark Sifuentes, Larry White, James Wilber, October 1993.
- *Bosque Action Plan*, AOSD, 1993.
- *Bosque Fire Management Study*, AOSD, 1992.
- *Rio Grande Valley State Park Management Plan*, NMED and AOSD, 1983.

3.2.5 Summary of Environmental Baseline Conditions Excluded from Agency Action

The existing Project environmental baseline conditions are attributable to many actions over the past 100 years, and spans the transition of fluvial geomorphic conditions from incised to sediment equilibrium. Much of the baseline floodplain terraces throughout the Project area are above the two-year recurring spring runoff flow. This ecosystem restoration Project has measures for increasing floodplain connectivity, inundation, and enhancing native riparian vegetation.

4 - Species Status and Life History

USACE requested information on federally listed species and habitat from the Service through the automated IPACs system (http://ecos.fws.gov/ipac), Consultation Code: 2ENNM00-2018-SLI-0777. The effects of the recommended action will be discussed for Southwestern Willow Flycatcher (*Empidonax traillii extimus*) (flycatcher), the Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*) (cuckoo), and Rio Grande silvery minnow (*Hybognathus amarus*) (minnow) based on their observed presence and critical habitat in the project area.

4.1 Southwestern Willow Flycatcher

4.1.1 Status and Distribution

A final rule was published in the February 27, 1995, Federal Register to list the flycatcher as an endangered species under the ESA with proposed critical habitat. The flycatcher also is classified as endangered (Group I) by the State of New Mexico (NMDGF 1987). The current range of the species includes southern California, Arizona, New Mexico, southern portions of Nevada and Utah, and southwestern Colorado (Service 1995). The species is likely extirpated from west Texas (Durst *et al.* 2007). In New Mexico, flycatchers are known to breed along the Rio Grande, and in the Zuni, San Francisco, and Gila River drainages. A recovery plan for the flycatcher was completed in 2002 (Service 2002).

4.1.1.1 Critical Habitat

Critical habitat for the flycatcher was designated in July 1997 (USFWS 1997); however, pursuant to an order from the U.S. District Court of Appeals Tenth Circuit, the USFWS conducted an economic analysis and re-designated critical habitat in October 2005 (Federal Register 2005). Most of the defined critical habitat along the MRG includes, in part, the Rio Grande floodway from the southern boundary of the Pueblo of Isleta downstream to the headwaters of Elephant Butte Lake at RM 62 (approximately 104 river miles), except for lands within Sevilleta and Bosque del Apache NWR, New Mexico.

The flycatcher is a riparian obligate species that nests in thickets associated with rivers, streams and wetlands where dense growth of willow, boxelder, Russian olive, saltcedar, or other plants are present (Finch and Stoleson 2000). Nests are frequently associated with an overstory of scattered cottonwood. Throughout the flycatcher's range, these riparian habitats are now reduced, widely separated, and occur in small and/or linear patches. Flycatchers nest in thickets of trees and shrubs approximately 12 feet or more in height. Surface water or saturated soil is usually present beneath or adjacent to occupied thickets (Phillips *et al*. 1964; Muiznieks *et al*. 1994). At some nest sites, surface water may be present early in the breeding season with only damp soil present by late-June or early-July (Muznieks et al. 1994; Sferra et al. 1995; Finch and Stoleson 2000). Habitats not selected for nesting include narrow (< 30 ft wide) riparian strips, small willow patches, and stands with low stem density (USFWS 2002). Areas not utilized for nesting may still be used during migration (Yong and Finch 1997).

4.1.2 Life History and Ecology

4.1.2.1 Flycatcher Breeding Chronology

The flycatcher is a late spring/summer breeder that builds nests and lays eggs in late May and early June, and fledges young in late June or early July (Sogge et al. 1993, Tibbitts et al. 1994). If re-nesting or second broods occur, they will fledge into mid-August (USFWS 2002). Based on data from flycatcher survey and nest monitoring along the MRG, flycatchers have been found in the area as early as May 6th; however, actual nest initiation has been documented to occur later in May (Ahlers et al. 2003). Flycatchers that re-nest or produce a second brood can remain in the nesting area through the end of August.

Flycatcher breeding chronology in the lower portion of the MRG is presented in Figure 8 and falls within the generalized breeding chronology of Southwestern Willow Flycatchers (based on Unitt 1987; Brown 1988; Whitfield 1990; Maynard 1995; Sogge 1995; Skaggs 1996; Sferra et al. 1997; Sogge et al. 2010). Extreme dates for any given stage of the breeding cycle may vary as much as a week from the dates presented. Egg laying begins as early as late May but more often starts in early to mid-June. Chicks can be present in nests from mid- June through early August. Young typically fledge from nests from late June through mid-August, but remain in the natal area 14 to 15 days. Adults depart from breeding territories as early as mid-August, but may stay until early-September in later nesting efforts.

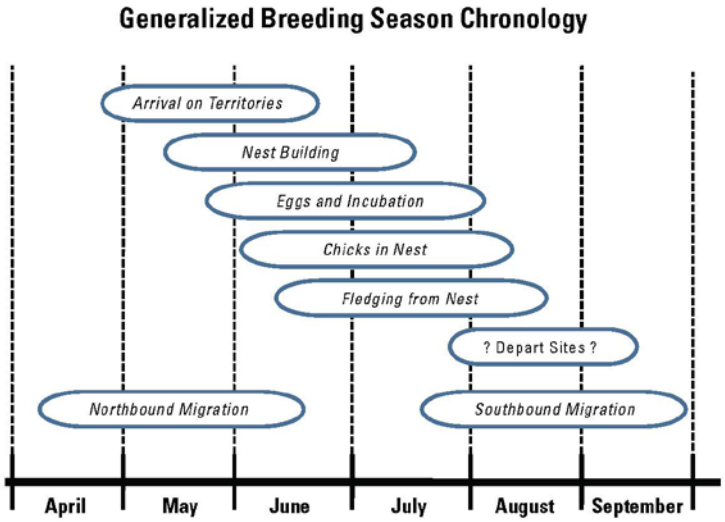

Figure 8: Generalized breeding chronology of the Southwestern Willow Flycatcher (from Sogge et al. et al. 2010).

4.1.2.2 Flycatcher Breeding Habitat

Nesting habitat for the flycatcher varies greatly by site and includes plant species such as willow, saltcedar, box elder, and Russian olive. Species composition, however, appears less important than plant and twig structure (D. Ahlers (Reclamation), personal communication, 2017), as slender stems and twigs are important for nest attachment. Nest placement is highly variable: nests have been observed at heights ranging from 14 to 33 feet and generally occur adjacent to or over water (D. Ahlers (Reclamation), personal communication, 2017). Along the MRG, breeding territories have been found in young and mid-age riparian

vegetation dominated by dense growths of willows at least 15 feet high, as well as in mixed native and exotic stands dominated by Russian olive and saltcedar.

A majority of the birds within the MRG have selected habitat patches dominated by native species, usually dense willows, for nesting. Within these willow patches, nests have been found on individual saltcedar plants, especially in older, taller willow patches where an understory of saltcedar provides suitable nesting substrate. It appears that younger trees in the understory having more slender vertical stems and twigs are selected for nest placement.

A critical component for suitable nesting conditions is the presence of water, usually provided by overbank flooding or some other hydrologic source. Along the Rio Grande, nests have been consistently found within 150 feet of surface water, usually a flowing channel (Moore and Ahlers 2005, 2008). Reclamation has found that 95 percent of all flycatcher nests in the Reclamation-surveyed areas of the MRG occur within 100 m of surface water, and 91 percent occur within 50 m (Moore and Ahlers 2008). The presence of surface water at the onset of nest site selection and nest initiation is likely critical, though not absolutely necessary. In rare cases in Arizona, birds have nested over 300 feet from water (Sogge et al. 2001). Nesting appears to be initiated after high flows and groundwater levels have created and maintained at least moist soil conditions underneath the nest tree.

Many flycatcher breeding sites are composed of spatially complex habitat mosaics, often including both exotic and native vegetation. Within a site, flycatchers often use only a part of the patch, with territories frequently clumped or distributed near the patch edge. Therefore, the vegetation composition of individual territories may differ from the overall composition of the patch (Sogge et al. 2002). Generally, four broad categories have been developed to describe species composition at breeding sites and include the following:

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

4.1.2.3 Riparian Habitat Description

Riparian habitat within all reaches of the MRG where flycatcher population sites occur includes dense stands of willows and other woody riparian plants adjacent to or near the river channel.

Breeding habitat suitability identifies all areas that are within 325 feet (100 m) of existing watercourses, ponded water, or in the zone of peak inundation. The five categories of flycatcher habitat that lie within 325 feet of water are defined as:

- *Highly Suitable Native Riparian* – Stands dominated by willow and/or cottonwood.
- *Suitable Mixed Native/Non-native Riparian* – Includes stands of natives mixed with non-natives.
- *Marginally Suitable Non-native Riparian* - Stands composed of monotypic saltcedar or stands of saltcedar mixed with Russian olive.

- *Potential with Future Riparian Vegetation Growth and Development* - Includes stands of very young sparse riparian plants on river bars that could develop into stands of adequate structure with growth and/or additional recruitment. This category requires regular monitoring to ascertain which areas contain all the parameters to become flycatcher habitat.
- *Low Suitability* - Includes areas where native and/or non-native vegetation lacks the structure and density to support breeding flycatchers or exceeds the hydrologic parameter of greater than 325 feet (100 m) from water. The presence of low suitability habitats may be important for migration and dispersal in areas where riparian habitats have been lost (i.e., agricultural and urban areas).

4.1.3 Reasons for Flycatcher Decline

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

Six general locations of flycatcher populations have been established throughout the MRG (Figure 9) based on formal surveys conducted by Reclamation since 1995.

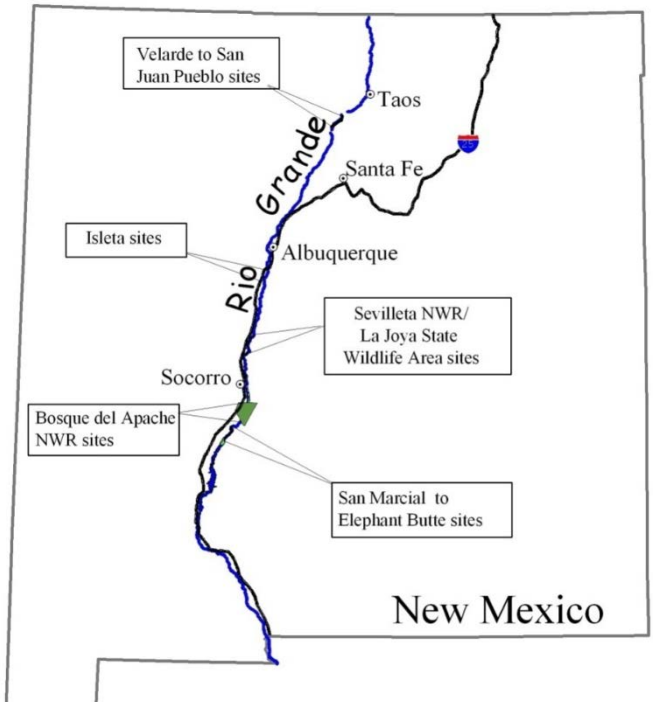

Figure 9: Six general locations of flycatcher populations along the Middle Rio Grande.

4.1.4 Southwestern Willow Flycatchers in the Action Area

4.1.4.1 Habitat Use during Migration

Flycatchers and many other species of Neotropical migrant land birds also use the Rio Grande riparian corridor as stop-over habitat during migration. Studies have shown that during spring and fall migration, flycatchers are more commonly found in willow habitats than in other riparian vegetation types (Yong and Finch 1997). These birds utilize a variety of vegetation types during migration, many of which are classified as "low suitability" for breeding habitat (Ahlers and White 1997).

Presence/absence surveys in this reach have detected migrating willow flycatchers in small willow patches adjacent to the river.

4.2 Western Yellow-billed Cuckoo

4.2.1 Status and Distribution

A final rule was published in the October 3, 2014, Federal Register (USFWS 2014b) to list the Western U.S. Distinct Population Segment (DPS) of the cuckoo as a Federally-threatened species. The State of New Mexico currently does not list the cuckoo under any formal protection category status.

The Service identifies cuckoos west of the Continental Divide as a DPS based on physical, biological, ecological, and behavioral factors. The current breeding range of the western DPS occurs locally along rivers west of the Continental Divide. In New Mexico, the boundary of the western DPS is between the Rio Grande and Pecos River watersheds (USFWS 2014). Cuckoo's currently breed in California, Arizona, New Mexico, Utah, Wyoming, Colorado, Idaho, and Texas (USFWS 2014). The current distribution in the western United States is still difficult to delineate as cuckoos often wander before and after breeding (Hughes 1999). In New Mexico, Western DPS cuckoos breed along the major river valleys, including the Rio Grande, San Juan, San Francisco, and Gila rivers (Howe 1986).

Proposed critical habitat for the Western U.S. DPS of the cuckoo was designated on August 15, 2014 (USFWS 2014). Proposed critical habitat was designated in 80 separate units in Arizona, California, Colorado, Idaho, Nevada, New Mexico, Texas, Utah, and Wyoming. Proposed critical habitat in the proposed project area is within Unit 52, NM-8, which consists of 61,959 acres (25,074 ha) in extent and is an approximate 170-mile (273-km)-long continuous segment of the Rio Grande from below Cochiti Dam in Sandoval County, and continuing south through the counties of Bernalillo and Valencia, ending in southern Socorro County above Elephant Butte Reservoir (USFWS 2014a).

The cuckoo is a riparian obligate species occurring in declining populations in scattered locations in the western U.S. during its breeding season, and nests almost exclusively in low to moderate elevation riparian woodlands with native broadleaf trees and shrubs that are at least 50 acres in size and at least 325 feet in width (USFWS 2013). Nests are typically associated with dense patches of broad-leaved deciduous trees, usually with a relatively thick understory (Hughes 1999). In the Western U.S. nests are most frequently placed in willows, and cottonwoods are used extensively for foraging. Portions of major rivers in New Mexico, Arizona, and California still contain large tracts of continuous native or mixed native riparian habitat, and are considered to be important strongholds for cuckoos (Hughes 1999). They may be restricted to extensive, moist riparian habitats because of humidity requirements for successful hatching and rearing

of young (Rosenberg et al. 1991, USFWS 2013). The cuckoo's nest cycle from egg laying to fledging is very rapid compared with other songbirds, requiring high energy resources over a short period, and smaller, fragmented habitats likely can't support sufficient prey items required for reproduction. Areas with strips of habitat less than 325 feet in width are rarely occupied by cuckoos (USFWS 2014). In addition, as the proportion of tamarisk increases, the suitability of the habitat for cuckoos decreases, and sites with a monoculture of tamarisk is unsuitable for breeding cuckoos (USFWS 2014).

Cuckoos begin arriving in New Mexico during late-May and June. Males begin their "coo-coo-coo" calls upon arrival on their breeding grounds and will continue all season if they are unsuccessful in attracting a mate. Newly-formed pairs travel for several days in search of a suitable nest site, frequently giving the "kowlp" and "knocking" call. The male will chase other males during this period (Halterman 1991). In the Southwest, its entire breeding cycle is geared to taking advantage of short term abundance of food. This holds true for everything from food induced laying, short incubation period and rapid development of young (Laymon 1980). Fall migration from its breeding grounds in New Mexico generally occurs from late-August through mid-September (Halterman et al. 2000).

The largest concentration of cuckoo territories along the Rio Grande in New Mexico occurs in the upper reaches of Elephant Butte Reservoir. The Reservoir pool is dominated by native vegetation, particularly to the west of the San Marcial Delta Water Conveyance Channel. This area became colonized by native willows as the reservoir receded between the late 1990's and early 2000's and are watered by the LFCC outfall. Vast expanses of multiple age classes of Goodding's and coyote willow habitat have developed in the upper end of the reservoir pool through the "narrows". These stands provide high quality breeding habitat for the cuckoo (Carstensen et al. 2015).

4.2.1.1 Population Trends in the Middle Rio Grande, 2009-2014

Prior to 2006, Reclamation collected incidental cuckoo detection data within the MRG while conducting flycatcher surveys (USBOR 2013). In 2006, Reclamation began formal presence/absence surveys (Halterman et al 2000) to more accurately determine cuckoo distribution and abundance within the MRG Basin. In 2009, Reclamation extended its survey area to include Belen south to Escondida. From 2009 through 2013, Reclamation's survey area for cuckoo's remained constant. In 2014, approximately 35.5 river-miles were added to the study area, from the south boundary of Isleta Pueblo near Los Lunas downstream to Highway 60 Bridge. The Reclamation study area in the MRG currently extends from the south boundary of Isleta Pueblo downstream to Elephant Butte Reservoir and has documented a population of cuckoos within the MRG floodway. The average annual number of cuckoo territories during Reclamation' surveys from 2009 to 2014 was 64. The greatest extent of suitable habitat and the largest number of cuckoo detections along the Rio Grande in New Mexico have occurred in the San Marcial reach. Since 2009, sites within the exposed pool of Elephant Butte Reservoir (a subset of San Marcial) have produced 56 percent of all cuckoo detections within Reclamation's MRG Study Area. The average annual estimate of relative population size from 2009 to 2014 was 54 territories, but fluctuated annually.

Table 4. Number of cuckoo detections and territories by river reach from 2006 to 2015 within the Middle Rio Grande Study Area (Carstensen *et al*. 2015; Ahlers et al. 2016).

River Reach	2006[a]	2007[a]	2008[a]	2009	2010	2011	2012	2013	2014[b]	2015
Belen*	n/s[c]	n/s	n/s	1/0	3/0	16/4	44/15	20/6	24/5	39/10
SevilettaNWR/ La Joya	n/s	n/s	n/s	4/2	1/0	6/2	36/12	19/6	9/2	18/5
San Acacia	n/s	n/s	n/s	8/1	3/0	6/1	19/4	20/5	15/4	27/8
Escondida	n/s	3/2	19/10	29/9	6/2	15/3	68/21	80/23	27/7	62/16
Bosque del Apache NWR	n/s	22/13	35/14	47/11	14/3	17/4	36/10	29/8	34/12	40/12
Tiffany	10/6	12/4	7/3	10/3	2/0	4/1	10/2	4/1	2/0	2/0
San Marcial[d]	30/10	40/16	47/15	46/13	27/6	43/12	25/8	30/10	29/12	5/2
Total	40/16	75/35	108/42	145/39	56/11	107/27	238/72	202/59	140/42	193/53

[a] 2006 through 2008 trends are not directly comparable due to varying degrees of survey efforts and survey area. A minimum of 3 surveys were conducted between 2006 and 2008. A minimum of 4 were conducted since 2009. Also, territories were estimated using a different technique beginning in 2009. [b] In 2014 an additional 35.5 river miles were added to annual surveys. [c] n/s = not surveyed. [d] Observations from the Elephant Butte subset of the San Marcial reach were not included in this table.

4.2.1.2 Critical Habitat

Critical habitat for the Western U.S. DPS was proposed on August 15, 2014 (USFWS 2014) in 80 separate units in Arizona, California, Colorado, Idaho, Nevada, New Mexico, Texas, Utah, and Wyoming. Proposed critical habitat in the action area is within Unit 52, NM-8, and includes the Rio Grande floodway from the southern boundary of the Pueblo of Isleta downstream to the upper reach of Elephant Butte Reservoir (river-mile 54). The proposed critical habitat unit 52 in the action area includes lands owned by Isleta Pueblo. These units are either occupied by cuckoos or provide a corridor for cuckoos moving north.

The Primary Constituent Elements (PCEs) of cuckoo critical habitat are:

1. *Riparian woodlands* - Mixed willow and cottonwood vegetation that contain habitat for nesting and foraging in contiguous or nearly contiguous patches that are greater than 325 feet (100 m) in width and 200 acres (81 ha) or more in extent. These habitat patches contain one or more nesting groves, which are generally willow dominated, have above average canopy closure (>70%), and have a cooler, more humid environment than the surrounding riparian and upland habitats.
2. *Adequate prey base* - Presence of a prey base consisting of large insect fauna (including cicadas, caterpillars, katydids, grasshoppers, large beetles, and dragonflies) and tree frogs for adults and young in breeding areas during the nesting season and in post-breeding dispersal areas.
3. *Dynamic riverine processes* – Dynamic river systems which provide hydrologic processes that encourage sediment movement and deposits that allow seedling germination and promote plant growth, maintenance, health, and vigor (e.g., lower gradient streams and broad floodplains, elevated subsurface groundwater table, and perennial rivers and streams). This allows habitat to regenerate at regular intervals, leading to riparian vegetation with variously-aged patches from young to old.

The Service is participating in government-to-government discussions with pueblos on New Mexico on cuckoo conservation actions and management plans for potential exclusion from the final designation of critical habitat. The pueblos conduct a variety of voluntary measures, restoration projects, and management actions to conserve riparian vegetation and protect riparian habitat (USFWS 2014b). The pueblos may propose amendments to their management plan for other endangered species, which will contribute to the conservation of the cuckoo (USFWS 2014). The Service may exclude Pueblo lands from the final designation of cuckoo critical habitat under section 4(b)(2) of the ESA.

4.2.2 Life History and Ecology

4.2.2.1 Cuckoo Breeding Chronology and Biology

In the Southwestern U.S., cuckoos typically arrive at their breeding grounds by late-May/early-June and initiate migration back to wintering grounds by late-August (Halterman et al. 2000). In New Mexico, nesting activities typically begin in mid-June and end in late August (Hughes 1999). No formal nest monitoring efforts have been conducted for the cuckoo along the MRG floodway.

Breeding often coincides with the appearance of massive numbers of cicadas, caterpillars, or other large insects (Ehrlich et al. 1992). In the Southwest, its "entire breeding cycle is geared to taking advantage of short term abundance of food; this holds true for everything from food induced laying, short incubation period and rapid development of young" (Laymon 1980). Cuckoos generally forage within the tree canopy and the higher the foliage volume the more likely cuckoos are to use a site for foraging. On the South Fork Kern River in California, caterpillars (primarily big poplar sphinx moth larvae) and katydids appear to be the preferred food, while tree frogs and grasshoppers appear to be "fast food" that can be caught quickly to placate the young while the adults then go after the preferred food (Laymon et al. 1997). Food availability is largely influenced by the health, density, and species of vegetation; for example, the big poplar sphinx moth larvae are found only in willows and cottonwoods and appear to reach their highest density in Fremont cottonwoods (USFWS 2014b).

Egg laying dates may vary even within a very small area, but generally occur between June and July. Four female cuckoos at a 269 acre (109 hectare) site on the Sacramento River in California laid their first eggs on June 12, July 5, July 12, and July 28 (Laymon 1980). Clutch size is one to five (commonly 2-3), largest when prey is abundant (Hughes 1999). Eggs are usually laid every second day, but the interval may be variable (Hughes 1999). The eggs are incubated from nine to 11 days (Hughes 1999) and young fledge the nests five to eight days after hatching (Halterman et al. 2015). On the Sacramento River all fourteen cuckoo nests that were tracked hatched 10 days after egg laying (Laymon 1985). Since the incubation/nestling time is so short, cuckoos can wait and take advantage of brief periods of prey abundance. They can also vary the number of eggs they lay in conjunction with prey abundance.

The nest is a loose platform (saucer) of sticks and twigs, lined with leaves and other vegetation (Ehrlich et al. 1988). Nests are typically well-concealed in dense vegetation (Laymon et al. 1997). Willow twigs, and possibly cottonwood leaves, are favored nest building materials (Laymon 1980). The nest is six to seven inches (15-17.5 cm) in diameter, and is usually placed two-thirds distance out from the trunk to the tip of the horizontal branches, though some are in forks or crotches of trees (Laymon and Halterman 1993). Nest heights range from 4.3 to 43 feet (1.3-13 m) and the breeding cycle at each nest is very rapid; from egg laying to fledging takes approximately 17 days (Halterman 2001).

Cuckoo nests are typically placed in dense patches of broad-leaved deciduous trees, usually with a relatively thick understory (Hughes 1999). Cuckoos often nest in willow, cottonwood, and mesquite (*Prosopis* spp.), but they will also utilize orchards (Laymon 1980). Of the limited nesting studies conducted for the cuckoo west of the Continental Divide, native vegetation primarily willows, and to a lesser extent, cottonwoods have been the nesting substrate most often documented. In California during six years of cuckoo studies on the Kern River, 95 of 96 nests found were placed in willows and one in a cottonwood (Laymon and Halterman 1990), and on the Santa Ana River, 22 of 24 nests were in willows, one was in a cottonwood and one in an alder (Hanna 1937, Laymon 1998). In the Lower Colorado region of Arizona (Colorado River, Bill Williams River, and Gila River) the main nest tree species used by the cuckoo are Goodding's willow and Fremont cottonwood (McNeil et al. 2011). No formal data is available for nesting substrate used by the cuckoo within the MRG floodway. However, three active cuckoo nests were found during Reclamation's telemetry studies from 2007 to 2008; of these, two were placed in Goodding's willow and one in a Rio Grande cottonwood (Sechrist et al. 2009).

Breeding territories can be comprised of two to three adults; the pair, and a helper male in addition to the pair that assists with tending to the nestlings. On the South Fork Kern River in California, approximately 30 percent of nests had an unrelated helper male attend the nest (Laymon 1998). During years with abundant food, cuckoos have been known to raise two or three broods, and while the helper male tends the young of the first clutch, the female can initiate a second clutch either with the same mate or with a new male (Halterman 2009). There have also been instances of communal nesting, with two pairs laying eggs and tending the young in the same nest (Laymon 1998).

4.2.2.2 Cuckoo Breeding Habitat

The cuckoo requires large patches of multi-layered riparian gallery forest, with cottonwood and willows with dense foliage, especially within 33 feet (10m) of the ground, and moist conditions (Hughes 1999). Cuckoo nests found on the Sacramento River in California have been correlated with large willow-cottonwood patches, dense understory's, high local humidity, low local temperature, and proximity to slow or standing water (Laymon 1980, Halterman 1991). A majority of cuckoo territories delineated by Reclamation within the MRG between 2009 and 2014 have been in riparian areas containing a native dominated canopy with an understory component, and very few have been found in areas with a native canopy without an understory. Furthermore, non-native canopies with an understory component contained only five percent of all cuckoo detections (Carstensen et al. 2015). A dense understory comprised of non-native saltcedar, Russian olive or native vegetation (e.g. *Salix* spp.) appears to be an important component for territory establishment for the MRG population (Sechrist et al. 2009).

The species may use patches of forest as small as 25 to 50 acres (10-20 ha) in area, and 325 feet (100 m) wide, but ideally habitat patches should be greater than 200 acres (>80 ha) or greater than 2,000 feet (>600 m) wide and contain open water within 325 feet (100m) of the bird's activity center (Laymon and Halterman 1989). Within the Lower Colorado River region, the average home range during the 2011 breeding season was about 50 acres (20 ha) (McNeil et al. 2011). In New Mexico, home range estimates for 10 cuckoo adults tracked in 2007 and 2008 within the San Marcial Reach of the MRG varied from 12 to 700 acres (5-282 ha), and averaged 202 acres (81.6 ha) based on their minimum convex polygon (Sechrist et al. 2009).

A healthy forest understory is likely a critical component of cuckoo foraging areas (Wiggins 2005). Cuckoos travel long distances in search of prey items, and may be dependent on the locations and abundance of large insects, but rarely traverse distances across unwooded spaces greater than 0.25 miles in their daily

foraging activities (USFWS 2014). On the South Fork Kern River in California cottonwoods are extremely important for foraging; two male cuckoos equipped with radio transmitters foraged much more in cottonwoods even though willows were the predominant species within the home range (Laymon and Halterman 1985).

Within the MRG floodway, the upper reaches of Elephant Butte Reservoir has the largest population of cuckoos and likely one of the largest within the Service's DPS designation for proposed listing (Ahlers et al. 2013). Following a recession in Elephant Butte Reservoir water levels from 1995 to 2003, several vast stands of native, Goodding's willow-dominated habitat became established, supporting an increased number of cuckoos. Conversely, habitat in the upper portion of the exposed reservoir associated with the Rio Grande and the western LFCC-fed portion, has begun to decline in quality due to either a reduced groundwater table or extended flooding; these areas are less suitable for cuckoos as they are being converted to either cattail marsh or dry, sparse saltcedar (Ahlers et al. 2013).

4.2.2.3 Riparian Habitat Description

Riparian habitat within all reaches of the MRG where cuckoo populations occur includes a variety of habitat types. However, the majority have been in areas that contain native-dominated canopy with a dense understory component consisting of native, non-native, or mixed vegetation.

4.2.3 Reasons for Cuckoo Decline

During the last two centuries, human induced hydrological, geomorphologic, and ecological changes have heavily influenced the composition and extent of floodplain riparian vegetation along the MRG (Bullard and Wells 1992; Dick-Peddie 1993). Fragmentation of forested breeding habitat may also play a role in population reduction of migratory birds (Lynch and Whigham 1984; Wilcove 1988). Other factors that may play a role in the decline of the cuckoo include livestock grazing, which affects understory vegetation and cottonwood/willow recruitment; and pesticide applications which decrease local food supplies and potentially induce toxic accumulations in cuckoos (Wiggins 2005). In addition, the rapid rate of deforestation in tropical areas has been cited as a possible reason for population declines in forest-dwelling migrant land birds (Lovejoy 1983; Robbins *et al*. 1989, Rappole and McDonald 1994). Non-native habitat is a major threat as it does not supply the cuckoo with essential food and adequate thermal cover (USFWS 2013).

4.3 Rio Grande Silvery Minnow

4.3.1 Status and Distribution

The minnow is currently listed as endangered on the New Mexico State list of endangered species, having first been listed May 25, 1979, as an endangered endemic population of the Mississippi minnow (*Hybognathus nuchalis*; NMDGF 1988). On July 20, 1994, the Service published a final rule to list the minnow as an endangered species with proposed critical habitat (USFWS 1994). The Service issued the final rule for minnow critical habitat on February 19, 2003 (USFWS 2003).

4.3.1.1 Critical Habitat

The Primary Constituent Elements (PCEs) for minnow critical habitat are:

1. Hydrologic regime capable of forming and maintaining a diversity of aquatic habitats, including backwaters, shallow side channels, pools, eddies, and runs to support all silvery minnow life-history stages;
2. Presence of eddies created by debris piles, pools, backwaters, or other refuge habitat within reaches of sufficient length to provide a variety of habitats with a wide range of depths and velocities;
3. Substrates of predominantly sand or silt;
4. Water temperatures that vary on a daily, seasonal and annual basis, and that annually range no lower than 1°C and no greater than 30°C; and
5. Water with reduced degraded conditions, such as decreased dissolved oxygen and increased pH.

Designated critical habitat for the MRG extends from Cochiti Dam downstream to the utility line crossing the Rio Grande at the upstream end of the Elephant Butte Reservoir. The designation excludes the tribal lands of Santo Domingo, Santa Ana, Sandia, and Isleta pueblos. The Service considered the Lower Rio Grande around Big Bend National Park, and the Pecos River between Ft. Sumner Dam and Brantley Reservoir for critical habitat, but elected not to so designate these areas even though they are essential to minnow conservation (e.g., possible re-introduction). For all of these reaches, the lateral extent of critical habitat includes those areas bounded by existing spoil banks or their replacement levees. In areas without these structures, the lateral extent of critical habitat is defined as 300 feet (91.4 m) of riparian zone adjacent to each side of the river.

Until the late 1950s, the Rio Grande minnow was distributed throughout many of the larger order streams of the Rio Grande Basin upstream of Brownsville, Texas, with a range extending to northern New Mexico (about 2,000 miles) in water lying primarily below 5,500 feet in elevation (1,676 m). This elevation coincides with the approximate vicinities of Abiquiu on the Chama River, Velarde on the Rio Grande, and Santa Rosa on the Pecos River. Today the minnow is restricted to a variably perennial reach of the Rio Grande in New Mexico, from the vicinity of Bernalillo downstream to the head of Elephant Butte Reservoir, a distance that fluctuates as the size of the pool of water in storage in Elephant Butte Reservoir changes, but that approximates 150 river miles (241 km).

Historically, the minnow was distributed throughout the Rio Grande Basin over a broad range of environmental parameters (including chemical, physical, hydrological, climatic, and biological attributes) that are typical of the arid southwest. Sublette *et al.* (1990) describe the taxonomic characteristics of the minnow and provides an overview account of the life history and species distribution. Bestgen and Propst (1996) provide a detailed morphometric study of the minnow and document the distinctiveness of the species. Population monitoring for minnows has been conducted at 20 sites between Angostura Diversion Dam and the Elephant Butte Reservoir pool since 1993 (Dudley and Platania 2008). Monitoring indicates the population has rebounded starting in 2004 with spring runoff flows greater than 2,000 cfs (Dudley and Platania 2007a), indicating the importance of overbanking floods in creating suitable habitat for population recruitment.

4.3.2 Life History and Ecology

4.3.2.1 Minnow Habitat

Floodplain habitat appears important for supporting minnow recruitment (Fluder *et al.* 2007; Gonzales *et al.* 2014; Hatch and Gonzales 2008; Porter and Massong 2004a, b; SWCA 2008), and habitat fragmentation is likely a major mechanism for extirpation of the minnow from most of its range (Medley and Shirey 2013; Dudley and Platania 2007b). Minnow habitat is typically described as shallow (0.7- 2.6 ft) water bodies with fine grained substrate (silt, sand) and slow water velocities (<1 ft/sec) (USFWS 2010). Minnows are most commonly collected in shallow water (<1.3 ft) with low water velocities (<0.32 ft/sec), primarily over silt and sand substrate (Dudley and Platania 1997). Minnows are capable of moving through narrower incised channels with faster water velocities by remaining in the boundary layer adjacent to the bank to avoid the main current (Porter and Massong 2004b). Surveys in 1977 to 1978 collected large numbers of minnows in adjacent aquatic habitats connected to the Rio Grande main channel (C. Painter, NMDGF, unpublished data, 1977-1978), such as the Albuquerque Oxbow, Elephant Butte Marsh (headwaters), the Low Flow Conveyance Channel, and various irrigation drains and canals.

The Rio Grande and Pecos River have been fragmented by dams and reservoirs, resulting in a total of 82 disconnected sub-reaches (Dudley and Platania 2007b). Barriers restricting fish movement between sub-reaches reduce the ability of fish species to re-colonize sub-reaches after local extirpation. While large dams and reservoirs prevent dispersal of fish upstream and downstream, smaller diversion dams may allow limited movement of some fish. The diversion dams on the MRG were designed to pass sediment, allowing passage of fish in both directions during the winter when no irrigation was occurring. Minnow populations also persist in shorter reaches that are unsuitable for other pelagic spawning fishes with semi-buoyant eggs (Dudley and Platania 2007b; Hoagstrom *et al.* 2008). The role of minnow dispersal and habitat connectivity within reaches may benefit from additional research (Rodriguez 2010). Less than two percent of tagged minnows released downstream of the ABCWUA drinking water diversion dam were detected moving upstream through the fish passage channel (Archdeacon and Remshardt 2012).

In addition to forming barriers to minnow movement, large reservoirs trap sediment, resulting in channel incision extending downstream from the dam. The extent of downstream incision is a function of scouring flows, time and sediment contribution from downstream tributaries (Massong *et al.* 2006; Schmidt *et al.* 2003). Channel incision also reduces annual connectivity to floodplain and riparian areas for many fish species (Coutant 2004). The loss of inundated riparian habitat for nursery areas limits recruitment by fish species with life histories that are dependent on this habitat. The correlation of October catch rates with spring flow above 2,000 cfs supports recruitment as a function of inundated habitat for the minnow. Loss of riparian connectivity within the Rio Grande floodplain has decreased the amount of critical habitat for the minnow.

The USGS modeled minnow habitat availability as a function of instream flow in the lower Isleta Reach between the Rio Puerco confluence and San Acacia diversion dam (Bovee *et al.* 2008). The study focused on hydraulic and structural habitat for juveniles (young-of-year, YOY) and adults at the lower range of flows typical of dry and normal summers in this reach of the river. The maximum area of suitable hydraulic habitat for adults was at flow between 40 to 80 cfs. The area of suitable adult habitat declined rapidly as flow increased above 150 cfs, shifting the preferred shallow, low velocity habitat to the margins of the river.

The USGS has quantified in-channel fish mesohabitat around Big Bend National Park (Moring et al. 2014) and the MRG (Braun et al. 2015). Both studies mapped mesohabitat over a range of seasonal streamflows. Fish were sampled by seining to evaluate species diversity and minnow density (catch per unit effort, CPUE).

Minnow densities (CPUE) and in-channel habitat use were documented in the project area for the Middle Rio Grande Bosque Restoration Project (USACE 2011, USGS 2015; SWCA 2015). Minnow habitat use (CPUE) was higher in backwaters, slackwaters, and pools than in runs and riffles (unpublished data).

The MRGCD irrigation system may provide habitat for minnows, particularly as refugia during river drying, with fish returning to the river as flow increases (Cowley *et al.* 2007). Declining occurrence of minnows in the irrigation system since the 1970s (C. Painter, NMDGF, unpublished data, 1977-1978; Lang and Altenbach 1994) indicate the need for more information about how irrigation practices affect minnow survivorship in the ditches. Cowley *et al.* (2007) suggests several concepts for managing the irrigation system to enhance habitat values for native fish species.

Ecologically, the minnow appears to be a physiological generalist with specific habitat requirements for completion of its life cycle to support recruitment, persistence and abundance of the species. Minnow primarily consume diatoms, cyanobacteria, and green algae associated with sand or silt substrates in shallow areas of the river channel (Propst 1999; USFWS 1999; Shirey *et al.* 2007). Dudley and Platania (1997) studied habitat preferences of the minnow in the MRG at Rio Rancho and Socorro, New Mexico. YOY minnows are generally captured in shallower and lower velocity habitats than adult individuals. Minnows used low velocity habitat with instream debris (cover) more frequently during winter months (Dudley and Platania 1996).

4.3.2.2 Minnow Spawning and Recruitment

Age and body length analyses by Cowley *et al.* (2006) indicate minnows had a maximum longevity of four to six years in the late 1800s. Data from minnow rescue in 2006 (USFWS 2007a) indicates five possible classes (Age 0-4) based on standard length size distribution. The majority of spawning individuals are Age one fish (1-year old) with older, larger fish (Age 2+) constituting less than 10 percent of the spawning population (Platania and Altenbach 1996). Reproductively mature females are typically larger than males. Each female may produce several clutches of eggs during spawning ranging from 2,000 to 3,000 (Age 1) to 5,000+ eggs (Age 2) per female (Platania and Altenbach 1996). Few adult minnows are captured by late summer, suggesting that spawning adults may either experience high post-spawning mortality or reduced catchability.

Minnows spawn from late April through June at water temperatures greater than 18°C (Medley and Shirey 2013; Platania and Dudley 1999, 2001). Peak egg production generally coincides with higher spring discharge produced either by snowmelt or water management operations. Minnows produce numerous semi-buoyant, non-adhesive eggs typical of the genus *Hybognathus* (Platania and Altenbach 1998) that are transported in the lower portion of the water column (Worthington et al 2013). The specific gravity of minnow eggs ranges from 1.012 to 1.00281 as a function of time post-fertilization (Cowley *et al.* 2005). Eggs produced by related species, such as *H. regius* (Raney 1939) and *H. hankinsoni* (Copes 1975), are non-adhesive and considered demersal. More data on the specific gravity of related species of *Hybognathus* may provide useful insights for understanding spawning behavior and site selection among minnow species. Egg hatching time is temperature-dependent, occurring in 24 to 48 hours at water temperatures of 20 to

30ºC (Platania 2000). Recently hatched minnow larvae are about 3.7 mm in length. Environmental variables that influence minnow spawning include photoperiod, increased flow, degree days (average temperature multiplied by the number of days), and water turbidity. Additional research should improve our understanding of environmental factors on the timing and duration of minnow spawning.

Nursery habitat consists of shallow inundated surfaces with low water velocities where eggs hatch without downstream displacement, and larval fish can readily find food (Gonzales et al. 2014; Medley and Shirey 2013; Pease *et al.* 2006; Porter and Dean 2007). Shallow water areas provide the productive habitats required by larval fishes to successfully complete their early life history (Dudley and Platania 2007a; Turner *et al.* 2010). The Collaborative Program has focused on creating additional shallow water habitats with appropriate environmental flows in the MRG (Grand *et al.* 2006; USACE 2009).

Platania and Altenbach (1998) discussed the difficulty for explaining the persistence of the minnow in the Rio Grande while other minnow species with semi-buoyant eggs were extirpated from the system. Medley and Shirey (2013) summarize observations that indicate minnows spawn on the floodplain and hypothesize that downstream eggs drift through channelized reaches indicates habitat degradation. Minnows from hatcheries did not demonstrate a strong upstream movement pattern (Archdeacon and Remshardt 2012).

Egg retention from the current into inundated riparian zones favorable for larval fishes provides a mechanism for minnow recruitment in the MRG (Widmer *et al.* 2007, 2010). Egg retention is consistent with the interactions of channel incision and hydrology leading to egg drift, declining recruitment and populations (Porter and Massong 2004b, 2005; Dudley and Platania 2007a, 2007b; Widmer *et al.* 2007, 2010). Larval minnow have been associated with low water velocity habitat including inlets, shelves, and side channels (Pease *et al.* 2006; Turner *et al.* 2010). Higher minnow densities (CPUEs), appear to be spatially associated with reaches with higher egg retention (Widmer *et al.* 2007).

The minnow spawning is closely tied to the annual spring flood (Medley and Shirey 2013). During the ascending limb of the hydrograph, minnows move into flooded riparian areas and backwaters to spawn. Habitat monitoring has documented minnow adults (Gonzales et al 2014; Hatch and Gonzales 2008; SWCA 2008), and eggs (SWCA 2008) on constructed nursery habitat sites. Floodplain habitat use by minnows suggests that nursery habitat is important for population management (USFWS 2010; Medley and Shirey 2013).

There has been annual monitoring of minnow egg drift (Table 5) since 2002 (Platania and Dudley 2002, 2017) to evaluate recovery goals. These samples provide no useful information on minnow recruitment. The duration of high flows during the April through June spawning season were positively correlated with minnow mean October densities, while extended low-flow periods were negatively correlated with minnow mean October densities (Dudley and Platania 2008). Elevated flows in seven of the past 10 years (2001-2010) have contributed to minnow recruitment compared with the 2002/2003, 2006 year-classes (Dudley and Platania 2015).

Reclamation has previously contracted egg entrainment monitoring from 2002 through 2016 (Table 5) as part of RPA elements in the BO (USFWS 2001, 2003b). After 2002, MRGCD has managed diversions to minimize entrainment during peak egg drift. Higher spring flows since 2003 have inundated riparian areas, providing nursery habitat for spawning and rearing. Nursery habitat is considered essential for minnow larvae and juvenile survival.

Table 5. Results of monitoring for silvery minnow eggs at irrigation diversion structures and at San Marcial. Values are absolute number of eggs collected.

Date	Albuquerque Main	Peralta Main	Belen Highline	Socorro Main	Totals	San Marcial [d]
2002 [b]	0	729	826	28	1,583	92,000
2003 [a,b]	3	26	48	-	77	13,292
2004 [a,b]	0	3	3	-	6	5
2005 [a,b]	1	1	3	-	4	-
2006 [a,b]	0	1	8	8	17	7,900
2007 [a,b]	0	49	43	2	94	10,995
2008 [a,c]	0	1	0	9	10	155
2009 [a,c]	0	12	3	29	44	645
2010 [a,c]	-	11	1	0	12	364
2011 [a,c]	-	8	4	13	25	96,266
2012 [a,c]	-	3	82	0	85	12,398
2013 [a,c]	-	1	0	0	1	1,745
2014 [a,c]	-	0	0	0	0	9,727
2015 [a,c]	-	3	0	0	3	6,356
2016 [a,c]	-	4	0	0	4	481
2017 [d]	-	-	-	-	-	129

[a] *Diversions managed to minimize entrainment of silvery minnow eggs.*
[b] *Porter and Dean 2007.*
[c] *Data provided to Reclamation by the Service. Monitoring for the Albuquerque Main was discontinued after 2009.*
[d] *Estimated number of eggs collected from Platania and Dudley 2002-2017.*

The "spawning spike" as a concept was refined to encompass recruitment flows based on the predictions of nursery habitat and minnow population trends following riparian habitat inundation from 2004 to 2008 (USACE 2007, 2008a).

4.3.2.3 Minnow Population Trends 1994-2017

Long-term monitoring of fish populations is fundamental for evaluating how management affects riverine fish communities and minnow populations. Fish community surveys have been conducted since 1993 (with the exception of 1998) in the Rio Grande of New Mexico between Angostura Diversion Dam (RM 209.7) and Elephant Butte Reservoir (RM 58.8). Survey methodology consists of single-pass seine samples (Dudley and Platania 2015) with results reported as count data, such as CPUE or catch per area sampled. Although the statistical properties of these indices (e.g., measures of bias, capture or detection probabilities, and variance) are unknown, these surveys document silvery minnow density (fish per 100 m^2) variability over time and space.

Minnow habitat use in the action area has been documented by several studies (Braun et al. 2015; SWCA 2015). Over the period 1993 to 2017, October counts were conducted in the Angostura, Isleta, and San Acacia reaches (Dudley and Platania 2017). The density of minnows (CPUE) varies several orders of magnitude across the years in response to spring flow and floodplain inundation (Figure 11).

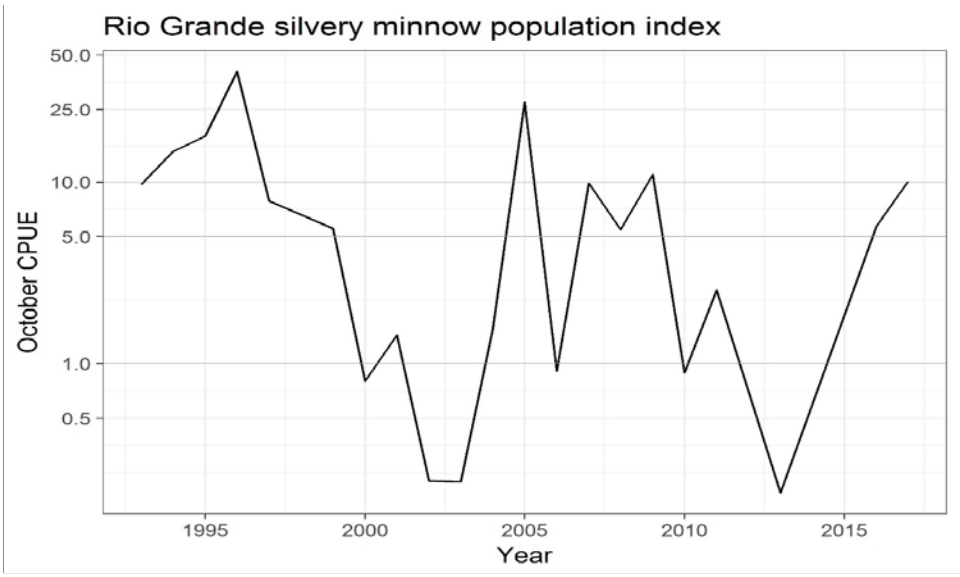

Figure 10. Rio Grande silvery minnow October population index.

4.3.3 Reasons for Minnow Decline

Understanding the effects of habitat degradation, connectivity and fragmentation on different fish species' life history patterns provides clues for analyzing future actions (Koster 1955). The range of the minnow has contracted significantly since the 1950s. The proposal to list the minnow as an endangered species discusses many factors that have led to the decline of the species (USFWS 1993). The minnow has several common factors for extinction prone species including specialized habitat requirements, restricted geographic distribution with limited opportunities for dispersal, and small but demographically-variable populations (Brown and Lomolino 1998).

4.3.3.1 Habitat Modification

Factors currently affecting minnow habitat include loss of habitat due to water impoundment; channel drying; channel straightening and other geomorphic channel alterations; and water pollution (USFWS 1994, 207b; Schmidt et al 2003). Impoundment of water in the Rio Grande by mainstem dams has affected the flow regime of the river, fragmented habitat, and resulted in geomorphological changes to the channel (USFWS 1994, 2007b). Habitat fragmentation and degradation (resulting from dams) may be a factor in the decline of the minnow, including the sequential decline and loss of fish from upstream to downstream (Platania and Altenbach 1998, Porter and Massong 2004a).

The conversion of riverine habitat into reservoirs creates barriers to minnow movement. Minnows are generally obligate riverine species that have not been documented using limnetic habitat. The unsuitability

of reservoir habitat creates barriers to minnow dispersal and does not provide refugial habitat for maintaining populations.

Flows in the MRG are extreme and highly erratic, including episodic flooding and, at times, intermittence (USACE 2007, 2009). Reservoir operations conducted by multiple Federal and non-Federal entities may reduce the size of the flood peaks, extend or decrease the duration of the snowmelt runoff (depending on the size of the runoff), and increase the volume of water entering the MRG valley during normal natural low flow periods (USFWS 2010). Managed flow regimes can alter minnow habitat by reducing the frequency and magnitude of overbank flooding, trapping nutrients, altering sediment transport regimes, prolonging summer base flows, and creating reservoir habitats that favor non-native fish species. The changes in hydrology may reduce minnow food supplies, alter its habitat, prevent dispersal, and provide non-native fish with a competitive advantage.

River engineering projects have variable effects on minnow habitat quality and area depending on how they are implemented. Traditional river engineering activities that have taken place over the past 100 years have confined the Rio Grande to a narrower channel and reduced the connectivity with adjacent riparian habitat. Channels have been straightened and deepened, and aquatic plants and snags have been removed to lessen hydraulic resistance. Sediment retention by upstream reservoirs results in channel incision, reducing surface water inundation. Conventional river engineering projects have reduced the retention time of water and organic matter, surface area and physical complexity of the habitat, and refugial habitats.

Channelization of the MRG has resulted from the placement of Kellner jetty jacks along the river to protect levees by retarding flood flows, trapping sediment, and promoting vegetation (USFWS 1994, 2007b). Meanders, oxbows, and other components of minnow habitat have been eliminated in order to pass water as efficiently as possible for agricultural irrigation and downstream deliveries. The loss of low-velocity nursery habitat (inundated riparian vegetation, backwaters, etc.) has likely reduced minnow larval and juvenile recruitment.

4.3.3.2 River Diversions and Dewatering

Dewatering (channel drying) is caused primarily by agricultural water diversion and by periodic drought. For minnows, these actions result in a fragmented range with reduced habitat area and connectivity (USFWS 1994, 2010). The impacts of water diversion may not be severe in years when an average or above average amount of water is available (USFWS 1994, 2007b). In years of below-average water availability river channel drying may be extensive from Isleta Diversion Dam downstream to Elephant Butte Reservoir (111 mi).

Dewatering is implicated in many studies of minnow range contraction from its historic extent. For example, Trevino-Robinson (1959) documented the early 1950s “cosmopolitan” occurrence of minnows in the Rio Grande downstream of its confluence with the Pecos River where, for “the first time in recorded history,” a portion of this reach of river went dry in 1953. Although Trevino-Robinson (1959) could not document any “apparent undesirable or severe after effects” from the drought, minnows have not been documented from this lower portion of the Rio Grande since the mid-1950s (in part, USFWS 1999). Edwards and Contreras-Balderas (1991) confirm the absence of the minnow from the Rio Grande below Falcon Dam, which is downstream of the Pecos confluence at Amistad Lake.

Drought leading to channel drying has also been implicated in the extirpation of the minnow from upstream reaches of the Rio Grande. Hubbs *et al.* (1977) documented the "inexplicable" absence of minnow from the Rio Grande in Texas between El Paso and its confluence with the Pecos River where Hubbs (1958) had earlier documented the species to occur. However, Chernoff *et al.* (1982) noted that much of this stretch, particularly the Rio Grande between El Paso and the mouth of the Rio Conchos, is at times dry. Sublette *et al.* (1990) documented the former occurrence of the minnow in the Rio Grande from Caballo Reservoir, New Mexico, downstream to El Paso, another stretch that is now often dry and from which the minnow has been extirpated. Thus, between 1950 and 1991, the Rio Grande minnow was extirpated from that portion of its historic range lying downstream of Caballo Reservoir to the Gulf of Mexico.

Observations suggest that during periods of such extreme water scarcity, the minnow seeks out cooler pool habitats associated with overhead cover, irrigation return flow, and shallow groundwater (USFWS 1994, 2007b). During periods of no flow, the minnow is thought to have survived in the irrigation ditches and drains, the reaches above the diversions, and in channels maintained by irrigation return flows or leakage from the diversion dams. River drying increases minnow mortality rates due both to decreasing water quality in temporary pools and the eventual disappearance of such pools as water seeps into the substrate.

It has been proposed that the entrainment of minnows (primarily eggs and larvae) in the infrastructure of irrigation systems that derive water directly from the Rio Grande could be a factor contributing to the decline of the species (e.g., USFWS, 1999). Egg entrainment in irrigation canals has been monitored since 2001 (e.g., USBOR 2003). These studies show that recent management actions have minimized egg entrapment in irrigation infrastructure.

4.3.3.3 Water Quality for Minnow Habitat

Water quality in the MRG varies spatially and temporally throughout its course primarily due to inflows of groundwater, as well as surface water discharges and tributary delivery to the river. Factors that are known to cause poor fish habitat include temperature changes, sedimentation, runoff, erosion, organic loading, reduced oxygen content, pesticides, and an array of other toxic and hazardous substances. Both point source pollution (e.g., pollution discharges from a pipe) and non-point source pollution (i.e., diffuse sources) affect Rio Grande water quality.

The expansion of cities and agriculture along the MRG may have adverse effects on river water quality (USFWS 1994, 2007b). During low flow periods, the increased proportion of municipal and agricultural discharge to native flow may allow pollutants to significantly degrade water quality. Agricultural water use appears to reduce nutrient availability in return flows to the river (Van Horn and Dahm 2008). Recent water-quality data have not identified limiting factors for minnows or habitat (NMED 2001, 2009; USFWS 2004; Marcus *et al.* 2005; Marcus *et al.* 2010).

4.3.3.4 Minnow Population Genetics

While population size (N) is an important variable for endangered species survivorship, the effective population size (Ne) of an endangered species is also crucial because it describes the genetic diversity of the population (Minckley *et al.* 2003). Genetic diversity determines the ability of species to cope with environmental variability (Gilpin and Soulé 1986). The effective size (and therefore genetic diversity) is reduced by genetic drift and inbreeding. Small effective population size can negatively impact long-term survival because reduced genetic variability can translate into a reduced ability to adapt to environmental

changes. These values are poorly understood for most species (Minckley *et al.* 2003). The minnow Ne is moderately low based on different estimators (PBS&J 2011).

Due to the increased efforts in captive propagation, recent studies by the Collaborative Program have focused on the genetic composition of the silvery minnow. Several studies since 2003 have demonstrated a decline in overall mitochondrial mtDNA and gene diversity in the silvery minnow (e.g., Osborne *et al.* 2005; Turner *et al.* 2006). The results are consistent with smaller overall population numbers and/or increasing relatedness of the females. In addition, studies need to be conducted on the genetic effects of stocking hatchery fish. Currently, these fish are artificially spawned in groups, where fish are assumed to form pairs. However, competition between males and gametic competition could produce effective numbers far smaller than those that are assumed. The effect of communal spawning on effective number must be assessed so the genetic consequences of stocking hatchery fish can be accurately measured and a true effective population number can be determined.

Finally, the changes in gene frequency caused by fish culture practices must be assessed (Minckley *et al.* 2003; AMEC Foster Wheeler 2016). Osborne *et al.* (2006) reported that genetic heterozygosity in captive-reared fish and wild fish were the same, with a loss only in allelic diversity. They also stated that hatchery-reared fish stocked into the wild will cause a lower effective breeding number and could cause a reduction in fitness of the entire population. However, the effects of domestication and inadvertent selection have not been studied in the minnow. Additional problems may occur due to the increased survival in wild genotypes brought into the hatchery that would have died in the wild. These fish survive due to lack of predation and to increased care, and then are stocked back into the river as brooders and are still considered to be "wild fish." This is critical because captive-reared fish could affect the natural population's level of fitness.

4.3.3.5 Competition, Predation, Disease

Accidental or intentional releases of fishes outside of their native ranges (including bait and aquarium sources) have established numerous exotic fish species in the Rio Grande Basin (Sublette *et al.* 1990), representing potential competitors or predators of the minnow. The minnow evolved sympatrically with about 90 other fish species, including those with similar feeding habitats. Competition among fish species often evokes resource partitioning through selective and interactive segregation.

Predation and competition with other fish species has been cited as a factor possibly contributing to the decline of the species (e.g., USFWS 1999). Predation by piscine and avian predators upon minnows has not been quantified, but probably has a minor role in declining minnow populations (USFWS 1994, 2007b). Swimming performance of minnows may provide a reasonable capability for escaping predators (Bestgen *et al.* 2003). Experiments using brassy minnows (*H. hankinsoni*) exhibited a change in habitat use when predators are present (Schlosser 1988). The turbidity of the Rio Grande serves to lessen the impacts of would-be predators on minnows because the effective predatory strike zone is shortened.

Fish confined to pools during periods of low-flow may experience outbreaks of *Ichthyophthirius multifilis* (caused by a protozoan and commonly called "ick") or *Lernaea* (a parasitic copepod, USFWS 1994, 2007b). Ongoing studies are examining the impact of disease and parasites on minnows (USFWS unpublished data).

4.3.4 Adaptive Management

The Collaborative Program Adaptive Management Framework Report (Caplan et al. 2018) identified population dynamics, reproduction, sampling methods and habitat as critical uncertainties for the minnow. Designing studies for these topics will provide a better foundation for decision making. Other independent science panels have identified research needs for minnow movement (PBS&J 2011), population monitoring (Hubert et al. 2016), and genetics (AMEC Foster Wheeler 2016).

4.4 Other Threatened and Endangered Rio Grande Species

The New Mexico Meadow Jumping Mouse was historically found along the Rio Grande, but there are no known populations or critical habitat in the project area. The Mexican Spotted Owl, may occur in Bernalillo County but they are unlikely to occur in the project area.

The primary constituent elements for the owl's critical habitat include mixed-conifer forest at elevations above 6,000 feet (USFWS 2004). The proposed action area does not have the appropriate vegetation for the species with an elevation less than 4,946 feet (NGVD29, Rio Grande at Albuquerque Gage, USGS 2015).

5 - Analysis of Effects of Proposed Action

This chapter provides an analysis of the effects of Corps' proposed action on listed species and their designated and proposed critical habitat. "Effects of the action" refers to the direct and indirect effects of the proposed action on listed species or critical habitat together with the effects of other activities that are interrelated or interdependent with that action, if any. These effects are considered along with the environmental baseline to determine the overall effect on a species (50 CFR § 402.02). For purposes of this BA, effects on listed species and critical habitat are analyzed individually with respect to the proposed action.

This chapter first addresses the analysis of specific project features or activities on the minnow, the flycatcher, and the cuckoo, and designated or proposed critical habitat for each species. A detailed description of the proposed action is found in Chapter 2. For ease of review, a brief synopsis of the discretionary activity associated with each component feature of the proposed action is provided in this Chapter, as well. This is followed by a section addressing effects on other listed species, and a final summary of all effect determinations.

5.1 Southwestern Willow Flycatcher

Based on the lack of suitable habitat in the proposed action area, it is unlikely that breeding flycatchers would occupy the project area during the habitat restoration construction period. It is very possible that migrants would be present in the project area in the spring and fall. Surveys at the locations where migrants are potentially detected would continue throughout the life of the project. If territorial flycatchers are detected on any locations where work is proposed, then consultation with the Service would be initiated.

Creation of willow swales in the proposed action areas would provide potentially suitable habitat for b flycatcher. Over time, as plants mature, these swales would create willow stands of preferred density and stature for breeding flycatchers.

Therefore, the Corps has determined that the proposed action may affect but is not likely to adversely affect, the flycatcher. Construction of the habitat restoration features described above may beneficially affect the flycatcher.

5.2 Western Yellow-billed Cuckoo

Over the years, numerous areas of the bosque throughout the Albuquerque reach have been “treated” in some form to reduce fire hazards by the City of Albuquerque, Ciudad Soil and Water Conservation District, and other agencies and private organizations. Areas treated within this reach have been managed variably; 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 acreages of dense woodlands while mature cottonwood stands remain devoid of understory vegetation required for breeding cuckoo populations.

Therefore, the Corps has determined that the proposed action may affect but is not likely to adversely affect, the cuckoo. Construction of the habitat restoration features described above may beneficially affect the cuckoo.

5.3 Rio Grande Silvery Minnow

Minnows are present in the study area (USACE 2017) and are expected to be present within the Proposed Action Area. The primary adverse effects of the Proposed Action on the minnow would result from construction at or near the bankline. The Proposed Action may affect the minnow and its critical habitat– directly, indirectly and beneficially as described below.

Direct Effects

The Proposed Action may affect, likely to adversely affect the minnow during construction of the habitat features proximal to the active river channel. Construction noise in the vicinity of the river may be a minor disturbance resulting in avoidance behavior by minnows. Construction equipment shall have sound suppression to minimize engine noise. Minnows may be disturbed as the coffer dam or silt curtain is installed (where needed). The silt curtain or coffer dam would be placed along the bank line and then pushed out into the channel to expand the bankline, under the supervision of Corps' Biologists. However, this form of disturbance would be minimal, short in duration, and the curtain/dam would exclude fish from contact with construction equipment and minimize mobilization of sediments. Construction at the channel openings would be monitored for minnows throughout construction. If minnows were confined to the immediate project area, work would cease until the fish leave of their own volition, or a Corps biologist, in consultation with the Service, determines that the potential for harassment is minimal. Findings of trapped, injured or dead minnows would be reported to the Service.

Occasional adverse effects are still likely beyond the construction period. High flows may deposit sediment in or at the openings of constructed channels so that isolated pools containing minnows may be formed. Minnows may become stranded in these isolated pools and die.

Indirect Effects

Sediment disturbance may result in indirect effects to the minnow such as decreases in primary production associated with increases in sedimentation and turbidity which potentially produce negative cascading effects through depleted food availability to zooplankton, insects, mollusks, and fish. Water quality measurements would be taken before, during and after construction activity.

Beneficial Effects

The Proposed Action is expected to establish diverse floodplain mesohabitats that support the minnow. Such habitat benefits the species through improved egg and larval retention, increased recruitment rates, and increased survival of both young-of-year and adult minnows. In the long term, the project is anticipated to have a beneficial effect on the minnow and its habitat, contributing to the improvement of the status of minnow into the future.

Based on the potential effects described above the Corps has determined that the Proposed Action may affect, but is not likely to adversely affect the endangered minnow.

Silvery Minnow Critical Habitat

The Proposed Action may affect, but is not likely to adversely modify designated Critical Habitat of the minnow. The Proposed Action is likely to have a positive long-term impact on three of the four primary constituent elements of critical habitat for the minnow. These include backwaters, shallow side channels, pools, and runs of varying depth and velocity; substrates of primarily sand and silt; and the presence of eddies created by debris piles, pools or backwaters, or other refuge habitat within unimpounded stretches of flowing water of sufficient length (i.e., river miles) that provide a variation of habitats with a wide range of depth and velocities. The proposed restoration project will create floodplain habitats that will inundate at lower flows than the adjacent floodplain. These habitats provide critical nursery habitat for minnow eggs and larvae and enhance opportunities for minnow recruitment. Construction of the habitat features channels would occur during the fall, winter, and spring when river flows are at a minimum. Short-term habitat disturbance will occur during the construction phase of this project. However, these effects will be limited in area and duration. The Corps would monitor the location for minnow and coordinate with the Service on whether minnow should be transported away from the project area if they are detected.

The critical habitat PCEs elements hydrologic regime, instream habitat, and fine sediments for substrate, water temperature, or water conditions would not be adversely affected by habitat feature construction. Therefore, the proposed action may affect, not likely to adversely modify or affect minnow critical habitat.

5.4 Other Threatened and Endangered Species

The proposed project area lacks the critical habitat primary constituent elements for the Mexican Spotted Owl and the New Mexico Meadow Jumping Mouse. As such, these species are not likely to occur within the proposed action area, and, based on the best available information, the proposed actions would have no effect on the mouse or the owl.

5.5 Summary of Effects, and Endangered Species Act Consultation

Table 7 below summarizes Corps' determination of the effects for all of the proposed actions. In consideration of all direct, indirect, and cumulative effects, the Corps' discretionary proposed actions would:

- May affect, but not likely to adversely affect, the Southwestern Willow Flycatcher;
- May affect, but not likely to adversely affect, the Yellow-billed Cuckoo;
- May affect, but not likely to adversely modify proposed critical habitat for the Yellow-billed Cuckoo;
- May affect, but not likely to adversely affect, the Rio Grande Silvery Minnow;
- May affect, but not likely to adversely modify designated critical habitat for the Rio Grande Silvery Minnow;
- Would not affect the New Mexico Meadow Jumping Mouse nor designated critical habitat; and
- Would not affect the Mexican Spotted Owl nor designated critical habitat.

Without the proposed project the river, floodplain, and the associated fish and wildlife would continue to experience adverse effects from Federal, state, and private actions, including new and long-term ongoing activities. The proposed project provides opportunities to restore some Rio Grande ecosystem biological components to benefit fish and wildlife resources. The proposed project represents the extensive coordination of ideas and planning on a multi-party level. The proposed project implementation and reporting of the monitoring results will also provide valuable information for future projects in a river-based ecosystem approach to restoration throughout the MRG. The proposed restoration plan incorporates many of the recommendations from the MRG Ecosystem: Bosque Biological Management Plan.

Table 6: Summary of determined effects to listed species and proposed or designated critical habitat.

Name	Effects Analysis	
Common (Species)	Species	Critical Habitat
Southwestern Willow Flycatcher	Present in Project action area as migrant only	Yes, designated, but not in Project action area
(Empidonax traillii extimus)	May beneficially affect, not likely to adversely affect	No effect
Western Yellow-billed Cuckoo	Yes, present in Project action area as migrant only	Yes, proposed in Project action area
(*Coccyzus americanus occidentalis)*	May beneficially affect, not likely to adversely affect	May beneficially affect, not likely to adversely modify or affect
Rio Grande Silvery Minnow	Yes, present in Project action area	Yes, designated in Project action area
(Hybognathus amarus)	May beneficially affect, not likely to adversely affect	May beneficially affect, not likely to adversely modify or affect
New Mexico Meadow Jumping Mouse	Not considered present in Project action area	Yes, designated, but not in Project action area
(*Zapus hudsonius luteus)*	No effect	No effect
Mexican Spotted Owl	Not considered present in Project action area	Yes, designated, but not in Project action area
(Strix occidentalis lucida)	No effect	No effect

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