Middle Rio Grande Flood Protection
Bernalillo to Belen, New Mexico:
Mountain View, Isleta and Belen Units

Integrated General Reevaluation Report and Supplemental Environmental Impact Statement

U. S. Army Corps of Engineers
Albuquerque District

DRAFT

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Albuquerque District

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EXECUTIVE SUMMARY

This integrated General Reevaluation Report (GRR) and Supplemental Environmental Impact Statement (SEIS) addresses alternative plans to provide higher levels of flood risk management to floodplain communities within the Bernalillo to Belen portion of the Middle Rio Grande floodway. This reach was included in a comprehensive plan for flood risk reduction in 1986 based on studies originally authorized in 1941. This GRR/SEIS is an interim response to determine (1) whether the authorized project is still implementable; (2) if any changes are necessary for implementation; and (3) seek additional Congressional authorization. The Middle Rio Grande Conservancy District (MRGCD) requested that USACE undertake a post-authorization study for the Middle Rio Grande Flood Control Project. This GRR/SEIS presents recommendations on future actions to best meet flood risk reduction needs within the study area.

The study area of the current GRR/SEIS investigation includes five study units (Mountain View, Isleta East, Isleta West, Belen East, and Belen West) located in Bernalillo and Valencia Counties, NM. The area extends approximately 20 river miles from Albuquerque's South Diversion Channel on the east bank of the Rio Grande, and from the U.S. Interstate 25 (I-25) bridge on the west bank, to immediately south of the railroad bridge south of Belen. The study area encompasses approximately 110 square miles of drainage area and includes one Pueblo and multiple small rural communities on both sides of the Rio Grande between Albuquerque and Belen. The communities of Los Lentes, Los Lunas, Los Chavez, Belen, Bacaville, Jarales and Pueblitos are located along the west bank of the Rio Grande. The communities of Mountain View, Bosque Farms, Peralta, Valencia, Tome, Adelino, La Constancia and Madrone are located along the east bank. The Pueblo of Isleta straddles the Rio Grande in the northern third of the study area. The Pueblo was established in the 1300s and is one of the largest of the nineteen Pueblos within New Mexico that are federally recognized tribal entities.

The Mountain View Unit is mainly suburban with some industrial and small businesses. Agriculture fields of alfalfa or hay and small farms still remain along the existing levees. The Isleta West and Isleta East Units are entirely within the Isleta Pueblo, and are almost completely rural with housing generally scattered throughout. Isleta Village is the main residential area, and a few businesses are found along the major paved roads. The Belen East and West Units have substantial municipalities along both banks of the Rio Grande with the remainder of the floodplain consisting of agricultural fields of mainly alfalfa or hay, scattered housing developments, small farms and businesses.

Severe floods in the study area include those occurring during the following years: 1828, 1851, 1865, 1874, 1886, 1903, 1905, 1911, 1920, 1928, 1929, 1935, 1941 and 1942. Most flooding resulted from heavy spring runoff caused by either especially heavy winter snows or snowpack melting quickly after warm spring rains. Other flood events were the results of large storms within the Rio Grande and tributary watersheds during the summer and fall. In 1889, streamflow gaging began and subsequent flood events could more accurately be measured: 1903 (18,900 cubic feet per second (cfs)), 1904 (33,000 cfs), 1920 (22,500 cfs), 1929 (24,000 cfs), 1935 (15,000 cfs), 1941 (24,600 cfs) and 1942 (18,400 cfs).

In 1929, much of the low lying land outside the banks of the Rio Grande within the study area was flooded, prompting construction projects to reduce flood risk over the next decade. From

1930 to 1935, the Middle Rio Grande Conservancy District (MRGCD) constructed 190 miles of spoil banks (non-engineered levees) in the Middle Rio Grande Valley. The spoil banks were constructed using material excavated from earthen channels and then side-cast, or “spoiled,” on the river-side of the excavated channel. The excavated channels served to drain irrigation water from agricultural fields on the landward side, and the spoil banks provided a degree of protection against future floods from the Rio Grande. The currently existing spoil banks from Bernalillo to San Acacia date to this time.

The Rio Grande Floodway through the study area is contained by these MRGCD-constructed spoil banks, which have been in place for over 80 years. In the decades that the spoil banks have been in place, river sediment has been deposited on the floodplain within the floodway, but not on the floodplain outside the floodway (landward of the spoil banks). Because sediment deposition has been contained between the spoil banks, the floodway has become elevated above the surrounding floodplain. At the same time, a large share of the floodplain outside the spoil banks has transitioned from agricultural to municipal, industrial and residential use. Spoil bank failure during a flood would now result in considerable non-agricultural damages and pose a significant life-safety hazard.

Observations of the performance of the existing spoil bank system during a higher flow dam release, as well as the results of numerical modeling of spoil bank seepage and stability, indicate that the existing spoil bank system may temporarily provide flood mitigation up to about the 10% Annual Chance Exceedance (ACE) for short duration flow events. The limited degree of flood risk management provided by the spoil banks is dependent on continuous monitoring and repair to maintain the integrity of the spoil bank system. There are three potential sources of Rio Grande flooding in the semi-urban project area downstream of Albuquerque. They are:

- Flood events in the regulated area upstream of Albuquerque;
- Rainfall-runoff flood events in the unregulated area upstream of Albuquerque;
- Rainfall-runoff flood events from the project area, downstream of Albuquerque. A single inflow to the Rio Grande, the South Diversion Channel (SDC) outfall south of Albuquerque, currently provides the only potential for significant local inflow between the Rio Grande at the Albuquerque, NM USGS gage (Albuquerque gage), located at the Central Avenue bridge over the Rio Grande in Albuquerque and the downstream end of the project area under existing conditions.

A Feasibility Report was completed in 1979 (1979 Feasibility Report) and the Chief of Engineers’ Report transmitted to Congress 23 June 1981. The recommended plan in the 1979 Feasibility Report consisted of the following features:

- Corrales Unit: Levee construction and raising an average of 2.8 feet above existing height. The unit extended from high ground in the vicinity of the Corrales Siphon downstream to immediately upstream of the Oxbow marsh area. The Corrales Unit construction was completed in 1997.

- Mountain View Unit: Levee construction and raising an average of 2.5 feet above existing height. The unit extended from the outlet of the Albuquerque South Diversion Channel to 3,000 feet downstream of the I-25 river crossing on the east side of the river.

- Isleta Unit – West: Proposed levee would be constructed and raised an average of 3.8 feet above existing height. The unit extended from the I-25 bridge and Atchison, Topeka and Santa Fe railroad bridge to the State Road 147 bridge approach at Isleta.

- Belen Unit – East: Levee construction and raising an average of 2.7 feet above existing height. The unit extended from high ground upstream of State Road 147 bridge crossing, to 3,700 feet downstream from the railroad bridge at Belen.

- Belen Unit – West: Levee construction and raising an average of` 3 feet above existing height. The unit extended from the Santa Fe Railroad track immediately downstream of Isleta Marsh to approximately 7,000 feet downstream of the railroad bridge at Belen.

- Compensation for impacts to fish and wildlife resources: Proposed creation of 75 acres of wetlands from carefully designed borrow areas, and 200 acres of woodland would be acquired in fee or easement.

Since the 1979 Feasibility Report was completed, the objectives of the Rio Grande and tributaries studies, surveys, reports, authorizations, appropriations and projects have been modified as conditions warranted. Events occurred that affected the project and resulted in expanding the scope of study for the Belen Units. The following paragraphs summarize these events.

- Endangered Species Status: In 1994, the Southwestern Willow Flycatcher and the Rio Grande silvery minnow, both of which inhabit the study area, were added to the Federal Endangered Species List under the provisions of the Endangered Species Act. Additionally, the study area is within designated critical habitat for both species. Finally, in 2014, the Yellow-billed Cuckoo was listed as threatened and may occur in the study area.

- Middle Rio Grande Basin Hydrologic Computations: USACE recognizes that hydrologic analyses of the Middle Rio Grande Valley must evaluate flood discharges resulting from both the long-duration regulated flows from the upstream reservoirs (which are predominantly snowmelt flood events) and the unregulated short-duration, high intensity flows originating in the contributing watershed downstream of the reservoirs (associated primarily with rainfall events). As a result, alternatives under consideration in the Middle Rio Grande Valley must include features to mitigate against both flood sources. Because the authorized plan addressed only impacts due to the unregulated peak flood discharges, additional analyses and design are required.

- Sponsor Financial Capabilities: In 1998, USACE authored separate limited reevaluation studies for the Belen East and West study units (Belen LRR) and for the Rio Grande Floodway, San Acacia to Bosque del Apache Unit, Socorro County, New Mexico (San Acacia LRR). MRGCD made a decision to proceed with San Acacia spoil bank replacement first. This decision was largely due to their financial capabilities. It therefore became necessary to focus on the completion of the San Acacia LRR and delay the completion of the Belen LRR studies for the Belen Units as described in the 1979 Feasibility Report. The Belen Units are accordingly incorporated into this GRR/SEIS.

- Levee Criteria: The recommended levee design reflects the latest design and construction criteria for levees. Levee design will incorporate modifications to address long duration flows as required by USACE Policy Guidance Letter Number 26 (1991). Any proposed plan must now incorporate design features to prevent seepage through the levee due to prolonged flow against the riverward toe. Additionally, a risk-based approach to assess project performance has been used to identify levee heights that reasonably maximize net benefits and form the basis of the National Economic Development (NED) plan.

- Habitat Mitigation: The 1979 Feasibility Report recommended the creation of 75 acres of wetlands for borrow areas and the acquisition of 200 acres for fish and wildlife mitigation. Though recent USACE policies, procedures and hydrologic studies indicate that the current engineering project may not require the use of borrow and associated mitigation measures, providing borrow from the floodplain for the recommended levee height creates cost effective opportunities for increasing floodplain connectivity for enhanced riparian habitat mitigation.

- The Corps now employs a risk-based approach to assess project performance.

Despite the changes in levee evaluation and conditions of the study area, the current GRR/SEIS recommended plan within the Bernalillo to Belen reach of the Rio Grande Floodway has not changed significantly from the authorized plan in the 1979 Feasibility Report. There have been refinements in the proposed levee alignments for the recommended plan, but no major changes in project location. For the Belen East and West Units, there have been deletions and additions to portions of the levee alignments (Figure 26). The following table shows changes in length of the proposed levees.

Table ES-1. Comparison of units 1979 to 2017.

Unit	1979 Length (miles)	2017 Length (miles)	Change (miles)
Corrales	12.6	Constructed 1997	
Mountain View	4.9	4.4	-0.5
Isleta West	3.2	3.2	0
Isleta East	Eliminated from Consideration	Eliminated from Consideration	N/A
Belen East	22.1	18.1	-4.0
Belen West	20.0	22.1	+2.1
Total	75.4*	47.8	

The recommended plan consists of constructing engineered levees for approximately 48 miles along four levee segments corresponding to four of the units. As was the case in 1979, the Isleta East Unit was not economically justifiable and was eliminated from further analysis. Levees would consist of earthen embankments with three on one side slopes and a fifteen foot top width. An associated maintenance road will be constructed along the land side toe of the levee. Levee heights were optimized to provide the highest net benefits and vary slightly depending on the levee unit. Levee heights are described as the number of feet above the point corresponding to the water surface elevation (WSEL) of the 1% annual change exceedance (ACE) event. In general, the levees would be 9 to 16 feet above the existing grade surrounding the spoil banks but will vary with local topography and along the alignments. Levee length and height within each unit are as follows:

- Mountain View Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 4.4 miles.
- Isleta West Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 3.2 miles.
- Belen East Unit: Levee with a height of 7 feet above the 1% ACE WSEL for 18.1 miles.
- Belen West Unit: Levee with a height of 7 feet above the 1% ACE WSEL for 22.1 miles.
- A flood forecast and warning system.

Performance, and therefore benefits, are optimized for all of the levee units. The recommended engineered levee system would reduce the flood risk to over 19,200 acres of mixed-use land with a current population estimated at 16,300 residents and an estimated $722,549,000 in damageable property.

The footprint of the levee at the preferred height would affect a total of approximately 305.8 acres of riparian habitat beyond the existing spoil banks. The recommended plan would require borrow material for construction. Borrow material could be acquired from commercial sources outside the project area, or from mitigation sites implementing terrace lowering for improved riparian forest vegetation. Terrace lowering for mitigation would lower 200-300 acres of the floodplain prior to planting willow and cottonwood trees, improving their connectivity to groundwater. Use of the excavated material in levee construction would reduce costs for both mitigation and construction while providing benefits for the ecosystem and flood protection.

Mitigation sites shall be identified during the design phase of the project due to uncertainties in funding and schedule. Site identification during the design phase supports flexible planning and reduces costs for relocating mitigation sites.Mitigation may be accomplished by vegetation management of 218.8 acres or more for native riparian trees, shrubs, forbs and grasses to create a mosaic of vegetation at and among sites to mitigate for the loss of suitable bird habitat. Management includes removal of invasive plant species and planting of native plant species. Enhanced habitat sites will be designed and constructed to produce approximately 128.9 acres of high quality cottonwood and willow riparian habitat features. Mitigation for loss of wetland ponds may be accomplished by excavation to maintain wetland surface area. Suitable excavated material may be spoiled into the levee to reduce mitigation costs. The required 15 foot-wide Vegetation Management Zone along the toe of the proposed levee (87.0 acres) will be seeded with suitable riparian grass species to minimize the potential for post-construction erosion, reduce the potential for colonization by invasive weed species, and provide vegetation usable by wildlife.

The preliminary recommendation of the District Engineer of the Albuquerque District, U.S. Army Corps of Engineers is that the report be finalized based on results of public review, internal policy review, Agency Technical Review, and Independent External Peer Review of this draft GRR/SEIS, and if warranted, recommended for authorization for implementation as a Federal project. The estimated first cost of the recommended plan is $253,273,000. The Federal portion of the estimated first cost is $190,329,000. The non-Federal sponsor identified for this project, MRGCD, will provide an estimated first cost of $62,944,000.

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***** Indicates sections required by NEPA for inclusion in an Environmental Impact Statement

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List of Acronyms

ACE	Annual Chance Exceedance
AF	Acre-feet
AFY	Acre-feet per year
APE	Area of potential effect
ARMS	Archaeological Records Management System
BCR	Benefit-cost ratio
Reclamation	U.S. Bureau of Reclamation
CDP	Census data population
CE-SPA	USACE, Albuquerque District
CE/ICA	Cost estimate/incremental cost analysis
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CNP	Conditional non-exceedance probability
CWA	Clean Water Act
EAD	Equivalent annual damages
EPA	U.S. Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
FRM	Flood risk management
GIS	Geospatial Information System
GRR/SEIS	General Reevaluation Report/Supplemental Environmental Impact Statement
HEC-EFM	Hydrologic Engineering Center-Ecosystem Functions Model (software)
HEC-FDA	Hydrologic Engineering Center-Flood Damage Assessment (software)
HEC-HMS	Hydrologic Engineering Center –Hydrologic Modeling System (software)
HEC-RAS	Hydrologic Engineering Center-River Analysis System (software)
HTRW	Hazardous, toxic, and radioactive waste
ITA	Indian Trust Asset
ITR	Independent technical review
IWR	USACE Institute for Water Resources
IWR-Plan	IWR planning software
LERDDS	Lands, easements, rights-of-way, relocation, and disposal areas

LiDAR	Light detection and ranging (aerial laser used to develop topography)
MRG	Middle Rio Grande
MRGCD	Middle Rio Grande Conservancy District, the non-Federal project partner
NAAQS	National Ambient Air Quality Standards
NED	National Economic Development
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
NHPA	National Historic Preservation Act
NMCRIS	New Mexico Cultural Resources Information System
NMED	New Mexico Environment Department
NRHP	National Register of Historic Places
OMRR&R	Operation, maintenance, repair, replacement and rehabilitation
OSE	Other Social Effects
P&G	Principles and Guidelines; USACE Planning Guidance Notebook (ER 1105-2-100)
PCEs	Primary constituent elements
PDT	Project development team
PED	Pre-engineering and design
PUBFh	Palustrine unconsolidated bottom (PUB), Semipermanently Flooded (F), Diked/Impounded (h). From Classification of Wetlands and Deepwater Habitats of the United States, Cowardin et al. 1979.
RED	Regional Economic Development
SDC	South Diversion Channel
SHPO	State Historic Preservation Office/Officer
SJC	San Juan Chama project
TCP	Traditional cultural property
THPO	Tribal Historic Preservation Office/Officer
TSP	total suspended particulates
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USC	U.S. Civil Code
USGS	U.S. Geological Survey
WRDA	Water Resources Development Act
WSEL	Water surface elevation

Regional Terms

Some of the terms used in the southwestern U.S. water resources planning may be unfamiliar to readers outside of the region. Definitions of some of these terms are provided here.

Arroyo – n. (Spanish for *stream)* a water-carved gully or channel: dry wash, ravine

Bosque – n. (Spanish for *woods* or *forest*) as used in the southwest, typically riparian habitat characterized by the presence of cottonwoods and other riparian trees

Mesa – n. (Spanish for *table*) a characteristic landform in arid climates, a mesa is an elevated area of land with a flat top and sides that are usually steep cliffs. It takes its name from its characteristic table-top shape.

Pueblo – n. (Spanish for *town* or *village)* 1.) any of some 25 Native American tribes living in established villages in northern and western New Mexico and northeast Arizona; 2.) a permanent village or community of any of the Pueblo peoples, typically consisting of multilevel adobe or stone apartment dwellings of terraced design clustered around a central plaza.

Rio – n. (Spanish for *river*) river.

1. PROJECT INFORMATION

1.1 Purpose and Need For the Project and Report*

The purpose of the proposed engineered levee system is to reduce flood risk along approximately 32 river miles of the Rio Grande in the communities between Albuquerque and Belen, NM. The Middle Rio Grande Flood Protection Bernalillo to Belen, New Mexico, General Reevaluation study investigated and determined the extent of Federal interest in a range of alternative plans designed to reduce the risk of flooding to these communities. The recommended engineered levee system would reduce the flood risk to over 19,200 acres of mixed-use land with a current population estimated at 16,300 residents and an estimated $722,549,000 in damageable property. The majority of the population within the study area is located within the floodplain for the 1% annual chance exceedance (ACE)[1] event (100-year storm).

1.1.1 Integrated Report

This report is an integrated draft General Reevaluation Report and Supplemental Environmental Impact Statement (GRR/SEIS). The report serves as the decision document for the Chief of Engineers to recommend a project for implementation that differs from the project authorized by Congress in 1986. The GRR/SEIS also serves as a supplemental environmental impact statement to the EIS prepared in 1979 for the same project.

For both purposes the report describes the planning process and the analyses used to evaluate a range of alternative plans and select the recommended alternative. This GRR/SEIS:

(1) describes the risk of flooding in the communities between Albuquerque and Belen, including surrounding unincorporated areas;

(2) evaluates a range of alternatives to reduce flood risk, including potential environmental impacts;

(3) describes measures to avoid, minimize or mitigate for potential environmental impacts;

(4) identifies a single plan for implementation;

(5) describes coordination, consultation, and public involvement for the study; and

(6) describes the status of compliance with Federal and State laws, Executive Orders and other requirements.

The previous Feasibility Report and EIS were completed in May 1979 (USACE 1979) and described a levee project for implementation that included seven units (Bernalillo, Corrales, Mountain View, Isleta East and West, and Belen East and West) as illustrated in Figure 3. The units correspond to reaches of the river that can be protected from floods by individual levee

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[1] [1] The probabilities (0.2%, 1%, 5%, 10%, 14 %, 20%) refer to the probability of a particular flow event is exceeded in any one year known as the annual change of exceedance (ACE). Therefore, the previous nomenclature of the "100-year flood" is more properly defined as the flood having a 1 percent chance of being exceeded in any one year. Similarly, the 5% ACE flood corresponds to the "20-year" flood, the 2% ACE flood corresponds to the "50-year" flood, and the 0.2% ACE flood corresponds to the "500-year" flood

systems. Only the Corrales levee system was constructed as part of the project. The Bernalillo levee system was not economically justified and has not been re-examined. The Isleta East Unit was not economically justified in 1979, and was re-examined in this study. Changes in Federal levee design criteria, hydrologic modeling and listing of four endangered species have prompted this reevaluation of the study completed in 1979.

This draft GRR/SEIS supplements the 1979 EIS and has been prepared, in part, to evaluate the potential environmental impacts of the alternatives that were considered in the 1979 as well as any new alternatives proposed during the current study. The GRR/SEIS provides for compliance with the National Environmental Policy Act (NEPA) and U.S. Army Corps of Engineers (USACE) procedures for implementing NEPA (Engineer Regulation 200-2-2). It includes an evaluation of the potential environmental impact of the project alternatives, and proposes mitigation measures including avoidance, minimization, and compensation to reduce, where feasible, any significant and/or potentially significant adverse impacts. USACE is the Federal Lead Agency under NEPA. On May 18, 2017, a notice of intent (NOI) to prepare the SEIS for the GRR/SEIS was issued by USACE and published in the Federal Register (FR; Col. 82, No. 95). The original NOI for the SEIS was published in the FR (Vol. 60, No. 227) on November 27, 1995.

1.1.2 Scope of the Reevaluation

The purpose of the GRR/SEIS is to determine:

- Whether the authorized project is implementable.
- Whether the authorized project is still the national economic development (NED) plan.
- What changes, if any, are necessary for feasible implementation of the plan.
- If these changes are within the approval authority delegated to the Division Commander, or USACE's Chief of Engineers, or if they would require additional Congressional authorization as outlined in ER 1105-2-100, as amended.

Preparation of this GRR/SEIS became necessary due to several changes that have occurred since the project was authorized in 1986. These include the following:

- A longer period of record for hydrological data is now available to allow improved and updated hydrological analysis.
- New levee design criteria that address long duration flows were adopted by USACE since 1993. Any proposed plan now must incorporate new design features that prevent seepage through the levee or its foundation due to prolonged flow against the riverward toe.
- USACE has departed from the freeboard methodology formerly used to account for uncertainty and has adopted a probabilistic determination of flood risk as the basis for designing levees.
- Three species occurring within the study area have been listed as threatened or endangered since 1994: the Southwestern Willow Flycatcher, the Western Yellow-billed Cuckoo, and the Rio Grande Silvery Minnow. The study area also includes critical habitat for two of those species.

1.1.2.1 *Report Organization*

The organization and chapter headings in this GRR/SEIS reflect both the plan formulation process and environmental documentation requirements. The headings corresponding to the chapters and sections required by NEPA for inclusion in an Environmental Impact Statement are noted with an asterisk (*). The report is organized to follow the six steps of the USACE planning process. The chapters in the report are briefly summarized below.

This chapter, Project Information, introduces the study by discussing the purpose and need, authority, study area, non-Federal sponsors, and previous investigations covering the Middle Rio Grande study area. The integrated nature of the report is also explained. The second chapter, Need for and Objectives of Action, covers the first step in the planning process (specification of water and related land resources problems and opportunities).

The third chapter, Plan Formulation, covers the third step in the planning process (formulation of alternatives), the fifth step in the planning process (comparison of alternative plans), and the sixth step of the planning process (selection of the recommended plan based upon the comparison of the alternative plans). This chapter provides a detailed description of the final alternative plans, including the no action alternative. The description of the action alternatives includes the purpose and construction details of the various measures, as well as the locations and specific measures included in each of the final alternatives.

The fourth chapter describes the Recommended Plan.

The fifth chapter, Existing and Expected Future Without-Project Conditions, describes the existing resources in the study area, including the physical, biological, cultural and socioeconomic conditions of the project area. The existing and forecasted future conditions without a Federal Flood Risk Management project make up the baseline to which other project alternatives are compared.

The sixth chapter, Future With-Project Conditions, evaluates the effects and significance of the final alternatives on those resources. Avoidance, minimization, and mitigation measures are also proposed to reduce any effects to less than significant. The chapter covers the second and fourth steps of the planning process (inventory, forecast and analysis of water and related land resources in the study area; evaluation of the effects of the alternative plans).

The remaining chapters of the GRR/SEIS include a full discussion of public involvement, review, and consultation (Chapter 7); information on compliance with applicable laws, policies, and plans (Chapter 8); post-authorization changes (Chapter 9); presentation of the recommendations (Chapter 10); a list the recipients of the draft GRR/SEIS (Chapter 11); a list the contributors to and preparers of the report (Chapter 11); references (Chapter 13); and a document index (Chapter 14). Lists of acronyms and abbreviations and regional terms have been included immediately following the Table of Contents on pp. xi - xiii.

1.1.3 Intended Uses of this Document

The GRR/SEIS was prepared to support a Federal recommendation on a potential project to reduce flood risk to the study area, and to disclose potential impacts of the project alternatives. Impacts are determined by projecting the environmental conditions in the future, with and without the project. This document also presents measures that could be implemented to avoid, reduce, and/or compensate for potential impacts to the environment. The GRR/SEIS will be circulated for 45 days for public and agency review and comment. All comments received will be considered and related changes incorporated into the final report, as appropriate. Following public and agency review, this report will be finalized and circulated for a 30-day state and agency review. USACE Headquarters has final authority for review and approval. Once approved, the report will be transmitted to the U.S. Congress for potential project authorization and funding of the Federal share of the project design and construction cost.

This draft and the final GRR/SEIS are identified as "Interim" documents to acknowledge that the proposed GRR/SEIS project will not address all water resource problems within the authorized study area. This terminology signals to Congress that there may be additional Federal interest within the study area for future studies or projects to address water resource needs.

1.2 Project Location, Study Area, and Project Area

Cities, towns and American Indian Tribes located along the Rio Grande, from its headwaters in Colorado to where it enters the Gulf of Mexico in Texas, have a long history of flooding and flood damages. For many years, municipalities and various agencies acknowledged and have studied these flood events. More recently, the listing of area aquatic and terrestrial species as threatened and endangered have resulted in a need for increased focus on the development of flood risk management alternatives that minimize environmental impacts and incorporate environmental features to mitigate any adverse impacts to fish and wildlife communities and habitats. This GRR/SEIS discusses the methods and findings of studies aimed to address the flooding problems and the interrelated environmental considerations. The 1979 study resulted in a feasibility report entitled "Middle Rio Grande Flood Protection, Bernalillo to Belen, New Mexico, Interim Feasibility Report" (1979 Feasibility Report) which documented the flooding problems along the Middle Rio Grande between Bernalillo and Belen.

1.2.1 Project Area

The study area of the current GRR/SEIS investigation includes five study units (Mountain View, Isleta East, Isleta West, Belen East, and Belen West) located in Bernalillo and Valencia Counties, NM. The area extends approximately 20 river miles from Albuquerque's South Diversion Channel on the east bank of the Rio Grande, and from the US Interstate 25 (I-25) bridge on the west bank, to immediately south of the railroad bridge south of Belen (Figure 1). The study area encompasses approximately 110 square miles of drainage area and includes one Pueblo and multiple small rural communities on both sides of the Rio Grande between Albuquerque and Belen. The communities of, Los Lentes, Los Lunas, Los Chavewhiz, Belen, Bacaville, Jarales and Pueblitos are located along the west bank of the Rio Grande. The communities of Mountain View, Bosque Farms, Peralta, Valencia, Tome, Adelino, La Constancia and Madrone are located along the east bank. The Isleta Pueblo straddles the Rio Grande in the northern third of the study area. The Pueblo was established in the 1300s and is one of the largest of the nineteen Pueblos within New Mexico that are federally recognized tribal entities.

The Mountain View Unit is mainly suburban with some industrial and small businesses. Agriculture fields of alfalfa or hay and small farms still remain along the existing levees. The Isleta West and Isleta East Units are entirely within Isleta Pueblo, and are almost completely rural with housing generally scattered throughout. Isleta Village is the main residential area, and a few businesses are found along the major paved roads. The Belen East and West Levee Units have substantial municipalities along both banks of the Rio Grande with the remainder of the floodplain consisting of agricultural fields of mainly alfalfa or hay, scattered housing developments, small farms and businesses.

Valencia County, NM had a population of 66,152 as of the 2000 Census. Most local businesses are located in, and 25 per cent of the population lives within the 1% ACE event (100-year storm) floodplain (Figure 2). Bernalillo County had 662,555 people as of the 2000 Census with most of the population in the City of Albuquerque. A smaller proportion of Bernalillo County residents live in the floodplains of the study area.

1.3 Study Sponsors and Participants

In the letter to the CE-SPA District Engineer, Lt. Colonel Lloyd Wagner, dated 3 December 1997, the Middle Rio Grande Conservancy District (MRGCD) requested that USACE undertake a post-authorization study for the Middle Rio Grande Flood Control Project. MRGCD indicated that they were aware of the cost-sharing requirements as described in Water Resources Development Act of 1996 (WRDA 1996) (50% Federal / 50% non-Federal sponsor cost sharing) and that, should it be determined that a project is economically feasible, environmentally sound and within their financial capabilities, the MRGCD would act as the local sponsor.

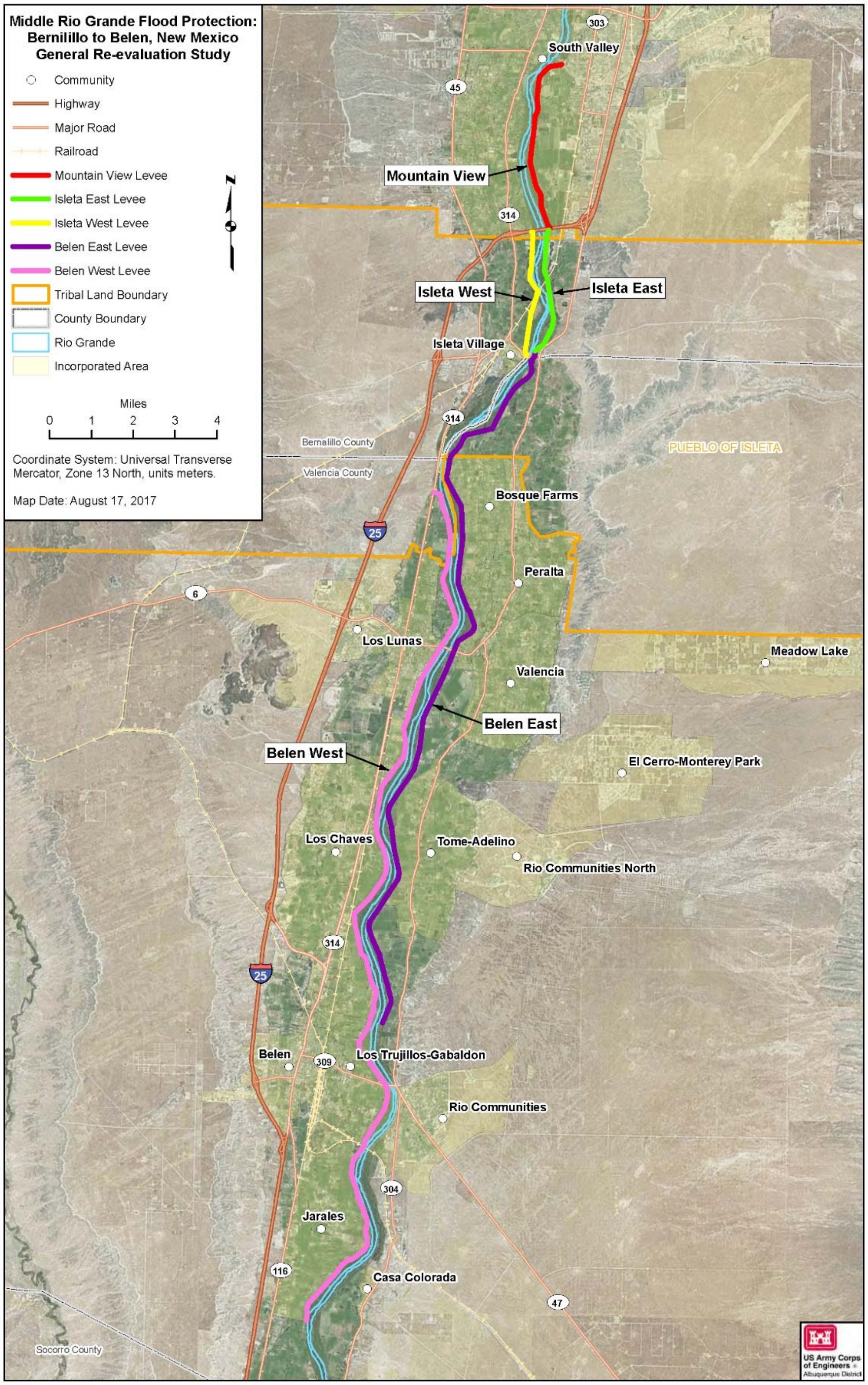


Figure 1 Study Area Map.

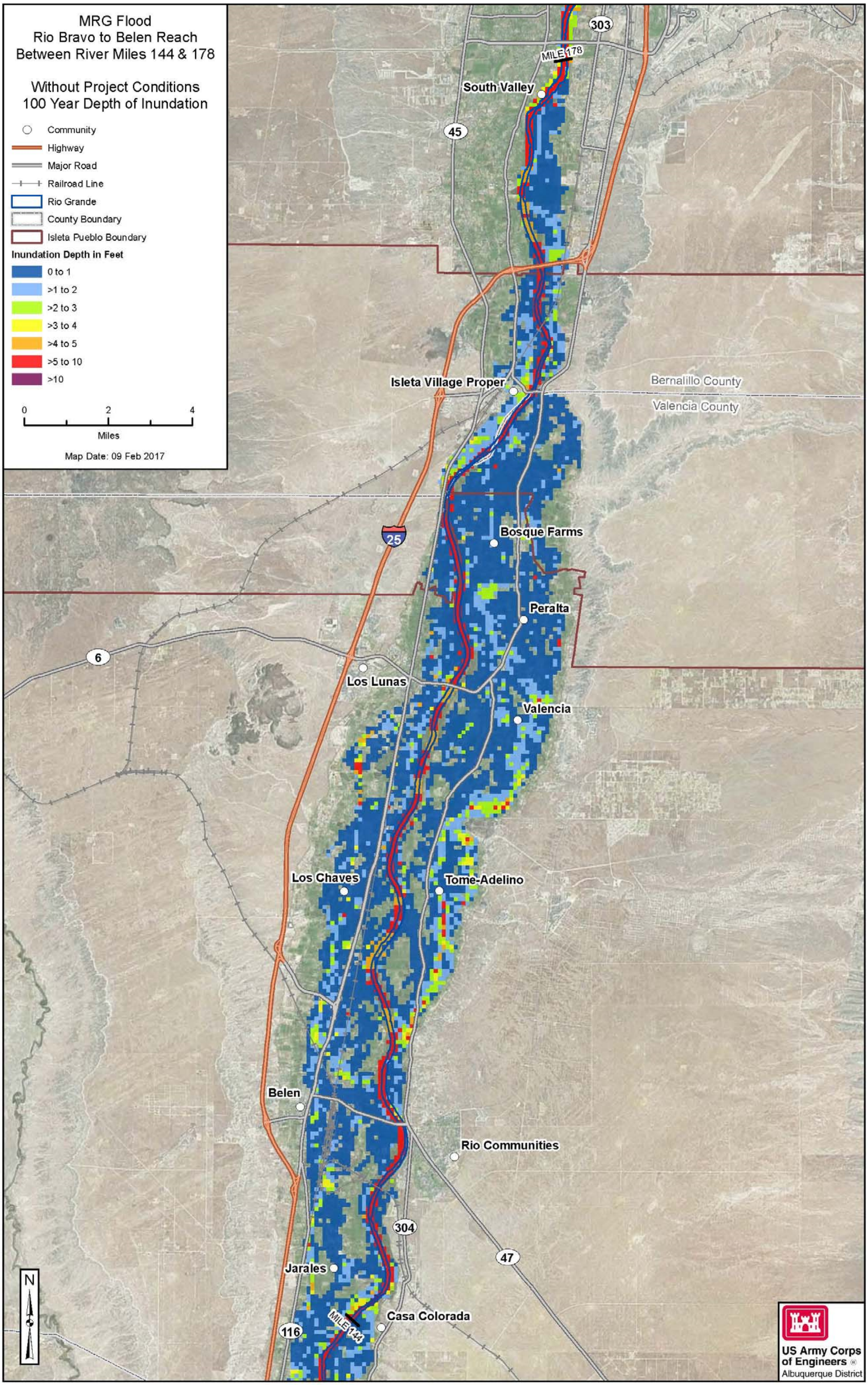


Figure 2 Present Conditions 1% ACE event floodplain

1.4 Authority

This GRR/SEIS has been prepared consistent with the following authorities for the Middle Rio Grande Bernalillo to Belen Flood Protection Bernalillo to Belen, New Mexico, project as provided by Congress:

Flood Control Act of 1941, Section 4 (Public Law (P.L.) 228, 77th Congress, 1st Session, H.R. 4911) which reads in part:

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

Construction of flood control features was authorized by the Flood Control Act of 1948 (Public Law 80-858, Section 203), in accordance with the recommendation of the Chief of Engineers, as found in House Document No. 243, 81st Congress, 1st Session, dated 5 April 1948, which reads as follows:

> *The comprehensive plan for the Rio Grande Basin as set forth in the report of the Chief of Engineers, dated April 5, 1948, and in the report of the Bureau of Reclamation, dated November 21, 1947, all in substantial accord with the agreement approved by the Secretary of the Army and the Acting Secretary of the Interior on November 21, 1947, is hereby approved except insofar as the recommendations in those reports are inconsistent with the provisions of this Act and subject to the authorizations and limitations set forth herein.*

Water Resources Development Act of 1986 Section 401 (P.L. 662, 99th Congress, November 17, 1986) which reads in part:

> *Authorization of Construction.--The following works of improvement for the control of destructive floodwaters are adopted and authorized to be prosecuted by the Secretary (of the Army) substantially in accordance with the plans and subject to the conditions recommended in the respective reports designated in this subsection, except as otherwise provided in this subsection: Middle Rio Grande, New Mexico.*
>
> *The project for flood control, Middle Rio Grande Flood Protection, Bernalillo to Belen, New Mexico: Report of the Chief of Engineers, dated June 23, 1981, at a total cost of $44,900.00, with an estimated first Federal cost of $33,700.00 and an estimated first non-Federal cost of $11,200.00. The Secretary is authorized also to increase flood protection through the dredging of the bed of the Rio Grande in the vicinity of Albuquerque, New Mexico, to an elevation lower than existed on the date of enactment of this Act. The project shall include the establishment of 75 acres of wetlands for fish and wildlife habitat and the acquisition of 200 acres of land for mitigation of fish and wildlife losses, as recommended by the District Engineer, Albuquerque District, in his report date June 13, 1979.*

A 3.2 mile levee system on the west bank at Corrales, NM was constructed as authorized. Changes in levee construction criteria, hydrologic considerations, listing of endangered species and non-federal sponsor capabilities have prompted a reevaluation of the project, as authorized, before any of the other levee systems were constructed.

1.4.1 Previous document

The project as detailed in the 1979 Feasibility Report included seven study units (Bernalillo, Corrales, Mountain View, Isleta East and West, and Belen East and West) as illustrated in Figure 3, below. By letter dated December 3, 1997, MRGCD requested that the USACE Albuquerque District conduct a new study to include the Mountain View and Isleta Units as originally authorized. The District included both Isleta West and Isleta East units in the analysis.

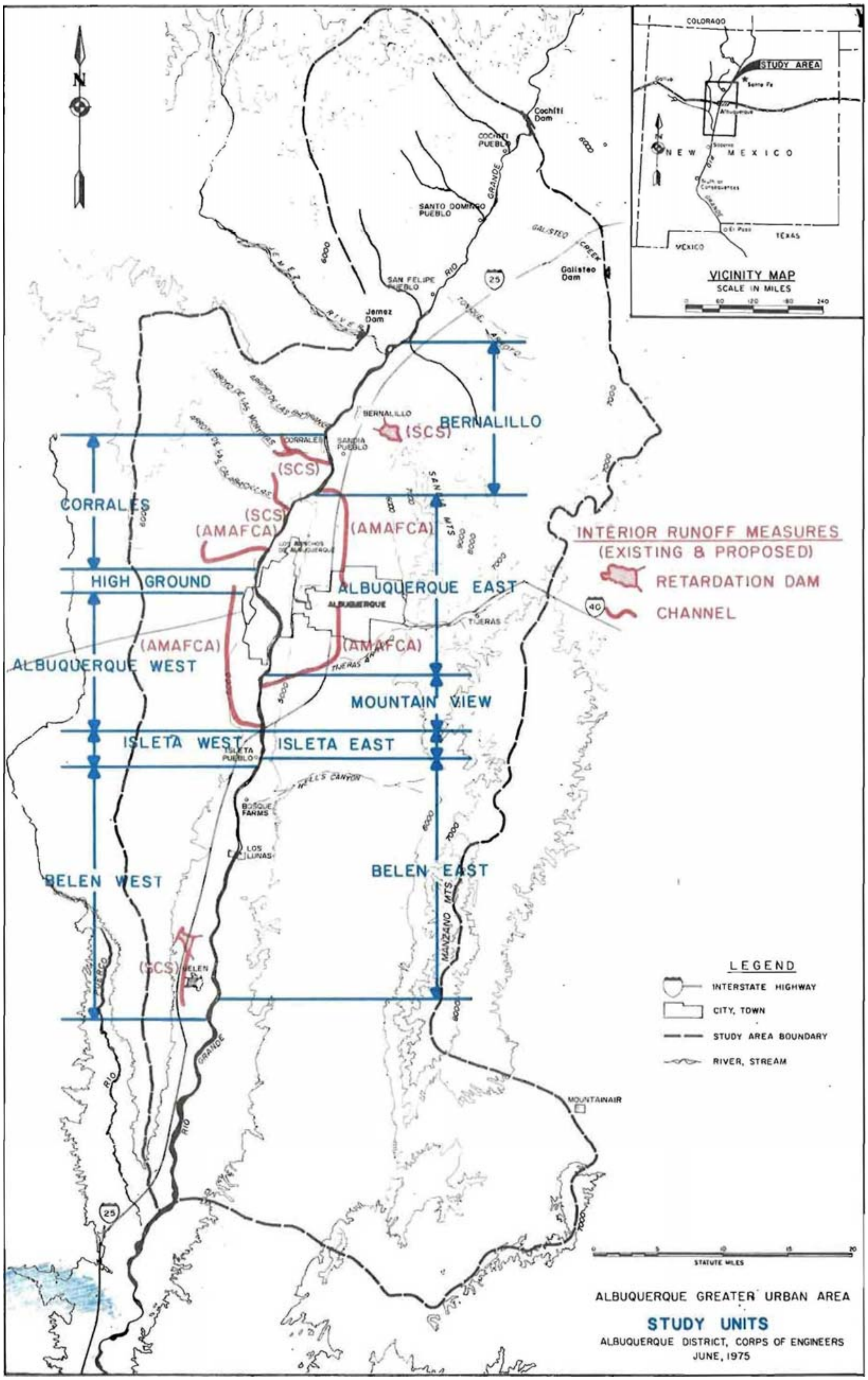


Figure 3 Map of the original 1979 Bernalillo to Belen Study Units.

1.5 Existing Programs, Studies, and Projects

Many studies and projects have been initiated in response to a series of Congressional actions within the Rio Grande Basin and particularly within the GRR/SEIS study area.

1.5.1 Existing Programs

1.5.1.1 *Middle Rio Grande Endangered Species Collaborative Program*

Through the Middle Rio Grande Endangered Species Collaborative Program, several signatories have completed construction of habitat restoration sites for endangered species in the Middle Rio Grande project area. Post-construction monitoring and studies ensure that these sites are functioning as designed.

1.5.1.2 *Rio Grande Environmental Management Program (RGEMP)*

The RGEMP was authorized by Section 5056 of the 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.

The first feasibility study under the program is currently being conducted by USACE in the Middle Rio Grande area from the Pueblo of Sandia just north of Albuquerque, downstream to the Pueblo of Isleta, just to the south of Albuquerque.

1.5.2 Existing Projects

1.5.2.1 *Cochiti Dam and Reservoir*

The Flood Control Act of 1960 authorized the construction of Cochiti Dam for flood and sediment control on the mainstem of the Rio Grande. Cochiti Dam is located in Sandoval County, about 50 river miles above Albuquerque, NM and on lands owned primarily by Cochiti Pueblo, a federally recognized American Indian tribe. Cochiti Dam is within the Cochiti Pueblo's territorial jurisdiction, with parts of the reservoir in Sandoval, Santa Fe and Los Alamos Counties. Cochiti Lake is about 20 miles long at maximum flood risk management pool. The permanent pool extends about 6.5 miles upstream from the dam and has a surface area of 1,200 acres. Construction on the dam began in 1965 and water storage began in 1973. The earthen fill dam is approximately 250 feet high and 5 ½ miles wide.

Cochiti Dam is an integral element of the system of Middle Rio Grande multipurpose dams. Cochiti Dam contributes to that system by: (1) regulating damaging flood flows; (2) retaining sediment; and (3) developing opportunities for the conservation and development of fish and wildlife resources within the Cochiti recreation pool; and (4) for recreation with water acquired from the Colorado River system via the U.S. Bureau of Reclamation’s (Reclamation) San Juan-Chama Diversion Project. Cochiti Lake flood risk management operations are primarily focused on the Middle Rio Grande Valley, controlling flows between Cochiti Lake and Elephant Butte Reservoir to the maximum channel capacity. Reservoir regulation for flood risk management is coordinated with the regulation of Abiquiu and Jemez Canyon Dams along with the uncontrolled release from Galisteo Dam. Cochiti Dam provides the only flood risk management reservoir for snowmelt runoff regulation on the mainstem of the Rio Grande.

1.5.2.2 *Galisteo Dam and Reservoir*

Galisteo Dam and Reservoir was authorized by the Flood Control Act of 1960. It is located on Galisteo Creek about 12 miles upstream of its confluence with the Rio Grande. The dam controls a drainage area of 596 square miles and reduces all floods originating in this watershed from a standard project magnitude to a non-damaging release of 5,000 cubic feet per second (cfs). Sediment deposition in the reservoir aids in reducing aggradation in the Rio Grande.

The dam is an earthen fill embankment 2,820 feet long with a maximum height of 158 feet. The outlet is an uncontrolled 10-foot diameter conduit 810 feet in length. There is no permanent pool maintained at Galisteo Dam and Reservoir.

1.5.2.3 *Jemez Canyon Dam*

Jemez Canyon Dam and Reservoir is located on the Jemez River, a tributary of the Rio Grande, 2.8 miles upstream of its confluence with the Rio Grande. The dam was the first project in the basin constructed under authority granted by the Flood Control Act of 1948. It was completed and placed in operation in 1953 and was initially operated as a ‘dry’ dam. The drainage area above the dam is about 1,034 square miles. The dam is situated in Sandoval County, about 5 miles northwest of Bernalillo and about 22 miles north of Albuquerque. The dam is a rolled earthen fill structure approximately 150 feet high and 870 feet wide. The project is located entirely on lands of the Pueblo of Santa Ana.

The purpose of the project is to provide flood and sediment control on the Rio Grande. The present storage capacity of Jemez Canyon Reservoir at spillway crest is 100,485 acre feet (June 1991 resurvey, adopted January 1992), of which 73,000 acre feet is reserved for flood risk management and 27,485 acre feet for deposition of sediment. An earthen fill levee about 2,900 feet long prevents backwater from inundating the old Santa Ana Pueblo near the upstream end of the reservoir area.

The initial operation for sediment retention was to hold a pool equivalent in volume to the daily inflow when the flow was 40 cfs or greater. This procedure did not prove effective in depositing or retaining sediment. Subsequent low flow reworked the sediment deposited and transported the material downstream when the reservoir was empty. Also, the pool was of insufficient size so that deposition occurred in the intake structure and against the gates causing them to be very difficult to operate. The State of New Mexico purchased San Juan-Chama Project water in 1979 to establish a 2,000 acre-foot sediment retention pool at Jemez Canyon Reservoir. In January 1986 the sediment pool was expanded to include the entire unused capacity of the sediment space to further improve the trap efficiency of the pool. Evaporation losses on the sediment pool were replaced annually with San Juan-Chama Project water. This pool improved sediment retention and resulted in less deposition at the gates.

At the end of 2000, the storage agreement between USACE and New Mexico Interstate Stream Commission (NMISC) expired. Subsequently, the pool was evacuated in 2001 and Jemez Canyon Dam is again being operated as a ‘dry’ dam with flood storage retention only. The two gates are set to a three-foot opening. There is normally no pool within the reservoir and little restriction to normal flow passing through the gates except for infrequent high peak events.

1.5.2.4 *Albuquerque North and South Diversion Channels*

The Albuquerque Diversion Channels Project was authorized for construction by the Flood Control Act of 1954. The purpose of the project is to provide flood risk management for the lowlands of the City of Albuquerque and vicinity by intercepting the runoff from the arroyos which drain the mesa and western slopes of the Sandia and Manzano Mountains located east of the project.

The North Diversion Channel is a concrete-lined channel throughout its entire length except for a short reach of leveed channel at the downstream end where it enters the Rio Grande. The design capacity of the channel varies from 5,100 cfs at the upstream end to 44,000 cfs at the downstream end. The project was of such large scope that it was divided into three phases for contractual and rights-of-way purposes. The North Diversion Dam was turned over to the local sponsor, the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), on 14 February 1969.

The South Diversion Channel is approximately 6.5 miles in length and is concrete lined towards the end of the project near its outlet to the Rio Grande; the remainder of the channel is lined with riprap.

1.5.2.5 *Middle Rio Grande Flood Protection, Albuquerque Levees*

USACE designed and constructed the Albuquerque Levees along the Rio Grande in the vicinity of Albuquerque, New Mexico, in the mid-1950s to provide protection against a flood peak of 42,000 cubic feet per second (cfs), with three feet of freeboard above the design water surface elevation. At the time, 42,000 cfs was considered the “Standard Project Flood” (“SPF”), with the probabilistic recurrence interval of 270 years (0.37% -chance). This design consideration preceded the construction of Cochiti Dam in the late 1960s. The east-bank levee is 18.8 miles long and extends from the southern boundary of Sandia Pueblo at the northern end to the confluence with Albuquerque’s South Diversion Channel outfall at the southern terminus. The west-bank levee is 8.2 miles long and extends from the Arenal Canal Heading (3,300 feet upstream of Central Avenue), south to a location approximately 6,400 feet downstream of the South Diversion Channel outfall.

1.5.2.6 *Middle Rio Grande Flood Protection, Corrales Unit*

The designation of the Corrales Unit as a separable element assisted in the orderly construction of the overall Middle Rio Grande Flood Protection project. This also met MRGCD’s priorities for construction sequence, and was feasible considering their budget capability.

Based on evaluations conducted in the mid-90s, the spoil banks had no positive seepage control features in the embankment or the foundation and tended to experience piping and severe backslide sloughing at flows corresponding to the annual flow event. During controlled releases from upstream reservoirs, the spoil banks have to be physically patrolled for damage, and require frequent repair. The spoil banks are subject to failure from very small and frequent flood events. Construction on the Corrales Levee was completed in 1997 and the project was transferred to the sponsor.

1.5.2.7 *Albuquerque West Levee*

Similar to the Corrales Unit, the construction of the Albuquerque West Levee as a separable unit was determined to be in the best interest of both Albuquerque's South Valley area property owners, as well as the MRGCD.

The Albuquerque West Levee is 3.2 miles in length and is located along the west side of the Rio Grande from the end of the Albuquerque Levees Phase III West levee, approximately 2.5 miles south of Rio Bravo BLVD SW and goes south to tie-in at the West I-25 roadway abutment. The purpose of this project was to provide storm water protection and to prevent loss of water delivery in accordance with Rio Grande Compact. This replaces a spoil bank constructed by the MRGCD in the 1960s as part of channelization work conducted by Reclamation. The current engineered levees project consists of engineering, designing, and construction of three miles of engineered levee as a reimbursable project under the Central New Mexico, Section 593 Program. Construction started in December 2008, and was completed in late 2013.

1.5.3 Studies

1.5.3.1 *Middle Rio Grande Biological Survey, Hink and Ohmart, 1984.*

The Biological Survey conducted by Hink and Ohmart is the seminal work for the middle reach of the Rio Grande. The report documents the type and status of vegetation and wildlife communities and sets out recommendations for conservation, restoration and further research.

1.5.3.2 *Middle Rio Grande Flow Frequency Study, Hydrologic Engineering Center (USACE 2006).*

The purpose of the Flow Frequency Study was to develop a flow frequency curve for the Rio Grande at Albuquerque. Peak flows at Albuquerque are caused by snowmelt and rainfall upstream of reservoirs on the Rio Grande and major tributaries, as well as from intense rainfall on areas downstream of the reservoirs. Separate flow frequency curves were developed for the snowmelt and rainfall runoff mechanisms, regulated flow from the reservoirs, and runoff from local areas downstream of the reservoirs. These separate flow frequency curves were then combined to form one flow frequency curve at Albuquerque.

1.6 Environmental Regulatory Framework

NEPA provides an interdisciplinary framework for Federal agencies to develop information that will help them to take environmental factors into account in their decision-making (42 USC Section 4321, 40 CFR Section 1500.1). NEPA requires the preparation of an EIS whenever a proposed major Federal action would result in significant effects on the quality of the natural and human environment. A "cooperating agency" is defined in NEPA regulations as any Federal agency, other than a lead agency, that has jurisdiction by law or special expertise with respect to any environmental impact involved in a proposed project or project alternative. A State or local agency of similar qualifications or, when the effects are on lands of tribal interest, a Native American tribe, may, by agreement with the lead agencies, also become a cooperating agency (40 CFR 1508.5). For the GRR/SEIS, MRGCD is a cooperating agency under NEPA.

2. NEED FOR AND OBJECTIVES OF ACTION*

2.1 Problems and Opportunities

2.1.1 Flooding

Severe floods in the study area include those occurring during: 1828, 1851, 1865, 1874, 1886, 1903, 1905, 1911, 1920, 1928, 1929, 1935, 1941 and 1942. Between 1940 and 2017 there have been thirteen years with flows above 7,000 cfs at the Albuquerque Gage. Five of these years occur following construction of Cochiti Dam. Most flooding resulted from heavy spring runoff caused by either especially heavy winter snows or snowpack melting quickly after warm spring rains. Other flood events were the results of large storms within the Rio Grande and tributary watersheds during the summer and fall.

In 1889, streamflow gaging began and subsequent flood events could more accurately be measured. Historic flood events included: 1903 (18,900 cfs), 1904 (33,000 cfs), 1920 (22,500 cfs), 1929 (24,000 cfs), 1935 (15,000 cfs), 1941 (24,600 cfs) and 1942 (18,400 cfs).

The 1929 event flooded much of the low lying land outside the banks of the Rio Grande within the study area and prompted construction of projects to reduce flood risk over the next decade. From 1930 to 1935, the MRGCD constructed 190 miles of spoil banks (non-engineered levees) in the Middle Rio Grande Valley. The spoil banks were constructed using material excavated from earthen channels and then side-cast, or “spoiled,” on the river-side of the excavated channel. The excavated channels served to drain irrigation water from agricultural fields on the landward side. Spoil banks provided negligible protection against future floods from the Rio Grande. The spoil banks from Bernalillo to San Acacia date from this time.

In the years that the spoil banks have been in place, sediment has deposited on the floodplain contained between the spoil banks on each side of the Rio Grande, but not on the floodplain on the landward sides of the spoil banks. Because sediment deposition has been contained between the spoil banks on both sides of the river, the floodway has become elevated above the surrounding floodplain. At the same time, a large share of the floodplain outside the spoil banks has transitioned from agricultural to municipal, industrial and residential use, such that now spoil bank failure during a flood would result in considerable non-agricultural damages and pose a significant life-safety hazard. Damage to adjacent irrigation infrastructure may occur at river flow greater than 4000 cfs.

Observations of the performance of the existing spoil bank system during a higher flow dam release (Section 5.1.3.4), as well as the results of numerical modeling of spoil bank seepage and stability (Appendix F, Section 4.1), indicate that the existing spoil bank system may temporarily provide flood mitigation for short duration flow events. Note that even the limited degree of flood risk management provided by the spoil banks is dependent on continuous monitoring, maintenance and repair to maintain the integrity of the spoil bank system.

There are three potential sources of Rio Grande flooding in the semi-urban project area downstream of Albuquerque. They are:

1. Flood events in the regulated area upstream of Albuquerque, as identified in the 2006 HEC report;

2. Rainfall-runoff flood events in the unregulated area upstream of Albuquerque, as identified in the 2006 HEC report;

3. Rainfall-runoff flood events from the project area, downstream of Albuquerque. A single inflow to the Rio Grande, the South Diversion Channel (SDC) outfall south of Albuquerque, currently provides the only potential for significant local inflow between the Rio Grande at Albuquerque, NM USGS gage (Albuquerque gage), located at the Central Avenue bridge over the Rio Grande in Albuquerque and the downstream end of the project area under existing conditions.

2.1.2 Opportunities

Opportunities exist to reduce the risk of damages caused by floods to structures and infrastructure within the floodplain of the Rio Grande within the study area. Increasing the safe channel capacity would also provide ecosystem benefits such as fluvial scouring and deposition.

2.2 Objectives and Constraints

2.2.1 Federal Objectives

The Federal objectives of water and related land resources project planning are to contribute to national economic development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders and other Federal planning requirements.

Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the Nation. Contributions to NED include increases in the net value of those goods and services that are marketed and also of those that may not be marketed.

The plan that is formulated consistent with these objectives is identified as the NED plan. Only the NED plan can be recommended for Federal action unless the Secretary of a department or head of an independent agency grants an exception to this rule. Exceptions may be made when there are overriding reasons for recommending another plan, based on other Federal, state, local and international concerns.

Ecosystem restoration is also one of the primary missions of the USACE Civil Works Program. The USACE objective is to contribute to national ecosystem restoration (NER) through increasing the net quality and/or quantity of desired ecosystem resources. NER measurements are based upon changes in ecological resource quality as a function of improvement in habitat quality or quantity, and expressed quantitatively in physical units or indices (not monetary units).

The 1979 study recommended the creation of 75 acres of wetlands for borrow areas and the acquisition of 200 acres for fish and wildlife mitigation. This was due to the fact that the 1979 proposed plan would have raised the existing spoil banks to an elevation sufficient to contain 42,000 cfs for flood risk management. At the time, this was considered similar with the original, current protection provided Albuquerque. More recent USACE policies, procedures and hydrologic studies within the Rio Grande valley indicate that the current engineering project may require the use of borrow and associated mitigation measures. If plan formulation of alternatives and preliminary civil design indicates the need for excavation of borrow areas, wetlands and riparian restoration acres will be included in the project mitigation plan.

2.2.2 Non-Federal Objectives

The project sponsor is MRGCD. Their objectives are:

- Reduce flood risk to developed areas between Albuquerque and Belen.
- Reduce damages to agricultural infrastructure from high flow events.
- Reduce cost of continual maintenance and repair of the existing spoil bank system.

2.2.3 Planning Objectives

Clear statements of specific planning objectives and constraints act as basic building blocks for developing alternative management measures and plans to alleviate stated problems and achieve opportunities. Through coordination with local and regional agencies, the public involvement process, site assessments, interpretation of prior studies and reports and review of existing water projects, specific planning objectives were identified for this feasibility effort. The water and related land resource problems and opportunities identified in this study are stated as specific planning objectives to provide focus for the formulation of alternatives. The planning objectives listed below reflect the problems and opportunities and represent desired positive changes along the Middle Rio Grande within the study area:

- Reduce the expected annual damages in the study area throughout the expected 50 year life of the project.
- Reduce the risk to human safety in the study area throughout the expected 50 year life of the project.

2.2.4 Planning Constraints

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that should not be violated. The planning constraints identified in the 1979 Feasibility Report and considered in this GRR/SEIS are as follows:

Completion of Section 106 Compliance – Identification, evaluation, and mitigation of adverse effects to national register eligible historic properties and traditional cultural properties (TCPs). Alternatives must include resolutions reached between consulting parties prior to construction.

Endangered species – The US Fish and Wildlife Service (USFWS) has designated stretches of the Rio Grande upstream and downstream of Isleta as critical habitat for the endangered Southwestern Willow Flycatcher and Rio Grande silvery minnow. Critical habitat for the Yellow-billed Cuckoo has not been designated at this time. The recommended alternative must minimize impact to these species and their habitat.

3. PLAN FORMULATION*

This chapter presents the results of the plan formulation process used in the development of alternatives to address the planning objectives for the project. It also describes the analysis used to arrive at the final set of alternatives as well as the decision-making process that led to the selection of a recommended plan. Alternative plan development includes identification of reasonable solutions to address the identified problems and an initial screening to eliminate inefficient and ineffective solutions. These solutions include operational changes or project features (called “measures”) that in varying combinations form the components of the alternative plans.

ER 1105-2-100, *Planning Guidance Notebook* dated 22 April 2000, as amended, provides the planning process used by the Project Delivery Team (PDT) in this feasibility study. The process identifies and responds to problems and opportunities associated with the study objectives and specific Federal, state and local concerns. USACE planning involves a systematic approach to making determinations during the feasibility study so that the interested public and decision-makers are fully aware of the basic assumptions employed. The data and information analyzed, the areas of risk and uncertainty, the reasons and rationales used and the significant implications of each alternative plan are exposed through this process. The planning process culminates in the selection of a recommended plan. This 6-step process is further described in Section 3.2.1.

The final product of the general reevaluation study is this GRR/SEIS. The GRR/SEIS serves as the basis for obtaining Congressional authorization of detailed design and construction of the recommended plan.

The requirements identified in this report may change slightly as project features are further refined during the Pre-construction Engineering and Design (PED) phase of the project. The project features, including actual lands required and estates to be acquired in those lands, may change after approval of the GRR/SEIS. As project features are further refined in subsequent implementation efforts, USACE will review the site determinations for the various project features set out in the report in accordance with established policies. This review may result in changes in design or land requirements for specific project features, while maintaining the overall benefit levels presented in the recommended plan. If there are substantive changes in the recommended plan and/or the requirements of this project based on more detailed analysis, then USACE will prepare necessary documentation.

3.1 Flood Risk Management Measures

The PDT and sponsor conducted a preliminary screening of management measures to evaluate the applicability of each measure for each reach and the potential for each measure to contribute to the planning objectives consistent with planning constraints. Flood risk management measures included those evaluated in the 1979 EIS. The results of these activities are summarized below.

3.1.1 Non-Structural Measures

Implementation of non-structural alternatives to reduce flood risk to existing economic improvements within the study area was considered, and included the following measures:

- Dry Flood Proofing – measures applied to a structure, or adjacent to a structure, to prevent entrance of flood waters.
- Wet Flood Proofing – measures applied to a structure and / or its contents that prevent flooding, or damage from flooding, by allowing flood water to enter the structure.
- Elevation – placing structures above flood waters via fill, extended foundation walls, piers, posts or piles.
- Relocation – moving structures out of harm's way.
- Floodwalls – gravity, cantilever, cellular, flat dam, buttress and counterfort designs to keep flood water from reaching the structure.
- Flood warning systems
- Evacuation plans

3.1.2 Structural Measures

Implementation of structural alternatives to reduce flood risk to existing economic improvements within the study area was considered, and included the following measures:

- Engineering and construction of levees.
- Detention dams on tributaries entering the Rio Grande downstream of Cochiti Reservoir.
- Excavation of the Rio Grande Channel to improve conveyance capacity.
- Placement of jetty jacks to slow velocities and trap sediment outside the active river channel.

3.2 Formulation and Evaluation of Initial Flood Risk Management Alternative Plans

3.2.1 Formulation Strategy

The plan formulation process was used to develop measures and elements used in solving identified problems and ultimately to develop an array of comprehensive alternatives from which a plan is recommended for implementation.

This section presents the rationale for the development of a recommended plan. It describes USACE's iterative six-step planning process used to develop, evaluate, and compare the array of management measures and preliminary alternatives that have been considered. The six steps used in the plan formulation process include:

1. The specific problems and opportunities to be addressed in the study are identified, and the causes of the problems are discussed and documented. Planning goals are set, objectives are established, and constraints are identified. This has been accomplished for the current study stage.

2. Existing and future without-project conditions are identified, analyzed, and forecast for a 50-Year Period of Analysis. The existing condition resources, problems, and opportunities critical to plan formulation, impact assessment, and evaluation are characterized and documented. This has been accomplished for the current study stage. A forecast of conditions that will exist for a 50-year period of analysis without a Federal project was used as the baseline.

3. Alternative plans are formulated that address the planning objectives. An initial set of alternatives are developed and evaluated at a preliminary level of detail, and are subsequently screened into a more final array of alternatives. A public involvement program was used to obtain public input to the alternative identification and evaluation process. Each plan is evaluated for its costs, potential effects, and benefits, and is compared with the No Action Alternative for the 50-year period of analysis. This step has been completed for this study.

4. Alternative project plans are evaluated for their potential to meet specified objectives and constraints, effectiveness, efficiency, completeness, and acceptability. The impacts of alternative plans are evaluated using the system of accounts framework (National Economic Development [NED], Environmental Quality [EQ], Regional Economic Development [RED], and Other Social Effects [OSE]) specified in the *Principles and Guidelines* adopted by the Water Resources Council, and ER 1105-2-100. This has taken place for the final array of alternatives and recommended plan during this phase of study.

5. Alternative plans are compared with one another and with the No Action Alternative. Results of analyses are presented (e.g., benefits and costs, potential environmental effects, trade-offs, risks and uncertainties) to prioritize and rank flood risk management alternatives. For the current study thus far, benefits and costs have been evaluated for the final array of alternatives, and a rationale is provided to justify selection of a recommended plan.

6. A plan is selected for recommendation, and related responsibilities and cost allocations are identified for project approval and implementation.

3.2.2 No Action Alternative

A “No Action Alternative” is required pursuant to NEPA. For the purposes of this GRR/SEIS, it is identified as the No Action Alternative, and is synonymous with the “without-project condition.” The No Action Alternative considers the likely future conditions in the project area in the absence of the Federally cost-shared and locally supported project. The No Action Alternative does nothing to alleviate risks to public health and safety. Under this alternative, there are neither changes to the existing non-engineered spoil banks nor the environment in and around the existing spoil banks. Catastrophic failures in the spoil banks may occur, but MRGCD will continue performing spoil bank maintenance and repair. The existing spoil banks will continue to provide minimal protection from flood events, but no additional flood risk management or reduction would be provided under the No Action Alternative. Without modification to the existing system, the study area would continue to be at risk during a flood, beginning with a very low flood event, and the affected community would be faced with continued economic development concerns.

3.3 Initial Alternatives Analysis

The flood risk management measures listed in Section 4.1 were analyzed to determine which would be carried forward for inclusion in a focused array of alternatives. Measures presented in the 1979 EIS are discussed briefly but detailed descriptions and the rationale for elimination of these measures can be found in that document.

3.3.1 Non-Structural Measures

The key characteristic of a non-structural approach is that it modifies susceptibility to flooding, as opposed to simply attempting to manage flood risk through structural methods such as dams, levees and channels. However, non-structural approaches may include use of some structural elements. Emergency preparedness plans or flood forecast and warning systems are examples of non-structural flood risk management measures that can be implemented. Having a comprehensive emergency preparedness plan or a flood forecast and warning system in place can help avoid confusion, prevent property damage and decrease risks to human health and safety.

Non-structural alternatives can also involve construction; although they are usually limited to the property being protected (i.e., floodproofing) or can be accomplished through an institutional change. Examples of floodproofing measures include coating the walls of flood prone structures with waterproof membranes, elevating the structures on their foundations above anticipated flood elevations or removing flood prone structures from the floodplain entirely.

Specific measures considered for this study include: floodproofing, raising structures, permanent evacuation within the floodplain, floodplain management, and flood forecasting/temporary evacuation. With respect to communities in the study area, the feasibility of implementing various floodproofing measures is based upon a number of factors such as the relative height of the anticipated water level at the structure and the type of construction for those structures.

3.3.1.1 *Emergency Preparedness*

Having an evacuation plan in place before a flood occurs can help avoid confusion, prevent property damage, and decrease the risks to human health and safety. The Bernalillo and Valencia County governments, as well as local communities are being encouraged to prepare flood response plans for the event of flooding. Response plans would encompass government buildings, community centers, education facilities and housing areas. The flood response plans would also include identifying critical equipment, records and supplies prior to the onset of a flood in order to aid the recovery of operations. They should further include specific flood fighting and evacuation plans to enhance the likelihood of success. Implementing these emergency operations is usually the responsibility of management, the homeowner, agency heads, elected officials or other persons with the authority to implement such plans.

3.3.1.2 *Flood Forecast and Warning System*

Important elements in the Nation's program to reduce flood damages include flood warning systems. Timely warnings can save lives and aid disaster preparedness, which has been shown to decrease property damage by an estimated $1 billion annually. A flood warning and preparedness system is often the most cost effective flood mitigation measure. It is comprised of computer hardware, software, technical activities and/or organizational arrangements aimed at decreasing flood hazards. Advanced warning is not generally effective in reducing structural damages outside of sandbagging efforts that require days to implement. The primary benefits of such a system are that they can allow for early evacuation of residents and reduction in damages to vehicles and structure contents. Advanced warning systems are generally not effective in preventing damage or allowing for evacuation in fast moving events such as flash floods, typical in cases of summer “monsoon” storms, or in the event of a dam breach.

Residential contents represent half the residential flood damages. It is assumed that an effective and understood flood warning system would allow residents to protect structure contents. Removing damageable items from the dwelling or raising them above flood stage would decrease estimated damages by some amount. The high residual damages to properties and to other infrastructure (roads, agriculture, utilities, public and commercial properties) suggests that a flood warning system is ineffective and incomplete as a stand-alone alternative.

3.3.1.3 *Wet Floodproofing*

Wet floodproofing can be defined as “permanent or contingent measures applied to a structure and / or its contents that prevent or provide resistance to damage from flooding by allowing flood water to enter the structure.” (FEMA 1993) Generally, this is limited to structures with living spaces above flood stage and crawlspaces, basements, and underground garages that would not sustain damages if flooded. These measures may require the structure be adequately anchored to its foundation, alteration of a structure’s design and construction, use of flood-resistant materials, adjustment of building operation and maintenance procedures, and the relocation and treatment of equipment and contents.

Wet floodproofing, in most cases, will require some human intervention when a flood is imminent. It is therefore extremely important that there be adequate time to execute such actions. This measure also requires some degree of periodic maintenance and inspection to ensure that all components will operate properly under flood conditions. These necessary inspections and maintenance activities must be described in an inspection and maintenance plan to ensure appropriate implementation.

3.3.1.4 *Dry Floodproofing*

A dry flood proofed structure is made watertight below the level that needs flood protection to prevent floodwaters from entering (Figure 4; FEMA 2007). Making the structure watertight requires sealing the walls with waterproof coatings, impermeable membranes, or a supplemental layer of masonry or concrete.

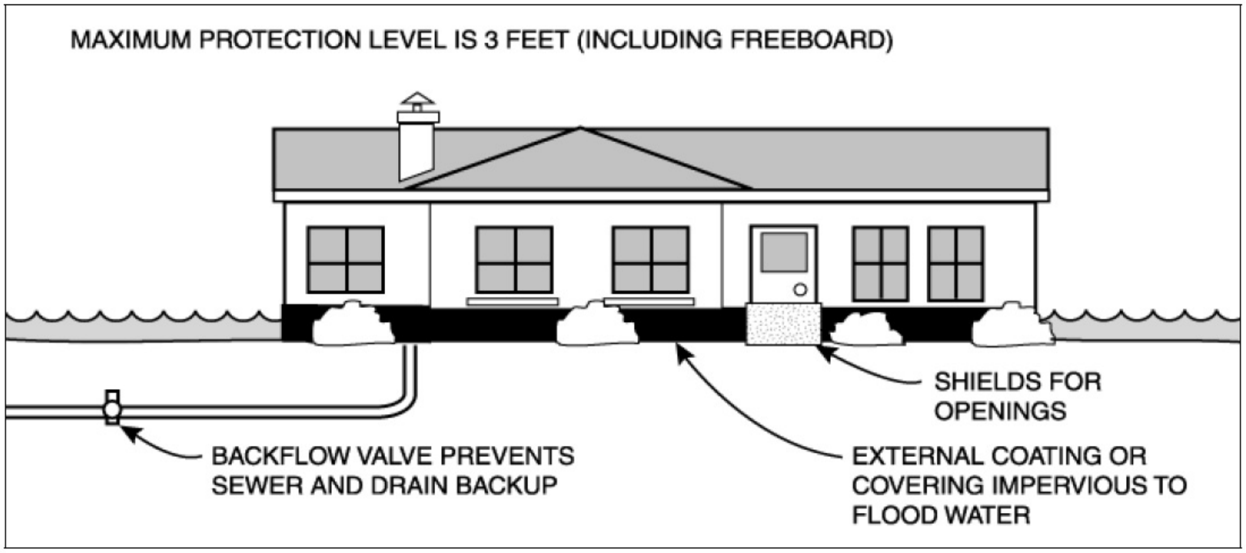


Figure 4 Typical dry floodproofed structure.

This type of floodproofing includes the following:

- Use of waterproof membranes or other sealants to prevent water from entering the structure through the walls;
- Installation of watertight shields over windows and doors; and,
- Installation of measures to prevent sewer backup.

There are technical considerations that must be taken into account in order to accurately determine whether dry floodproofing will be successful. Generally, masonry and masonry veneer walls can usually withstand the water pressures of floods less than three feet in depth (Figure 4). Masonry and masonry veneers are also resistant to moisture damage and can be made watertight with sealants. In flood depths greater than three feet, these types of walls require reinforcement.

Dry floodproofing is not recommended when:

- A structure's construction quality is less than good or excellent;
- Structures are located in areas where flood waters may be greater than three feet in depth;
- Structures are located in areas where flood waters may stand for days;
- Structure walls are constructed of adobe;
- Structure's foundational soils are very permeable; or,
- The owner is unwilling to implement dry floodproofing.

3.3.1.5 *Raising Structures in Place*

When a structure is properly elevated, the living or commercial area will be above all but the most severe floods (such as the flooding from the 2% ACE event flood). Several elevation techniques are available. In general, they involve (1) lifting the structure and building a new, or extending the existing, foundation below it or (2) leaving the structure in place and either building an elevated floor within the house or adding a new upper story.

During the elevation process, structures originally built on basement, crawlspace, and open foundations are separated from their foundations, raised on hydraulic jacks, and held by temporary supports while a new or extended foundation is constructed below. The living area is raised and only the foundation remains exposed to flooding. Masonry structures are more difficult to lift, primarily because of their design, construction, and weight, but lifting these homes is possible. For structures with slab-on-grade foundations where the slab forms both the floor of the structure and either all or a major part of the foundation, the structure is left attached to the slab and both are lifted together. After the structure and slab are lifted, a new foundation is constructed below the slab. Raising a slab-on-grade structure is more difficult and more costly.

Raising structures in place is not recommended when:

- Structure’s construction quality is less than low cost (i.e. mobile homes and portable buildings), good or excellent;
- Structures are located in areas where flood velocities may be greater than 3 feet /second (foundation walls) or 5 feet / second (posts or fill);
- Structures are located in areas where flood depths may be greater than 6 feet (piers);
- Structure walls are constructed of adobe;
- Structure’s foundational soils are very permeable; or,
- The owner is unwilling to implement structural raising.

3.3.1.6 *Acquisition and/or Relocation of Structures*

One method of reducing future damage from floods is for the community to acquire a property and relocate an existing flood prone structure to a new site outside the floodplain. In general, single-story, wood frame structures over a crawlspace or basement foundation are easiest to relocate. Multi-story and solid masonry structures are the most difficult to relocate because their greater size and weight requires additional lifting equipment and makes them more difficult to stabilize during the move. Adobe structures, which are common in the study area, are like masonry structures as they consist of unfired bricks stacked to form walls and covered with a stucco veneer. Slab-on-grade foundations complicate the relocation process because they make the installation of lifting equipment more difficult.

The relocation process is complex, expensive, and requires extensive pre-move planning (FEMA 2005). However, it may be a cheaper alternative than acquiring and demolishing a flood prone structure (Table 1).

Non-structural alternatives that require the acquisition of land in fee will not be considered for Indian Lands within the study area. The Pueblo Land Act of 1924 prohibits the selling of any Pueblo Indian land; therefore, permanent evacuation costs will be based upon the purchase of the structures only in these areas.

Table 1 Non-structural measures and relative cost

Construction Type	Existing Foundation	Measure	Retrofit	Relative Cost
Frame, Masonry Veneer, or Masonry	Crawlspace or Basement	Wet Floodproofing	Wet floodproof crawlspace to a height of 4 feet above lowest adjacent grade or wet floodproof unfinished basement to a height of 8 feet above basement floor	Lowest
Masonry Veneer or Masonry	Slab-on-Grade or Crawlspace	Dry Floodproofing	Dry floodproof to a maximum height of 3 feet above lowest adjacent grade	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Barrier Systems	Levee constructed to 6 feet above grade or floodwall constructed to 4 feet above grade	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Elevation	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Relocation	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Elevation	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Relocation	Elevate on continuous foundation walls or open foundation	Highest
Frame, Masonry Veneer, or Masonry	Slab-on-Grade, Crawlspace, Basement, or Open Foundation	Demolition	Demolish existing building and buy or build a home elsewhere	Varies

3.3.1.7 *Non-structural considerations*

Non-structural alternatives were considered in the initial screening of measures. Additional local non-structural measures were identified that could be implemented by Bernalillo and Valencia Counties, and the communities within the study area:

- Development of new building codes that could specify building design and materials for both new buildings and repair of flood-damaged structures in the flood plain.
- Flood forecasting and temporary evacuation plans which will be developed in conjunction with the structural alternatives.
- Sponsors and community participation in the National Flood Insurance Program which can also be developed in conjunction with structural alternatives.

3.3.2 Structural Measures

Structural measures generally are constructed features such as dams, levees or channels that alter the characteristics of the flood to prevent floodwaters from reaching damageable property. Dams capture and slowly release floodwater in a non-damaging flow. Levees and floodwalls physically prevent floodwaters from reaching property while channels carry floodwaters safely around or past damage areas.

In the Middle Rio Grande, detention structures constructed upstream of the study area serve to reduce the magnitude and/or timing of a flood to prevent damage to property and infrastructure. As discussed, these structures do not eliminate the potential for damaging floods from the upper Rio Grande or unregulated tributaries downstream of Cochiti Reservoir. There remains a significant risk of flooding in the study area.

The 1979 Feasibility Report evaluated a number of structural measures and combination thereof. The alternative found to be most complete, efficient and effective was construction of a system of engineered levees to along the same alignment as the existing spoil banks. The current GRR/SEIS incorporates engineering design and geotechnical requirement changes that have occurred since 1979 in the analysis and design of levees along the same alignment. Figure 5 illustrates a cross section of a levee with irrigation infrastructure and riparian zone.

Engineered Levees

An engineered levee is an earthen embankment constructed parallel to the river provide a barrier between floodwaters and damageable properties. Each study unit would include one or more levee segments tied into high ground. Seepage barriers would reduce damages to irrigation infrastructure at river flows above 4000 cfs. Controlled pipes, gates or culverts (penetrations) incorporated into the levee would allow local storm water or irrigation canals to drain to the river when the river is not at flood stage. These penetrations would close to prevent floodwater from the river to flow through the levee.

Engineered levees are designed to take into account the foundation conditions beneath the levee, the suitability of the levee materials, and the methods of levee construction. Levee design is based, in part, on the results of site investigations into foundation conditions and available construction materials. By adapting the levee design to the available materials and local conditions, engineered levees provide a predictable response to possible future conditions.

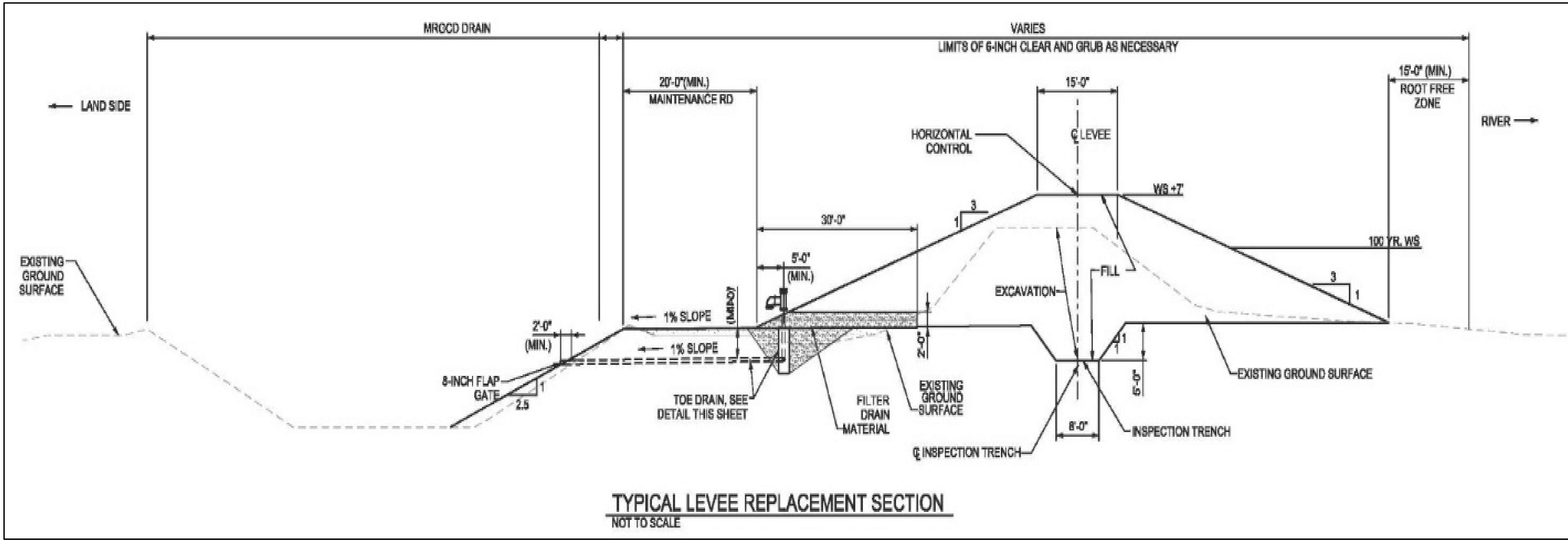


Figure 5 Typical section showing irrigation infrastructure, levee features, and vegetation management zone.

In contrast, spoil banks are the by-product of a canal excavation where the excavated material is placed, or "spoiled," to the side of the canal. Spoil banks typically receive little or no compaction during construction, and the suitability of the material for construction and the condition of the underlying foundation materials are unknown.

Detention Dams

Detention dams are earthen dams constructed to capture and slowly release flood flows from any of the tributary channels entering the Rio Grande in the uncontrolled portion of the watershed downstream of Cochiti Reservoir. Detention dams would likely be dry dams and would be completely evacuated of water within 96 hours of detention in compliance with New Mexico State Engineer requirements.

Channel Excavation

Channel excavation would include mechanical removal of sediment from the Rio Grande active channel and overbank areas within the floodway to provide some design capacity for flood flows. Excavated sediment would be disposed of outside the existing floodway.

Placement of Jetty (Kellner) Jacks

A jetty jack is a standard unit; they are routinely the same form. It is typically composed of three 16-foot long 4 in. x 4 in. x ¼ in. steel angles. These three angles are bolted together at their midpoints. The angles are placed back to back with their longitudinal axes at right angles to each other. The angles are fastened into place and form three sets of intersecting planes, their common point at the center. The planes are maintained by lacing with wire at 15-inch intervals, then linking several structures together in a line with thick cable. The cables extend in a continuous line through the units and are fastened at each end of the jetty to anchors. The anchors typically are standard creosoted 8-foot railroad ties buried about halfway into the ground. Usually about 16 units are assembled and positioned at a time. Placement of jetty jacks would not act as a stand-alone measure but would be combined with other structural measures. Jetty jacks are placed in the overbank areas to slow velocities and trap sediment outside the active river channel to prevent the channel from meandering and protect levees from erosion.

3.3.3 Measures Eliminated or Carried Forward

Non-structural and structural measures that were analyzed and either eliminated or carried forward in the 1979 Feasibility Report and during subsequent analyses are listed in Table 2.

Table 2 Measures investigated and eliminated or carried forward further analysis.

Analysis Conducted	**Measure**	**Discussion**	**Carried forward for detailed evaluation**
1979	Flood Warning Systems and Evacuation Planning	Flood warning systems and evacuation planning are incomplete as stand-alone measures, however, can be combined with any other measure.	Yes

Analysis Conducted	**Measure**	**Discussion**	**Carried forward for detailed evaluation**
1979	Raising Structures in Place or Relocation of Structures to Outside of the Floodplain	Prevalent construction of residences, public and commercial buildings is slab-on-grade. Such structures are impractical to raise through normal jacking procedures. This measure was eliminated from further study. In 2009, the foundations of these same types of structures are still built on slab-on-grade foundations.	No
1979	Dry Flood Proofing (to include the waterproofing of walls) or Wet Flood Proofing	A common construction material in the study area is adobe; an unfired brick dried in sunlight. Adobe walls when saturated will fail, causing the entire structure and most of the contents, to be lost. Therefore, flood proofing of this type of structure must include waterproofing of walls, as well as doors and windows. The cost of flood proofing this type of structure in 1979 averaged almost three times that of other construction types.	Yes
1979	Relocation or Permanent Evacuation	The relocation process is complex, expensive, and requires extensive pre-move planning. Relocation cost estimates exceed the depreciated replacement costs of the majority of structures in the Rio Grande floodplain. Acquisition is more costly than relocation and therefore is uneconomical.	No
1979	Tributary Detention Reservoirs Only	This measure used exclusively would not be effective in providing an acceptable level of flood risk management. Seven arroyos below the Cochiti and Galisteo Dams were investigated. If a single dam were placed in each arroyo and working under the assumption that models used in 1979 were accurate, only about 40% of the drainage area would be controlled, as stated in the 1979 Feasibility Report. The remaining drainage area could still produce flood peaks exceeding the capacities of all the 1979 study units except the Albuquerque Units.	No
1979	Channel Excavation Only	Channel excavation depth was assumed to be 3 feet, the water surface profile elevation would be reduced by 2 feet, but flood peak elevations would remain 2 feet above the existing non-engineered capacity. The dredging depth judged to be sufficient to carry the required flows (42,000 cfs) was approximately 6 feet for the	No

Analysis Conducted	**Measure**	**Discussion**	**Carried forward for detailed evaluation**
		entire 60 river miles of the original study area. Besides the economic infeasibility, other problems included the disposal of dredged materials and large maintenance costs. With more recent knowledge regarding ecosystem viability, this measure would no longer be viable because it would damage the existing ecosystem by disconnecting the bosque from the active channel and by lowering the water table.	
1979	Reservoir on Tonque Arroyo with Engineered levees	This would reduce the peak flow assuming that the storm system is located over that particular drainage area. The only savings in engineered levees would be a reduction in earthworks quantities, because toe drains, levee protective works and hydraulic control structures would be the same as for the levee alternatives without the Tonque Arroyo Dam. This alternative was economically infeasible. Since this alternative was primarily focused on benefits for the Bernalillo Unit, which is no longer part of this study, this measure was not given further consideration in this study.	No
1979	Channel Excavation with Engineered levees	Assuming that all dredged materials were used as engineered levee materials, the estimated costs for construction were double that of engineered levees alone.	No
1979	Jetty Jacks as Levee Protection Works	The current sediment regime no longer favors jetty jacks as a means of levee protection due to the construction of upstream flood risk management structures (*i.e.*,. Cochiti, Jemez Canyon and Galisteo). These structures have removed much of the sediment from the regulated flows, which jetty jacks rely upon to operate effectively. Therefore, new jetty jack fields will not be proposed in this GRR. However, some existing jetty jacks may be retained in place.	No
Current Study	Setback Levee	Analysis of this measure shows that there are extremely limited areas where setbacks could be applied in the study area due to existing development and infrastructure. The additional cost of infrastructure relocation, and acquisition of lands or easements render this measure uneconomical and inefficient.	No

3.3.3.1 *Evaluation of Non-Structural Measures*

Emergency Preparedness

Relative to other measures presented, emergency preparedness provides high life safety risk reduction but minor reduction in monetary damages. Some damages to vehicles and structure contents would be prevented through this measure, however, it is by itself an incomplete solution. The Bernalillo County Office of Homeland Security and Emergency Management, and the Valencia County Office of Emergency Management should collaborate with the New Mexico Department of Homeland Security and Emergency Management and USACE Floodplain Manager to create a seamless flood response plan prior to completion of project construction. **This measure is carried forward for consideration in combination with other measures**.

Flood Forecast and Warning System

For snow melt runoff in the regulated portion of the watershed, there is approximately 12 hours' notice for high flows from Cochiti Reservoir. For rainfall events in the unregulated portion of the study area, there is approximately 30 minutes to an hour notice for high flows. It is likely that coordinated releases from Cochiti would allow adequate flood warning for either voluntary or mandatory evacuation. For rainfall events, flood forecast and warning would likely be limited to warning to shelter in place. Some damages and a reduction of life safety risk would be accomplished however, it is by itself an incomplete solution. **This measure is carried forward for consideration in combination with other measures.**

Wet Floodproofing

Few of the structures located within the 0.2% ACE floodplain meet the requirements for wet floodproofing, e.g. this measure is not recommended for frame construction or for structures located in an area where flood flows rise slowly. Floodproofing does nothing to remove agriculture or transportation infrastructure from the floodplain and therefore would represent an incomplete solution to the flood problem. **Due to the incomplete nature and limited applicability of this floodproofing method, it was not carried forward for alternative evaluation.**

Dry Floodproofing

Few of the structures located within the 0.2% ACE floodplain meet the requirements for dry floodproofing, such as areas where floodwaters may stand for days. This technique is not applicable for areas subject to flash flooding (less than one hour) or where flow velocities are greater than three feet per second. It would also not be applicable to mobile homes, due to the type of construction and typical lack of anchoring to a foundation.

Aside from the cost, dry floodproofed homes and businesses can still suffer flood damages due to the potentially incomplete nature of the solution. Enclosures for windows and doors require human intervention in order to fully implement the solution and this action would have to occur in a very short time frame. Once again, floodproofing does nothing to remove agriculture or transportation infrastructure from the floodplain and therefore would represent an incomplete solution to the flood problem. **Due to the incomplete nature and limited applicability of this floodproofing method, it was not carried forward for alternative evaluation.**

Acquisition and/or Relocation of Structures

The relocation process is complex, expensive, and requires extensive pre-move planning (FEMA 2005). FEMA estimates relocation costs at between $99 and $116 per square foot (1999 dollars), which exceeds the depreciated replacement costs of the majority of structures in the Rio Grande floodplain (FEMA 2009:3-28, Table 3-9). **Due to the incomplete nature and inefficiency of this floodproofing method, it was not carried forward for alternative evaluation.**

Acquisition requires the purchase of the flood prone property and structure(s), demolition of the structure(s), relocation assistance, and applicable compensation as required under Federal and State law. This alternative typically requires voluntary relocation by the property owners and/or eminent domain rights exercised by the non-Federal sponsor. This technique is more costly than relocation and therefore is uneconomical. As with relocations, acquiring properties in a floodplain has limited utility. Repurposing land for a public good, such as a park, is also infeasible, as it would represent an incomplete solution to the flood problem. **Due to the incomplete nature and inefficiency of this floodproofing method, it was not carried forward for alternative evaluation.**

3.4 Focused Array of Alternatives

Following screening of measures as discussed in Section 3.3, a focused array of alternatives was developed. The alternatives address the study objectives to varying degrees. The remaining alternatives include a levee system in combination with an emergency warning and evacuation plan. While other non-structural measures were shown to be incomplete, inefficient and/or ineffective as stand-alone measures, these measures could be used on a limited basis to provide flood risk management in combination with levees. The alternative identified as the “Authorized Plan” refers to the levee system recommended in the 1979 EIS. This reevaluation also examines various levee lengths and alignments using current levee engineering criteria and accounting for changes in conditions in the study area. Although discounted in the 1979 Feasibility Report, the Isleta East Unit was also reexamined to determine whether or not conditions had changed to warrant inclusion in a new project recommendation. No significant development has occurred in the floodplain associated with this unit that warrants its inclusion of a structural component to a flood risk management plan.

3.4.1 Authorized Plan

The Authorized Plan consists of the components that were recommended in the 1979 EIS and authorized for construction by Congress. It is necessary to reevaluate the authorized levee segments due to changes in design criteria and guidance that have occurred since 1979. The reevaluation will also determine the extent to which the Authorized Plan will meet the current objectives of the study.

3.4.2 Levee Length and Alignment, Current Analysis

The initial screening points to levees as a more effective and potentially complete alternative method of flood risk management in the study area. The next step is to evaluate the length and location of levees for each of the individual study units. In general, levees must be connected to high ground on the upstream and downstream ends to establish a complete barrier between the floodwater and damageable property. In some cases the downstream terminus can be extended down-valley so that floodwater that flanks the levee cannot flow in the reverse direction and reach areas that were protected from downstream flow.

Levee alignments were evaluated where optional connections to high ground or tie-ins were available. High ground in many cases consists of natural land features, highways, railroad embankments, or embankments of existing irrigation and storm water facilities. Different alignments were also developed to avoid environmentally sensitive areas and poor foundation conditions. For the purposes of this document a “setback” is an alignment of the levee landward of the existing spoil bank for some distance. A setback will make some area of land accessible to flood or overbanking flows. This hydrologic connection has the potential to provide environmental benefits by increasing the area of riparian habitat where appropriate conditions exist.

Table 3 provides a summary of the alternative levee lengths and alignments for each unit.

Table 3 Summary of Authorized and Analyzed Levee Lengths

Alternative	**Description**	**Length (Approximate)**
No Action	No Federal Action	
Mountain View Unit		
Authorized Plan	Extends from the South Diversion Channel to approximately 0.7 miles south of I-25 on Isleta Pueblo.	5 miles
Alignment A*	Extends from the South Diversion Channel to I-25.	4.3 miles
Isleta East Unit		
Authorized Plan	The approximately 0.7 miles of the Mountain View Unit south of I-25.	
Alignment A	Extension of the Mountain View Unit downstream to the south end of the Isleta Lakes developed area.	0.5 miles
Alignment B	Extension of the Mountain View Unit downstream to tie in to the railroad embankment at the south end of the Isleta Lakes developed area.	0.6 miles
Alignment C	Extension of the Mountain View Unit downstream to tie in to the railroad embankment at the south end of the Isleta Lakes developed area. Includes an approximate 8 acre setback at the southern end.	0.6 miles
Alignment D	Extension of the Mountain View Unit downstream to tie in to the railroad embankment at the south end of the Isleta Lakes developed area. Alignment does not include setback area.	0.7 miles
Isleta West Unit		
Authorized Plan	Levee alignment from the Pueblo border to NM 147 on the downstream end. Several sections of double levee.	3.2 miles
Alignment A*	Levee from I-25 to the Atchison, Topeka and Santa Fe Railroad crossing.	1.5 miles
Alignment B	Levee from I-25 to the Atchison, Topeka and Santa Fe Railroad crossing, with minor alignment changes.	1.5 miles

Alternative	**Description**	**Length (Approximate)**
Alignment C	Levee from I-25 to the Atchison, Topeka and Santa Fe Railroad crossing, with minor alignment changes.	1.6 miles
Alignment D	Levee from I-25 to the Atchison, Topeka and Santa Fe Railroad crossing, with setback alignment.	1.8 miles
Alignment D+	Levee from I-25 to the Atchison, Topeka and Santa Fe Railroad crossing, with setback alignment. Setback area is approximately 53 acres.	1.8 miles
Alignment E*	Levee from Atchison, Topeka and Santa Fe Railroad to NM 147. Small setback to alignment.	1.2 miles
Alignment E+	Levee from Atchison, Topeka and Santa Fe Railroad to NM 147. Small setback to alignment. Setback area is approximately 10 acres.	1.2 miles
Belen East Unit		
Authorized Plan	Levee alignment from NM 147 south to just south of the Atchison, Topeka and Santa Fe Railroad crossing downstream of Highway 309. Northern portion has a double levee segment.	22.1 miles
Northern Alignment*	Authorized Plan alignment. Double levee segment modified to single levee.	Included in Southern Alignment lengths
Southern Alignment A	Shortens Authorized Plan alignment by ending approximately 4.6 miles to the north.	17.6 miles
Southern Alignment B*	Shortens Authorized Plan alignment by ending approximately 3.4 miles to the north.	18.8 miles
Southern Alignment C	Shortens Authorized Plan alignment by ending approximately 2.7 miles to the north.	19.4 miles
Southern Alignment D	Shortens Authorized Plan alignment by ending approximately 2.4 miles to the north, ending at Highway 309.	19.7 miles
Southern Alignment E	Shortens Authorized Plan alignment by ending approximately 0.8 miles to the north, ending at the Atchison, Topeka and Santa Fe railroad.	21.4 miles
Southern Alignment F	Extends Authorized Plan alignment by ending approximately 0.8 miles to the south.	23 miles
Belen West Unit		
Authorized Plan	Levee tie-in to high ground approximately 1.6 miles north of the Isleta border to approximately 1.6 miles south of Atchison, Topeka and Santa Fe railroad.	18.6 miles
Northern Alignment*	Authorized Plan alignment.	Included in Southern Alignment lengths

Alternative	Description	Length (Approximate)
Southern Alignment A	Extension of Authorized Plan alignment to approximately 2.4 miles south of Atchison, Topeka and Santa Fe railroad.	19.6 miles
Southern Alignment B*	Extension of Authorized Plan alignment to approximately 5 miles south of Atchison, Topeka and Santa Fe railroad.	21.7 miles

** Shaded rows indicate alternatives that were carried forward for evaluation and identification of the NED Plan.*

3.5 Comparison of Focused Array of Alternatives and Measures and Decision Criteria

The alternatives are evaluated for their potential to meet specified objectives and constraints, effectiveness, efficiency, completeness, and acceptability. The *Principles & Guidelines* definitions of completeness, effectiveness, efficiency, and acceptability are provided below.

- **Completeness –** Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. This may require relating the plan to other types of public or private plans if the other plans are crucial to realization of the contributions to the objective.
- **Effectiveness –** Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.
- **Efficiency –** Efficiency is the extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment.
- **Acceptability –** Acceptability is the workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with existing laws, regulations, and public policies.

Table 4 shows how each of the structural alternatives comply with these four criteria.

Table 4 Alternatives compared to decision criteria.

Alternative	Completeness	Effectiveness*	Efficiency	Acceptability
No Action	No	No	No	No
Mountain View Unit				
Authorized Plan	Yes	No	No	Yes
Alignment A	Yes	Yes	Yes	Yes
Isleta East Unit				
Authorized Plan	No	No	No	Yes
Alignment A	No	No	No	No
Alignment B	No	Yes	No	No
Alignment C	No	Yes	No	No
Alignment D	No	Yes	No	No
Isleta West Unit				
Authorized Plan	Yes	Yes	No	No
Alignment A	Yes	Yes	Yes	Yes
Alignment B	Yes	No	No	No
Alignment C	Yes	No	No	No
Alignment D	Yes	No	No	No
Alignment D+	Yes	No	No	No
Alignment E	Yes	Yes	Yes	Yes
Alignment E+	Yes	No	No	No
Belen East Unit**				
Authorized Plan	Yes	No	No	Yes
Northern Alignment	Yes	Yes	Yes	Yes
Southern Alignment A	No	No	No	No
Southern Alignment B	Yes	Yes	Yes	Yes
Southern Alignment C	Yes	Yes	No	No
Southern Alignment D	No	Yes	No	No
Southern Alignment E	No	Yes	No	No
Southern Alignment F	Yes	No	No	No
Belen West Unit**				
Authorized Plan	Yes	No	No	Yes
Northern Alignment	Yes	Yes	Yes	Yes
Southern Alignment A	No	Yes	No	No
Southern Alignment B	Yes	Yes	Yes	Yes

Alternatives shaded blue in the first column were carried forward for identification of NED Plan.
***** *No alignments are effective with short levee heights due to error bands in hydraulic modelling.*
****** *Construction of levee on only one side of the river transfers risk to the other side in the Belen Units.*

3.6 Executive Order 11988, Floodplain Management

The following sections discuss the analysis undertaken during plan formulation to comply with Executive Order (E.O.) 11988 – Floodplain Management. ER 1165-2-26 provides the general guidance and policy for USACE's implementation of E.O. 11988 for all civil works projects. Paragraph 7 of the regulation states:

> *"…It is the policy of the Corps of Engineers to formulate projects which, to the extent possible, avoid or minimize adverse impacts associated with use of the base flood plain and avoid inducing development in the base flood plain unless there is no practicable alternative. The decision on whether a practicable alternative exists will be based on weighing the advantages and disadvantages of flood plain sites and non-flood plain sites. Factors to be taken into consideration include, but are not limited to…the functional need for locating the development in the flood plain…The test of practicability will apply to both the proposed Corps action and to any induced development likely to be caused by the action."*

To comply with E.O. 11988 and ER 1165-2-26, projects are formulated and recommended that, to the extent possible, avoid, minimize and/or mitigate adverse effects associated with use of the flood plain, and avoid inducing incompatible development in the flood plain unless there is no practicable alternative. Achieving flood and coastal storm risk management objectives generally cannot avoid locating actions in riverine or coastal flood plains. The steps outlined in the numbered bold paragraphs below are consistent with the E.O. 11988 decision process. They are also consistent with guidelines established by the Floodplain Management Guidelines for Implementing E.O. 11988, Water Resources Council, February 10, 1978 (43 FR 6030). Figure 1 of that document is reproduced as Figure 6 below.

1. Determine if the proposed action is in the base flood plain.

The overall purpose of the project is to reduce flood risk to urban and urbanizing parts of the study area. The final array of alternatives involves construction of engineered levees located in the base 1% ACE floodplain. For the purpose of this study, the base floodplain is delineated as all areas that are at risk of being flooded by the 1% ACE event flow. In other words, the base floodplain has been delineated assuming existing spoil banks do not provide protection from the 1% ACE event. This definition of the base floodplain addresses the USACE requirement in ER 1105-2-101 to describe a project's performance using risk and uncertainty methods and for purposes of studies. For this reason, the entire study area was evaluated for E.O. 11988 compliance.

2. If the action is in the base floodplain, identify and evaluate practicable alternatives to the action or to location of the action in the base floodplain.

The study has evaluated all practicable alternatives by following the six-step planning process and evaluating a wide range of measures and alternatives using available information, professional judgment, and risk-informed decision making to achieve the project purpose of reducing flood risk to urban and urbanizing parts of the study area. Practicable alternatives (structural and non-structural) that were considered included the following:

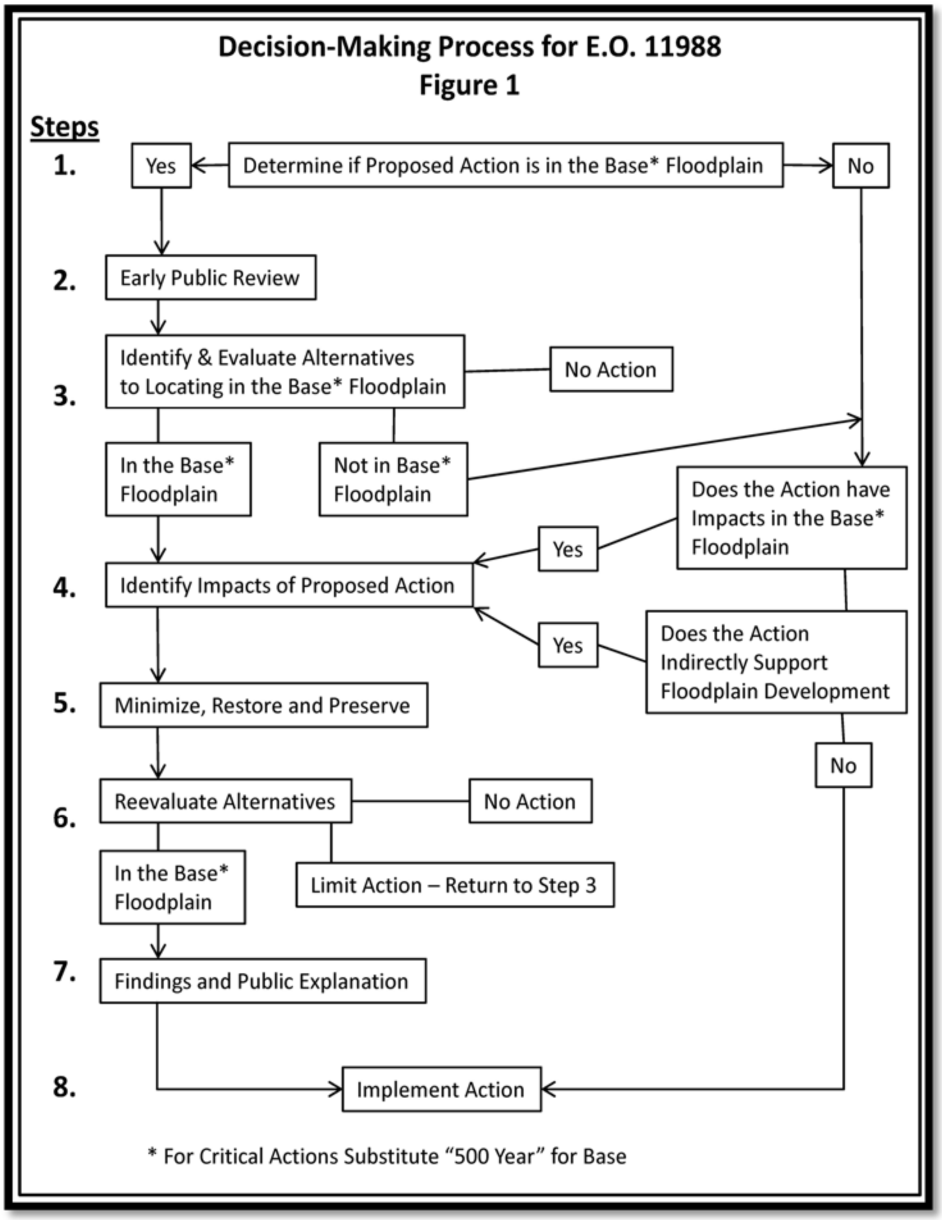


Figure 6 Decision making process for E.O. 11988.

Figure 6, above, outlines the analysis process as described in 43 FR 6030, U.S. Water Resources Council, Floodplain Management Guidelines for Implementing E.O. 11988, dated February 10, 1978.

- No Action: This alternative would involve no Federal action within the base flood plain as a result of this study. No additional reductions in flood risk to the area would be realized.

- Flood proofing and raising existing structures and infrastructure: This was determined not to be a cost effective alternative.
- Ring levees: Inclusion of ring levees may be effective in some study areas, but will need to be incrementally cost effective to be a practicable alternative.
- Construction of engineered levee to replace existing spoil banks.

Detailed analyses were performed for the final array of alternatives and have demonstrated that structural improvements are the only practicable and cost effective alternatives that achieve the objectives of the project. Implementation of the proposed structural measures will reduce the flood risk to thousands of commercial, institutional, and residential structures, and transportation, and protect infrastructure of value to MRGCD, the non-federal sponsor.

3. If the action must be in the floodplain, advise the general public in the affected area and obtain their views and comments.

Several public scoping meetings have been held and public comments received on the proposed study. Coordination with interested parties and resource agencies has been on-going through the course of the study. Additional opportunities for public input and comment will be provided during the review period for the draft GRR/SEIS.

4. Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial floodplain values. Where actions proposed to be located outside the base floodplain will affect the base floodplain, impacts resulting from these actions should also be identified.

a. Beneficial impacts due to the action.

The existing spoil banks along the east and west banks of the Rio Grande currently provide questionable flood risk management benefits for the communities between Albuquerque and Belen. The recommended plan will provide improved flood risk reduction to a large population and critical infrastructure already in place within the floodplain.

b. Adverse impacts due to the action.

The final array of alternatives may facilitate further development within the study area, however, there are some measures which would temper the development. Floodplain management plans required as a part of project implementation, as well as local general plans, could include building code requirements to elevate new construction above the 1% ACE flood elevation, however these types of building code requirements do not address protection of existing infrastructure.

c. Expected losses of natural and beneficial floodplain values.

The natural floodplain is not significantly reduced within the study area by the recommended plan. The natural floodplain has already been greatly reduced within the study area by the manner in which the existing spoil bank system was constructed in the early 20th Century. The system was constructed with the spoil banks in close proximity to the active 1930s river channel to maximize development of arable land for agriculture, followed by urban growth of communities into unincorporated areas of Bernalillo and Valencia Counties. The effects of the existing spoil bank system will continue in the No Action Alternative.

5. If the action is likely to induce development in the base floodplain, determine if a practicable non-floodplain alternative for the development exists.

There are currently no practicable alternatives to continued floodplain development with the study area. The Mountain View, Isleta West, Belen East and West areas would see improved flood risk management from the proposed alternatives and already have dispersed development. Potential future development of the floodplain would be infill of urbanized areas and conversion of agricultural areas to urban or semi-urban land use.

6. As part of the planning process under the *Principles and Guidelines (P&G)*, determine viable methods to minimize any adverse impact of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no action" alternative.

As discussed, the historic placement of spoil bank structures and agricultural infrastructure precludes opportunities for restoration or enhancement of natural flood plain values.

There are potential alternatives to development in the flood plain, but they fall into the responsibilities of the local communities to implement through planning documents and building codes. Analyses for this reevaluation have determined that the most effective approach to flood risk management is structural improvement of the spoil bank system through construction of engineered levees.

7. If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.

The public will have an opportunity to comment on this analysis and determination when the Draft Integrated GRR/SEIS is released for concurrent public, resource agency, independent external peer and USACE technical, policy and legal reviews.

8. Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.

Existing spoil banks were historically placed in close proximity to the river channel during the 1930s reducing the extent of natural flood plain within the study area. Existing infrastructure, such as transportation routes, housing, agricultural improvements, levees and drains, limits the potential for restoration of the Rio Grande natural hydrology and ecosystem functions. The proposed alignments have little or no unmitigated adverse effects to existing flood plain values.

Critical Actions. Repeat steps 1 through 8 above for critical actions in the critical action flood plain for the full range of potential residual flood risks. The critical action flood plain is defined as the 500-year flood plain (0.2% ACE event flood plain).

1. Determine if the proposed action is in the critical action flood plain.

The critical action floodplain (0.2% ACE or 500-year floodplain) consists of the entire study area delineated in Figure 1-3. Proposed actions being analyzed by this study are within the critical action flood plain.

2. If the action is in the critical action floodplain, identify and evaluate practicable alternatives to the action or to location of the action in the base floodplain.

There are no practicable alternatives to the proposed actions being situated within the critical action floodplain. See Base Flood Plain Step 2.

3. If the action must be in the critical action floodplain, advise the general public in the affected area and obtain their views and comments.

See Base Floodplain Step 3 above.

4. Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the 0.2% flood plain will affect the 0.2% flood plain, impacts resulting from these actions should also be identified.

a. Beneficial impacts due to the action.

The final array of alternatives would reduce flood risk to existing critical infrastructure within the flood plain. Flood plain management plans that further restrict siting of critical infrastructure within the 0.2% flood plain would provide additional risk reduction.

b. Adverse impacts due to the action.

The final array of alternatives may facilitate further development within the study area. This could result in construction of additional critical infrastructure within the flood plain.

c. Expected losses of natural and beneficial flood plain values.

See Base Floodplain Step 4 above for the expected losses of natural and beneficial floodplain values discussion.

5. If the action is likely to induce development in the critical action floodplain, determine if a practicable non-floodplain alternative for the development exists.

There may be opportunities to locate some future critical facilities outside the critical action floodplain. However, facilities such as schools and fire stations must be placed within close proximity to any future development. Therefore, if development occurs as expected, there will be no practicable non-critical action floodplain alternative for these critical facilities.

6. As part of the planning process under the *Principles and Guidelines*, determine viable methods to minimize any adverse impact of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no action" alternative.

See Base Floodplain Step 6 above.

7. If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.

See Base Floodplain Step 7 above.

8. Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.

As a result of the analysis required for compliance with E.O. 11988, USACE has made a determination that the proposed levee alignments have little or no unmitigated adverse effects to floodplain areas and are therefore compliant with E.O. 11988.

3.6.1 Result of E.O. 11988 Analysis

Based on the analysis required for compliance with E.O. 11988 as discussed above, the proposed levee alignments in Mountain View, Isleta West, and Belen East and West units result in a policy compliant array of alternatives.

3.7 Economics

3.7.1 Use of HEC-FDA 1.2.5 and Special Considerations for the Study Area

Consistent with the requirements set forth in EC 1105-2-412, "Planning Models Improvement Program: Model Certification," HEC-FDA version 1.2.5 was used to compute average annual and equivalent annual damages (EAD). USACE guidance stipulates that the plan that reasonably maximizes net NED benefits, consistent with the Federal objective, be identified. Project benefits for flood risk management measures are identified through successive iterations of existing and future without-project scenarios, changing key hydrologic and/or hydraulic variables as the measures warrant. HEC-FDA is the only model certified for formulation and evaluation of flood risk management plans using risk analysis methods, and was used in this study. Damages are computed in August, 2013 price levels using the fiscal year 2013 Federal discount rate of 3.75%. The period of analysis is 50 years.

There were special conditions in the GRR/SEIS study area that required changes to how HEC-FDA performs its analysis. First, HEC-FDA is set up expecting an incised channel with overbank flooding areas higher than the channel. The Rio Grande River is perched in many portions of the study area, meaning the river sits higher within its banks than many of the lower spots in the overbank areas. A typical effect of perched channels is severe events can have LOWER stages than less severe, more frequent events, as the river breaks through its banks and rushes into the expansive (and lower) overbanks. A second consequence of the perched channel is different banks of the same damage reach can have different water surface elevations for the same event.

The study team developed "virtual" channels to address HEC-FDA's limitations to handle perched channels. For each damage reach, hydraulic water surface elevations were computed for the main channel, the left (east) overbank and the right (west) overbank locations. The HEC-FDA model contains three streams for purposes of analysis, identified in this appendix as the "Rio Grande," the "Rio Grande LOB" (left overbank, east of the channel), and the "Rio Grande ROB" (right overbank, west of the channel). Each stream has its own water surface profiles, exceedance-probability functions, and stage-discharge functions. The economic inventory was assigned to either the left or right overbank "stream."

A second issue created by perched channels is an exaggeration of the damages associated with frequent, though relatively not severe, events. The hydraulics appendix notes that there is considerable concern over the quality of the existing spoil banks, such that upstream dam releases are kept to below 7,000 cfs, which corresponds to somewhere between the 20% and 10% ACE events in this study. The FLO-2D model showed overbank depths with the 50% and 20% ACE events, which didn't seem reasonable for this evaluation. Therefore, a beginning damage depth was applied in HEC-FDA corresponding to the present condition, 20% ACE water surface elevation. This ensures that the model for events more frequent than the 20% ACE event does not indicate damage to the floodplain inventory, as these flows are expected to be contained within the banks of the Rio Grande. Absent the starting damage elevations, average annual damages were more than double what is presented here.

3.7.2 Potential flood damages

It is currently estimated that the mean 1% ACE flood would cause damages of about $393.7 million in the study area. Table 5 through Table 8 present the single occurrence damages associated with the 10%, 2%, 1%, and 0.2% ACE flows in the assorted floodplains for each bank of the Rio Grande, for the present and future without-project conditions. These tables were generated using HEC-FDA results for descriptive purposes only, to better understand the nature of the damages reported by HEC-FDA. HEC-FDA does not generate point estimates of flows, stages, or damages for a specific event. The software essentially performs a statistical analysis of hydrology, hydraulic, and economic information using concepts of risk and uncertainty, meaning that a specific event frequency can have a range of flows, stages, and damages as a result of all the variables entered into the study. HEC-FDA was used to compute average and equivalent annual damages for structures and their contents only. Other damage categories were evaluated by identifying damages associated with the same event frequencies, as described below. This study’s hydrology and hydraulic evaluations assume that flood events of a magnitude greater than the 20% chance event damage structures, contents, and vehicles in the flooding areas analyzed. It should be noted that many intangible damages (such as loss of life, disruption to community services, and increased health risks) that could occur because of flooding are not represented in these damage values, therefore damage estimates are conservative.

3.7.3 Average annual damages

Risk and uncertainty analysis was used to derive average annual damages. Hydrologic and hydraulic uncertainty was combined through simulations within HEC-FDA. When flooding from all sources is considered, the study area faces the risk of approximately $105.4 million in equivalent annual damages. Sediment deposition over the period of analysis is expected to slightly increase those damages, which have been discounted to present value, summed, and amortized over the period of analysis. Table 9 and Table 10 present the average annual damages that could occur from flooding in the study area without any flood protection, by land use category and floodplain for the present and future hydraulic conditions. Table 11 discounts the future damages to present values, and presents the equivalent annual damages (EAD).

Table 5 Single occurrence damages (East Bank, present).

SINGLE OCCURRENCE DAMAGES (EAST BANK) WITHOUT PROJECT CONDITIONS (PRESENT) MIDDLE RIO GRANDE FLOODPLAIN (x $1,000 May, 2016 price level)								
	EVENT							
Land Use Category	10%		2%		1%		0.20%	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Residential	37,557		40,647		40,772		53,437	
Res. Content	10,778		11,684		11,723		15,429	
Commercial	3,095		3,297		3,318		4,277	
Comm. Content	17,149		17,868		17,903		20,024	
Public	2,680		2,987		2,996		3,327	
Pub. Content	3,992		4,344		4,350		4,855	
Apartment	0		0		0		4	
Apt. Contents	0		0		0		1	
Outbuildings	1,893		2,023		2,032		2,969	
Out. Contents	1,813		1,944		1,953		2,840	
Subtotal - Structures	**45,225**		**48,955**		**49,118**		**64,015**	
Subtotal - Contents	**33,732**		**35,840**		**35,929**		**43,150**	
Subtotal - Structures and	**78,956**		**84,795**		**85,047**		**107,165**	
Streets, roads	94,887		97,175		97,792		152,403	
Utilities	4,978		5,096		5,126		8,019	
Railroad	8		8		8		140	
Vehicles	5,196.00		5,202.00		5,950.00		6,430.00	
Agriculture	73		77		78		103	
Irr. Drains	596		612		617		951	
Aircraft	0		0		0		0	
Recreation	0.00		0.00		0.00		0.00	
Emergency Costs	2,770.42		2,894.47		2,919.27		4,128.16	
Total	**187,465**		**195,859**		**197,538**		**279,339**	

Table 6 Single occurrence damages (West Bank, present).

SINGLE OCCURRENCE DAMAGES (WEST BANK) WITHOUT PROJECT CONDITIONS (PRESENT) MIDDLE RIO GRANDE FLOODPLAIN (x $1,000 May, 2016 price level)								
	EVENT							
Land Use Category	10%	0%	2%	0%	1%	0%	0.20%	0.00%
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Residential	18,875		18,974		19,021		21,607	
Res. Content	5,710		5,739		5,754		6,534	
Commercial	8,022		8,058		8,076		8,850	
Comm. Content	36,046		36,437		36,632		46,033	
Public	3,699		3,717		3,726		4,089	
Pub. Content	4,267		4,282		4,290		4,638	
Apartment	303		304		304		335	
Apt. Contents	82		83		83		93	
Outbuildings	1,702		1,715		1,720		1,991	
Out. Contents	1,866		1,877		1,883		2,137	
Subtotal - Structures	**32,602**		**32,767**		**32,847**		**36,870**	
Subtotal - Contents	**47,971**		**48,418**		**48,641**		**59,436**	
Subtotal - Structures and	**80,573**		**81,185**		**81,488**		**96,306**	
Streets, roads	75,664		78,075		78,821		137,441	
Utilities	3,986		4,128		4,173		7,288	
Railroad	69		69		69		145	
Vehicles	4,766.00		4,771.00		5,542.00		6,515.00	
Agriculture	52		53		54		79	
Irr. Drains	567		577		581		883	
Aircraft	22,500		22,500		22,500		22,500	
Recreation	0.00		0.00		0.00		0.00	
Emergency Costs	2,822.66		2,870.38		2,898.42		4,067.36	
Total	**191,000**		**194,229**		**196,126**		**275,225**	

Table 7 Single occurrence damages (East Bank, future).

SINGLE OCCURRENCE DAMAGES (EAST BANK)
WITHOUT PROJECT CONDITIONS (FUTURE)
MIDDLE RIO GRANDE FLOODPLAIN
(x $1,000 May, 2016 price level)

Land Use Category	EVENT 10% Mean	SD	2% Mean	SD	1% Mean	SD	0.20% Mean	SD
Residential	32,057		40,278		40,398		51,163	
Res. Content	9,228		11,577		11,614		14,765	
Commercial	1,988		3,267		3,281		4,123	
Comm. Content	7,594		17,794		17,829		19,625	
Public	2,889		2,916		2,927		3,278	
Pub. Content	4,254		4,293		4,301		4,774	
Apartment	0		0		0		4	
Apt. Contents	0		0		0		1	
Outbuildings	1,425		2,012		2,020		2,808	
Out. Contents	1,294		1,934		1,943		2,687	
Subtotal - Structures	**38,359**		**48,473**		**48,626**		**61,376**	
Subtotal - Contents	**22,371**		**35,599**		**35,687**		**41,851**	
Subtotal - Structures and Contents	**60,729**		**84,072**		**84,313**		**103,227**	
Streets, roads	98,243		100,976		123,161		197,031	
Utilities	5,147		5,280		6,445		10,590	
Railroad	8		8		8		140	
Vehicles	5,365		5,388		5,469		6,524	
Agriculture	76		79		80		127	
Irr. Drains	607		626		737		1,391	
Recreation	0		0		0		0	
Emergency Costs	2,553		2,946		3,303		4,785	
Total	**172,728**		**199,375**		**223,516**		**323,816**	

Table 8 Single occurrence damages (West Bank, future).

SINGLE OCCURRENCE DAMAGES (WEST BANK)
WITHOUT PROJECT CONDITIONS (FUTURE)
MIDDLE RIO GRANDE FLOODPLAIN
(x $1,000 May, 2016 price level)

Land Use Category	EVENT							
	10%	0%	2%	0%	1%	0%	0.20%	0.00%
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Residential	18,961		19,083		19,132		21,293	
Res. Content	5,734		5,772		5,786		6,438	
Commercial	8,022		8,058		8,076		8,681	
Comm. Content	36,047		36,437		36,632		44,025	
Public	3,703		3,720		3,729		4,006	
Pub. Content	4,270		4,286		4,293		4,538	
Apartment	303		304		304		327	
Apt. Contents	82		83		83		90	
Outbuildings	1,709		1,724		1,729		1,957	
Out. Contents	1,870		1,882		1,887		2,097	
Subtotal - Structures	**32,698**		**32,889**		**32,969**		**36,264**	
Subtotal - Contents	**48,003**		**48,459**		**48,682**		**57,189**	
Subtotal - Structures and Contents	**80,701**		**81,348**		**81,651**		**93,453**	
Streets, roads	77,224		79,873		97,320		185,274	
Utilities	4,067		4,221		5,163		10,076	
Railroad	69		69		69		142	
Vehicles	4,780		4,782		5,555		6,481	
Agriculture	53		55		55		98	
Irr. Drains	574		587		690		1,211	
Aircraft	22,500		22,500		22,500		22,500	
Recreation	0		0		0		0	
Emergency Costs	2,850		2,902		3,195		4,789	
Total	**192,817**		**196,337**		**216,198**		**324,023**	

Table 9 Average annual damages (present).

AVERAGE ANNUAL DAMAGES (PRESENT) BY LAND USE CATEGORY

(x$1,000, May, 2016 price level)

LAND USE CATEGORY	Average Annual Damages (x$1,000, May, 2016 price level)		
	East Bank	West Bank	Total
Residential	22,643.97	10,484.54	33,128.51
Commercial	8,372.92	18,831.98	27,204.90
Public	3,616.53	3,581.51	7,198.04
Apartments	0.29	165.93	166.22
Outbuildings	1,687.11	1,519.51	3,206.62
Subtotal - Structures and Contents	36,320.82	34,583.47	70,904.29
Streets, roads	10,961.15	8,895.18	19,856.38
Utilities	575.06	469.83	1,044.89
Railroad	2.07	8.68	10.75
Vehicles	6,912.54	4,185.92	11,098.46
Agriculture	7.68	5.41	13.10
Irr. Drains	68.98	65.14	137.95
Aircraft	0.00	220.02	220.02
Recreation			
Emergency Costs	821.69	722.23	1,543.92
TOTAL			**104,829.76**

Table 10 Average annual damages (future).

AVERAGE ANNUAL DAMAGES (FUTURE)
BY LAND USE CATEGORY

(x$1,000, May, 2016 price level)

LAND USE CATEGORY	Average Annual Damages (x$1,000, May, 2016 price level)		
	East Bank	West Bank	Total
Residential	25,224.07	9,477.60	34,701.67
Commercial	8,446.06	16,087.26	24,533.32
Public	4,899.84	3,023.10	7,922.94
Apartments	0.07	142.23	142.30
Outbuildings	1,703.33	1,357.62	3,060.95
Subtotal - Structures and Contents	40,273.37	30,087.81	70,361.18
Streets, roads	11,907.81	9,613.27	21,521.13
Utilities	624.96	509.37	1,134.33
Railroad	2.17	8.91	11.08
Vehicles	7,816.27	3,668.47	11,484.74
Agriculture	8.01	5.61	13.62
Irr. Drains	74.45	69.48	148.91
Aircraft	0.00	165.21	165.21
Recreation			
Emergency Costs	909.49	658.40	1,567.89
TOTAL			**106,408.09**

Table 11 Equivalent annual damages.

EQUIVALENT ANNUAL DAMAGES BY LAND USE CATEGORY

(x$1,000, May, 2016 price level)

LAND USE CATEGORY	Equivalent Annual Damages (x$1,000, May, 2016 price level) (3.125% discount rate, 50 year period of analysis)		
	East Bank	West Bank	Total
Residential	23,533.28	10,137.45	33,670.73
Commercial	8,398.26	17,885.90	26,284.16
Public	4,058.87	3,389.03	7,447.90
Apartments	0.21	157.76	157.97
Outbuildings	1,692.70	1,463.71	3,156.41
Subtotal - Structures and Contents	37,683.32	33,033.85	70,717.17
Streets, roads	11,285.30	9,141.06	20,426.40
Utilities	592.14	483.37	1,075.52
Railroad	2.10	8.76	10.86
Vehicles	7,224.04	4,007.56	11,231.60
Agriculture	7.80	5.48	13.28
Irr. Drains	70.85	66.63	141.70
Aircraft	0.00	201.13	201.13
Recreation			
Emergency Costs	851.92	700.20	1,552.12
TOTAL	**57,717.48**	**47,648.04**	**105,369.79**

3.8 Identification of the NED Plan

To identify the recommended plan, a levee height optimization analysis was conducted to determine approximate maximization of net benefits. The tables and figures in this section, below, demonstrate the analysis conducted to optimize levee height for each of the units. The levee heights are described as 1% ACE water surface elevation (WSEL) plus a height. The inflection points in the benefits analysis are circled in red on both the tables and graphs. Note that for the Isleta West Unit, the benefits continue to rise with increasing levee height. However, the Pueblo of Isleta expressed concerns related to obscuring visual sightlines to the river along that reach. As a result, a levee height of Base Levee + 4 feet was supported and provides reasonably maximized benefits to the Unit.

For the Belen West Unit, net benefits maximize at the Base Levee + 6 foot height. However, for the Belen East Unit, net benefits maximize at the Base Levee + 7 foot height. To prevent a levee superiority issue, the PDT determined that the combined net benefits for Belen East and Belen West Units would be reasonably maximized if both units are built to the Base Levee + 7 foot height. No special considerations were needed for optimization of the Mountain View Unit.

Table 12 Comparison of costs and equivalent annual benefits for the proposed Mountain View East Levee.

COMPARISON OF COSTS AND EQUIVALENT ANNUAL BENEFITS FOR THE PROPOSED MOUNTAINVIEW EAST LEVEE (x$1,000, August, 2013 price level)	Base Levee	Base Levee +1'	Base Levee +2'	Base Levee +3'	Base Levee +4'	Base Levee +5'
Construction Cost	12,275.30	12,371.08	12,661.11	13,207.87	13,450.95	15,726.82
Real Estate						
PED (9%)						
Total First Cost	12,275.30	12,371.08	12,661.11	13,207.87	13,450.95	15,726.82
IDC (xx months construction, 3.5%)*						
Total, Interest During Construction						
Total Investment	12,275.30	12,371.08	12,661.11	13,207.87	13,450.95	15,726.82
Avg. Ann. Cost (3.5%, 50yr. project life)	488.47	492.28	503.82	525.58	535.25	625.82
OM RR&R						
Total Avg. Ann. Cost	488.47	492.28	503.82	525.58	535.25	625.82
Equivalent Avg. Ann. Benefits	301.38	573.77	730.73	804.46	833.65	843.46
Benefit/Cost Ratio	0.62	1.17	1.45	1.53	1.56	1.35
Net Benefits	-187.09	81.48	226.91	278.88	298.39	217.65

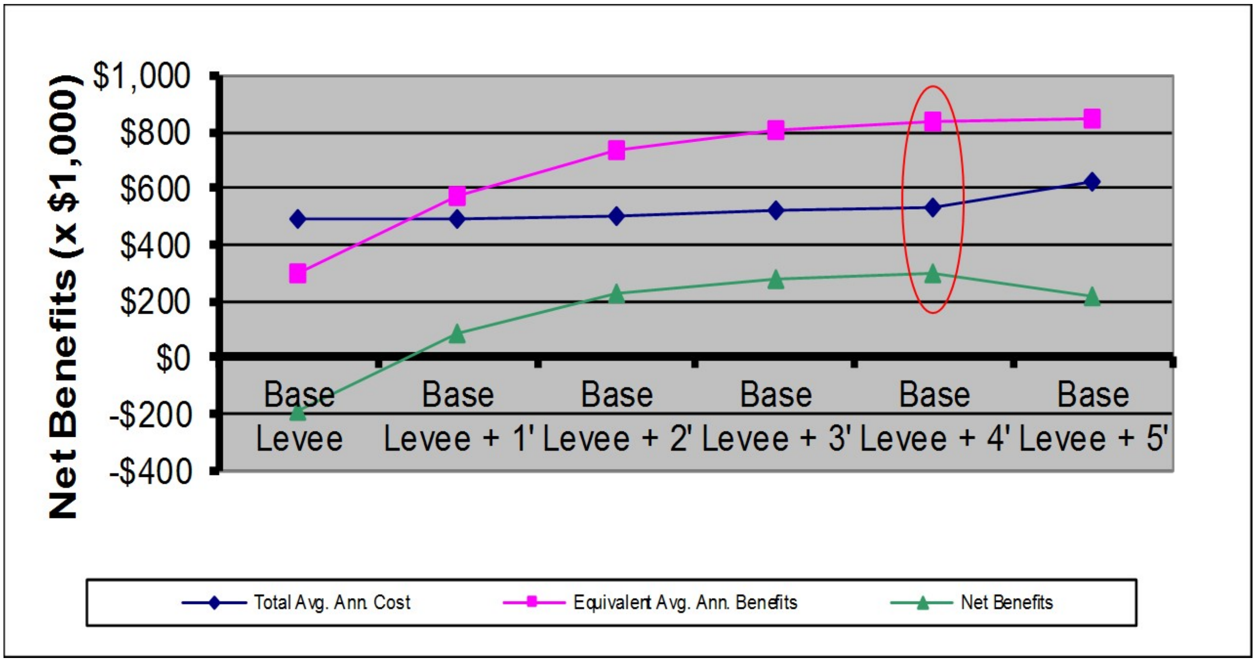


Figure 7 Benefit optimization graph, proposed Mountain View East levee.

Table 13 Comparison of costs and equivalent annual benefits for the proposed Isleta West Unit levee.

COMPARISON OF COSTS AND EQUIVALENT ANNUAL BENEFITS FOR THE PROPOSED ISLETA WEST LEVEE (Alignment E) (x$1,000, June, 2016 price level)						
	Base Levee	Base Levee + 1'	Base Levee + 2'	Base Levee + 3'	Base Levee + 4'	Base Levee + 5'
Construction Cost*	8,670.43	9,258.32	9,863.99	11,295.18	12,261.43	13,590.17
Real Estate						
PED (9%)						
Total First Cost	8,670.43	9,258.32	9,863.99	11,295.18	12,261.43	13,590.17
IDC (xx months construction, 3.125%)*						
Total, Interest During Construction						
Total Investment	8,670.43	9,258.32	9,863.99	11,295.18	12,261.43	13,590.17
Avg. Ann. Cost (3.125%, 50 yr. project life)	345.02	368.42	392.52	449.47	487.92	540.79
OM RR&R						
Total Avg. Ann. Cost	345.02	368.42	392.52	449.47	487.92	540.79
Equivalent Avg. Ann. Benefits	-762.13	-406.90	14.19	341.96	526.93	602.69
Benefit/Cost Ratio	-2.21	-1.10	0.04	0.76	1.08	1.11
Net Benefits	-1,107.15	-775.31	-378.32	-107.50	39.01	61.90

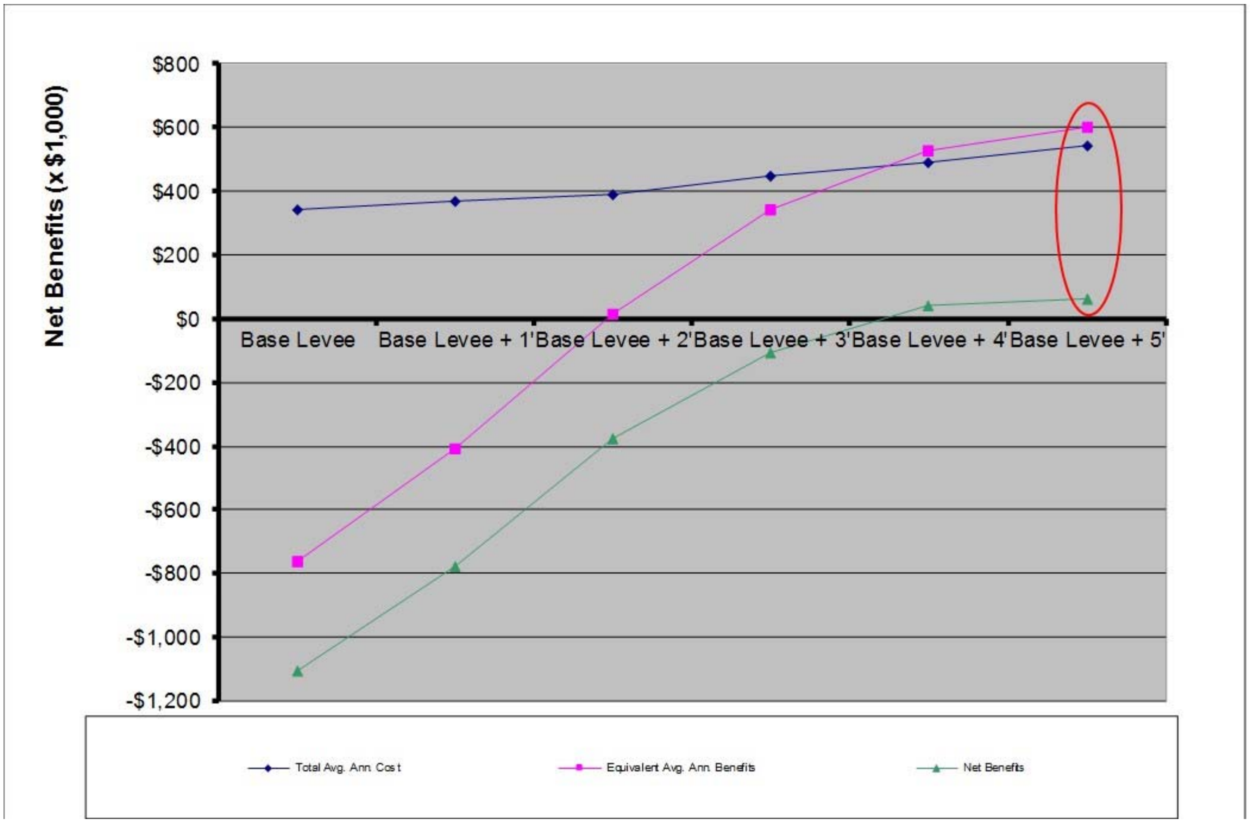


Figure 8 Benefit optimization graph, proposed Isleta West Unit levee.

Table 14 Comparison of costs and equivalent annual benefits for the proposed Belen East Unit levee.

COMPARISON OF COSTS AND EQUIVALENT ANNUAL BENEFITS FOR THE PROPOSED BELEN EAST LEVEE ALT. A (x$1,000, August, 2013 price level)									
	Base Levee	Base Levee + 1'	Base Levee + 2'	Base Levee + 3'	Base Levee + 4'	Base Levee + 5'	Base Levee + 6'	Base Levee + 7'	Base Levee + 8'
Construction Cost*	74,132.56	80,060.04	83,729.67	85,348.05	91,784.29	102,600.55	116,107.29	126,172.43	141,523.32
Real Estate									
PED (9%)									
Total First Cost	74,132.56	80,060.04	83,729.67	85,348.05	91,784.29	102,600.55	116,107.29	126,172.43	141,523.32
IDC (xx months construction, 3.5%)*									
Total, Interest During Construction									
Total Investment	74,132.56	80,060.04	83,729.67	85,348.05	91,784.29	102,600.55	116,107.29	126,172.43	141,523.32
Avg. Ann. Cost (3.5%, 50 yr. project life)	2,949.95	3,185.83	3,331.85	3,396.25	3,652.37	4,082.78	4,620.25	5,020.77	5,631.63
OMRR&R									
Total Avg. Ann. Cost	2,949.95	3,185.83	3,331.85	3,396.25	3,652.37	4,082.78	4,620.25	5,020.77	5,631.63
Equivalent Avg. Ann. Benefits	-69,741.32	-28,551.51	7,895.10	33,674.41	47,889.19	53,802.65	55,800.19	56,391.92	56,564.18
Benefit/Cost Ratio	-23.64	-8.96	2.37	9.92	13.11	13.18	12.08	11.23	10.04
Net Benefits	-72,691.27	-31,737.33	4,563.25	30,278.16	44,236.82	49,719.88	51,179.94	51,371.15	50,932.55

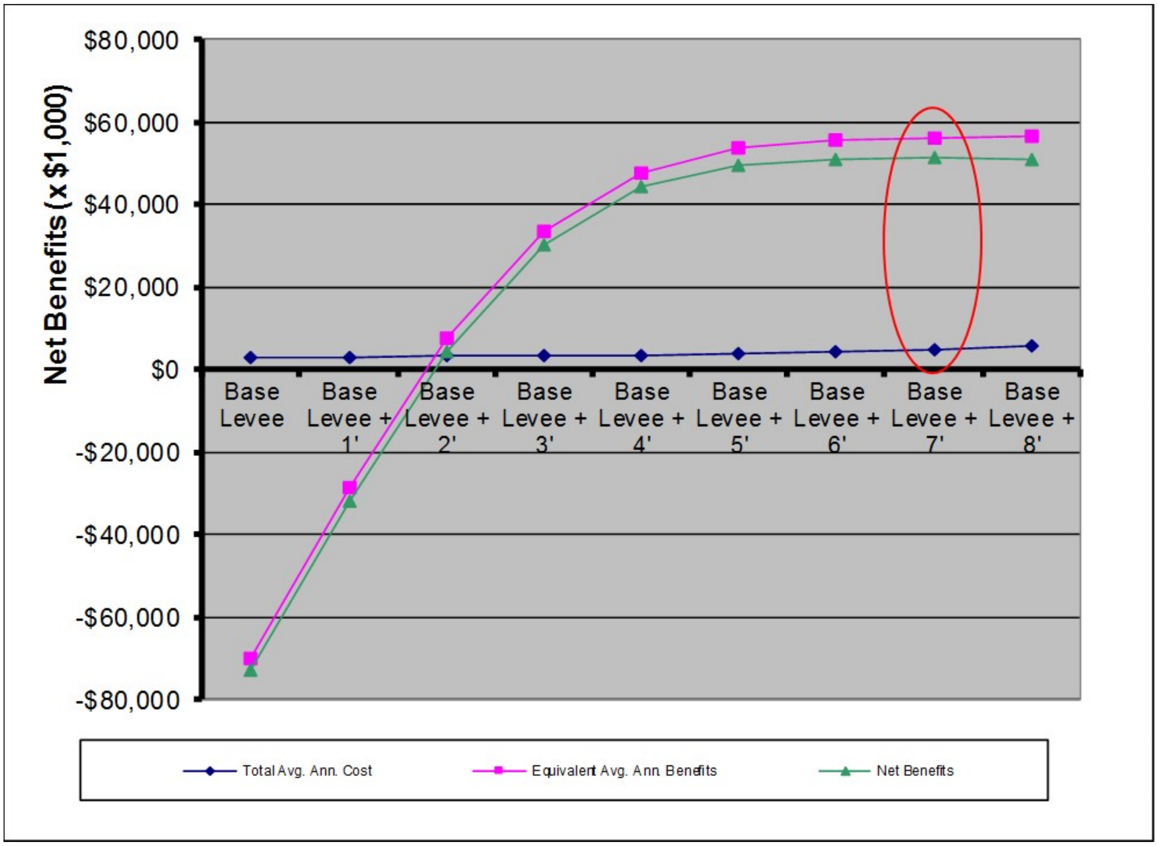


Figure 9 Benefit optimization graph, proposed Belen East Unit levee.

Table 15 Comparison of costs and equivalent annual benefits for the proposed Belen West Unit levee.

COMPARISON OF COSTS AND EQUIVALENT ANNUAL BENEFITS FOR THE PROPOSED BELEN WEST LEVEE (Alignment B) (x$1,000, August, 2013 price level)									
	Base Levee	Base Levee +1'	Base Levee +2'	Base Levee +3'	Base Levee +4'	Base Levee +5'	Base Levee +6'	Base Levee +7'	Base Levee +8
Construction Cost	47,454.16	48,679.99	54,857.37	60,737.45	64,667.08	76,693.58	85,600.19	96,070.89	108,299.15
Real Estate									
PED (9%)									
Total First Cost	47,454.16	48,679.99	54,857.37	60,737.45	64,667.08	76,693.58	85,600.19	96,070.89	108,299.15
IDC (xx months construction, 3.5%)*									
Total, Interest During Construction									
Total Investment	47,454.16	48,679.99	54,857.37	60,737.45	64,667.08	76,693.58	85,600.19	96,070.89	108,299.15
Avg. Ann. Cost (3.5%, 50 yr. project life)	1,888.34	1,937.12	2,182.94	2,416.92	2,573.29	3,051.86	3,406.28	3,822.94	4,309.54
OM RR&R									
Total Avg. Ann. Cost	1,888.34	1,937.12	2,182.94	2,416.92	2,573.29	3,051.86	3,406.28	3,822.94	4,309.54
Equivalent Avg. Ann. Benefits	-69,849.44	-20,687.89	14,167.79	32,330.96	40,561.62	43,917.02	45,097.09	45,461.94	45,578.74
Benefit/Cost Ratio	-36.99	-10.68	6.49	13.38	15.76	14.39	13.24	11.89	10.58
Net Benefits	-71,737.78	-22,625.01	11,984.85	29,914.04	37,988.33	40,865.16	41,690.81	41,639.00	41,269.20

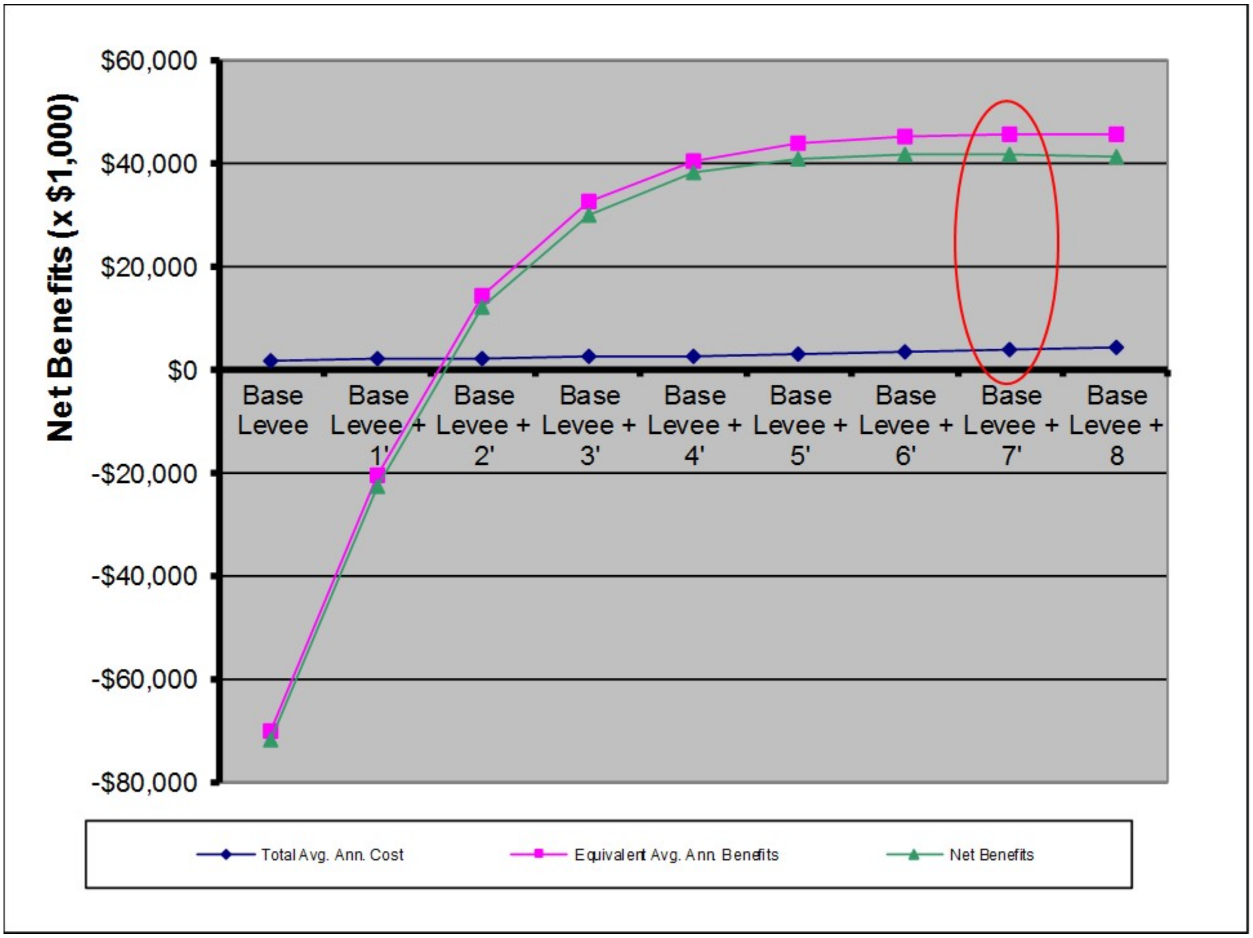


Figure 10 Benefit optimization graph, proposed Belen West Unit levee.

3.9 Alternatives Considered In Detail

Four alternatives are considered for NEPA analysis including the No Action (Alternative A), the authorized plan from 1979 (Alternative B), the preferred alignment with higher levee heights (Alternative C), and the preferred alignment with lower levee heights for the Belen Units (Alternative D). Alternative levee alignments that were considered during plan formulation were not evaluated. The Isleta East Unit was also eliminated from further evaluation due to the very low flood protection benefits (Appendix D).

Alternative A, the No Action Alternative, is used as the basis for comparing the benefits of the without-project conditions to the other alternatives. Alternative B (the Authorized Plan, as outlined in the 1979 Feasibility Report) is similar to the other alignments, and was designed for a higher flow volume for the 1% ACE water surface. Alternative C is the NED plan composed of the alignments that are complete, effective, efficient, and acceptable (Table 4). The Mountain View and Isleta West Units would have a 4 foot height above the 1% ACE WSEL, and the Belen East and West Units would have a 7 foot height above the 1% ACE WSEL (Table 16). Alternative D has the same alignments as Alternative C, the NED plan (Table 4), with the Belen East and West Units having a 4 foot height above the 1% ACE WSEL. Alternative D does not maximize economic benefits.

3.9.1 No Action Alternative (Alternative A)

A No Action Alternative is required pursuant to NEPA (Table 3). The No Action Alternative considers the likely future conditions in the project area in the absence of the Federally cost-shared and locally supported project. The No Action Alternative does nothing to alleviate risks to public health and safety. Under this alternative, there are neither changes to the existing non-engineered spoil banks nor the environment in and around the existing spoil banks. Catastrophic failures in the spoil banks may occur, but MRGCD will continue performing spoil bank maintenance and repair. The existing spoil banks will continue to provide minimal protection from flood events of a magnitude of less than the 20% ACE. There would be no loss of riparian habitat with the No Action Alternative. With this alternative, 16,300 people and critical infrastructure will continue to be at risk throughout the study area.

3.9.2 The 1979 Authorized Plan* (Alternative B)

The Rio Grande and tributaries studies and projects were initiated in response to a series of Congressional actions authorizing studies and projects within the Rio Grande Basin and particularly within the report's study area (Figure 1; USACE 1979). Most of those authorities are listed in Section 1.1. In 1984, the Middle Rio Grande Flood Protection, Bernalillo to Belen, New Mexico, project began in response to the 1979 Feasibility Report and to the 23 June 1981 Chief's Report (SUBJECT: Middle Rio Grande Flood Protection, Bernalillo to Belen, New Mexico). The plan as recommended in 1979 consisted of the following units:

- Corrales Unit: Levee construction and raising an average of 2.8 feet above existing height. The unit extended from high ground in the vicinity of the Corrales Siphon downstream to immediately upstream of the Oxbow marsh area. The Corrales Unit construction was completed in 1997 (construction ended at La Orilla upstream of the Oxbow marsh area).
- Mountain View Unit: Levee construction an average of 2.5 feet above existing spoil bank height. The unit extends on the east side of the river from the south outlet of the Albuquerque South Diversion Channel to 3,000 feet downstream of the I-25 river crossing.
- Isleta Unit – West: Levee construction an average of 3.8 feet above existing spoil bank height. The unit extends from the Interstate 25 bridge and Atchison, Topeka and Santa Fe railroad bridge, to the NM 147 bridge approach at Isleta.
- Belen Unit – East: Levee construction an average of 2.7 feet above existing spoil bank height. The unit extends from high ground upstream of NM 147 bridge crossing, to 3,700 feet downstream from the railroad bridge at Belen.
- Belen Unit – West: Levee construction and raising an average of`3.0 feet above existing height. The unit extends from the railroad track immediately downstream of Isleta Marsh to approximately 7,000 feet downstream of the railroad bridge at Belen.

See Table 3 and Table 4 for comparison of the authorized project with the alignments considered. Compensation for impacts to fish and wildlife resources included the proposed creation of 75 acres of wetlands from carefully designed borrow areas, and 200 acres of woodland would be acquired in fee or easement. An alternative approach for habitat mitigation is described in Section 3.10 and Appendix E.

3.9.3 Preferred Alignment at NED Height* (Alternative C)

The Preferred Alternative at NED height (Alternative C) consists of the following units:

- Mountain View Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 4.4 miles.
- Isleta West Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 3.2 miles.
- Belen East Unit: Levee with a height of 7 feet above the 1% ACE WSEL for 18.1 miles.
- Belen West Unit: Levee with a height of 7 feet above the 1% ACE WSEL for 22.1 miles.
- A flood forecast and warning system.

The Mountain View and Isleta West units would have a levee height of the Base Levee or the 1% ACE WSEL + 4 feet. The levee height for the two Belen Units would be the 1% ACE WSEL + 7 feet based on the NED analysis. Performance, and therefore benefits, are optimized for the Mountain View, Isleta West, Belen East and West Units. Construction methods, vegetation management, real estate and permit requirements would be the same as for other alternatives. The preferred alternative levee height would result in a larger cross section and therefore a larger overall footprint. The footprint of the levee at the preferred height would affect approximately 305.8 more acres of riparian habitat (USACE 2017).

Alternative C would require borrow material for construction. Borrow material could be acquired from commercial sources outside the project area, or from mitigation sites implementing terrace lowering for improved riparian forest vegetation. Terrace lowering for mitigation would lower 200-300 acres of the floodplain prior to planting willow and cottonwood trees, improving their connectivity to groundwater. Use of the excavated material in levee construction would reduce costs for both mitigation and construction while providing benefits for the ecosystem and flood protection.

3.9.4 Preferred Alignment at Base Height* (Alternative D)

Alternative D using the preferred alignment at the 1% ACE WSEL consists of the following units:

- Mountain View Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 4.4 miles.
- Isleta West Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 3.2 miles.
- Belen East Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 18.1 miles.
- Belen West Unit: Levee with a height of 4 feet above the 1% ACE WSEL for 22.1 miles.
- A flood forecast and warning system.

The upstream Mountain View and Isleta West units would be the same as that in the recommended plan discussed in Sections 4.11 and 4.12. Alternative D at the Base Levee height (1% ACE WSEL + 4 feet) would result in a smaller levee that does not maximize the NED benefits for the two Belen Units.

Performance and therefore benefits are less for the Belen Units. Appurtenant structures, tie-backs and non-earthen structures would be the similar, but appropriately sized for the shorter levee height of the Belen Units as compared to the recommended plan. Construction methods, vegetation management, real estate and permit requirements would be the same for the shorter levee height. The lower levee height would result in a smaller cross section and therefore a smaller overall footprint. The smaller levee footprint would affect approximately 216.8 acres of riparian habitat (USACE 2017).

The volume of borrow material for Alternative D would be significantly lower than for the recommended plan, because the lower levee height requires less material to construct. This results in lower costs for acquiring borrow, making this alternative less expensive, but with lower benefits than Alternative A with higher levees. Mitigation would be limited to removal of invasive trees like Russian olive and Salt cedar, and replanting native vegetation. Terrace lowering of floodplains to enhance native riparian ecosystems would require hauling and disposal of excavated materials, increasing mitigation costs.

3.10 Mitigation Sites and Actions

Mitigation for habitat loss is a requirement to compensate for the loss of habitat due to a Federal action. Section 906(d) of the WRDA 1986 states that project alternatives must support recommendations with a specific plan to mitigate for fish and wildlife losses.

Mitigation sites shall be identified during the design phase of the project due to uncertainties in funding and schedule. Site identification during the design phase supports flexible planning and reduces costs for relocating mitigation sites. Spatial analysis shall combine vegetation mapping (Siegle et al. 2013) with geological layers to screen preliminary sites based on lower habitat value and suitable soils for mitigation. Sites with higher densities of invasive salt cedar and Russian olive generally have lower value than native vegetation. Sites with higher percentages of silt and clays (>20%) have better soils for supporting native riparian vegetation. Terrace lowering for habitat restoration may require excavation of materials. Suitable excavated material may be spoiled into the levee to reduce mitigation costs. Suitable excavated material from other agency restoration projects may also be available for levee construction.

Mitigation may be accomplished by vegetation management of 218.8 acres or more for native riparian trees, shrubs, forbs and grasses to create a mosaic of vegetation at and among sites to mitigate for the loss of suitable bird habitat. Management includes removal of invasive plant species and planting of native plant species. Removal of non-native vegetation may be accomplished using manual and mechanical treatment methods (USACE 2011). Removal of non-native vegetative species will take place between August 15 and April 15 of each year to avoid bird nesting seasons. Some habitat may be mitigated by planting supplemental patches of native trees and shrubs in selected areas within the gallery forest. Enhanced habitat sites will be designed and constructed to produce approximately 128.9 acres of high quality cottonwood and willow riparian habitat features.

The required 15 foot-wide Vegetation Management Zone (see Section 4.1.9) along the toe of the proposed levee (87.0 acres) will be seeded with suitable riparian grass species to minimize the potential for post-construction erosion, reduce the potential for colonization by invasive weed species, and provide vegetation usable by wildlife.

Mitigation for loss of wetland ponds may be accomplished by excavation to maintain wetland surface area. Suitable excavated material may be spoiled into the levee to reduce mitigation costs.

Down-cutting of the Rio Grande in the project vicinity has resulted in a lowering of groundwater level in terraces adjacent to the river. As a result, some terrace vegetation is under stress from reduced access to groundwater. Terrace lowering for habitat restoration may be required and this will necessitate excavation of large volumes of materials. Suitable excavated material may be used for levee construction to reduce mitigation costs. Suitable excavated material from other agency restoration projects may also be available for levee construction.

3.11 Selecting the Recommended Plan

Based on the analysis presented in Section 4.9, the levee heights that provide reasonably maximized net benefits for the four units are as follows:

- Mountain View – 1% ACE WSEL + 4 feet.
- Isleta West – 1% ACE WSEL + 4 feet.
- Belen East – 1% ACE WSEL + 7 feet.
- Belen West – 1% ACE WSEL + 7 feet.

The analysis is summarized in Table 16.

Table 16 Results of benefit-cost analysis of levee heights.

Unit	NED Plan		
	Investment Cost*	Annual Cost* (2.875%, 50 years)	Equivalent Annual Net Benefits
Mountain View	$13,450,949	$523,816	$309,832
Isleta West	$12,261,431	$529,237	$49,439
Belen East	$126,172,431	$4,913,488	$51,478,434
Belen West	$96,070,890	$3,741,254	$41,720,688
Total	**$247,955,702**	**$9,707,795**	**$93,558,393**

** 2017 dollars and Fiscal Year 2017 discount rate.*

3.12 The Recommended Plan

The recommended plan consists of the following components:

- Mountain View Unit
    - Approximately 4.4 miles
    - Height = 1% ACE WSEL + 4 feet
- Isleta West Unit
    - Approximately 3.2 miles
    - Height = 1% ACE WSEL + 4 feet
- Belen East Unit
    - Approximately 18.1 miles
    - Height = 1% ACE WSEL + 7 feet
- Belen West Unit
    - Approximately 22.1 miles
    - Height = 1% ACE WSEL + 7 feet
- Flood forecast and warning system

Implementation of the recommended plan will reduce flood risk for approximately 12,400 people and critical infrastructure throughout the study area.

3.13 Environmental Considerations and Mitigation

The construction footprint of the recommended plan would extend beyond the riverward toe of the existing spoil bank throughout the project area, removing approximately 306 acres of vegetation in the floodway. The Vegetation Management Zone (see Section 4.1.9) would be approximately 87 acres along the levee.

3.13.1 Regional Context

The Rio Grande is the fifth longest river in North America, and one of the top ten endangered rivers in the world (Wong et al. 2007). The Rio Grande in New Mexico comprises 484 miles (26% of total length). Riparian corridors comprise less than one percent of New Mexico's landscape (USEPA and NMED 1998), yet they are the most important ecosystems in the state (Roelle and Hagenbuck 1995). The Rio Grande floodplain contains patches of undeveloped bosque consisting of cottonwood and willow riparian habitat. Historically, flooding and scour were the basic processes that created and maintained a patchwork of variable age class forest stands in the bosque (Crawford et al. 1993; Scurlock 1998). The surface area of wet meadows, marshes, and ponds has decreased by 73% along 250 miles of the Rio Grande floodplain in New Mexico.

3.13.2 Study Area

GIS was used to map the riparian gallery forest, wetlands, and pond habitat in the study area for the effects analysis (Appendix E). The baseline riparian habitat within the floodway between the spoil banks is approximately 5633 acres excluding the active river channel (Appendix E). Native riparian gallery forest comprises 28% of the floodway area, and mixed gallery forest (including invasive species) comprises over 69% of the floodway area. Levee construction would result in a net loss of 218.8 acres of floodway with 87 acres converted to the Vegetation Management Zone (USACE 2017). A biological assessment describing the effects of the recommended plan Impact Analysis and Compensatory Mitigation

This Habitat Mitigation Monitoring and Adaptive Management Plan (Appendix E) describes the process for documenting the habitat types in the study area, the potential impacts caused by the recommended plan, and the mitigation area that would compensate for habitat losses. The loss of habitat for the Southwestern willow flycatcher is 29.6 acres and the Yellow-billed cuckoo is 212.5 acres (USACE 2017). There is no loss of habitat for the Rio Grande silvery minnow. The habitat mitigation plan (Appendix E) proposes vegetation management and terrace lowering measures to enhance riparian forest vegetation for these two species.

4. RECOMMENDED PLAN

A recommended plan was chosen on the basis of the analysis of the various alternatives and the decision-making process described in Chapter 3. This chapter more fully describes the TSP, as well as the procedures and cost sharing that will be required for implementation of the plan if it becomes the plan recommended to, and authorized by, Congress. A schedule (Section 4.3) and a list of further studies (Section 4.4) are also included.

4.1.1 Features and Accomplishments

The recommended plan for the project consists of the following:

- Mountain View Unit
    - Approximately 4.4 miles
    - Height = 1% ACE WSEL + 4 feet
- Isleta West Unit
    - Approximately 3.2 miles
    - Height = 1% ACE WSEL + 4 feet
- Belen East Unit
    - Approximately 18.1 miles
    - Height = 1% ACE WSEL + 7 feet
- Belen West Unit
    - Approximately 22.1 miles
    - Height = 1% ACE WSEL + 7 feet

A typical levee section is shown in Figure 11 below (Shown at larger scale in Figure 5). The figure shows a view from the perspective of the east bank of the Rio Grande looking downstream; reverse for the west bank.

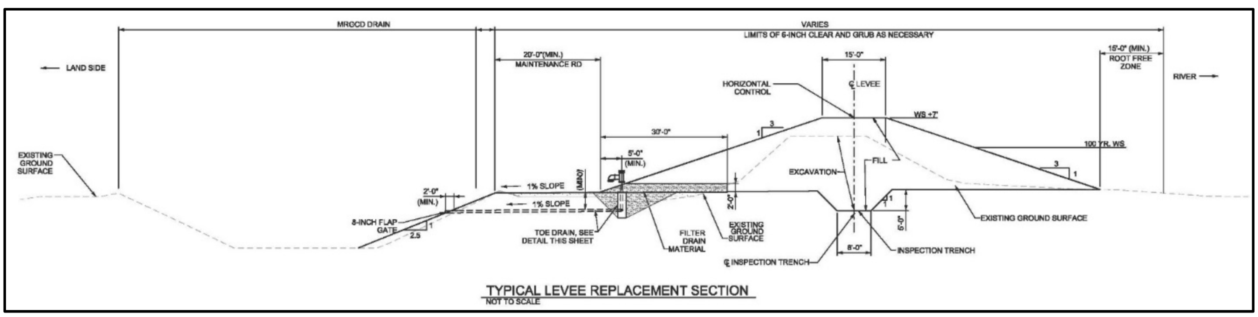


Figure 11 Typical levee section.

The following figures show the proposed levee alignments for each unit.

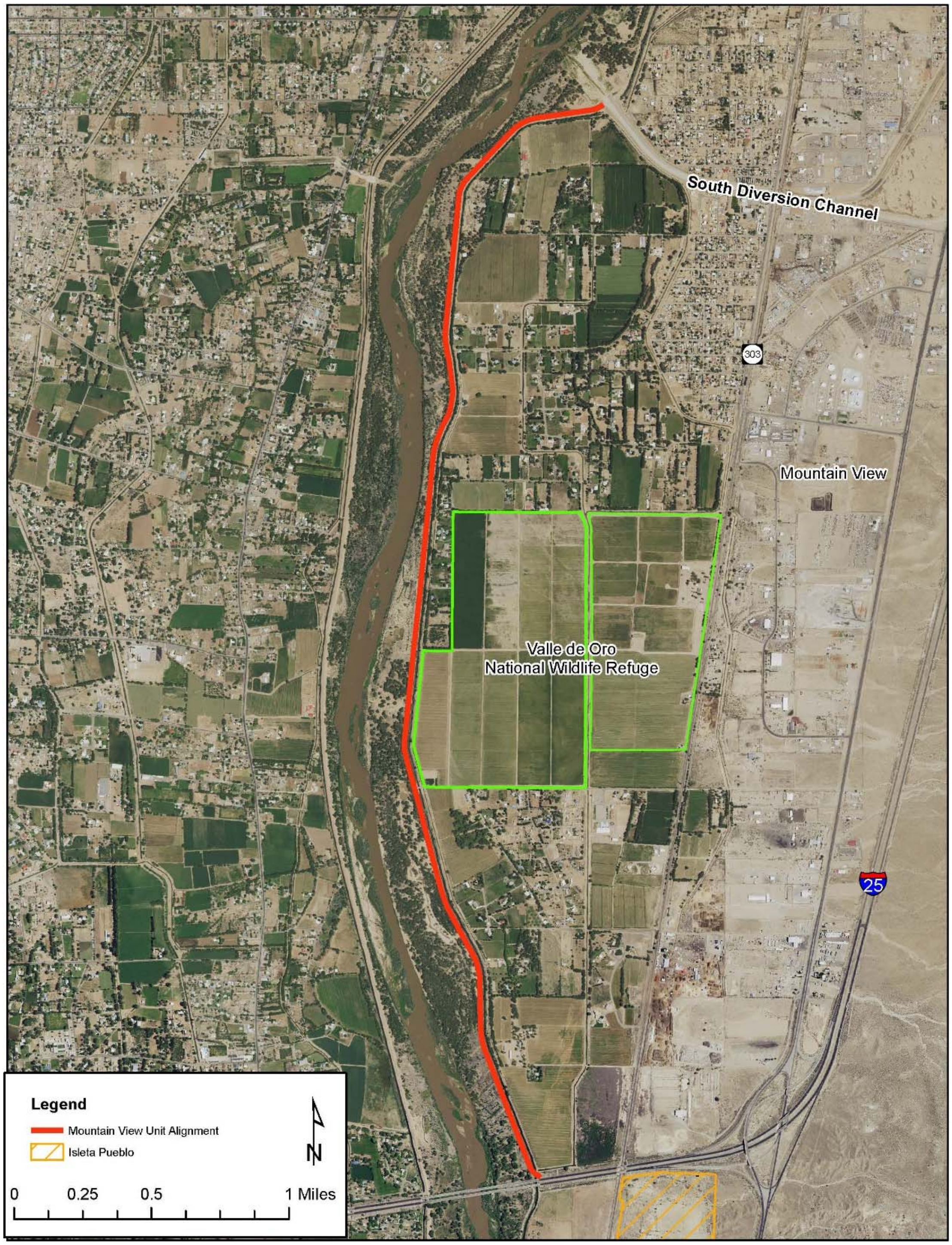


Figure 12 Mountain View Unit.

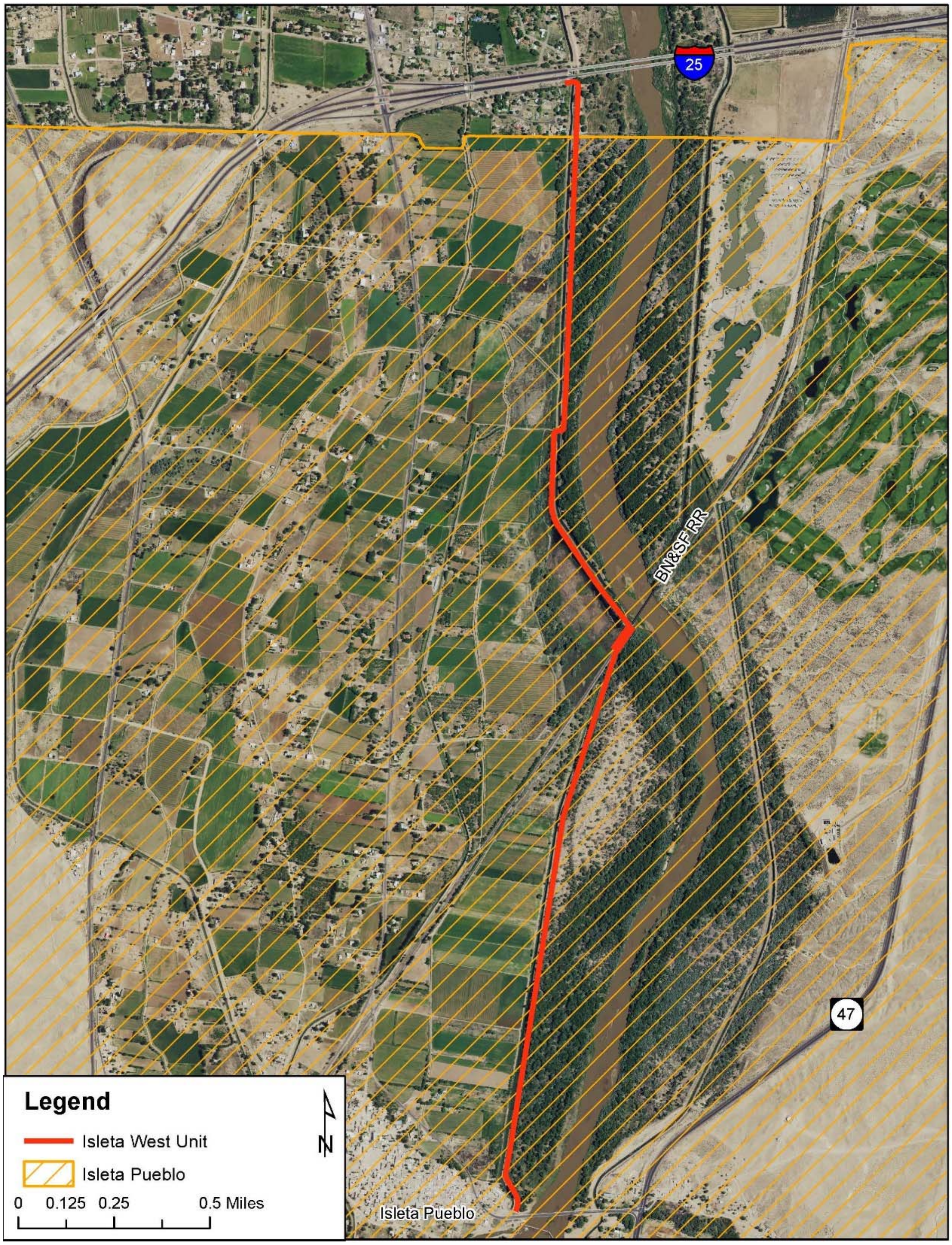


Figure 13 Isleta West Unit.

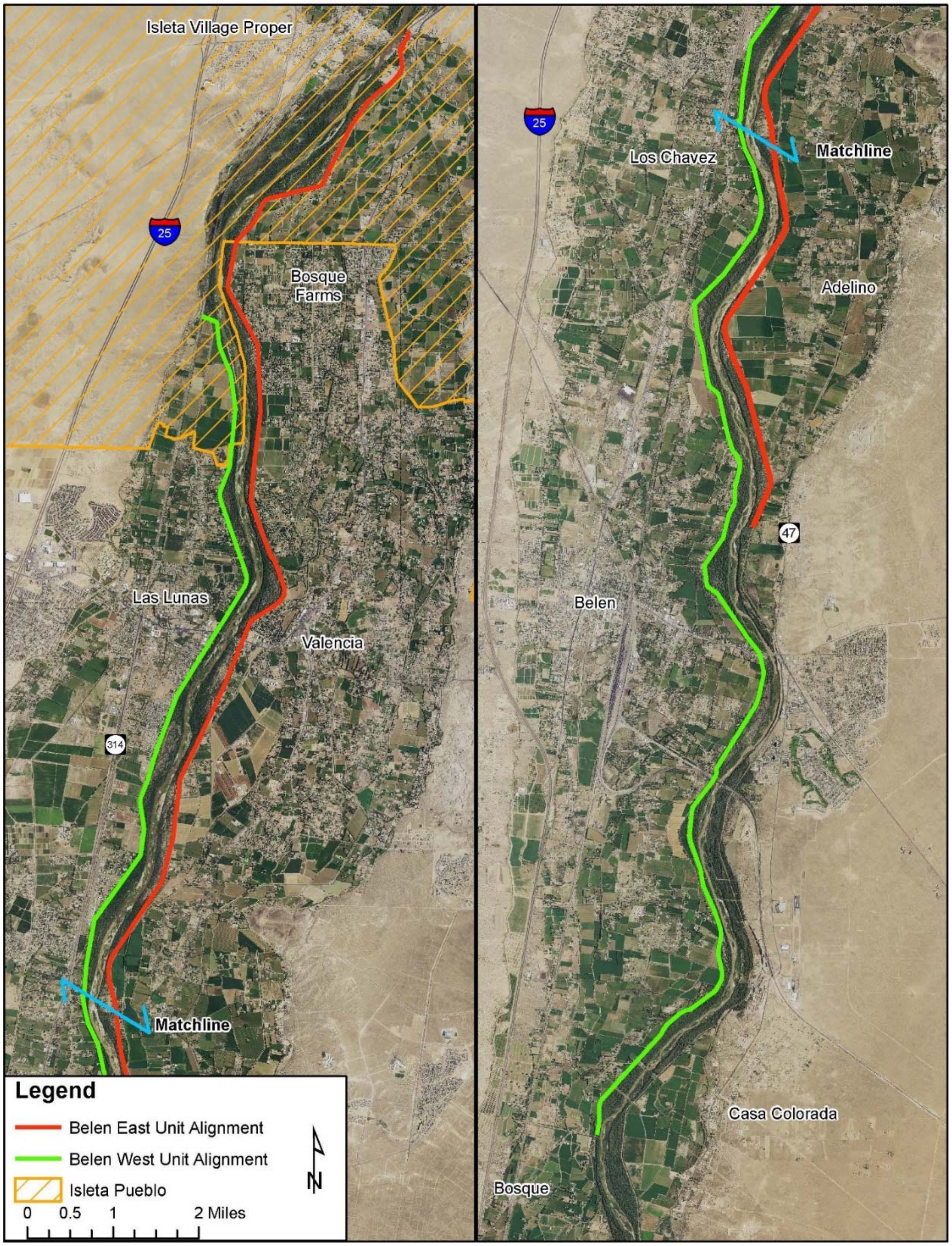


Figure 14 Belen East and Belen West Units.

The recommended plan also includes a flood forecast and warning system for all the units. Implementation of the recommended plan will reduce flood risk for approximately 16,300 people and critical infrastructure throughout the study area.

4.1.2 Staging Areas

Construction staging and access for equipment and materials would take place within the landside project easements where practical, on publically owned lands, or on offsite areas where the non-Federal sponsor would negotiate the temporary use of private lands for this purpose.

On certain reaches a waterside earthen bench is present and staging could take place on either the landside or riverward of the levees; however any riverward use would be restricted to the approved construction season and mandatory environmental safeguards would be strictly enforced. The actual size, quantity and location of these temporary sites will be dependent upon the extent of the construction project phase. For the purposes of evaluating impacts, it was estimated that approximately one acre of staging area would be required for every mile of levee construction.

4.1.3 Levee Borrow Material Requirements

The existing spoil bank will be the main source of material for construction of the recommended plan. The volume of the existing spoil bank is based on numerous measured sections along the length of the spoil bank. A volume loss of about 10% is anticipated due to the presence of deleterious or otherwise unsuitable material in the spoil bank; unsuitable material will be removed before soils are placed as engineered fill in the recommended plan.

The volume of material available from the existing spoil bank after removal of unsuitable material was adjusted to account for a gain in volume as the spoil bank is disturbed during demolition (using a bulking factor of 1.18), and a loss in volume as the soil is subsequently compacted during construction of the recommended plan (using a bulking factor of 0.79).

The resulting volume of spoil bank material was compared to the volume needed for the recommended plan in order to estimate the amount of additional material needed (borrow) for construction, or the amount of excess material that will need to be removed (waste).

4.1.4 Material Balance

The Mountain View and Isleta West levee units have more material available from the existing spoil banks than is needed to construct the recommended plan (Table 17).

Table 17 Material balance, Mountain View and Isleta West Units.

Levee Unit	**Waste** (cu yd)	**Borrow** (cu yd)
Mountain View	15,214	--
Isleta West 1	--	8,311

In contrast, the existing spoil banks for the Belen levee units do not provide enough material to construct the recommended plan, resulting in a material shortfall (Table 18).

Table 18 Materials balance, Belen East and Belen West Units.

Levee Unit	**Waste** (cu yd)	**Borrow** (cu yd)
Belen East	--	722,748
Belen West	--	492,069
Total Borrow Required		**1,207,914**

Although about 5,000 cu yd of suitable fill can presumably be exported from the Mountain View and Isleta West spoil banks for use in constructing the Belen levees, there is a remaining shortfall of about 1.2 million cu yd.

4.1.5 Borrow Specifications

Because this project is only in the preliminary stages of design, detailed borrow specifications have not been established.

4.1.6 Borrow Sources

The most desirable source of borrow for the Belen East and West levees will be the excavations that may be required as part of the environmental mitigation of the project impact. Areas potentially requiring mitigation are adjacent to the proposed construction and thus hauling costs would be at a minimum. Also, areas potentially requiring mitigation are within the Rio Grande floodplain and may be more likely to meet the borrow specifications for fines content than fill from commercial sources.

In the event that borrow is not available from mitigation of floodplain areas, other borrow resources will have to be identified. To account for the possible cost of obtaining borrow material from outside the project area, a cost assumption was made that sufficient quantities of appropriate borrow materials will be available within 25 miles of the project.

4.1.7 Mitigation

As described in Chapter 3, several studies in the various plant communities within the Rio Grande floodway have documented their use and relative value to wildlife. Many of these studies (Thompson et al. 1994; HAI 2010) have used a common riparian vegetation classification system (from Hink and Ohmart, 1984) and have documented the utilization of various floristic/structural communities for birds and, to a lesser extent, small mammals. These relationships form the basis for determining the relative impacts of project alternatives on wildlife given the extent and type of affected plant communities. The footprints of project features were overlaid onto 2012 riparian vegetation coverage (Siegle et al. 2013). This was reviewed to estimate potential changes to vegetation types due to the project features.

4.1.8 Habitat effects common to all alternatives

The footprint of the recommended plan extends beyond the riverward toe of the existing spoil bank, affecting 305.8 acres. The 87 acre Vegetation Management Zone (see next section) would be replanted with grasses. Approximately 128.9 acres of native riparian forest and 158.3 acres of mixed gallery forest would be affected (Appendix E, Table 4). About 30 acres of suitable flycatcher habitat and 218.8 acres of suitable cuckoo habitat would be affected.

4.1.9 Changes due to the Vegetation Management Zone

USACE Engineer Technical Letter (ETL) 1110-2-583, Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures (USACE 2014) requires that no woody vegetation be allowed to grow on the levee or within 15 feet of the toe of the levee on either side. This prevents root penetration into the levee that can compromise its structural integrity and allows for unobstructed visual inspections on a periodic basis. Although this Vegetation Management Zone is often referred to as the "Vegetation-free Zone," the term is somewhat of a misnomer because grasses and most herbaceous plant species are grown within the zone: Only woody plant species are restricted.

The recommended plan would remove 87.0 acres of existing riparian vegetation to establish the Vegetation Management Zone. During construction, existing vegetation would be removed to accommodate the levee and the Vegetation Management Zone adjacent to the riverward toe. Vegetation removal in preparation of construction would include the removal of the above-ground stems, root crowns and roots greater than 0.5-inch in diameter. Removal methods may include clearing and grubbing, scraping, or root-plowing and raking. Following construction, a 15-foot-wide zone along the riverward toe of the levee would be permanently maintained to be devoid of trees and shrubs.

Vegetation removal and clearing and grubbing activities for the Vegetation Management Zone – and for all proposed construction – would occur between August 15 and April 15 to avoid disturbance of nesting migratory birds. Vegetation removal outside of that period would only be performed after a survey by a biologist has confirmed that disturbance to nesting migratory bird species can be avoided.

4.1.10 Mitigative Vegetation Establishment

This section summarizes the draft mitigation plan for the recommended plan. The draft mitigation plan does not include recommendations that may result from the ongoing consultation with the USFWS.

The P&S describes the process and content of mitigation plans to be included in feasibility-level reports such as this GRR/SEIS. This mitigation plan also conforms to the requirements contained in Section 2036 of the WRDA 2007.

(a) Recommended mitigation measures

The following recommended revegetation measures would compensate for unavoidable losses of fish and wildlife resources for the recommended plan, including listed species and their designated critical habitat. Vegetation management measures are described in detail in Appendix E. Mitigation sites shall be identified during the design phase of the project due to uncertainties in funding and schedule. Site identification during the design phase supports flexible planning and reduces costs for relocating mitigation sites.

Measure A: Non-native tree removal

The footprint of the recommended plan would remove approximately 128.9 acres of native riparian habitat, and 158.3 of mixed gallery (non-native) vegetation, consisting primarily of dense shrubs. The loss of mixed gallery forest habitat will be mitigated by identifying areas for selective tree removal, and planting with native shrubs to enhance the habitat value.

Methods for reducing the density of non-native vegetation include both manual and mechanical treatment methods (USACE 2011). Removal of non-native vegetative species will take place between August 15 and April 15 of each year, when possible, to avoid bird nesting seasons and requirements, notably, under the Migratory Bird Treaty Act, which constrains activities with the potential to impact nesting birds. Follow-up treatment with herbicides, or root ripping (raking approximately 6 to 12 inches below grade in order to remove roots) may be implemented.

Measure B: Riparian shrub and tree planting

The footprint of the recommended plan would displace approximately 218.8 acres of riparian vegetation, consisting primarily of dense shrubs. The equivalent acreage will be planted with variable densities of native riparian trees, shrubs, forbs and grasses to create a mosaic of vegetation at and among sites to mitigate for the loss of suitable bird habitat. Recommended plants for riparian mitigation are described in Appendix E, Table 10.

Measure C: Grass seeding along the riverward corridor of the Vegetation Management Zone

The 15-foot-wide corridor along the riverward toe of the proposed levee (87.0 acres) will be seeded with suitable riparian grass species to minimize the potential for post-construction erosion; reduce the potential for colonization by invasive weed species; and to provide vegetation usable by wildlife. ETL 1110-2-583 requires that plantings in this zone be limited to grass species. Periodic mowing and herbicidal spot-treatment may be required to control woody and invasive herbaceous species within this corridor. These maintenance activities will be performed by USACE in the year following seeding and by the project sponsor, thereafter, as part of the operations, maintenance, repair, replacement and rehabilitation (OMRR&R) requirements. The area requiring such seeding along the proposed 48-mile levee entails approximately 87 acres.

Measure D: Enhanced riparian habitat features (terrace lowering, channels, swales)

The enhanced habitat sites will be designed and constructed to produce high quality cottonwood and willow riparian habitat features. The enhanced habitat sites will be located in the Belen reach on both sides of the river to reduce transportation costs and distribute habitat mitigation through about 26 river miles of the project area (Belen East and West levee). The area of individual sites may range between 5 and 25 acres.

The footprint of the recommended plan would remove approximately287.2 acres of riparian vegetation. The preliminary volume of borrow materials for the recommended plan is estimated at 1.22 million cu yd (USACE 2017; equivalent to 250 acres excavated to a 3-foot depth). The feature design plan will define the site perimeter, shape, topography, and other habitat elements to be excavated. Each site will be less than 25 acres in area. Grubbing and clearing of enhanced habitat features will only be permitted to occur outside the breeding bird season (September through March).

Measure E: Pond and wetland

Pond and wetland mitigation is currently focused on avoiding impacts by realigning the levee or excavation to maintain the wetland or pond surface area.

Measure F: Land acquisition for habitat restoration

Land acquisition for habitat restoration (including habitat conservation easements) may be used to replace habitat loss due to encroachment on the floodway by the recommended levee alignment. Lands adjacent or near the floodway may be acquired for habitat mitigation. Riparian habitat restoration within the floodway, but outside the project area, may be used to replace habitat loss due to encroachment on the floodway by the selected levee alignment.

(b) Cost Effectiveness / Incremental Cost Analysis

Sufficient long-term monitoring has been conducted in habitats within the river corridor of the Middle Rio Grande Valley that the relative value of various riparian types has been documented for bird communities. Avian densities have been determined for a large variety of riparian communities based on their floristic and structural characteristics. These scaled indexes have been frequently used in cost effectiveness analyses for USACE restoration projects and mitigation plans. Appendix E summarizes avian density values over an array of habitat types found within the project area. Avian density values were used to determine the abundance of breeding- season birds within a given area of affected habitat types, as well as proposed post-construction plantings. Although a common index of bird abundance was used to characterize the value of these habitats, it should be acknowledged that grassland and shrub habitats support a different suite of bird species, and that each type is necessary to mitigate for unavoidable effects.

IWR-Plan software was used to perform cost effectiveness and incremental cost analyses. The costs of vegetation planting measures described above were estimated from actual costs of recent USACE contracts with a 15.8% contingency.

Measure A entails removal of non-native vegetation in support of increasing native vegetation density and the incremental cost per unit output. Measure B entails the establishment of shrubs and trees, and their incremental cost per unit output increases with successively dense planting prescriptions. Measure C entails seeding to establish vegetation and their incremental cost per unit output are similar. The incremental cost per unit output increases with successively dense planting prescriptions.

Measure D, the excavation of enhanced habitat features, will create habitat with shallower depth to groundwater and improved floodplain connectivity to the river hydrograph for establishing native riparian vegetation. Measure E entails the mitigating wetland features.

4.1.11 Invasive Plant Species and Noxious Weeds

About 50% of the vegetation that will be removed for construction of the levees currently consists of exotic-dominated or mixed native-exotic shrub stands. Treatments to minimize colonization by invasive plant species and noxious weeds would be included in the contract specifications for the establishment of native riparian shrubs and trees and in the operation and maintenance requirements. All methods of treatment during establishment and later maintenance would be subject to the approval of local land management agencies, including the State of New Mexico Land Office, USFWS Valle de Oro National Wildlife Refuge, MRGCD and Reclamation.

In all planted areas, invasive weeds would be treated with manually applied, appropriate and approved herbicides when needed over the first 10 years following planting. Treatment would be applied to germinated or resprouted herbaceous species and salt cedar. Periodic mowing prescribed for maintenance of the Vegetation Management Zone would also facilitate the control of invasive species.

4.1.12 Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R)

Upon completion of the project, it will be turned over to the sponsor for OMRR&R. USACE will provide MRGCD with a manual summarizing the duties necessary for proper operation of the project.

In general, OMRR&R will consist of maintaining the Vegetation Management Zone free of woody vegetation larger than 0.5-inch-diameter stems or trunks. The sponsor will be responsible for maintaining levee integrity by repairing runoff erosion, eliminating rodent burrows in the levee, replacing rip rap lost in flow events, and inspecting and cleaning seepage infrastructure regularly. MRGCD must also be available to perform annual inspections of the levee system with USACE personnel.

The sponsor's responsibility for project operation and maintenance begins when the project is turned over to the sponsor following construction, and continues indefinitely. During this phase, the community will realize the full benefits of the project, and responsibility passes from USACE to MRGCD. USACE involvement after construction will normally consist of periodic assessments and routine inspections to ensure that the project is being properly maintained and is functioning as intended.

4.1.13 Real Estate

Property within the footprint of this project is managed by Reclamation and maintained and operated by the MRGCD. Borrow and disposal sites are to be located on the MRGCD property, or appropriate instruments will be obtained for use of commercial sites. Based on the Draft Real Estate Plan (Appendix I), the real estate required for the levee footprint, temporary construction easement, and staging areas has already been secured by the MRGCD on behalf of Reclamation as part of previous Federally-funded projects. Therefore, all lands, easements, rights-of-way, relocations, and dredged material disposal areas (LERRD) credit would only apply to any staging, borrow and/or waste areas required for the project, estimated at approximately 250-500 acres.

MRGCD is the underlying fee and easement owner of the majority of the land in the northern part of the project and most of the lands in the southern part of the project, according to the relevant land records of the real estate required for the project. MRGCD holds the underlying fee interest for approximately 444.4 acres, and Reclamation holds approximately 609 acres where the recommended plan will be constructed. This area includes approximately 485 acres for the levee footprint and 47 acres for temporary construction easements 15 feet and 22 feet wide. MRGCD will provide USACE with an authorization for entry for all required LERRD. However, ongoing litigation has brought into question ownership of MRGCD assets. For that reason, USACE has obtained signatures from both MRGCD and Reclamation in order to proceed with any project that contains real property involving the lands in question.

4.1.14 Plan Economics and Cost Sharing

The project first cost, estimated on the basis of 2016 price levels, is estimated at $253,273,000. Table 19 displays each cost by project feature. Estimated average annual costs of approximately $44,000,000 were based on a 2.875% interest rate, a period of analysis of 50 years, and construction ending in 2036. Table 20 shows the project first costs. The total average annual flood damage reduction benefits are $255,000,000 with a benefit-cost ratio (BCR) of 6.8 to 1.0.

Table 19 Cost break-out for TSP.

Cost Account	**Description**	**Total First Costs ($1,000)***
1	Lands and Damages	$67
2	Relocations	$2,090
11	Levees and Floodwalls	$230,811
18	Cultural Resources Data Recovery**	$1,496
18	Cultural Resources Survey***	$2,493
30	Planning, Engineering, and Design	$3,318
31	Construction Management	$12,998
	Total Project First Cost	$253,273.00

***** *Costs are in October 2016 price levels at 2.875%, for a 50-year period of analysis.*
*** Cultural Resource Data Recovery Costs are approximately 0.8% of Federal cost.*
**** Cultural Resource Survey Costs are approximately 1.0% of total project cost. These costs will be included in the Planning, Engineering, and Design account in the final report and cost estimate.*

Table 20 Summary of cost sharing responsibilities for the TSP*.

Item	**Federal***	**Non-Federal***	**Total***
Project Features	$233,304		$233,304.00
LERRDs	$0	$2,157	$2,157
PED	$2,489	$830	$3,318
Construction/Project Management	$12,998		$12,998
Subtotal	**$248,791**	**$2,987**	**$251,777**
5 percent Cash Contribution	-$12,464	$12,464	
Adjustment	-$47,494	$47,494	
Subtotal	$188,833	$62,944	$251,777
Percent of Subtotal	75%	25%	100%
Cultural Resources (Data Recovery)	$1,496	$0	$1,496
Total	$190,329	$62,944	$253,273

** Costs ($1,000s) are in October 2016 price levels at 2.875 percent, for a 50-year period of analysis.*

4.1.15 Risk and Uncertainty

In general, the ability of the recommended plan to accomplish the intended objectives depends on the following: the validity of pertinent assumptions, base data, and analytical techniques used in this study; the successful completion of future studies, designs, and construction; and appropriate OMRR&R after construction.

4.1.16 Residual Risk

The recommended plan greatly reduces the risk of flooding downstream of Albuquerque south to Belen and areas immediately adjacent. Even with the levee improvements, a slight residual risk of flooding within the city remains. This risk would be in the form of overtopping or flanking of levees during very infrequent events (greater than 200-year). Figure 15 shows the with-project 1% ACE floodplain. When compared to Figure 2, the without-project 1% ACE inundation area shows that the recommended plan greatly reduces, but does not completely eliminate, flood risk for the rarest flood events.

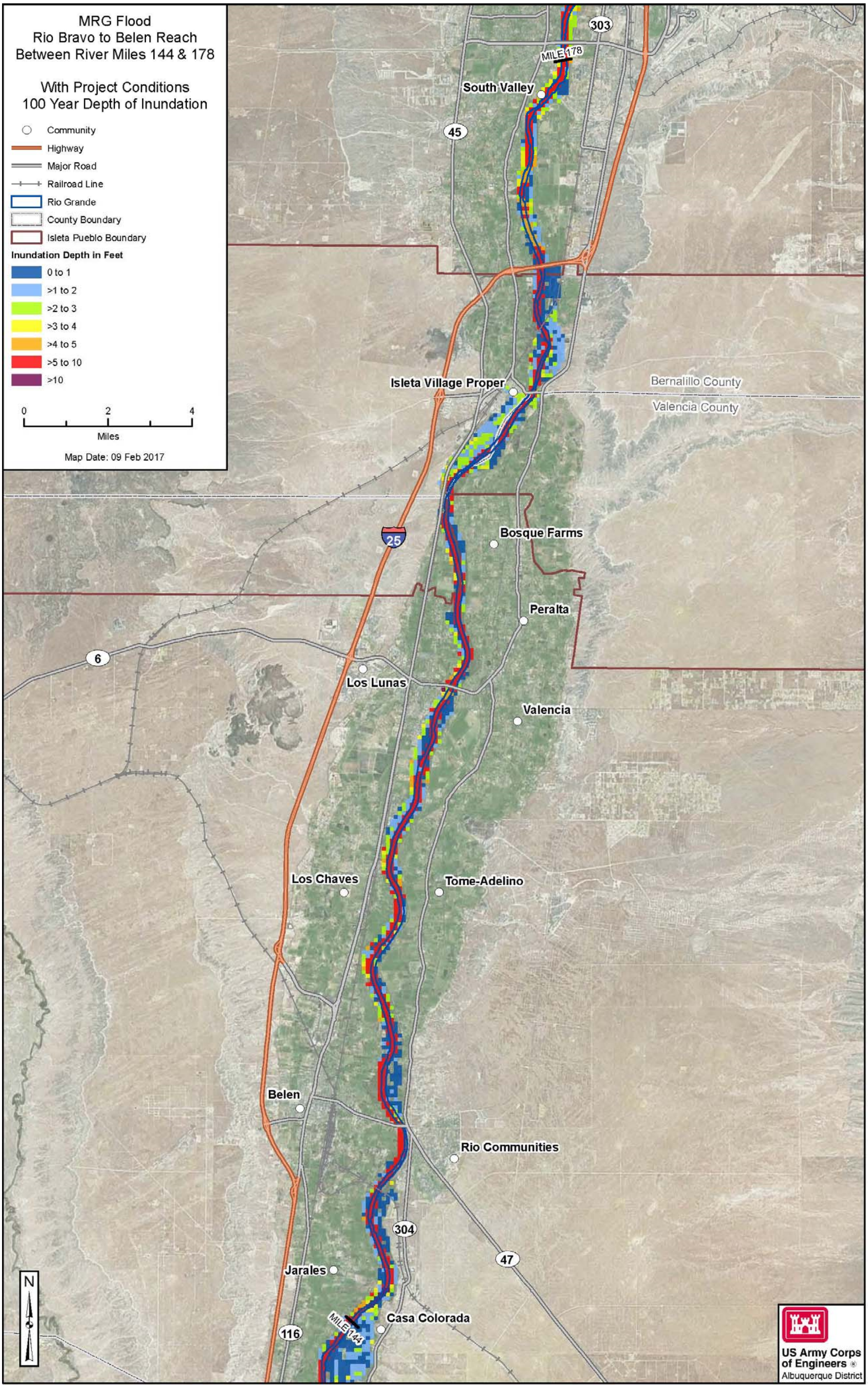


Figure 15 Map showing the with-project 1% ACE event floodplain.

4.1.17 Executive Order 11988

To comply with E.O. 11988, projects are formulated and recommended that, to the extent possible, avoid, minimize and/or mitigate adverse effects associated with use of the floodplain, and avoid inducing incompatible development in the floodplain unless there is no practicable alternative. Achieving flood and coastal storm risk management objectives generally cannot avoid locating actions in riverine or coastal floodplains. The requirements below are consistent with the E.O. 11988 decision process displayed in Figure 1 in the Water Resources Council, Floodplain Management Guidelines for Implementing E.O. 11988, February 10, 1978 (43 FR 6030).

ER 1165-2-26 provides the general guidance and policy for USACE's implementation of EO 11988 for all civil works projects. Paragraph 7 of the regulations states: "It is the policy of the Corps of Engineers to formulate projects which, to the extent possible, avoid or minimize adverse impacts associated with use of the base flood plain and avoid inducing development in the base flood plain unless there is no practicable alternative. The decision on whether a practicable alternative exists will be based on weighing the advantages and disadvantages of flood plain sites and non-flood plain sites. Factors to be taken into consideration include, but are not limited to, the functional need for locating the development in the flood plain. The test of practicability will apply to both the proposed Corps action and to any induced development likely to be caused by the action."

Based on the analysis conducted in Chapter 4, Section 4.6, the recommended plan is compliant with the E.O.

4.1.18 Environmental Operating Principles

The Recommended Plan supports each of the seven USACE Environmental Operating Principles (EOPs). These EOPs are:

1. Foster sustainability as a way of life throughout the organization.
2. Proactively consider environmental consequences of all USACE activities and act accordingly.
3. Create mutually supporting economic and environmentally sustainable solutions.
4. Continue to meet our corporate responsibility and accountability under the law for activities undertaken by USACE, which may impact human and natural environments.
5. Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs.
6. Leverage scientific, economic and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner.
7. Employ an open, transparent process that respects views of individuals and groups interested in USACE activities.

The environmental operating principles are met in the following ways:

Environmental balance and sustainability (EOP 1, 2, 3 &4):

- Project avoids or minimizes environmental impacts while maximizing future safety and economic benefits to the community.

Planning with the environment (EOP 1, 2, 4, and 5):

- USACE worked with resource agencies during the planning phase to minimize impacts to the environment.
- The recommended plan allows for expanded floodplain flooding in widened bypass area.

Integrate scientific, economic and social knowledge base (EOP 6)

- USACE sought advice from a panel of experts on the status and likelihood of erosion on the Rio Grande.

Seeks public input and comment (win-win solutions) (EOP 7)

- USACE held stakeholder meetings and public workshops throughout the process
- USACE worked with local groups to achieve a balance of project goals and public concerns

4.1.19 USACE Campaign Plan

The mission of USACE is to provide vital public engineering services in peace and war to strengthen the Nation's security, energize the economy and reduce risks from disasters. In order to meet this mission, the agency has developed the USACE Campaign Plan (FY13-18) as a component of the corporate strategic management process to establish priorities, focus on the transformation initiatives, measure and guide progress, and adapt to the needs of the future. The goals of the Campaign Plan are:

<u>Goal 1 - Support National Security</u>

- Objective 1a – Support Combatant Commands and other U.S. government agencies
- Objective 1b – Partner with Installation Management Communities
- Objective 1c – Achieve National/Army energy security and sustainability goals
- Objective 1d – Support the Engineer Regiment

<u>Goal 2 - Transform Civil Works</u>

- Objective 2a – Modernize the Civil Works project planning program and process
- Objective 2b – Enhance Civil Works budget development with a systems Watershed–Informed approach
- Objective 2c – Deliver quality solutions and services
- Objective 2d – Deliver reliable, resilient and sustainable infrastructure systems

<u>Goal 3 - Prepare for Tomorrow</u>

- Objective 3a – Enhance interagency disaster response and risk reduction capabilities

- Objective 3b - Enhance interagency disaster recovery capabilities
- Objective 3c - Enhance interagency disaster mitigation capabilities
- Objective 3d – Strengthen Domestic Interagency Support

Goal 4 - Reduce Disaster Risk

- Objective 4a – Maintain and advance DoD and Army critical enabling technologies
- Objective 4b – Build trust and understanding with strategic engagement, communication, and cyber-security
- Objective 4c – Streamline USACE business, acquisition and governance processes
- Objective 4d – Build ready and resilient people and teams through talent management / leader development

The recommended plan is responsive to these goals and objectives by:

Delivering reliable, resilient and sustainable infrastructure systems: USACE designed a project that avoids or minimizes environmental impacts while maximizing future safety and economic benefits to the community

Delivering quality solutions and services: USACE designed a project that avoids or minimizes environmental impacts through engineered levee alternatives while providing flood risk management for public safety of communities south of Albuquerque on the Middle Rio Grande.

Building trust and understanding with strategic engagement, communication, and cyber-security: The PDT organized and participated in stakeholder meetings and public workshops throughout the process and worked with local groups to achieve a balance of project goals and public concerns.

Building ready and resilient people and teams through talent management / leader development: The study successfully employed the use of District Quality Control, ATR, Risk Analysis, and IEPR to assist in the review of the development of a technically sound recommendation of Federal Interest.

4.2 Plan Implementation

This section describes the remaining steps to achieve potential authorization by Congress of the Project for implementation.

4.2.1 Report Completion

The draft GRR/SEIS will be circulated for public and agency review for 45 days. Public meetings will be held to obtain comments from the public, agencies, and other interested parties. After completion of the public review period, comments will be considered and incorporated into the GRR/SEIS as appropriate. Comments received during the public and agency review period, as well as responses to them, will be presented in an appendix. The final GRR/SEIS will be provided to any public agency that provides public review comments.

4.2.2 Report Approval

The final GRR/SEIS will be circulated for 45 days to agencies, organizations, and individuals who have an interest in the recommended plan. All comments received will be considered and incorporated into the final GRR/SEIS as appropriate. This project is being coordinated with all appropriate Federal, state, and local government agencies. USACE Headquarters will coordinate the public comments, receive comments from affected Federal and State agencies, and complete its own independent review of the final report.

After its review of the final GRR/SEIS, including consideration of public comments, USACE Headquarters will prepare the Chief of Engineers' Report. The Chief’s Report will be submitted to the Assistant Secretary of the Army (Civil Works), who will coordinate with the Office of Management and Budget and submit the report to Congress.

4.2.3 Project Authorization and Construction

Once the final Chief’s Report is approved by the Chief of Engineers and the project is authorized by Congress, construction funds must be appropriated by Congress before a Project Partnership Agreement (PPA) can be signed between USACE and MRGCD, allowing final design and construction.

4.2.4 Division of Responsibilities

<u>Federal Responsibilities</u>

USACE will accomplish preliminary engineering and design (PED) studies. Once the project is authorized and funds are appropriated, a project partnership agreement would be signed with MRGCD as the non-Federal sponsor. After the sponsor provides the cash contribution, and the lands, easements, rights-of-way, relocations, and disposal areas (LERRDs), as well as assurances, the Federal Government will begin construction of the project.

<u>Non-Federal Responsibilities</u>

Specific items of local cooperation are identified in Chapter 10, Recommendations.

<u>Views of Non-Federal Sponsor</u>

The non-Federal sponsor, MRGCD, supports the TSP. Throughout the development of the GRR/SEIS, there has been significant coordination with MRGCD as well as other stakeholders.

<u>Financial Capability of Sponsor</u>

The total estimated non-Federal first cost of the project is $62,944,000 including LERRDs, using 2016 price levels. Actual costs may be slightly greater at the time of construction due to inflation. The total estimated value for the project lands, including LERRDs, is $2,157,000. The non-Federal sponsor will be required to provide self-certification of financial capability for the final report as required by USACE guidance.

<u>Project Cost-Sharing Agreements</u>

A Design Agreement must be executed between USACE and the non-Federal sponsor in order to cost share the development of detailed plans and specifications. Once the design is approved, but before construction is started, the USACE and MRGCD would execute a Project Partnership

Agreement. This agreement would define responsibilities of the non-Federal sponsor for project construction as well as OMRR&R and other assurances.

4.3 Schedule

If the project is authorized in 2019, construction activities could start as early as 2021. Table 21 contains a schedule showing the approval and construction phases of the project.

Table 21 Project Schedule.

Phase	Scheduled Dates
Division Commander's Transmittal to HQUSACE	2018
Chief of Engineers Report	2018
Potential Authorization	2019
USACE and Sponsor Sign Design Agreement	2019
Preconstruction Engineering and Design	2019-2021
USACE and Sponsor Sign Project Partnership Agreement	2021
Initiate Construction	2021
Complete Physical Construction	2042

4.4 Further Studies

During the PED phase, several additional studies would be conducted as part of developing detailed designs for the project. These studies include:

- Additional geotechnical analysis of underlying substrates.
- Detailed seismic hazard analysis for levee designs.
- Identification of borrow sources for approximately 1.2 million cubic yards of soil suitable for levee construction.
- Additional hydraulic analysis including most current modeling data.
- Topographic and ground surveys for project design.
- Preconstruction surveys to avoid direct impacts to nesting birds and other sensitive species.
- Water quality analysis of construction activities and methods.
- An update of the 2015 Phase I Environmental Site Assessment to identify potential hazardous materials and wastes within the project area.
- Intensive cultural resources survey, evaluations, and mitigation as appropriate, in consultation with the State Historic Preservation Officer (SHPO), and Native American Tribes; as specified in the Programmatic Agreement (PA).

As mentioned in Chapter 1, this study will only address water resources issues within a specific area within the Middle Rio Grande authority, and is therefore, called an “Interim” document. Additional studies to address other water resource issues within the Middle Rio Grande basin could be initiated based on Congressional direction.

5. EXISTING AND EXPECTED FUTURE WITHOUT-PROJECT CONDITIONS

The alternatives that were evaluated, resulting in the selection of the TSP, were developed in response to the existing conditions along the Rio Grande within the project area. If the project is not constructed some existing conditions may remain unchanged while others may deteriorate over time resulting in an increasing threat to public health safety and wellness. This chapter presents information on the existing physical and biological environment, along with socioeconomic and cultural conditions, and evaluates the effects over time of not constructing the TSP.

5.1 Physical Environment*

5.1.1 Climate and Climate Change

5.1.1.1 *Existing Conditions*

The climate in the Middle Rio Grande Valley is arid continental with large daily and seasonal temperature differences. Summers tend to be hot and dry; winters tend towards cool and humid. Peak precipitation occurs during the late summer/early fall during the peak of the North American Monsoon (monsoon), with a secondary peak in winter. Spring and fall tends towards warm and dry. Temperatures at Albuquerque, located on the north end of the project area, have a monthly average daytime maximum above freezing in all months. Monthly overnight minimum temperatures are typically average below 32°F in winter, with relative large diurnal temperature ranges due to aridity. In summer, average monthly high temperatures exceed 80°F in all months. July is the hottest month, with temperatures ameliorating in late July and August due to the typical late afternoon cloudiness of the monsoon season. Monthly overnight low temperatures typically exceed 60°F in summer. At Albuquerque, precipitation averages 9.45 inches per year. For most of the year, monthly precipitation totals less than 0.75 inches, except during the July-October period when monthly precipitation averages greater than 1.0 inch.

The historic climate trends in the study area reflect the predominantly low-elevation, agricultural setting of the cooperative observer stations used in this analysis. These sites are at elevations comparable to the study area. Over the period 1951-2015, temperature has risen significantly in the Middle Rio Grande. Daytime high temperatures have risen at about 0.22 to 0.37°F/decade in the months January to June, with peak rates of warming in March of 0.90°F/decade. Nighttime low temperatures have also risen significantly in many months, particularly in the period January through June, with warming rates ranging from 0.12 to 0.39°F/decade. Increases in both daytime and nighttime temperatures have resulted in statistically-significant increases in mean monthly temperatures in all months but October and December. Extreme maximum temperatures in late spring-early summer (March, April, May and June) increased 0.19 to 0.78°F/decade. The most extreme overnight temperatures also display an upward trend in the late winter and spring, ranging from 0.24 to 1.04°F/decade. Precipitation and snow fall in the study area show little in the way of significant trends over the period of analysis.

5.1.1.2 *Future Without-Project Conditions*

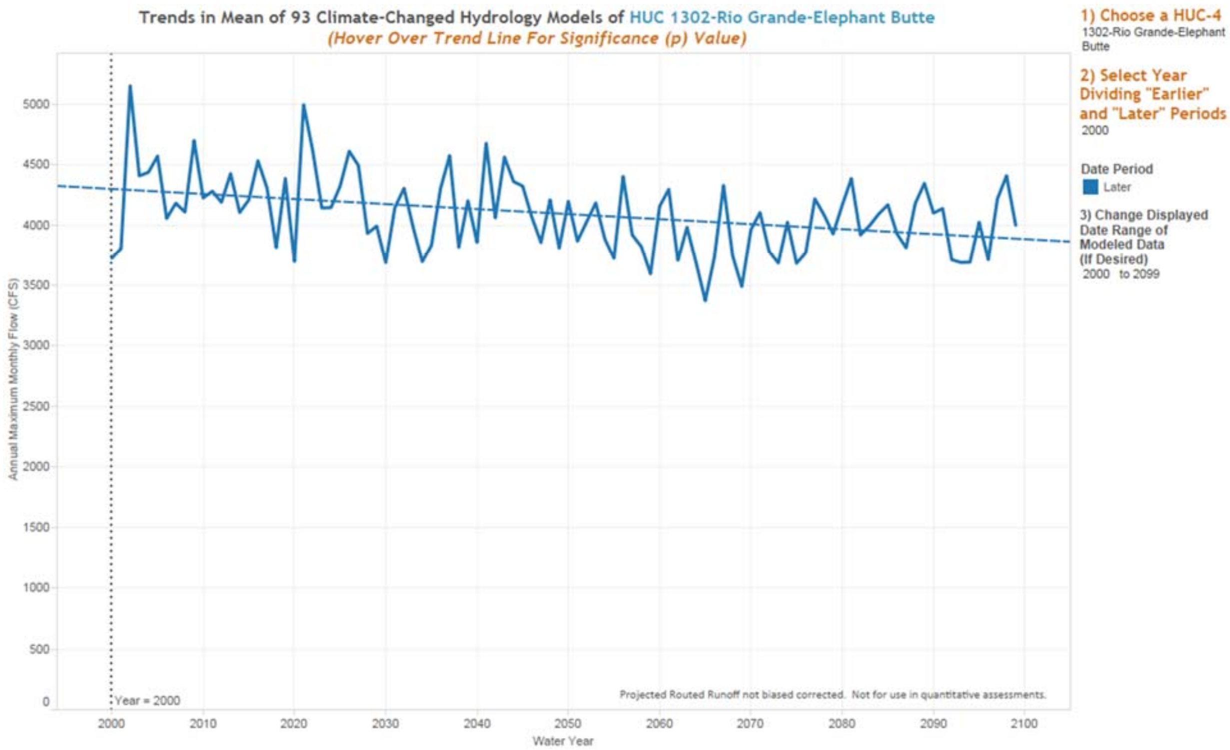
Climate models project substantial warming of 5-7°F over the 21st century as compared to late 20th century averages. Modeled warming by as much as 8.5 to 10°F may occur by 2100 under plausible high emissions (large radiative forcing) scenarios (Melillo et al. 2014). Even with no net changes in precipitation, such warming will exert profound effects on regional hydrology by altering snowpack, reducing spring runoff and increasing evaporation rates.

Under the future without-project condition, average stream flow along the Rio Grande, and average annual maximum monthly stream flows are anticipated to decrease due to reductions in sustaining snow packs in the Rio Grande headwaters (Reclamation et al. 2013; Elias et al. 2015). Snow pack loss is likely to result from:

- Decreases in winter snow fall (snow falls as rain, running off/infiltrating instead of remaining as snow);
- Earlier snow melt (extended snowmelt season, winter runoff, sublimation under warmer spring temperatures);
- Extended growing season, with resulting increases in transpiration and soil moisture loss.

As a result, spring runoff is likely to peak earlier and lower in the future, and base flows during the monsoon season are likely to be lower than historically (Figure 16).

However, wet winters are still likely to occur, resulting in years of high spring runoff. In addition, warmer eastern Pacific sea surface temperatures are likely to exist, with the potential to increase the amount of moisture that could be transported into the study area from the tropics, particularly in the summer and fall. Warmer air has the potential to hold more moisture, and both empirical and theoretical studies suggest a future in which the number of storms stays approximately the same but the frequency of large storms increases (as a fraction of the total). Data do not yet exist by which to accurately quantify future storm magnitudes or frequencies, but this phenomena has already been observed in all regions of the U.S. in recent decades (Melillo et al. 2014). Future flood risk, especially in the summer and fall, is likely to be comparable to the present.



Data comes from the USACE Inland Hydrology online tool (https://rsgis-tableau.han.ds.usace.army.mil/t/CCAdaptation/views/ECB2014-10/AboutthisTool?:embed=y&:display_count=no, accessed 15 March 2016).

Figure 16 Trends in stream flow, HUC 1302, Rio Grande-Elephant Butte.

5.1.2 Geology

The project area lies immediately south of the city of Albuquerque in central New Mexico. Albuquerque is located in the Rio Grande rift, a broad physiographic and structural depression composed of a series of north-trending, elongate topographic and structural basins extending from southern Colorado to northern Mexico. The structural basins are characterized by abundant late Quaternary faults, Quaternary volcanism, and thick accumulations of basin sediment fill (Morgan et al. 1986).

The project area lies within the Albuquerque Basin, the largest of the Rio Grande rift basins. The eastern margin of the Albuquerque Basin is bordered by active and potentially active faults adjacent to the Sandia, Manzanita, and Manzano mountain uplifts. The Albuquerque Basin is bordered to the west by the Albuquerque Volcanoes and on the north and northeast by the west-tilted Española Basin and late rift-stage volcanic fields. The Socorro Basin lies to the south (Grauch and Connell 2013).

Syn-rift sediments, known as the Santa Fe Group (Spiegel and Baldwin 1963), were deposited in the Albuquerque Basin during latest Oligocene through early Pleistocene time. Sediment thickness in boreholes in the basin center exceeds 14,000 feet (Lozinsky 1994; May and Russell

1994). Sediments of the Santa Fe Group include alluvial, aeolian, fluvio-lacustrine, and volcaniclastic detritus that were deposited within internally drained basins (Chapin and Cather 1994).

After local tilting and erosion, the ancestral Rio Grande became organized as a through-going drainage system, depositing fluvial sediments starting by early Pliocene time (Connell 2004).

5.1.2.1 *Site Geology*

Within the Rio Grande rift, the Rio Grande flows from north to south transporting sediments from northern New Mexico and southern Colorado. Geologic mapping by Connell (1997, 1998a, 1998b; Connell et al. 1995) shows that this alluvium is inset into Pleistocene alluvium, alluvial-fan deposits, and Tertiary bedrock that comprise the adjacent piedmont slopes. This inset trough of Holocene (Recent) alluvium is known as the inner Rio Grande valley.

The project area is located within the inner Rio Grande valley. The inner Rio Grande valley is underlain primarily by saturated, unconsolidated sandy alluvium which consists predominantly of sand and gravel with discontinuous interbeds of silt and clay (Kelson et al. 1999). Groundwater in the inner valley is very shallow, with depths beneath most of the valley of less than 40 feet (Hitchcock and Kelson 2007).

Typical alluvial deposits in the project site are variable and discontinuous. Foundation materials along the proposed levee alignment are predominantly sands, silty sands, and sandy clays. These soils are generally suitable as foundation material provided that locations where low-density materials have been identified receive adequate preparation. Weak clay layers composed of high-plasticity clay are also locally present.

5.1.2.2 *Faults and Seismic Activity*

The Rio Grande rift region in north-central New Mexico contains numerous late Quaternary faults, demonstrating that there is a real potential for significant strong ground motion in the Albuquerque region (Wong et al. 2004). Paleoseismic studies of major faults in the region suggest that, although infrequent, several major faults in the Albuquerque area have experienced large earthquakes in the late Holocene (Machette et al. 1998; Personius et al. 1999, 2001). These data provide direct evidence for the occurrence of large earthquakes of magnitude (M) 7 or greater in the Albuquerque area, despite the scarcity of moderate and large historical earthquakes (Hitchcock and Kelson 2007).

The consequences of a large earthquake in the vicinity of the project area would be significant because of the high likelihood of liquefaction-related ground failures in the inner Rio Grande valley. Sediments in the inner Rio Grande valley are highly susceptible to liquefaction (Kelson et al. 1999).

Liquefaction is the liquefying of certain sediments during seismic ground-shaking, resulting in temporary loss of support to overlying sediments and structures. Poorly consolidated, water saturated fine sands located within 30 to 50 feet of the surface typically are considered most susceptible to liquefaction.

The existing spoil banks in the project area are constructed over alluvial deposits that may be susceptible to liquefaction due to a seismic event, leading to excessive settlement or failure of the spoil bank slopes.

5.1.2.3 *Ground Shaking*

Earthquake ground shaking varies from place to place and hazard maps are available to estimate the potential ground shaking for a particular location. The hazard depends on the magnitudes and locations of likely earthquakes, how often they occur, and the properties of the rocks and sediments that earthquake waves travel through (USGS 2017).

Most of New Mexico (including the project area) is subject to a Moderate Seismic Hazard (USACE 2016, Appendix C), and a standard seismic study must be performed to properly assess the response of the foundation and structures to the earthquake events possible at the project site (USACE 2016).

The effect of seismic loads on the design of the proposed levees was assessed using a horizontal ground acceleration value of 0.20 g, equivalent to a return period of 475 years by Wong et al. (2004) and 2,475 years by the USGS (2017).

5.1.3 Hydrology, Hydraulics and Sedimentation

5.1.3.1 *Hydrology*

The purpose of the hydrology study is to estimate the frequency of flows of different magnitudes in the Rio Grande through the project area. Some of the applications are:

- The hydrology will be used to evaluate the potential of flooding with and without a proposed flood control levee in the project area.
- The hydrology will be used as the basis for with- and without-project floodplains.
- Economic benefits for flood frequency events will be estimated based on the hydrology.

See Figure 17 for a map of the Rio Grande Watershed and subwatersheds upstream of the study area.

The Hydrologic Analysis presented herein has undergone independent technical review (ITR) and has been certified by CESPA. Copies of the ITR Certification are included as Attachment 6 in Appendix H.

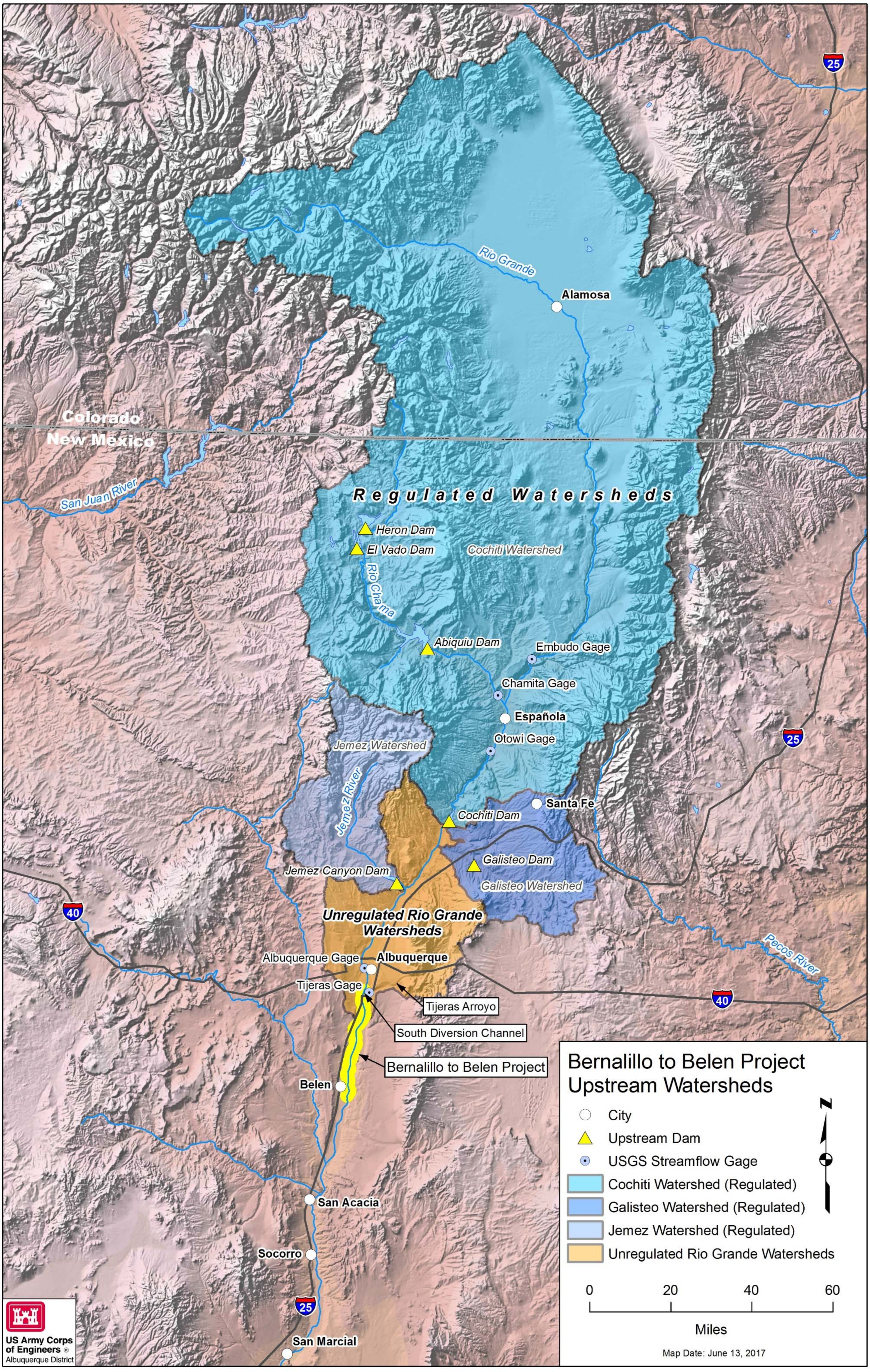


Figure 17 Rio Grande Watershed and subwatersheds upstream of the study area.

Overview of Hydrology in the Project Area

The Rio Grande watershed upstream of Albuquerque has an area of 17,440 square miles, of which 16,535 square miles is regulated by dams.

- Cochiti Dam is 48 river miles upstream of Albuquerque at the gage, and it directly regulates the Rio Grande upstream of the Albuquerque gage. The area of the Cochiti Dam watershed is 14,900 square miles. The dam is located on the Cochiti Pueblo in Sandoval County, NM.
- The Jemez Canyon Dam, also in Sandoval County, NM, controls 1034 square miles of the Jemez River watershed. The Jemez River confluence with the Rio Grande is 25 river miles upstream of the Albuquerque gage. The Jemez Canyon Dam is presently operated as a dry dam, although it had a permanent pool for approximately half of the 44 years it has been in service.
- Galisteo Dam is a dry, ungated dam that controls 600 square miles of the Galisteo Creek watershed. Galisteo Creek enters the Rio Grande 46.5 miles upstream of Albuquerque.

Downstream of these structures, there is an additional 900 square miles of unregulated watershed that contributes directly to flooding in the Rio Grande floodway in Albuquerque.

The USACE 2006 report is a study of flood frequencies for the Rio Grande in Albuquerque. The location in Albuquerque for this hydrology is the Albuquerque gage on the Rio Grande at the Central Avenue bridge in Albuquerque. The flow frequency determined by the HEC Middle Rio Grande study is a combined frequency based on:

- Regulated flood flows from the reservoirs upstream of Albuquerque, predominantly snowmelt floods, and
- Flood flows from unregulated local areas downstream of the reservoirs, primarily from rainfall runoff.

The results of the HEC Middle Rio Grande study were used to develop the Rio Grande hydrology in the project area. The 2006 HEC report for the Rio Grande at the Albuquerque gage is included as Attachment 2 in the Appendix H. Table 22 includes flood peaks from the HEC report associated with the frequency flood events from both regulated and unregulated areas that contribute to the project site.

Table 22 Peak Flood Flows for the Rio Grande Gage in Albuquerque (at Central Avenue) both from Upstream Regulated Areas and Upstream Unregulated Areas

Return Period (Years)	% Chance Exceedance	Flood Events from Regulated Areas- Peak Flows (cfs)	Flood Events from Unregulated Areas – Peak Flows (cfs)
2	50	5600	5260
5	20	7380	8100
10	10	7510	10300
50	2	7750	16100
100	1	7750	18900
200	0.5	10300	22100
500	0.2	14300	26700

Flood Flows from Rainfall Runoff Events in the Project Area

In the project area, floods are primarily from the Tijeras Arroyo watershed and transmitted to the Rio Grande via the South Diversion Channel (SDC). The SDC is the only major arroyo that directly enters the Rio Grande between the Albuquerque gage at Central Avenue and the downstream study limit. Flow from other tributaries to the Rio Grande through the study area is blocked by levees and does not reach the river.

The SDC enters the Rio Grande from the east immediately south of Albuquerque. The SDC includes 2 separate drainage areas.

- The SDC watershed proper is 7 square miles, and is not of adequate size to affect the hydrology of the river.
- The Tijeras Arroyo drainage area is 133 square miles.

A map of the SDC and Tijeras Arroyo watersheds is provided in Figure 18.

The Tijeras Arroyo watershed is a fan-shaped area lying to the southeast of Albuquerque. The arroyo is 28 miles in length. The upstream portion of the Tijeras Arroyo begins on the east side of the mountains, follows the fault line between the Sandia and Manzano mountains and emerges as a canyon onto a broad, sloping plain, or mesa, near Kirtland Air Force Base (KAFB). Mountainous uplands comprise approximately 60% of the area of the Tijeras Arroyo watershed. The channel between the upstream boundary of KAFB to the upstream limit of the Village of Tijeras is 11.6 miles in length and its slope is approximately 0.016 ft/ft. Table 2.2 shows peak flow frequency values for the Tijeras Arroyo used for this study.

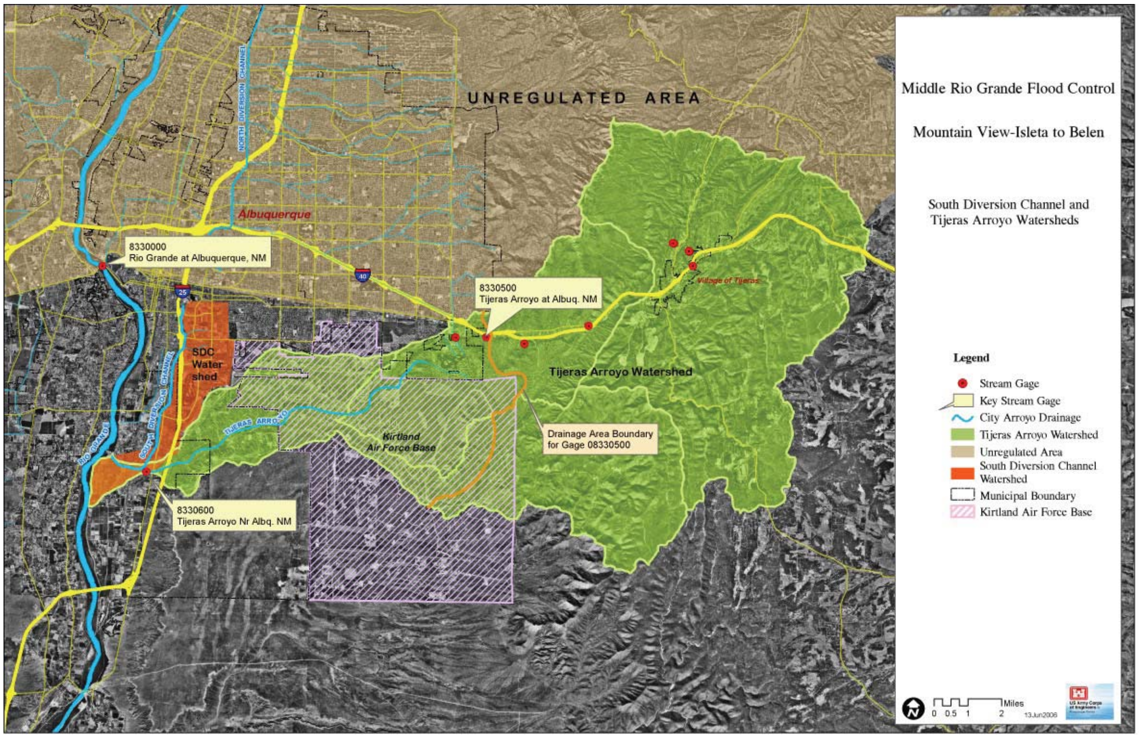


Figure 18 South Diversion Channel (SDC) and Tijeras Arroyo Watersheds.

<u>Summary of Hydrologic Analysis in the Project Area</u>

There are three potential sources of Rio Grande flooding in the project area downstream of Albuquerque. They are:

- Flood events in the regulated area upstream of Albuquerque, as identified in the 2006 HEC report.
- Rainfall-runoff flood events in the unregulated area upstream of Albuquerque, as identified in the 2006 HEC report.
- Rainfall-runoff flood events from the project area, downstream of Albuquerque. A single inflow to the Rio Grande, the South Diversion Channel (SDC) south of Albuquerque, provides the only potential for significant local inflow between the Albuquerque gage and the downstream end of the project area under existing conditions.

Snowmelt events from tributaries are not a factor downstream of Cochiti, Galisteo and Jemez Canyon Dams. The tributary areas are relatively small (typically less than 200 square miles), and all have significant variability in the range of elevations present. For example, the elevation of the Tijeras Arroyo at its downstream gage is 5000 ft. NGVD 1929 and the drainage area is 128 square miles. The elevation in the highest part of the Tijeras Arroyo watershed exceeds 9,500 feet. The snowpack that can accumulate during winter and spring months at high elevations are exposed to warmer temperatures over a period of months. Rapid warming is not normally experienced over the whole range of elevations. The result for small watersheds is very slow snowmelt over a period of months that does not produce runoff of significance.

Further discussion regarding the flood frequency results and the independence of the three flooding sources are discussed in detail in Exhibit A of Appendix H.

It is necessary to evaluate the without-project conditions in order to meet USACE requirements for feasibility level evaluation. In this study, flood flows from the three sources of flooding were routed separately downstream through the project area, in order to estimate their individual contributions to flooding in the project area. It is assumed that the spoil banks, which are not engineered levees, will uniformly fail throughout the area.

For the flood routing scenario, estimated flooding from each of the three sources was evaluated at selected locations. Then they were combined to estimate the total flood flow frequency at each location for without-project conditions.

5.1.3.2 *Flood Events from Regulated Areas*

The 2006 HEC report includes a frequency analysis for floods from regulated areas contributing to Rio Grande flooding at the Albuquerque gage. These are predominantly snowmelt flood events.

Table 22 includes flood peaks associated with the frequency flood events. Hydrographs for these floods are plotted in Figure 4. These hydrographs were provided to the Albuquerque District by the HEC for use in flood routing models.

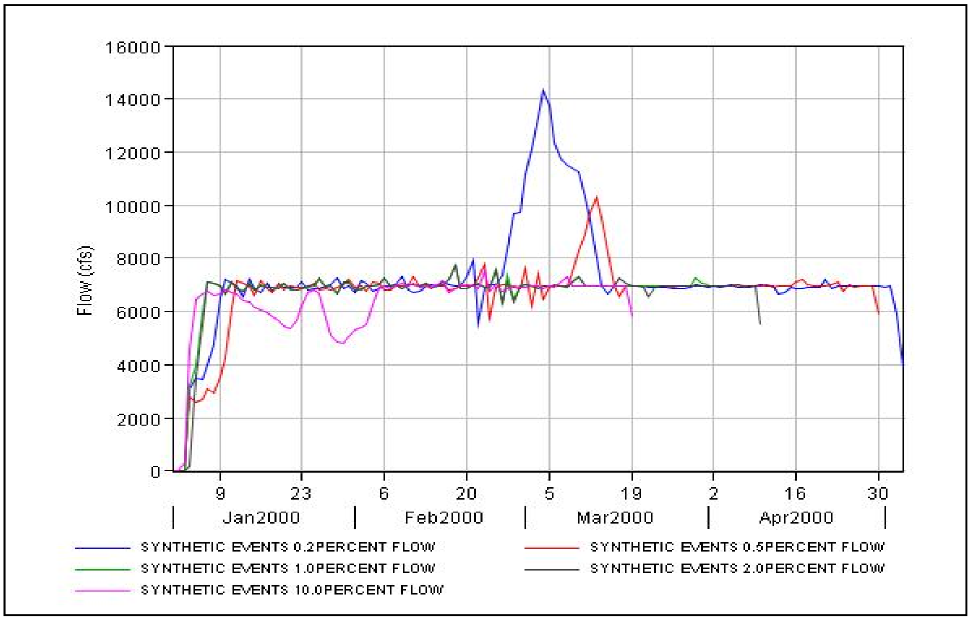


Figure 19 Hydrographs at the Albuquerque Gage for flood events from regulated areas upstream of Albuquerque (provided to the Albuquerque District by the HEC as Supplemental Information to the HEC 2006 Report).

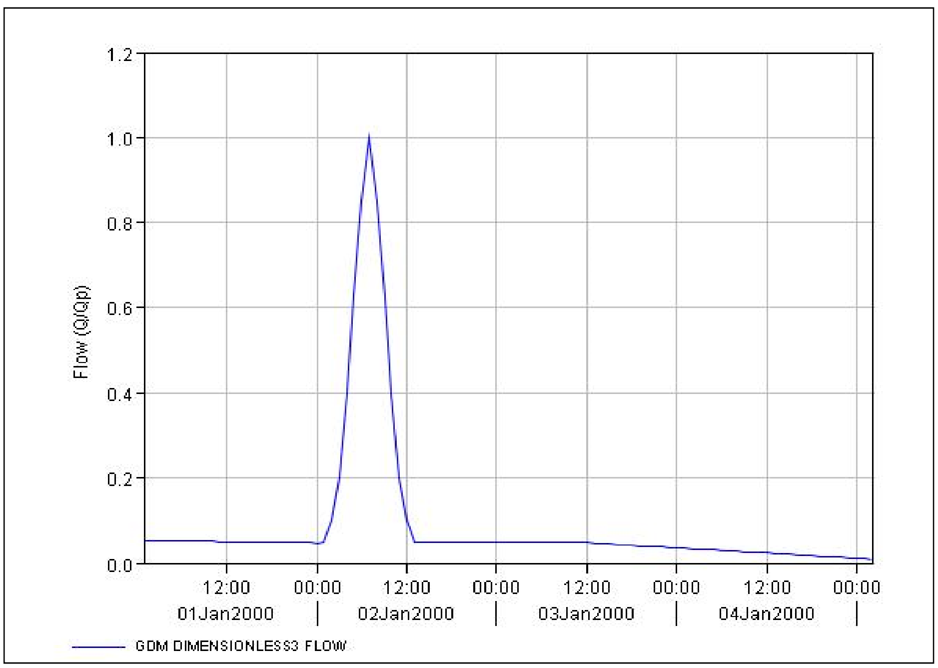


Figure 20 Dimensionless hydrograph at the Albuquerque gage for flood events from unregulated areas upstream of Albuquerque (provided to the Albuquerque District by the HEC as Supplemental Information to the HEC 2006 Report).

5.1.3.3 *Flood Flows from Unregulated Areas - Albuquerque and Upstream*

The 2006 HEC hydrology for Albuquerque includes a frequency analysis for floods from unregulated areas contributing to Rio Grande flooding at the Albuquerque gage. These floods are associated with rainfall runoff events. Table 22 includes flood peaks from unregulated areas associated with the frequency flood events. Figure 5 is the HEC dimensionless hydrograph for floods from unregulated areas upstream of Albuquerque. It was provided to the Albuquerque District by the HEC together with the 2006 HEC report.

Flood Flows from the SDC and Tijeras Arroyo

As discussed earlier, flood flows from the SDC and Tijeras Arroyo watersheds are associated with rainfall runoff events. Table 22 includes flood peaks from this unregulated watershed associated with various frequency flood events. Hydrographs for these floods are plotted in Figure 21. These 6-hour hydrographs correspond with the 6-hour design storm. The flood flow associated with these unregulated hydrographs are typically represented by a high peak but short duration and will therefore attenuate rapidly as they are routed downstream.

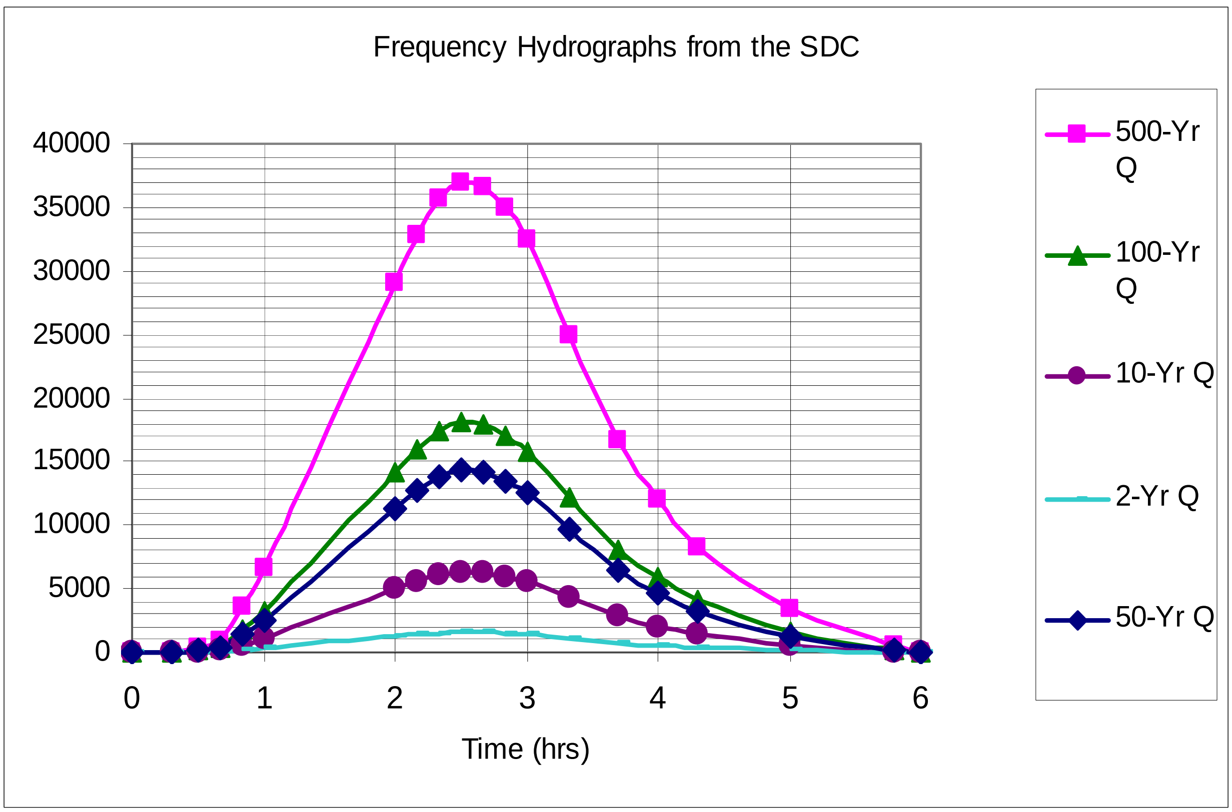


Figure 21 - Frequency flood hydrographs from the SDC and Tijeras Arroyo.

5.1.3.4 *Routing of Flood Components through the Project Area*

The FLO-2D Flood Routing Model

Frequency flood events for three sources of flooding (regulated and unregulated floods in Albuquerque, and floods from the SDC) were routed downstream in the Rio Grande to evaluate the characteristics of these floods as they move through the project area.

A FLO-2D model was used for routing. FLO-2D is a 2-dimensional unsteady flow numeric model that can be used to evaluate hydraulics in floodplains and open channels. It is used for several projects in the Middle Rio Grande and is well suited for modeling overbank flows. The FLO-2D model reach was the Rio Grande between the Albuquerque gage (at the Rio Grande and Central Avenue in Albuquerque) and the Rio Grande gage at Bernardo (south of the project area). The flood routing models are very conservative, in that losses from infiltration and evaporation are not included.

The without-project scenario for the hydrologic routing model represents existing and future without-project conditions. The spoil banks were removed from the model, to reflect the USACE assumption that the spoil banks, as non-engineered levees, would not remain viable in a flooding situation.

Cross sections extending across the floodplain were selected throughout the reach for evaluating the flood routing with the FLO-2D Model. This was done in order to evaluate the maximum flow passing a given section through the channel, the floodway, and the floodplain at a given time. The criteria for selecting cross section locations were based on the need to capture the hydraulic characteristics of the flooding. Cross sections used in this analysis are listed in Table 23.

Hydrographs Used for Routing

Hydrographs used for routing flood flows from both local unregulated flood events and floods from regulated areas upstream of the Albuquerque gage as well as the Tijeras Arroyo were previously discussed. Normally, rainfall runoff events occur in the months of July through October. A flow of 500 cfs is typical in the Rio Grande during those months, and a steady flow of 500 cfs was used in the FLO-2D model as the base flow in the Rio Grande for the rainfall runoff events.

Table 23 Cross sections used in analyzing the project area downstream of the Albuquerque gage.

Cross Section #	**Range Line**	**River Mile**	**FLO-2D Grid #**	**Location**
1 (Gage)	509	183.4	5033	Central Ave. Bridge, Albuquerque
2	561.5	178.3	6662	Rio Bravo Bridge, Albuquerque
3	575	177.1	7165	SDC & Tijeras Arroyo Confluence
4	623	172.6	8602	I-25 Bridge
5	655	169.3	9351	Isleta Diversion Structure
6	700	165.1	10497	Bosque Farms
7	738.1	161.4	11979	Los Lunas Bridge (Hwy 6)

8	799	155.4	14636	Los Chaves
9	858.1	149.5	16447	Bridge at Belen (Hwy 309)
10	878	147.7	16888	Belen Railroad Bridge

Hydrology – Future Conditions Without-Project

The hydrology associated with rainfall-runoff flood events in the unregulated area upstream of Albuquerque and rainfall-runoff flood events from the project area downstream of Albuquerque at the Tijeras Arroyo are not expected to change significantly for future conditions without the project. However, releases in the regulated area upstream of Albuquerque may be affected as the spoil banks continue to deteriorate. It may be difficult to make operational releases in the 7,000 cfs range without causing unacceptable stress to the spoil banks. If operational releases cannot be maintained at the 7,000 cfs level during extreme events, it could result in a spill from Cochiti Dam sooner than would be expected under existing conditions because reservoir storage would increase to offset the decreased release. In the spring of 2005 an attempt was made to release up to the 7,000 cfs operational release flow. However, at 6,000 cfs there was concern of spoil bank failure at some locations. Since there was adequate storage capacity available in Cochiti Reservoir, the release rate was reduced.

Figure 22 Potential spoil bank failure

5.1.3.5 *Hydraulics*

Overview of Hydraulic Analysis

The hydraulic analysis is part of evaluating the potential of flooding and proposed actions to alleviate high water conditions. It is used in conjunction with the sediment analysis. Specific applications for the hydraulic analysis in the project area include:

- With- and without-project floodplains.
- Input to economic analysis.
- Input to risk assessment, used to determine damage-frequency relationships and design parameters such as levee heights.
- Evaluation of design for the recommended plan.
- Evaluation of environmental impacts of the recommended plan.
- Estimate damages induced by recommended plan.

Two numeric models were used for the hydraulic analysis. They are:

- HEC-RAS, the River Analysis System, was used to analyze hydraulics at bridges and was also used to aid in the with-project analysis and design.
- FLO-2D, a 2-dimensional hydraulic model, was used for the hydrologic routing and for the without-project analysis. It was also used for the with-project hydrologic routing and design.

Further discussion regarding model development for both the FLO-2D 2-dimensional hydraulic model and the HEC-RAS River Analysis System is included in Exhibit A of Appendix H.

<u>Without-Project Hydraulic Analysis</u>

The Rio Grande in the study area is characterized by setback spoil bank levees that contain the floodway. The spoil banks have been in place for more than 50 years, and in that period of time sediment has deposited between them. As a result of these sediment deposits, the floodway has become elevated above the surrounding floodplain. The difference in elevation between the floodway and the floodplain varies, but the floodway is elevated by as much as 5 to 10 feet above the surrounding floodplain in many locations.

FLO-2D is a 2-dimensional hydraulic model. It was used for without-project conditions because of its ability to evaluate the flooding once flows leave the river channel and move onto the floodplain.

<u>Without-Project FLO-2D Flood Routing</u>

Flood routing refers to the downstream movement of flood peaks, their duration, and rate of attenuation. These three attributes vary depending on the source of the flooding. Snowmelt flooding is controlled, for the most part, by reservoirs. Reservoir releases from Cochiti Dam resulting from snowmelt flooding typically occur as a steady flow in the Rio Grande that can take place over a period of months. Present guidance for the maximum regulated reservoir release limits flow at Albuquerque to 7,000 cfs, though it has been higher at times in the past.

The steady long-term portion of snowmelt floods has no significant attenuation as it moves downstream.

Spillway flow at Cochiti Dam can also result from snowmelt floods coming from upstream of the reservoirs, and is expected to begin at approximately the 0.5% ACE flood event. Spillway flow occurs in addition to reservoir releases, but unlike reservoir releases the flow is not controlled.

Routing of rainfall runoff events from non-regulated areas results in significant attenuation through the study reach due to low flood flow volumes, and to storage in both the channel and overbank areas. Rainfall runoff floods tend to be short duration, flashy events, resulting in high peak flows but low overall flow volumes. That is in contrast with spillway flow: attenuation for spillway flow is gradual, whereas for rainfall-runoff flooding attenuation is dramatic.

Another of the causes for the attenuation is the large volume of storage available in the channel, which is wide and shallow. Widths typically range from 500 feet to 600 feet, with flow depths on the order of 4 feet for the 10% ACE flood event. Therefore the low volume from these flood flows quickly spread out in the floodway.

The high rate of attenuation of rainfall runoff floods is also the result of the large amount of flow in the floodplain and overbanks. There is significant storage in the overbanks. Overbank flow, because of vegetation in the overbanks, is slower than channel flow, and delays the portion of the flood peak that is not carried in the channel, thus reducing flood peaks. Table 24 gives the results of routing flows for the 0.2% ACE event through the project for the same flow scenarios discussed for existing conditions.

Note the rapid attenuation for the rainfall-runoff events (Unregulated Area below Cochiti & South Diversion Channel Flow) versus the non-attenuating flow from the regulated areas.

The complete results of the without-project hydraulic routing for both existing and future conditions are included in Exhibit A of Appendix H.

Table 24 Results of routing flows for the 0.2% ACE event for the without-project condition with the Albuquerque West Levee in place.

Cross Section #	**Location**	**Regulated Flow**	**Unregulated Area Below Cochiti**	**South Diversion Channel Flow**
1 (Gage)	Central Ave. Bridge, Albuquerque	14408	26051	N/A
2	Rio Bravo Bridge, Albuquerque	14278	22508	N/A
3	SDC & Tijeras Arroyo Confluence	14280	21179	34721
4	I-25 Bridge	14550	11744	12480
5	Isleta Diversion Structure	14217	8426	6786
6	Bosque Farms	14185	6631	4255
7	Los Lunas Bridge (Hwy 6)	14152	5075	3982

8	Los Chaves	14106	4841	3942
9	Bridge at Belen (Hwy 309)	14210	4751	4018
10	Belen Railroad Bridge	14102	4708	3911

Without-Project Inundation Mapping

FLO-2D runs were conducted to determine flood inundation for the without-project condition and were used to aid in the economic analysis for determining damages. The without-project inundation maps are shown in the folder labeled Inundation Map Books. The Inundation Map Books are located in the Appendix H, Attachment 7 - Inundation Mapping/Inundation Map Books/Without-Project.

Risk and Uncertainty

A primary purpose of the hydraulic risk analysis is to estimate variability of the water surface. High, expected, and low flow scenarios were developed for the without-project hydraulic models under existing conditions. The reaches described below in Table 25 were used as locations to evaluate the standard deviation of the water surface elevations. Also, the controlling flood event is given which considers the effects of attenuation. These standard deviations can then be used in the economic risk evaluation.

Hydraulic parameters in the without-project model were varied to estimate variability of water surface elevations. Table 26 shows examples of the modifications that were made to develop high and low risk scenarios by varying the channel and overbank Manning’s n-values.

The controlling flood events at the various cross-sections for existing conditions are included in Table 25.

Table 25 Hydraulic cross section locations.

Cross Section	Location	Controlling Flood Event
1	Central Ave. Bridge, Albuquerque	Unregulated Area below Cochiti
2	Rio Bravo Bridge, Albuquerque	Unregulated Area below Cochiti
3	SDC & Tijeras Arroyo Confluence	Tijeras Arroyo (South Diversion Channel)
4	I-25 Bridge	Unregulated Area below Cochiti
5	Isleta Diversion Structure	Regulated Flow, Cochiti & Jemez Releases
6	Bosque Farms	Regulated Flow, Cochiti & Jemez Releases
7	Los Lunas Bridge (Hwy 6)	Regulated Flow, Cochiti & Jemez Releases
8	Los Chavez	Regulated Flow, Cochiti & Jemez Releases
9	Bridge at Belen (Hwy 309)	Regulated Flow, Cochiti & Jemez Releases
10	Belen Railroad Bridge	Regulated Flow, Cochiti & Jemez Releases

Table 26 Hydraulic modeling parameters varied for the risk analysis, existing conditions.

Risk Parameter	Risk Scenario		
	Low n-value	Expected n-value	High n-value
Channel n-value	0.025	0.030	0.035
Overbank n-value	0.080	0.100	0.120
Sediment	N/A	N/A	Sediment plug from the Tijeras Arroyo

** n-values are Manning's roughness values, which represent how rough or smooth a channel is. High n-values represent very uneven, rocky or vegetated surfaces that introduce turbulence and may reduce flow velocities; Low n-values represent smoother channels that do less to alter flow velocities or character.*

5.1.3.6 *Sediment Analysis*

Methodology for the Aggradation/Degradation Analysis

The purpose of this analysis was to estimate the future condition regarding aggradational and degradational trends for use in hydraulic river system modeling for the project. Surveyed range lines from 1972, 1992, and 2002 provided by Reclamation were used to analyze the long-term aggradation and degradation trends for the general study area. The area of analysis was from range line 514 (approximately 5 miles upstream of the project just downstream from the Central Avenue Bridge) to range line 1000 (approximately 9 miles downstream of the project between the Jarales Road Bridge and the US Hwy 60 Bridge at Bernardo). Twenty-two range lines were analyzed in this area of analysis. Station and elevation data from these surveys were input into an Excel spreadsheet. An algorithm was then used to calculate the area between a datum (5500 feet) and the cross section elevations for each range line for each year. The difference between these cross sectional areas from year to year was used as the basis to analyze aggradational and degradational trends.

The cross sectional areas for each year were then compared for 1972 to 1992, 1972 to 2002, and for 1992 to 2002. In each case, the area from the later year was subtracted from the area from the earlier year. A positive value indicated an aggradational trend for that range line and a negative value indicated a degradational trend. These values were plotted against the range line numbers in order to determine where the reach had a general aggradational or degradational trend.

After an initial analysis of the three data sets, the 1972 to 2002 data were chosen for quantification of trends. The reasons for this included the presence of some questionable survey results from the 1992 surveys, and by using the 1972 to 2002 data set, these errors would not affect the trend estimate. Also, the 1972 to 2002 data provide the longest period of record, producing a better estimate of long-term trends than can be obtained from shorter periods of analysis.

In addition, a survey of aerial photos was made to try to determine physical factors that may affect the sedimentation and boundaries for the different reaches. Four separate subreaches showing similar trends were identified:

- Subreach 1, which is almost entirely upstream of the project area with engineered levees on both sides of the river, runs from range line 514 to 580 (Central Avenue Bridge to the South Diversion Channel). Subreach 1 showed a degradational trend ranging from -0.03 to -0.05 feet per year.
- Subreach 2 extends from subreach 1 (South diversion Channel) to the Isleta Diversion Dam (near range line 653). Subreach 2 showed a slight degradational trend of -0.01 feet per year for all three range lines analyzed in this subreach. Subreach 2 includes spoil berms on both sides of the river except on the west side from the South Diversion channel to the Interstate 25 Bridge (Albuquerque West Levee).
- Subreach 3 starts below the Isleta Diversion Dam and extends to include range line 801 near Los Chavez. Subreach 3 showed an aggradational trend ranging from 0.1 to 0.2 feet per year. While aggradation below a dam goes against common thought, this is supported by anecdotal evidence. Aggradation in this reach may be explained by the diversions that take place above the dam (approximately 650 cfs during irrigation season). The decrease in flow downstream may cause a decrease in sediment transport capability, resulting in an aggradational reach. Subreach 3 includes spoil berms on both sides of the river for the entire reach.
- Subreach 4 begins downstream from subreach 3 (Los Chavez) and extends to include range line 1000 (located between Jarales and Bernardo). The end of the project area is approximately at range line 895 near Jarales. Subreach 4 shows a slight degradational trend ranging from 0 to -0.02 feet per year. Subreach 4 includes spoil berms on both sides of the river for the entire reach.

Figure 23, below, shows the average yearly aggradation or degradation for the range lines analyzed for the period of 1972 to 2002.

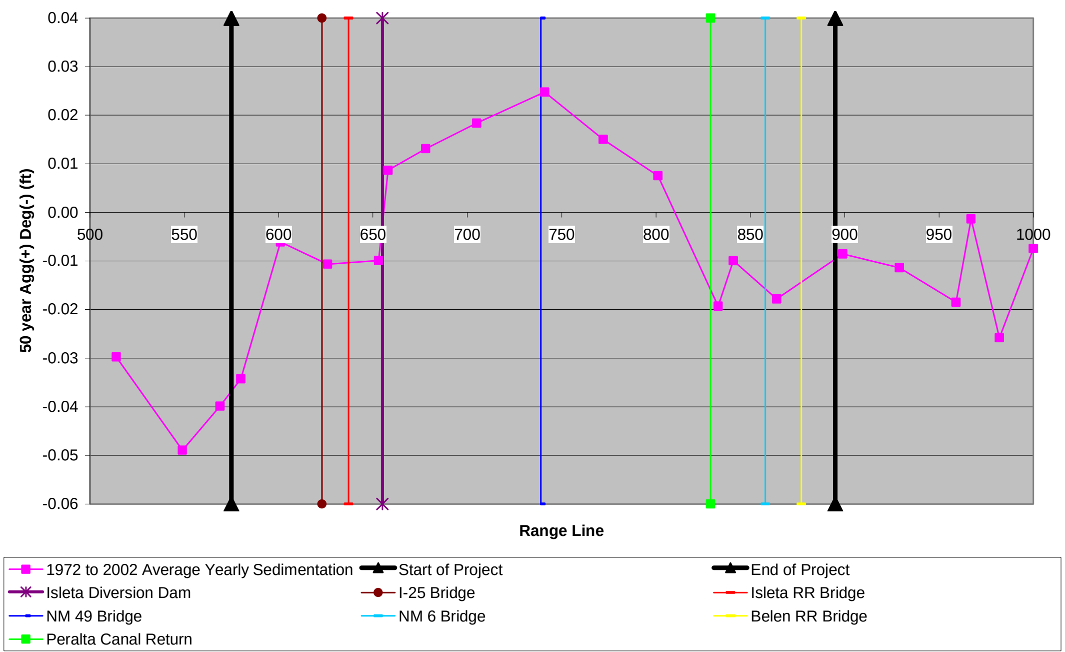


Figure 23 Average yearly sedimentation in the channel of the Rio Grande in the project area.

<u>Conclusions - Sediment Analysis</u>

The data show that the channel and overbank elevations are changing slowly for the entire project reach. Within the project reach, degradational areas had only minor losses over time, and therefore degradation was not included in the future conditions models. This is considered to be the more conservative approach as degradational reaches increase their capacity for passing flood flows over time.

The aggradational reach downstream of Isleta Diversion Dam is fairly consistent, with rates ranging from just under 0.01 feet/year up to 0.025 feet/year. The recommend future conditions models incorporate 0.02 feet/year aggradation for this reach. This would result in total aggradation of 1 foot through this reach (Isleta Diversion Dam to Los Chavez) over a 50-year period.

5.1.3.7 *Summary of Existing and Expected Future Without-Project Conditions*

This evaluation of hydrology and hydraulics provides an estimate of the magnitude and potential for flooding in the project area. These analyses provided flood peaks, volume and expected duration, along with the corresponding river depths and velocities. Sediment movement, a significant factor in the Rio Grande, was also analyzed.

Hydrology and hydraulics have been addressed in past studies for the Middle Rio Grande. The hydrology, hydraulic and sediment analyses were reevaluated and refined using new data and the improved analytic techniques now available.

The hydrology and hydraulic analyses provided estimates of the various frequency flows in the Rio Grande through the project area which were used to evaluate the potential for flooding with and without the proposed flood risk reduction measures in the project area. These estimates also allowed for the development of inundation mapping for various flood frequency events through the project area. Inundation information was then used to determine potential damages in the project area and the economic benefits for the recommended plan.

5.1.4 Water Quality

Section 404 of the Clean Water Act provides for the protection of waters of the United States from impacts associated with irresponsible or unregulated discharges of dredged or fill material in aquatic habitats, including wetlands as defined under Section 404(b)(1). Without the proposed levee construction, waters of the United States and wetlands, as defined in Section of the Clean Water Act, would continue to be potentially impacted by the activities of Federal, State, local and private entities. The actual activities and extent of impact are not predictable.

Although the Rio Grande has a well-defined channel throughout the proposed action area, flows in portions of the area frequently exceed the bank elevation and inundate the overbank area adjacent to the channel. For the purposes of evaluation, the ordinary high water mark (OHWM) relative to Section 404 was estimated to be the water surface elevation of the 50%-exceedance discharge based on mean-daily-discharge values at the USGS stream flow gage at for the period 1974 through 2002. This discharge was determined to be 5,660 cfs by Parametrix (2008).

Section 401 of the Clean Water Act requires that a Water Quality Certification Permit be obtained for anticipated discharges associated with construction activities or other disturbance within waterways in the project area. Regulatory authority for the issuance of water quality certification resides with the New Mexico Environment Department (NMED), Surface Water Quality Bureau.

New Mexico’s Water Quality Control Commission has designated stream uses and standards in the proposed action area (NMED 2009). Designated uses for the reach from Mountain View to Belen include irrigation, habitat for marginal warm water aquatic life, wildlife habitat, livestock watering, and secondary contact recreation (fishing, boating). Based on a 2009 water quality review by the NMED Surface Water Bureau, designated uses for marginal warm water aquatic life and secondary contact recreation were not fully supported (NMED 2009). The survey concluded that aluminum and *Escherichia coli* were the probable cause of the impaired uses, with the probable sources of impairments including avian sources (waterfowl and/or other); impervious surface/parking lot runoff; municipal (urbanized high density area); municipal point source discharges; natural sources; on-site treatment systems (septic systems and similar decentralized systems); and wastes from pets.

5.1.5 Air and Sound Quality

The recommended plan area is located in the U.S. Environmental Protection Agency’s (USEPA’s) designated Air Quality Control Region 8, which is an attainment area for criteria pollutants. The USEPA, through the Clean Air Act, regulates and sets standards for pollutant levels in the air. Primary National Ambient Air Quality Standards (NAAQS) are established for the sole purpose of protecting public health. NAAQS have been established for total suspended particulates smaller than 10 microns (PM_{10}), sulfur dioxides (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), ozone (O_3), and lead (Pb). The good air quality in the region is attributed to the low population and correspondingly low number of motor vehicles, and the absence of heavy industry discharging particulate matter into the atmosphere. Infrequently, high levels of total suspended particulates and CO occur in the proposed project area as a result of wind-blown dust and winter atmospheric inversions, which trap wood smoke and auto emissions in the lower layers of the atmosphere.

Regulations of the New Mexico Environmental Improvement Division's Prevention of Significant Deterioration Program (PSDP) allow air quality to deteriorate in small incremental amounts above existing levels of pollution in attainment areas throughout the state, which includes the majority of New Mexico. The PSDP divides state lands into three classes: Class I areas contain clean air and, therefore, only very small increases in air contaminant levels are permitted; Class II areas contain moderately clean air and, therefore, only moderate increases of air contaminant levels are permitted; and Class III areas are areas of extensive growth with concomitant increases in air contaminant levels. New Mexico does not contain any Class III areas: the majority of areas in New Mexico, and those in the majority of the proposed project area, are designated Class II. The study area does not contain any Class I areas. For Class I areas, the annual allowable PSDP increments are: 2 µg/m for SO_2; 5 µg/m for total suspended particulates; and 2.5 µg/m for NO_x. Significant annual emission rates for CO, NO_x, and SO_2 are 100, 40, and 40 tons per year, respectively. Air quality in the future without-project would continue unchanged from existing conditions.

Sound levels in the proposed project area are low, which is typical in rural, agrarian areas. Major sources of intermittent noise in the area are attributed to automobile traffic, farm operations, railroad operations, and MRGCD's maintenance operations. Sound levels in the future without-project would continue unchanged from existing conditions.

5.2 Hazardous, Toxic, and Radioactive Waste Environment*

5.2.1 Existing Conditions

Existing conditions were identified by performance of a Draft Phase I Environmental Site Assessment (Draft Phase I Assessment)of the 55 mile long section of spoil banks located along the Rio Grande from south Albuquerque to Belen, NM. USACE completed the Draft Phase I Assessment in 2015. The purpose was to evaluate the potential for the presence or threatened release of hazardous, toxic, and radioactive waste (HTRW) within the limits and site vicinity of the project area.

No Recognizable Environmental Conditions (RECs) were identified on the spoil bank system. Current interviews with MRGCD, Reclamation, and Isleta Pueblo personnel suggest that prior to 1990 when the gates were installed to limit unauthorized access to the river, solid residential waste was regularly dumped along the river. The keyed gate system has deterred such dumping and no residential trash on the spoil bank was observed during a reconnaissance of the area. In the Isleta Pueblo portion of the project, several areas of construction debris were noted; however, this debris contains no hazardous materials. There have been no documented spills or sources of contamination along the spoil banks, and none were observed during the reconnaissance. As there are no contamination sources documented or observed, there appears to be no threat of contamination being transported and impacting any potential receptors during a potential extreme flood event. Also, no hazardous materials were observed that will interfere with the construction of the engineered levees.

The Draft Phase I Assessment will be updated for the final report. An additional survey of the proposed construction area for presence of possible HTRW contamination will be conducted during preconstruction engineering and design and prior to construction as required.

5.2.2 Future Without-Project Conditions

Future without-project conditions were identified for the project area in order to evaluate the potential for the presence or threatened release of HTRW within the limits and site vicinity of the planned civil works project.

The existing spoil banks are much less likely to withstand a high flow event as compared to the recommended plan. HTRW issues are likely to occur if the spoil banks fail, as discussed below.

The Isleta Pueblo and Los Lunas municipal waste water plants are very close to the spoil banks and across the riverside drains. Also numerous residences located several hundred feet from spoil banks on both sides of the river have septic systems. Failure of the spoil banks during a flood event may cause sewage and the contents of the septic systems to be released into flood waters with possible widespread sewage contamination.

Numerous propane tanks and above ground storage fuel tanks were observed in residential yards adjacent to the spoil banks. A fair amount of residential debris such as tires, old vehicles, demolition materials of unknown disposition, trash, scrap lumber, and dead vegetation were also observed during the site reconnaissance in residential yards adjacent to both spoil banks. This residential debris would undoubtedly be swept away by flood waters.

Various agricultural fields that produce primarily corn, alfalfa, and hay, are located several hundred feet to the east of the spoil bank, across the riverside drain. The degree to which fertilizer, pesticide, and herbicide applications in these fields may have impacted the local water systems could not be ascertained. A flood event that caused failure of spoil banks would likely result in a HTRW hazard to surface water.

5.3 Biological Environment*

The Rio Grande is the fifth longest river in North America, and one of the top ten endangered rivers in the world (Wong *et al.* 2007) because of water over-extraction. The Rio Grande in New Mexico comprises 484 miles (26% of total length), with 1,224 miles (65%) forming the Texas-Mexico border. Regulation of water in the Rio Grande has changed the mosaic of vegetation types once present in the valley. The wetlands were greatly reduced by construction of irrigation infrastructure in the 1930s, and the cottonwood trees are dying as they reach the end of their lifespan. From 1935 to 1989, surface area covered by wet meadows, marshes, and ponds declined by 73% along the Middle Rio Grande floodplain (Scurlock 1998). Reclamation, in cooperation with MRGCD, manages 40% of the Rio Grande floodway in New Mexico. The majority of the riparian forest (bosque) managed by these two agencies is downstream of Isleta Pueblo.

The major plant communities in the active floodplain include woodlands, shrublands, grasslands, and emergent wetlands (Tetra Tech 2004). The extent of the recommended plan was analyzed using riparian vegetation coverage mapped in 2012 (Siegle et al. 2013). Historically, the dynamic nature of the Rio Grande supported a patchwork of plant communities, including cottonwood forests. In spite of the occasionally catastrophic effects of large floods, the riparian community benefited from the effects of periodic inundation when the river overflowed its banks during the high spring runoff.

5.3.1 Riparian Forest Community

The cottonwood forests that border the Rio Grande in central New Mexico are remnants of a unique and diminishing habitat known locally as the bosque, a Spanish word for forest. These riparian forests provide habitat for a wide variety of plants and animals. At least 80% of vertebrate wildlife occurring in New Mexico use riparian areas at some stage of their lives and 50% are permanent residents (NMDGF 2004). Riparian areas support a greater diversity of breeding birds than all other habitats in the state combined (NMDGF 2004). In addition, the Middle Rio Grande is a critical travel corridor for migrating birds connecting Central and South America to North America along the Rio Grande Flyway.

Despite the various disturbance factors listed above, the Middle Rio Grande valley supports one of the highest value riparian ecosystems remaining in the Southwest (Crawford, *et al.*, 1993). Woodland, shrubland, grassland, and emergent wetland plant communities currently occupy approximately 12,700 acres bordering the Rio Grande (see Appendix E). Table 4 in Appendix E summarizes the spatial analysis for the affected vegetation and habitat in the proposed project area.

Studies by Hink and Ohmart (1984) and Thompson *et al.*, (1994) have characterized wildlife use of the various plant associations that make up the riparian plant community in the proposed project area. These characterizations conclude that the riparian community, as a whole, supports a rich assemblage of vertebrate species, particularly birds. The highest numbers of vertebrate wildlife were found in marshes; cottonwood stands with a dense understory of Russian olive or coyote willow; and Russian olive shrub stands.

Without the project, there would be no change to the existing spoil bank footprint throughout the project area. Limiting the peak flow to the current safe channel capacity, as dictated by the performance of the spoil banks, will reduce the opportunities for natural processes to scour habitat within the floodway to create a mosaic of riparian habitat succession. Without scouring there will likely be a lack of regeneration of native species resulting in senescence and loss of key plant species from this important riparian habitat.

5.3.2 Wetland Plant Community

There are several wetlands, as defined in Section 404(b)(1) of the Clean Water Act, that have been identified within the study area for levee construction alternatives. Wetlands in the Middle Rio Grande Valley included wet meadows, marshes, sloughs, ponds, and small lakes. These wetlands were formed in part by the meandering of the river, and constitute a significant component of the floodplain ecosystem. Emergent wetlands scattered throughout the floodway comprise 459 acres of the study area (3.6% of all vegetation types).

The current status of the aquatic ecosystem is degraded, and it is likely to continue to degrade into the future under without-project conditions, with fragmentation of remaining habitat, floodplain aggradation, increasing depths to groundwater, and channel narrowing, resulting in the loss of wetlands. Increasing the safe channel capacity provides opportunities to increase floodway scouring that would support wetlands.

5.3.3 Invasive Plant Species and Noxious Weeds

The principal noxious weeds known to occur commonly in the project area include perennial pepperweed (Class A), as well as salt cedar and Russian olive (Class C). Other invasive species that are prevalent in recently disturbed areas include kochia, tumbleweed, and yellow sweet clover.

In the future, invasive species and noxious weeds will continue to thrive and spread within the floodway and on adjacent lands, especially in areas of substrate disturbance. Without the proposed project, the invasive plant species and noxious weeds would remain a dominant habitat component.

5.3.4 Special Status Species

USACE submitted a Draft Biological Assessment on January 6, 2017 to the USFWS for consultation on the endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*), the Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*), and Rio Grande silvery minnow (*Hybognathus amarus*).

5.3.4.1 *Southwestern Willow Flycatcher (Empidonax traillii extimus)*

A final rule was published February 27, 1995 listing the Southwestern Willow Flycatcher *(Empidonax traillii extimus*; flycatcher) as a Federally endangered species (USFWS 1995). Flycatcher surveys in the Middle Rio Grande have documented their presence in the project area (USACE 2017; Appendix E). The inundation height of riparian vegetation is not likely to change from the current conditions.

5.3.4.2 *Yellow-billed Cuckoo (Coccyzus americanus occidentalis)*

A final rule was published October 3, 2014 listing the Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis;* cuckoo) as a Federally threatened species (USFWS 2014). The status of the cuckoo including biology, range, and population trends are discussed in the biological assessment (USACE 2017; Appendix E). The inundation height of riparian vegetation is not likely to change from the current conditions.

5.3.4.3 *Rio Grande Silvery Minnow (Hybognathus amarus)*

A final rule was published July 20, 1994 listing the Rio Grande silvery minnow (*Hybognathus amarus*; minnow) as a Federally endangered species with critical habitat (USFWS 1994). The lateral extent of minnow critical habitat is bounded by the spoil piles (USFWS 2003). The status of the silvery minnow including biology, range, and population trends are discussed in the biological assessment (USACE 2017; Appendix E). Minnows require inundated floodplain for nursery habitat as a function of spring runoff (USFWS 2010).

5.3.4.4 *Other Threatened and Endangered Rio Grande Species*

The New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*) was historically found along the Rio Grande, but there are no known populations or critical habitat in the project area. The Northern Aplomado Falcon (*Falco femoralis*) is considered extirpated from New Mexico, with an experimental non-essential population based on the Armendaris Ranch in Socorro County. The Interior Least Tern (*Sternula antillarum athalassos*) is a vagrant along the Rio Grande. The Mexican Spotted Owl (*Strix occidentalis lucida*), Piping Plover (*Charadrius melodus*), and Chiricahua leopard frog (*Lithobates chiricahuensis*) are Federally Endangered or Threatened species of concern that may occur in Bernalillo or Valencia counties (USFWS 2013), but they are unlikely to occur in the project area.

5.3.4.5 *Future without Project*

There would be no changes to the special status species and their critical habitat without the project. The floodway area, geomorphic processes, and river flow would continue with the existing conditions and processes without the project.

5.4 Cultural Resources*

Section 106 of the National Historic Preservation Act [54 U.S.C. § 300101 et seq.] (NHPA) and its implementing regulations, 36 CFR Part 800, require Federal agencies to take into account the effects of their undertakings (e.g., projects or permits) on historic properties. Historic properties are legally considered to be those properties (cultural resources) eligible for listing on the National Register of Historic Places (NRHP). To be eligible for listing, a property must have "the quality of significance in American history, architecture, archeology, engineering, and culture" that can be "present in districts, sites, buildings, structures, and objects" and which must "possess integrity of location, design, setting, materials, workmanship, feeling, and association" and meet at least one of a set of four criteria relating to association with historical events, historically significant people, distinctive characteristics of a period or style, and/or are likely to yield information important to prehistory or history. There are many examples of historic properties, including archaeological sites, historic buildings, Traditional Cultural Properties (TCPs), and historic districts.

In order to comply with Section 106 of the NHPA, Federal agencies must consult on the effects of their undertakings on historic properties with the State Historic Preservation Officer (SHPO), or in the case of undertakings on tribal lands of Tribes that have assumes the role of the SHPO pursuant to Section 302702 of the NHPA, with the Tribal Historic Preservation Officer (THPO) of that Tribe. For this project, a portion of the project occurs on Isleta Pueblo tribal lands. Isleta Pueblo has assumed the role of the SHPO and appointed a THPO, and therefore USACE conducted NHPA consultation with the Isleta Pueblo THPO for the portion of the project located on Isleta Pueblo lands, and with the New Mexico SHPO for all other portions of the project area. Historic properties, therefore, were considered separately for tribal and non-tribal lands within the proposed project area.

5.4.1 Summary of Cultural Resources Inventory

A review of USACE records and the New Mexico Cultural Resources Information System (NMCRIS) database in 2013 showed that 111 surveys, 60 previously recorded sites and 4

NRHP-listed properties fall within one-half mile of the proposed alignments on non-tribal lands; none of which fall within the proposed area of potential effect (APE). Two sites, LA 100485 and LA 111617 appear to fall within the APE, but these historic irrigation ditches run parallel to, but outside of it. The entire proposed alignment was previously surveyed, and no historic properties other than the spoil banks themselves were located in the APE. The surveys of the spoil bank alignments were conducted by the Office of Contract Archeology, University of New Mexico (OCA); one in 1998 for the reach from Isleta Pueblo southward to Belen (Bargman 1998), and the other in 2000 for the Mountain View Unit (McEnany 2001).These reports are included as attachments to Appendix C. Each of these surveys covered the existing spoil bank alignment including the spoil bank itself, as well as the toe of the levee on either side to encompass the entire proposed construction area.

No sites were identified in the Mountain View Unit during the 2000 OCA survey, and the three sites located during the 1998 OCA survey (LA 50255, LA 111616 and LA 111617) are located outside of the currently recommended plan. As stated above, the most recent NMCRIS database search confirmed that no new historic properties have been identified within the APE for the project in the years since the OCA surveys were completed. The spoil banks themselves, however, are historic and will be impacted by the recommended plan. The spoil banks were constructed in the 1930s by MRGCD and are an important part of the overall flood protection system in the Middle Rio Grande Valley; a system that includes the levees, riverside drains and irrigation canals as well as other features such as jetty jack fields and other sediment retention features. This system as a whole is widely considered to be eligible for inclusion in the NRHP, although individual features within the system are rarely recorded as sites.

A review of USACE records and the NMCRIS database in 2015 showed that 56 surveys, 16 previously recorded sites and one NRHP-listed property fall within one-half mile of the proposed alignments on Isleta Pueblo lands; none of which fall within the proposed APE. Two sites, LA 153624 and LA 153625 appear to fall within the APE within the NMCRIS database, but after consulting the original site documentation for each site, both of these historic sites are actually located adjacent to, and outside of the APE. The entire proposed alignment on Isleta Pueblo land has been surveyed, and no historic properties other than a TCP (discussed in detail below), and the spoil banks themselves were located in the APE. As stated above, the survey of the spoil bank alignment for the reach on Isleta Pueblo land was conducted by the OCA in 1998 (Bargman 1998). The survey covered the existing spoil bank alignment including the spoil bank itself, as well as the toe of the levee on either side to encompass the entire proposed construction area. Two other surveys were conducted that covered the remaining portion of the APE on Isleta Pueblo lands on the west side of the river north of Isleta Village. The first was conducted by Cibola Research Consultants in 2006 (Marshall and Walt 2006), and no historic properties were located within the proposed APE. The second was performed by USACE in 2013 and 2014 (Decker 2015), and documented in a USACE report by Jeremy T. Decker titled, A 63.4-Acre Cultural Resources Inventory of Proposed Levee Alignments for the Bernalillo to Belen Flood Protection Project on the Pueblo of Isleta, Bernalillo and Valencia Counties, New Mexico. The USACE survey documented 13 isolated occurrences and one new prehistoric artifact scatter, LA 177391, which was located in the proposed alignment of a section of levee that was originally considered as an alternative, but that levee is not included in the final array of alternatives for the project. This report is included as an attachment to Appendix C.

5.4.2 State and National Register-Listed Properties

No National Register-listed properties are located within the APE. Isleta Pueblo (NR# 75001162, New Mexico State Register # 247) is listed on the NRHP and New Mexico State Register and is located directly to the west of the APE. The project, however, will have no effect to the historic Isleta Village.

5.4.3 Expectations for Future Cultural Resources Inventories

At present, the entire project area has been surveyed for cultural resources. However, construction of the recommended plan will be a multi-year, multi-phase undertaking and for this reason it is not possible to identify all necessary staging areas, borrow pits, spoil areas, and access routes. As these areas are identified during planning for each construction phase, USACE will perform cultural resources inventories and consultation with the SHPO and/or THPO as appropriate prior to beginning construction of each phase.

5.4.4 Expected Future Without-Project Conditions

Without the recommended plan, any historic properties within the project's APE would be expected to remain in approximately their current condition. The historic spoil banks would not be removed and reconstructed, and would retain their current function and alignment. Loss and degradation due to failure of spoil banks is unquantified but expected.

5.4.5 Indian Trust Assets*

Indian Trust Assets (ITAs) are a legal interest in assets held in trust by the U.S. Government for Indian tribes or individuals. The U.S. has an Indian Trust Responsibility to protect and maintain rights reserved by or granted to Indian tribes or individuals by treaties, statues, executive orders, and rights further interpreted by the courts. The Secretary of the Department of the Interior (DOI), acting as the trustee, holds many assets in trust. Some examples of ITAs are lands, minerals, water rights, hunting and fishing rights, titles and money. ITAs cannot be sold, leased, or alienated without the express approval of the U. S. Government. The Indian Trust Responsibility requires that all Federal agencies take all actions reasonably necessary to protect such trust assets. The Department of Defense's American Indian and Alaska Native Policy, signed by Secretary of Defense William S. Cohen on October 20, 1998, and DOI's Secretarial Order 3175 require that USACE, as the project's Lead Federal Agency, consult with tribes and assess the impacts of its projects on ITAs. If any ITAs are identified and are to be impacted, further consultation on measures to avoid or minimize potential adverse effects will take place. If the project results in adverse impacts, consultation regarding mitigation and/or compensation will take place.

Consistent with the Department of Defense's American Indian and Alaska Native Policy of 1998, and pursuant to 36 CFR 800.2(c)(2)(i), tribal consultation on this project was conducted in 2010 with all Native American tribes that indicated they have concerns in Bernalillo and Valencia Counties. To date, no tribal concerns regarding ITAs have been brought to the attention of the USACE. The only potential ITA of concern in the proposed project area is Isleta Pueblo's water rights. The USACE will continue to consult with Isleta Pueblo regarding potential impacts to ITAs throughout the life of the project. Without the recommended plan there will be no impacts to ITAs.

5.5 Socioeconomic Environment*

5.5.1 Demography

The city of Albuquerque in Bernalillo County is the largest population center in the study area. Based on the 2010 U. S. Census, Albuquerque had 546,360 people, Belen 7,221, and Los Lunas 14,935. In 2010, Bernalillo County had 662,555 people while Valencia County had 76,574. The primary employers in Bernalillo County are social services including education and health care, with research and engineering services at a national laboratory. Without the recommended plan the population is expected to continue growing in Bernalillo and Valencia Counties.

5.5.1.1 *Flood Hazards*

Since the main river channel within the study area is in equilibrium or slowly aggrading, it is predicted to continue this trend into the future, the positive effects of the spoil bank would be reduced, and flood depths in the overbanks would increase due to less storage capacity in the floodway. Thus, the hazards due to flooding in the watershed would likely increase in the future if no remedial actions are taken to address the existing water resource problems. This would indicate that the existing capacity of the spoil bank will decrease in the future, without the implementation of a Federal project.

It is expected that MRGCD would continue to maintain the existing spoil bank to its current standards. It is currently assumed that the existing spoil bank would continue providing protection to the floodplain on both sides of the river from flood events of a magnitude of less than the 20% ACE. The low aggradation rate (~1’ in 50 years) would eventually increase seepage through the spoil banks, as well as an increase in the energy of flood flows that would leave the floodway during a breach.

5.5.1.2 *Flooding Problems*

Table 27 and Table 28 summarize the estimated single occurrence damages associated with various flood events for the Mountain View to Belen reach of the Rio Grande.

Table 27 Single occurrence damages (east bank) – future without-project conditions.

SINGLE OCCURRENCE DAMAGES (EAST BANK)
WITHOUT PROJECT CONDITIONS (FUTURE)
MIDDLE RIO GRANDE FLOODPLAIN
(x $1,000 May, 2016 price level)

Land Use Category	EVENT							
	10%		2%		1%		0.20%	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Residential	32,057		40,278		40,398		51,163	
Res. Content	9,228		11,577		11,614		14,765	
Commercial	1,988		3,267		3,281		4,123	
Comm. Content	7,594		17,794		17,829		19,625	
Public	2,889		2,916		2,927		3,278	
Pub. Content	4,254		4,293		4,301		4,774	
Apartment	0		0		0		4	
Apt. Contents	0		0		0		1	
Outbuildings	1,425		2,012		2,020		2,808	
Out. Contents	1,294		1,934		1,943		2,687	
Subtotal - Structures	**38,359**		**48,473**		**48,626**		**61,376**	
Subtotal - Contents	**22,371**		**35,599**		**35,687**		**41,851**	
Subtotal - Structures and Contents	**60,729**		**84,072**		**84,313**		**103,227**	
Streets, roads	98,243		100,976		123,161		197,031	
Utilities	5,147		5,280		6,445		10,590	
Railroad	8		8		8		140	
Vehicles	5,365		5,388		5,469		6,524	
Agriculture	76		79		80		127	
Irr. Drains	607		626		737		1,391	
Recreation	0		0		0		0	
Emergency Costs	2,553		2,946		3,303		4,785	
Total	**172,728**		**199,375**		**223,516**		**323,816**	

Table 28 Single occurrence damages (west bank) – future without-project conditions.

SINGLE OCCURRENCE DAMAGES (WEST BANK) WITHOUT PROJECT CONDITIONS (FUTURE) MIDDLE RIO GRANDE FLOODPLAIN (x $1,000 May, 2016 price level)								
	EVENT							
Land Use Category	10%	0%	2%	0%	1%	0%	0.20%	0.00%
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Residential	18,961		19,083		19,132		21,293	
Res. Content	5,734		5,772		5,786		6,438	
Commercial	8,022		8,058		8,076		8,681	
Comm. Content	36,047		36,437		36,632		44,025	
Public	3,703		3,720		3,729		4,006	
Pub. Content	4,270		4,286		4,293		4,538	
Apartment	303		304		304		327	
Apt. Contents	82		83		83		90	
Outbuildings	1,709		1,724		1,729		1,957	
Out. Contents	1,870		1,882		1,887		2,097	
Subtotal - Structures	**32,698**		**32,889**		**32,969**		**36,264**	
Subtotal - Contents	**48,003**		**48,459**		**48,682**		**57,189**	
Subtotal - Structures and Contents	**80,701**		**81,348**		**81,651**		**93,453**	
Streets, roads	77,224		79,873		97,320		185,274	
Utilities	4,067		4,221		5,163		10,076	
Railroad	69		69		69		142	
Vehicles	4,780		4,782		5,555		6,481	
Agriculture	53		55		55		98	
Irr. Drains	574		587		690		1,211	
Aircraft	22,500		22,500		22,500		22,500	
Recreation	0		0		0		0	
Emergency Costs	2,850		2,902		3,195		4,789	
Total	**192,817**		**196,337**		**216,198**		**324,023**	

5.5.1.3 *Damageable Property*

Recent development in the study area has occurred outside the floodplain, and it is anticipated that this trend will continue. Future flood damages resulting from basin development or growth in the floodplains are not expected to be significant. Table 29 shows the number of structures within the footprints of various probability events. However, future without-project flood damages to existing properties are expected to increase in parts of the study area due to sediment aggradation within the Rio Grande. In addition, without implementation of a Federal project, agricultural lands within the project area would likely be subjected to increased flood damages due to higher runoff in the watershed and continued aggradation of the main river channel.

Table 29 Mean number of structures within the floodplain, future without-project conditions.

NUMBER OF STRUCTURES - EAST BANK
WITHOUT PROJECT CONDITIONS (FUTURE)
MIDDLE RIO GRANDE FLOODPLAIN

Land Use Category	EVENT							
	10%		2%		1%		0.20%	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Residential	1,954		2,347		2,347		2,794	
Commercial	155		213		213		268	
Public	25		30		30		39	
Apartment	0		0		0		1	
Outbuildings	1,985		2,500		2,500		2,830	
Vehicles	1,382		1,738		1,740		2,105	
TOTAL STR.	**4,119**		**5,090**		**5,090**		**5,932**	

NUMBER OF STRUCTURES - WEST BANK
WITHOUT PROJECT CONDITIONS (FUTURE)
MIDDLE RIO GRANDE FLOODPLAIN

Land Use Category	EVENT							
	10%		2%		1%		0.20%	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Residential	1,431		1,445		1,446		1,575	
Commercial	160		160		160		180	
Public	44		44		44		47	
Apartment	9		9		10		11	
Outbuildings	1,886		1,889		1,890		1,992	
Vehicles	1,200		1,201		1,201		1,348	
Aircraft	10		10		10		11	
TOTAL STR.	**3,530**		**3,547**		**3,550**		**3,805**	

5.5.2 Land Ownership

Reclamation and MRCGD claim ownership of the Rio Grande floodway, including the spoil banks, in the project area (see section 4.1.13). The USFWS operates and maintains the Valle de Oro National Wildlife Refuge, adjacent to the proposed Mountain View unit. It is anticipated that future Federal interest in the lands between and adjacent to the spoil bank would remain as they are today. Lands located within the floodway would likely remain in their current status since they would continue to be subject to periodic flooding due to their locations in the floodplains. Therefore, without the implementation a Federal project, it is anticipated there would be no changes in land ownership within the study area in the future. Consequently, no substantial changes in land ownership or land use are expected in the future without-project conditions.

5.5.3 Land Use

No substantial changes in land use are expected in the future without-project conditions.

5.5.3.1 *Residential and Municipal*

The communities between Albuquerque and Belen represent a substantial portion of the suburban residential population in the project area. The growth of these communities is anticipated to continue. Important county and municipal infrastructure, including wastewater treatment facilities, government buildings, and other facilities are located within the project area.

5.5.3.2 *Valle de Oro National Wildlife Refuge*

The Valle de Oro National Wildlife Refuge (Refuge) is adjacent to the Mountain View Unit of the project. The 570 acre refuge is unique in its location adjacent to a major metropolitan area. The refuge is managed to create wildlife habitat from former agricultural fields. The refuge offers environmental education and recreation while preserving open space.

5.5.3.3 *Transportation Facilities*

The primary transportation facilities affected by the Rio Grande within the project area are highways and railroad. The Burlington Northern Santa Fe Railway Company (BNSF) principal north-south line parallels the Rio Grande between Albuquerque and Belen, with a single track crossing the Rio Grande on Isleta (Isleta Unit), and a dual track crosses the Rio Grande south of Belen (Belen Unit). Several highways traverse the study area, including I-25, and state highways NM 147, NM 6, NM 309, and NM 346.

5.5.3.4 *Operation and Maintenance of Rio Grande Floodway*

Reclamation is responsible for operation and maintenance activities within the Rio Grande floodway throughout the proposed project area to support delivery of native water to Elephant Butte Reservoir under the Rio Grande Compact (Reclamation 2015; USFWS 2016).

5.5.3.5 *Irrigation, Agriculture, and Flood Risk Management*

The MRGCD, the non-Federal project partner, constructs, maintains, modifies, repairs, and replaces irrigation and flood risk reduction structures and facilities throughout the project area to ensure the proper functioning of these facilities for their intended purposes (Reclamation 2015).

Agriculture dominates existing land use within the proposed project area. Within the Rio Grande floodplain, there is irrigated farming and livestock pasturage, with livestock grazing on the bordering terraces and mountains. Valley lands are almost entirely developed for irrigated agriculture. Both authorized and unauthorized livestock grazing also occurs within the riparian zone.

Irrigated agriculture is an important component of the economy and way of life for people living along the Rio Grande. MRGCD was formed in 1925, primarily because of concerns over a decrease in irrigated areas in the Middle Rio Grande Valley resulting from water shortages, poor drainage, inadequate irrigation facilities, and periodic flooding. From 1925 to 1935 the MRGCD constructed El Vado Dam (a storage reservoir on the Rio Chama), four major irrigation diversion dams on the Rio Grande (one of which is the Isleta Diversion Dam), two canal headings, and 345 miles of main irrigation canals. It also rehabilitated old irrigation ditches. The Isleta Diversion

Dam diverts water from the Rio Grande to provide irrigation water to fields in the Pueblo of Isleta, Los Lunas, and Belen areas.

MRGCD is responsible for maintaining spoil bank flood control structures on either side of the floodway (Reclamation 2015; USFWS 2016). Any breach of the spoil banks would be promptly repaired. It is also likely that additional sediment would be piled on top of or adjacent to the existing spoil bank as materials from the floodway are removed.

5.5.3.6 *Water Conservation and Delivery*

The primary use of water in the proposed project area is for domestic, municipal, and irrigation purposes. Recreation and fish and wildlife benefits are incidental to these primary objectives.

Whereas infiltration of surface water is considered a loss in terms of delivery of surface waters to downstream users, there is an unquantified benefit to the local groundwater recharge. The groundwater aquifer in this area is used for municipal and agricultural water supply. Recharge is necessary to sustain this valuable resource.

5.5.3.7 *Future Land Use Without-Project Conditions*

Without the project, future land use is expected to remain similar to current trends. Residential and municipal land use is anticipated to increase. Agricultural use of lands outside the floodway would continue. MRGCD's maintenance of spoil bank flood risk reduction structures, diversions and delivery infrastructure would remain unchanged. Water conservation and delivery would continue. Reclamation would continue maintenance of the floodway for water delivery. The Refuge would implement plans for converting farmland into wildlife habitat. Transportation facilities would continue to function with regular maintenance.

5.5.4 Environmental Justice

On February 11, 1994, then President Clinton issued Executive Order 12898, Federal Actions to Address Environmental Justice in Minority and Low-Income Populations. This Executive Order requires Federal agencies to identify and address disproportionately high or adverse human health and environmental effects of Federal programs, policies, and activities on minority and low-income populations. An accompanying memorandum and guidance from the White House Council on Environmental Quality emphasized that Federal agencies would analyze the environmental effects, including human health, economic and social effects, of Federal actions, including effects on minority communities and low-income communities as part of the NEPA analysis and provide opportunities for community input.

In April of 1995, the EPA released a guidance document entitled Environmental Justice Strategy: Executive Order 12898. In short, this document defined the approaches by which the EPA would ensure that disproportionately high environmental and/or socioeconomic effects on minority and low-income communities are identified and addressed. Further, it established agency-wide goals for all Native Americans with regard to Environmental Justice issues and concerns.

Consideration of environmental justice concerns includes compilation of race and ethnicity data and the poverty status of populations. The 2015 estimated median household income in Bernalillo County was $47,725 and $41,703 in Valencia County. The percent of the residents were classified as living in poverty was 19% in Bernalillo County and 19.8% in Valencia

County; both were lower than New Mexico as a whole (20.4%), but higher than the U.S. (13.5%) (U.S. Census Bureau, 2017).

Minority populations, as defined by the U.S. Census Bureau, are significant in both counties. Bernalillo County is composed of Hispanics (49.2%) and Native American (6.0%). Valencia County has a higher percentage of Hispanics (59.9%) and lower percentage of Native Americans (5.7%). New Mexico is 48% Hispanic and 10.5% Native American, which is higher than the U.S. as a whole (U.S. Census Bureau, 2017).

Given the high probability of flooding in the study area, residents are at risk of incurring flood damages to homes and contents. Depending on the location of homes in the floodplain and depth of flooding for a given flood event people residing here risk losing some portion of the contents of their home, and would be faced with the costs of clean-up, repair or, in extreme cases, total loss of the structure. These losses, or the annual cost of insurance to offset these losses, present a significant financial burden especially to low income households. For those residents living in poverty, the loss would be catastrophic.

In the future without-project condition, the high probability of flooding remains in the study area. Future development is unlikely to change the demographics in Bernalillo and Valencia Counties and the study area. Losses of property, agricultural production, or annual cost of insurance to offset the losses represent a significant financial burden especially to the low income households. For those residents living in poverty, the loss would continue to be catastrophic.

5.6 Aesthetics*

The evaluation of visual qualities is a value judgment and is subjective, differing according to the perception of each individual. The general visual setting of the proposed project area is thought to be of high aesthetic quality, with the exception of sporadic litter and domestic garbage. The Middle Rio Grande Valley, with its irrigated fields, riparian forest and woodland, and river channel, forms a verdant corridor in an arid and sparsely vegetated land. The riparian forest and woodland is thought to possess moderate to high visual qualities, while the existing spoil bank has lower aesthetic appeal because of the sparsity of vegetation on the spoil bank and disturbed soils. While the spoil bank presents a visual obstruction it also provides an elevated vantage point to view both floodway and former floodplain viewsheds.

The future without-project condition of the aesthetic value of the proposed project area would remain largely as it is today, which is thought to be of moderate to high visual quality. There are no data to indicate that the existing aesthetic characteristics of the study area, including the irrigated fields, riparian forest, woodlands, and river channel, would change significantly in the future without the implementation of a Federal project.

6. FUTURE WITH-PROJECT CONDITIONS*

This chapter evaluates the *future with-project conditions*, commonly also known in the NEPA process as conditions resulting from implementation of the recommended plan as this plan is described in Chapter 4. Evaluation of these conditions is part of the study process that considers what would happen in the future if a Federal project is implemented. Because these projections become more unpredictable the farther into the future they are made, the *future with-project conditions* were defined to a point 50 years into the future and are also called the Project Year 50 conditions.

The recommended plan (Alternative C) is a 47.8 mile levee to replace the existing spoil banks as described in section 4.1.1. The recommended plan reduces levee length by 15 miles from the 1979 plan (Alternative B). The higher levee elevation for the Belen East and Belen West segments in the recommended plan increases the area (305.8 acres) of affected riparian vegetation over the base levee (Alternative D, 216.8 acres). The proposed 219 acres of mitigation in the recommended plan is greater than the 130 acres of mitigation in Alternative D.

6.1 Physical Environment*

6.1.1 Climate and Climate Change

There is no difference with respect to climate change between the future with-project and future without-project condition. Construction of this project will have no significant effect on future climate in the project area, and will result in no significant changes to greenhouse gas sources or sinks.

6.1.2 Geology

In general, geologic conditions will not change with the construction of the pro recommended plan with the exception of reduced seepage beneath the proposed levee compared to the existing spoil bank, and a greatly reduced likelihood of avulsions of sediment and water in the event of a flood from the proposed levees compared to the existing spoil banks. Similarly, the recommended plan will be more resilient under seismic ground-shaking than the existing spoil banks, but the underlying risk of ground-shaking from future movement on nearby earthquake faults will be unchanged. A preliminary seismic evaluation was performed to assess the effect of seismic loads on the design of the proposed levees (Appendix F). A detailed seismic hazard analysis will be required because the results of the preliminary seismic evaluation indicate that earthquake loads may govern levee stability.

6.1.3 Hydrology, Hydraulics and Sedimentation

6.1.3.1 *Hydrology: Results of FLO-2D Flood Routing for the With-Project Condition*

This analysis describes how the recommended plan would behave under the current sedimentation regime (current with-project condition 2008), and how the recommended plan will behave if current trends in sedimentation continue into the future (future with-project condition 2058). The future with-project condition assumes that sedimentation trends will continue as described in the sedimentation analysis in section 5.1.3.9. The FLO-2D routing was performed for both scenarios. For the purposes of with-project flood routing, engineered levees were assumed to exist for the entire length of the project in the same location as the existing Rio Grande spoil banks. This was considered to be the most conservative approach for flood routing to determine proposed levee height. Levee height assumed for the with-project condition was set to elevation 5020 (over 100 feet high) to insure overtopping cannot occur. Results of flood routing for the selected cross sections are listed in Tables 28 through 30 for the current with-project condition (2008). These cross sections were selected based on damage reaches and locations where attenuation would suggest a change in levee height and are the same locations used in the without-project analysis (Table 23).

Since engineered levees exist in the with-project condition, attenuation will occur within the floodway as opposed to spreading throughout the flood plain. Snowmelt flooding is controlled, for the most part, by reservoirs. Reservoir releases from Cochiti Dam resulting from snowmelt flooding typically occur as a steady flow in the Rio Grande that can take place over a period of months. Present guidance for the magnitude of these reservoir releases limit flow at Albuquerque to 7,000 cfs. The steady long-term portion of snowmelt floods has no significant attenuation through the project reach. In large events (0.5% ACE & 0.2% ACE events) spillway flow can occur in addition to reservoir releases, but unlike reservoir releases the flow is not controlled. Spillway flow can also be of long duration resulting in no significant attenuation (see Table 26 – Albuquerque floods from regulated areas showing little if any attenuation).

Routing of rainfall runoff events from the unregulated areas, unlike the regulated flow, shows significant attenuation through the 30-mile project reach. One factor leading to the high amount of attenuation for the rainfall-runoff events is the relatively low volume of the peak hydrographs.

Another of the causes for the attenuation is the large volume of storage available in the floodway, which is wide and shallow. Widths typically range from 500 feet to about 1,000 feet, with flow depths on the order of 4 feet for the 10% chance flood event. There is significant storage in the overbanks, even for the with-project model. Overbank flow, because of vegetation in the overbanks, is slower than channel flow, and delays the portion of the flood peak that is not carried in the channel, thus reducing flood peaks (See Table 27 – Albuquerque floods from unregulated areas and Table 28 – Floods from Tijeras Arroyo showing the attenuation which occurs as flow moves downstream through the project area).

Table 30 Current with-project condition (2008) flood peaks after routing - Albuquerque floods from regulated areas.

Cross Section #	**River Mile**	**2-YR Q_P (cfs)**	**5-YR Q_P (cfs)**	**10-YR Q_P (cfs)**	**20-YR Q_P (cfs)**	**50-YR Q_P (cfs)**	**100-YR Q_P (cfs)**	**200-YR Q_P (cfs)**	**500-YR Q_P (cfs)**
Gage 1	183.4	5595	7373	7500	7605	7735	7735	10297	14305
2	178.3	5579	7344	7461	7569	7689	7690	10206	13907
3	177.1	5583	7337	7452	7557	7679	7684	10226	14015
4	172.6	5569	7322	7419	7486	7649	7652	10237	14228
5	169.3	5980	7698	7771	8068	8119	8232	11096	15234
6	165.1	5541	7303	7389	7462	7615	7616	10224	14248
7	161.4	5528	7294	7375	7452	7601	7604	10202	14243
8	155.4	5506	7256	7329	7408	7551	7554	10112	14014
9	149.5	5499	7266	7332	7416	7571	7573	10218	14460
10	147.7	5500	7263	7331	7414	7569	7572	10180	14196

Table 31 Current with-project condition (2008) flood peaks after routing - Albuquerque floods from unregulated areas.

Cross Section #	**River Mile**	**2-YR Q_P (cfs)**	**5-YR Q_P (cfs)**	**10-YR Q_P (cfs)**	**20-YR Q_P (cfs)**	**50-YR Q_P (cfs)**	**100-YR Q_P (cfs)**	**200-YR Q_P (cfs)**	**500-YR Q_P (cfs)**
1-Gage	183.4	5147	7434	9344	12884	15542	18361	21577	26108
2	178.3	4930	6757	7692	9270	12044	14854	17834	21801
3	177.1	4898	6723	7753	8974	10755	13491	16652	21106
4	172.6	4825	6535	7071	7765	8877	10865	13494	18452
5	169.3	5033	6061	6620	7642	8563	10064	12606	17119
6	165.1	3592	4705	5065	6393	6918	8221	10089	13768
7	161.4	3518	4543	4789	5211	5698	7085	8875	11941
8	155.4	3398	4490	4605	4955	5208	5513	6094	8922
9	149.5	3179	4402	4548	4799	5045	5273	5638	7557
10	147.7	3076	4320	4527	4785	5030	5262	5624	7480

Table 32 Current with-project condition (2008) flood peaks after routing - floods from Tijeras Arroyo.

Cross Section #	**River Mile**	**2-YR Q_P (cfs)**	**5-YR Q_P (cfs)**	**10-YR Q_P (cfs)**	**20-YR Q_P (cfs)**	**50-YR Q_P (cfs)**	**100-YR Q_P (cfs)**	**200-YR Q_P (cfs)**	**500-YR Q_P (cfs)**
1-Gage	183.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	178.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	177.1	2029	4521	6550	9710	15199	16041	21855	30219
4	172.6	1906	4228	5946	7445	9237	9505	13213	21694
5	169.3	1783	4554	5716	6212	7258	7371	10306	16853
6	165.1	1570	2736	3447	4205	5085	5215	6716	11170
7	161.4	1353	2475	3270	4009	4768	4829	5485	8890
8	155.4	1228	2282	3012	3826	4570	4616	5133	5864
9	149.5	1173	2117	2749	3551	4476	4518	4953	5441
10	147.7	1189	2059	2677	3420	4370	4428	4921	5421

6.1.3.2 *Hydrology: With-Project Combined Frequency Analysis*

The with-project combined frequency analysis was performed using HEC-FDA for both current conditions and future conditions. These results were used by HEC-FDA to determine levee heights using the risk analysis for flood damage reduction studies. This analysis began at the South Diversion Channel (cross section 3 / Damage Reach 1) and extended through Belen (cross section 10 / Damage Reach 8). These cross sections, damage reaches and levee reaches are identified in Table 33.

Table 33 Cross sections used in analyzing the with-project levee from the SDC through Belen.

Cross Section #	Range Line	River Mile	FLO-2D Grid #	Location	Levee Reach	Damage Reach
3	576	177.1	7165	SDC & Tijeras Arroyo Confluence	Mountain View	1
4	624	172.6	8602	I-25 Bridge	Isleta North	2
5	657	169.3	9351	Isleta Diversion Structure	Isleta South	3
6	700	165.1	10497	Bosque Farms	Bosque Farms	4
7	740	161.4	11979	Los Lunas Bridge (Hwy 6)	Los Lunas	5
8	799	155.4	14636	Los Chaves	Los Chaves	6
9	859	149.5	16447	Bridge at Belen (Hwy 309)	Belen	7
10	878	147.7	16888	Belen Railroad Bridge	Belen South	8

The routed flows used for the current with-project condition are shown in Table 34 and were taken from Tables 29, 30 and 31 based on the highest flow for each frequency event at each of the given cross sections. For the with-project condition, flood peaks are generally dominated by rainfall-runoff storm events from the South Diversion Channel downstream to the Isleta Diversion (River Mile 169.3). From the Isleta Diversion downstream to the end of the project, flood peaks are dominated by large volume snowmelt floods that are regulated by the reservoirs upstream of Albuquerque. The routed flood peaks shown in Table 34 are also the discharge-probability inputs for the HEC-FDA program under the “HydEng” tab for the exceedance probability functions with uncertainty at each cross section for the current with-project condition.

Table 34 Current with-project condition flood peaks after routing - floods from all sources.

Cross Section #	River Mile	2-YR Q_P (cfs)	5-YR Q_P (cfs)	10-YR Q_P (cfs)	20-YR Q_P (cfs)	50-YR Q_P (cfs)	100-YR Q_P (cfs)	200-YR Q_P (cfs)	500-YR Q_P (cfs)
3	Mt. View	5583	7337	7753	9710	15199	16041	21855	30219
4	Isleta N	5569	7322	7419	7765	9237	10865	13494	21694
5	Isleta S	5980	7698	7771	8068	8563	10064	12606	17119
6	Bosque Farm	5541	7303	7389	7462	7615	8221	10224	14248

7	Los Lunas	5528	7294	7375	7452	7601	7604	10202	14243
8	Los Chaves	5506	7256	7329	7408	7551	7554	10112	14014
9	Belen	5499	7266	7332	7416	7571	7573	10218	14460
10	Belen South	5500	7263	7331	7414	7569	7572	10180	14196

The resulting confidence limit curves are given in Appendix H for the current with-project condition HEC-FDA output for each levee reach. The output is given in both tabular form and plotted form for each levee reach. This analysis was conducted for both the current with-project condition and the future with-project condition and is included in the HEC-FDA Risk Analysis Program included as Attachment 10 in Appendix H.

The FDA Model was used to help determine levee heights for the hydraulic analysis and also used in the economic analysis for the purpose of estimating damages.

6.1.3.3 *Hydraulics: With-Project Hydraulic Analysis*

The location of the existing Rio Grande spoil banks previously described provided the basis for which the alignment was determined for the with-project engineered levees used in this analysis. The FLO-2D 2-dimensional hydraulic model was used for the with-project hydraulic analysis in order to determine the attenuation of the flood hydrograph with the engineered levees in place. The flows determined from FLO-2D at each cross section were then used in the HEC-RAS Model to determine water surface elevations. The HEC-RAS Model was also used for determining the with-project standard deviations for hydraulic risk. This effort was conducted for both the current with-project conditions and the future with-project conditions. Results of with-project hydraulic risk is presented in Section 6.1.3.4 of this report.

The with-project HEC-RAS model for the expected condition uses a Manning’s n of 0.030 for the active channel and a Manning’s n of 0.10 for the left and right overbank areas from the channel banks to the levees on either side. The results were then input into the HEC-FDA program at each section for all eight frequencies.

For each of the flood frequencies that were considered, a separate project was developed to determine the elevation to achieve a 90% conditional non-exceedance probability levee height for that event. This analysis was conducted for both the current with-project condition and the future with-project condition and is included in the HEC-FDA Risk Analysis Program included in Attachment 10 of Appendix H.

6.1.3.4 *Hydraulics: With-Project Hydraulic Risk*

The HEC-RAS Model described previously was used for determining the with-project standard deviations for hydraulic risk and is included as Attachment 9 in Appendix H. This effort was conducted for both the current with-project conditions and the future with-project conditions. Table 35 shows the modifications that were made to develop high and low risk scenarios.

Table 35 Hydraulic parameters varied for the with-project risk analysis in the HEC-RAS model.

Risk Parameter	**Risk Scenario**		
	Low n-value	**Expected n-value**	**High n-value**
Channel n-value*	-0.005	0.030	+0.005
Overbank n-value	-0.020	0.100	+0.020
Sediment (Range Line Extent)	Current – None added Future – 1' (653-801)	Current – None added Future – 1' (653-801)	Simulated sediment plug fills channel for Current & Future conditions

** n-values are Manning's roughness values, which represents how rough or smooth a channel is. High n-values represent very uneven, rocky or vegetated surfaces that introduce turbulence and may reduce flow velocities; Low n-values represent smoother channels that do less to alter flow velocities or character.*

The basis for the Low, High, and Expected n-values given is the assumption of a confined cross section for the Rio Grande floodway between the levees as shown in the HEC-RAS Model, whereas the without-project scenario considered the effects of the entire valley floodplain section in the FLO-2D model (resulting in a wider variation in n-values). However, the magnitude of change between Low, High, and Expected n-values for the with-project condition are consistent when compared to the without-project condition. A simulated sediment plug was considered for all sections in the with-project modeling based on recommendations from the USACE Sedimentation Subject Matter Expert. Inclusion of a sediment plug in the model was based on recent occurrences of sediment plugs of various lengths in the San Acacia to Bosque del Apache reach of the Rio Grande, just downstream from the project reach. Following plug formation, the sediment can subsequently be transported downstream. The sediment condition for the High n-value scenario was handled differently for the with-project condition than for the without-project condition, since the effect of engineered levees will tend to confine flows (and mobilize sediment) within the levee section for large events. Therefore, any sediment deposits are confined within the floodway rather than deposited in the historic valley floodplain under high flow conditions.

There are several recent examples of sediment plugs occurring downstream of this reach in the Rio Grande from Bosque Del Apache National Wildlife Refuge to Elephant Butte Reservoir. The most recent occurrences were in the summer of 2007 and the spring of 2009. Additional discussion concerning sediment plugging is included in Appendix H, Exhibit A.

The controlling flood events at most frequencies for the with-project condition at the various cross–sections are given in Table 36.

Table 36 The controlling flood events at most frequencies for the with-project condition at the various cross–sections.

Cross Section	**Damage Reach**	**Location**	**Controlling Flood Event**
3	1	SDC & Tijeras Arroyo Confluence	Unregulated Areas below Cochiti & SDC
4	2	I-25 Bridge	Unregulated Areas below Cochiti & SDC
5	3	Isleta Diversion Structure	Unregulated Areas below Cochiti & SDC
6	4	Bosque Farms	Regulated by Cochiti & Jemez Releases
7	5	Los Lunas Bridge (Hwy 6)	Regulated by Cochiti & Jemez Releases
8	6	Los Chaves	Regulated by Cochiti & Jemez Releases
9	7	Bridge in Belen (Hwy 309)	Regulated by Cochiti & Jemez Releases
10	8	Belen Railroad Bridge	Regulated by Cochiti & Jemez Releases

The standard deviations were calculated for each index point in the eight levee reaches for a full range of flows covering the confidence intervals calculated for the discharge-probability curves. The results were then entered into the HEC-FDA program under the “HydEng” tab for “Stage-Discharge Function with Uncertainty” for each damage reach for both the current with-project condition and the future with-project condition.

For each of the flood frequencies that were considered, a separate project was developed to determine the elevation to achieve a 90% conditional non-exceedance probability (CNP) levee height for that event corresponding to each levee reach. Levee elevations were adjusted in an iterative process until 90% CNP was achieved for each event being investigated. This analysis was conducted for both the current with-project condition and the future with-project condition and is included in the HEC-FDA Risk Analysis Program included in Attachment 10 of the Appendix H.

The final hydraulic results using HEC-FDA Risk Analysis for Flood Damage Reduction Projects provide information in determining the most appropriate levee height for design based on the economic analysis.

Examples of the “Project Performance” output are provided below for current Without-Project Conditions and current With-Project 1 Conditions (500 year project – 2% ACE event) for comparison. This comparison shows that a project is needed to achieve a 90% CNP since under the existing condition a 90% CNP cannot be achieved for any of the flood events listed including the 10% ACE event. A CNP below 90% as shown in Figure 24 for the without-project condition indicates little confidence that the flood conveyance system would perform adequately and would therefore result in flood damage to surrounding communities for a given flood frequency event.

Project Performance

File Help

MRG Flood Project Project Performance
by Damage Reaches for the Without
(Without project condition) plan for Analysis Year 2008
(Stages in ft.)
Plan was calculated with Uncertainty

Without Project Base Year Performance Target Criteria:
Event Exceedance Probablility = 0.01
Residual Damage = 5.00 %

Stream Name	Stream Description	Damage Reach Name	Damage Reach Description	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)			Conditional Non-Exceedance Probability by Events					
					Median	Expected	10	30	50	10%	4%	2%	1%	.4%	.2%
Rio Grande	Channel & Floo	8 - Belen RR	Belen RR Bridge to E	levee	0.0032	0.1285	0.7473	0.9679	0.9990	0.8024	0.7977	0.7894	0.7891	0.5593	0.3922
		7 - Belen	Belen Hwy Bridge to	levee	0.0042	0.2286	0.9254	0.9985	1.0000	0.7042	0.7008	0.6932	0.6930	0.4920	0.3567
		6 - Los Chaves	Los Chaves to Belen	levee	0.0014	0.1675	0.8401	0.9898	0.9999	0.7963	0.7948	0.7903	0.7901	0.6676	0.5585
		5 - Los Lunas	Los Lunas to Los Ch	levee	0.0062	0.3636	0.9891	1.0000	1.0000	0.5866	0.5833	0.5784	0.5782	0.4393	0.3491
		4 - Bosque Farr	Bosque Farms to Los	levee	0.0011	0.1415	0.7825	0.9779	0.9995	0.8121	0.8120	0.8120	0.8120	0.6976	0.5901
		3 - Isleta South	Isleta Diversion to Bc	levee	0.0035	0.2587	0.9499	0.9994	1.0000	0.6866	0.6819	0.6793	0.6769	0.5189	0.4050
		2 - Isleta North	I-25 Bridge to Isleta [	levee	0.0042	0.2145	0.9106	0.9976	1.0000	0.7156	0.6948	0.6514	0.6463	0.4822	0.3484
		1 -Mountain Vie	South Diversion Cha	levee	0.0325	0.1706	0.8460	0.9907	0.9999	0.7715	0.5756	0.3403	0.3029	0.1208	0.0684

Figure 24 MRG flood project performance by damage reaches for the without-project condition.

A CNP of 90% or above as shown in Figure 25 for the with-project condition indicates a high level of confidence that the flood conveyance system would perform adequately and would therefore result in reduced risk to surrounding communities to receive flood damage from a given flood frequency event.

Project Performance

File Help

MRG Flood Project Project Performance
by Damage Reaches for the With Project 1
(500 Year Levee Height) plan for Analysis Year 2008
(Stages in ft.)
Plan was calculated with Uncertainty

Without Project Base Year Performance Target Criteria:
Event Exceedance Probablility = 0.01
Residual Damage = 5.00 %

Stream Name	Stream Description	Damage Reach Name	Damage Reach Description	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)			Conditional Non-Exceedance Probability by Events					
					Median	Expected	10	30	50	10%	4%	2%	1%	.4%	.2%
Rio Grande	Channel & Floo	8 - Belen RR	Belen RR Bridge to E	levee	0.0002	0.0017	0.0166	0.0411	0.0805	0.9982	0.9981	0.9979	0.9979	0.9740	0.9045
		7 - Belen	Belen Hwy Bridge to	levee	0.0002	0.0055	0.0532	0.1278	0.2392	0.9922	0.9918	0.9913	0.9913	0.9629	0.9017
		6 - Los Chaves	Los Chaves to Belen	levee	0.0001	0.0111	0.1057	0.2437	0.4280	0.9847	0.9840	0.9834	0.9834	0.9539	0.9043
		5 - Los Lunas	Los Lunas to Los Ch	levee	0.0001	0.0133	0.1251	0.2841	0.4875	0.9819	0.9813	0.9806	0.9806	0.9489	0.9004
		4 - Bosque Farr	Bosque Farms to Los	levee	0.0001	0.0082	0.0786	0.1850	0.3357	0.9875	0.9871	0.9864	0.9825	0.9552	0.9018
		3 - Isleta South	Isleta Diversion to Bc	levee	0.0001	0.0058	0.0562	0.1345	0.2510	0.9923	0.9909	0.9897	0.9833	0.9535	0.9017
		2 - Isleta North	I-25 Bridge to Isleta [	levee	0.0005	0.0007	0.0074	0.0183	0.0364	0.9999	0.9999	0.9997	0.9990	0.9865	0.9041
		1 -Mountain Vie	South Diversion Cha	levee	0.0003	0.0007	0.0074	0.0185	0.0366	0.9999	0.9999	0.9996	0.9992	0.9740	0.9009

Figure 25 MRG flood project performance by damage reaches for the with-project condition.

A summary of results from the FDA output is provided below for the 90% CNP providing levee heights for the 1% chance, 0.5% chance, and 0.2% chance events. Results are provided for both the current with-project condition (Table 37) and the future with-project condition (Table 38).

Table 37 FDA Results for With-Project Analysis - Present

FDA Results for With-Project Analysis - Current 2008 With-Project Levee Heights
Elevations are Given in Feet - NAVD88 Datum

Location	River Station	Channel Invert	0.002 500 year Flow Rate (CFS)	500 year WSEL	500 year Levee Elev.	Levee Height above expected 500 yr WSEL
Tijeras Arroyo Confluence	176.9	4919.39	30219	4929.35	4932.85	3.5
I-25 River Crossing	172.46	4899.46	21694	4907.03	4910.45	3.42
Isleta Diversion Structure	169.29	4885.06	17119	4890.91	4894.3	3.39
Bosque Farms	165.26	4866.84	14248	4871.72	4874.6	2.88
Los Lunas Bridge	161.48	4848.48	14243	4854.34	4857.3	2.96
Los Chaves	155.92	4823.47	14014	4829.13	4832.3	3.17
Belen Highway Bridge	150.34	4798.64	14460	4805.97	4809.3	3.33
Belen RR Bridge	148.3	4789.33	14196	4796.41	4798.8	2.39

Location	River Station	Channel Invert	0.005 200 year Flow Rate (CFS)	200 year WSEL	200 year Levee Elev.	Levee Height above expected 200 yr WSEL
Tijeras Arroyo Confluence	176.9	4919.39	21855	4927.97	4931	3.03
I-25 River Crossing	172.46	4899.46	13213	4905.46	4908.3	2.84
Isleta Diversion Structure	169.29	4885.06	12606	4890.07	4893.3	3.23
Bosque Farms	165.26	4866.84	10224	4871.03	4873.7	2.67
Los Lunas Bridge	161.48	4848.48	10202	4853.68	4856.5	2.82
Los Chaves	155.92	4823.47	10112	4828.39	4831.4	3.01
Belen Highway Bridge	150.34	4798.64	10218	4804.89	4808	3.11
Belen RR Bridge	148.3	4789.33	10180	4795.61	4797.7	2.09

Location	River Station	Channel Invert	0.01 100 year Flow Rate (CFS)	100 year WSEL	100 year Levee Elev.	Levee Height above expected 100 yr WSEL
Tijeras Arroyo Confluence	176.9	4919.39	16041	4926.87	4929.25	2.38
I-25 River Crossing	172.46	4899.46	9505	4904.61	4907.2	2.59
Isleta Diversion Structure	169.29	4885.06	10064	4889.49	4892.4	2.91
Bosque Farms	165.26	4866.84	7616	4870.64	4873.1	2.46
Los Lunas Bridge	161.48	4848.48	7604	4853.17	4855.8	2.63
Los Chaves	155.92	4823.47	7554	4827.93	4830.6	2.67
Belen Highway Bridge	150.34	4798.64	7573	4804	4806.9	2.9
Belen RR Bridge	148.3	4789.33	7572	4794.94	4796.7	1.76

Table 38 FDA Results for With-Project Analysis - Future

FDA Results for With-Project Analysis - Future (2058) With-Project Levee Heights
Elevations are Given in Feet - NAVD88 Datum

Location	River Station	Channel Invert	500 year Flow Rate (CFS)	500 year WSEL	500 year Levee Elev.	Levee Height above expected 500 yr WSEL
Tijeras Arroyo Confluence	176.9	4919.39	30407	4929.38	4933	3.62
I-25 River Crossing	172.46	4899.46	23170	4907.26	4910.9	3.64
Isleta Diversion Structure	169.29	4886.06	18310	4892.12	4895.1	2.98
Bosque Farms	165.26	4867.84	14237	4872.72	4874.9	2.18
Los Lunas Bridge	161.48	4849.48	14223	4855.34	4857.7	2.36
Los Chaves	155.92	4824.47	14082	4830.01	4832.6	2.59
Belen Highway Bridge	150.34	4798.64	14415	4805.96	4809.3	3.34
Belen RR Bridge	148.3	4789.33	14514	4796.46	4798.9	2.44

Location	River Station	Channel Invert	0.005 200 year Flow Rate (CFS)	200 year WSEL	200 year Levee Elev.	Levee Height above expected 200 yr WSEL
Tijeras Arroyo Confluence	176.9	4919.39	21915	4927.98	4931	3.02
I-25 River Crossing	172.46	4899.46	13483	4905.52	4908.4	2.88
Isleta Diversion Structure	169.29	4886.06	12914	4891.13	4893.8	2.67
Bosque Farms	165.26	4867.84	10220	4872.03	4874	1.97
Los Lunas Bridge	161.48	4849.48	10205	4854.68	4856.9	2.22
Los Chaves	155.92	4824.47	10136	4829.29	4831.7	2.41
Belen Highway Bridge	150.34	4798.64	10182	4804.88	4808	3.12
Belen RR Bridge	148.3	4789.33	10180	4795.61	4797.7	2.09

Location	River Station	Channel Invert	0.01 100 year Flow Rate (CFS)	100 year WSEL	100 year Levee Elev.	Levee Height above expected 100 yr WSEL
Tijeras Arroyo Confluence	176.9	4919.39	16025	4926.87	4929.3	2.43
I-25 River Crossing	172.46	4899.46	10853	4904.61	4907.2	2.59
Isleta Diversion Structure	169.29	4886.06	10273	4889.49	4892.9	3.41
Bosque Farms	165.26	4867.84	7614	4870.64	4873.4	2.76
Los Lunas Bridge	161.48	4849.48	7600	4853.17	4856.1	2.93
Los Chaves	155.92	4824.47	7555	4827.93	4830.9	2.97
Belen Highway Bridge	150.34	4798.64	7564	4804	4806.9	2.9
Belen RR Bridge	148.3	4789.33	7563	4794.94	4796.7	1.76

6.1.3.5 *Recommended Plan Inundation Mapping*

FLO-2D runs were conducted to determine flood inundation for the with-project condition and were used to aid in the economic analysis for determining damages. The with-project Inundation Map Books are located in Appendix H, Attachment 7 - Inundation Mapping/Inundation Map Books/Tentatively Selected Plan.

6.1.3.6 *Residual With-Project Inundation Mapping Extents*

In determining the TSP, various levee heights were considered and the associated residual damage areas mapped. This mapping shows the extent to which residual damages are reduced as levee heights are increased. The approach taken to delineate with-project floodplain extents for various frequency flows were accomplished using the FLO-2D, 2-dimensional hydraulic model described previously. Levee heights within the model were set at the 0.5% ACE event WSEL. The residual with-project floodplain mapping (flood inundation maps) considered the three different flooding sources: flows from the unregulated area below Cochiti (substantially rainfall runoff), regulated flow (substantially spring runoff), and the South Diversion Channel flow (substantially rainfall runoff from Tijeras Arroyo). This was accomplished by running each event separately. The model was run using the 0.2% ACE event hydrographs for each flooding source. Inundation maps were developed for each flooding source separately as well as a combined flood inundation map that considered the effects from all three flooding sources superimposed onto one map. This resulted in a total of four separate inundation maps. The results are shown in the Appendix H, Attachment 13 – Residual Inundation Mapping.

6.1.3.7 *Interior Drainage Analysis*

An interior drainage analysis was conducted for the 1986 General Design Memorandum entitled *Middle Rio Grande Flood Protection Bernalillo to Belen, NM - General Design Memorandum No. 1, Volume I Main Report* dated April 1986(1986 GDM). That analysis is considered to be applicable for the current study and is discussed in Paragraph 6-01, Interior Flooding Evaluation and 8-03 Interior Flooding (1986 GDM - Interior Flooding Evaluation). Additionally, a report provided in support of the 1986 GDM was prepared by Resource Technology, Incorporated entitled; Interior Drainage Analysis General Design Memorandum Middle Rio Grande Flood Protection, Bernalillo to Belen, New Mexico, dated March 1985 (Interior Drainage Analysis – RTI 1985).

The 1986 GDM - Interior Flooding Evaluation, section 8-03 on page VIII-2, states:

> *"The phrase 'interior flooding' refers to flooding caused by blocked drainage behind the riverside levees. The floodplain behind these man-made structures is protected from exterior (Rio Grande) flood water, but the interior runoff still remains as a potential problem. Tributary arroyos draining large watersheds usually have direct outlets through the levees, but smaller drainage areas usually do not have a direct outlet and could create interior flooding. Approximately 60 of these smaller drainage areas were identified and analyzed in this study. However, only in one area do tributary floodwaters reach the levee and pond behind it, even under SPF conditions. In the Belen East Unit, where the largest watersheds are*

> *located, the valley floor is so wide that SPF flows of nearly 30,000 cfs reach the levee only at Pond 4 at the lower end of the project. See Plate 13H."*

In section 8-17.5 on page VIII-13:

> *"The selected plan consists of leaving 2800 feet of existing levee unimproved at the lower end of Pond 4 (see Plates 17H and 18H). This would allow flows in the Rio Grande in excess of approximately 11,000 cfs to flow into Pond 4. This is the only feasible plan formulated that would not induce interior flooding and still be in accordance with EC 1110-2-247."*

It should be noted that the 2800 feet of existing levee (cited above) is in reality spoil bank.

These reports provide detailed hydrologic and hydraulic information for drainage areas outside the existing spoil banks and recommendations concerning the conveyance of these flows to the Rio Grande. See Appendix H, Attachment 14 - Interior Drainage Analysis.

6.1.3.8 *Sedimentation: Methodology for the aggradation/degradation analysis*

The sedimentation methodology and analysis presented for existing conditions in section 3.1.3.6 of this report also applies for with-project conditions. The conclusions from that analysis are provided in the following section.

6.1.3.9 *Sedimentation: Conclusions*

The channel and overbank elevations were relatively stable for the entire reach. Within the project reach, subreaches were only slightly degradational, therefore exclusion of degradation is recommended for future conditions models. This would also be the more conservative approach.

The aggradational reach downstream of Isleta Diversion dam is fairly consistent, with rates ranging from just under 0.01 feet/year up to 0.025 feet/year. Recommend future conditions models incorporate 0.02 feet/year aggradation for this reach. This would result in total aggradation of 1 foot through this reach over a 50-year period.

6.1.4 Water Quality

In general water quality within the study area would remain the same or possibly decline slightly for the current and future with-project conditions. Population growth in the Upper and Middle Rio Grande Valley is expected to continue a moderate growth in the areas of Albuquerque and Santa Fe. Population growth and changes in land use within the study area are not expected to change dramatically in the future (see section 3.5). Demand on limited water resources within the Rio Grande Basin would increase and potentially impact water quality through slight increases in salinity and other pollutants from use and re-use of water for municipal supply and irrigation.

For the recommended plan two activities relating to proposed work below the ordinary high water mark (OHWM) are: 1) earthen levee construction; and 2) placement of riprap along the riverward slope and toe of the levee.

6.1.5 Air and Sound Quality

Under future conditions, with-project, no projected effects on air quality are expected in the proposed project area, and the area is expected to remain in attainment for criteria pollutants. Current sound levels in the area would continue to be affected by existing conditions, and would not change in the future with-project condition.

6.2 Hazardous, Toxic, and Radioactive Waste Environment*

The future with-project condition was identified for the area of the Draft Phase I Assessment completed in 2015, a 55 mile long section of flood control spoil banks located along the Rio Grande from south Albuquerque to Belen New Mexico. The planned project is to replace the identified spoil banks with an engineered levee system. Construction of the engineered levee system will limit releases of HTRW and will not affect known or unknown HTRW sites within the limits of the project. A material management plan will be prepared during PED, to provide response guidance in the unlikely event that HTRW materials are encountered during project implementation.

6.3 Biological Environment*

6.3.1 Riparian Plant and Animal Community

The recommended plan would affect approximately 305.8 acres of riparian vegetation while Alternative D would affect 219 acres within the floodway. All areas disturbed by construction activities shall be re-vegetated following construction. The recommended plan would mitigate approximately 218.8 acres with appropriate levels of native shrubs and trees (up to 30% tree canopy cover) on or in close proximity to each phase of levee construction. The recommended plan includes 250 acres of terrace lowering. Alternative D would mitigate 130 acres with no terrace lowering. The mitigation plan measures include removal of invasive plants species, planting variable densities of shrubs and trees, terrace lowering and willow swales, and other riparian ecosystem measures.

6.3.2 Wetland Plant Community

Two perennial freshwater ponds with peripheral wetlands (PUBFh), as defined in Section 404(b)(1) of the Clean Water Act, have been identified within the proposed project area. The two ponds are located within the recommended plan footprint. Both of the ponds would be partially filled adjacent to the levee to support wet meadow or sedges for the vegetation management zone. The impacts to the affected wetland and pond habitat within the construction footprint of the levee will be addressed in the mitigation plan (Appendix E). The perimeter of the ponds may be extended away from the levee to maintain the same surface area and wetland vegetation.

6.3.3 Invasive Plant Species and Noxious Weeds

Invasive species and noxious weeds will continue to thrive and spread within the Rio Grande floodway and on adjacent lands, especially in areas of substrate disturbance. MRGCD would continue its maintenance program along the alignment of the engineered levee, including regular mowing. A 15 foot wide Vegetation Management Zone (see Section 4.1.9) will be maintained free of woody vegetation along the riverward toe of the levees.

6.3.4 Special Status Species

6.3.4.1 *Southwestern Willow Flycatcher (Empidonax traillii extimus)*

Based on the distribution of nesting flycatchers and the incorporation of conservation measures, levee construction is not likely to adversely affect the flycatcher. The recommended plan would result in the loss of habitat for the flycatcher is 29.6 acres, which may adversely affect critical habitat (USACE 2017). Mitigation under the recommended plan includes 219 acres of vegetation management and terrace lowering up to 250 acres. Alternative D would affect 217 acres of flycatcher habitat, and mitigate 130 acres with no terrace lowering.

6.3.4.2 *Yellow-billed Cuckoo (Coccyzus americanus occidentalis)*

Based on the cuckoo's nesting patterns, home range size, and the incorporation of conservation measures, levee construction is not likely to adversely affect the cuckoo. The loss of habitat for cuckoo is 212.5 acres, which may adversely affect its critical habitat (USACE 2017). Mitigation under the recommended plan includes 219 acres of vegetation management and an unknown area of terrace lowering. Alternative D would affect <124 acres of cuckoo habitat, and mitigate 130 acres with no terrace lowering.

6.3.4.3 *Rio Grande Silvery Minnow (Hybognathus amarus)*

The proposed construction would reduce the risk of silvery minnow stranding outside of the floodway, and retain higher flows in the floodway for creating complex aquatic and floodplain habitat (USACE 2017). Levee construction is not likely to adversely affect the minnow. The recommended plan would result in the loss of minnow critical habitat along the toe of the spoil bank (USACE 2017). Mitigation measures in the recommended plan would increase floodplain connectivity and nursery habitat for the minnow. Alternative D would not increase nursery habitat for the minnow.

6.3.4.4 *Other Threatened and Endangered Rio Grande Species*

The New Mexico Meadow Jumping Mouse (*Zapus hudsonius luteus*), the Interior Least Tern (*Sternula antillarum athalassos*), the Northern Aplomado Falcon (*Falco femoralis*), Mexican Spotted owl *(Strix occidentalis lucida)*, Piping Plover *(Charadrius melodus)*, and Chiricahua leopard frog (*Lithobates chiricahuensis*), Alamosa springsnail *(Tryonia alamosae)*, Chupadera springsnail *(Pyrgulopsis chupaderae)*, Socorro springsnail *(Pyrgulopsis neomexicana)* and Socorro isopod *(Thermosphaeroma thermophilus)*, and the Pecos sunflower (*Helianthus paradoxus* Heiser) occur outside the proposed project area. The recommended plan would have no effect on these species, and would have no effect on designated New Mexico Meadow Jumping Mouse critical habitat (USACE 2017).

6.4 Cultural Resources*

A total of two historic properties, including the existing spoil banks and a Traditional Cultural Property (TCP) on Isleta Pueblo land, are present in the project area and have the potential to be affected by the recommended plan. The TCP, while not falling directly within the proposed construction limits, is located directly adjacent and could potentially be impacted by construction of the engineered levees. In consultation with Isleta Pueblo cultural committee it was determined that the best course of action will be to fence the edge of the construction area on the riverward side of the levee with orange construction fencing for a distance of 100 meters north and south of the general TCP location provided by Isleta Pueblo. The fencing will stay in place for the entire duration of construction, and no construction activities will be allowed beyond the fence in the bosque. In addition, this area has been proposed for use as a mitigation site for habitat lost due to construction, and planting of native vegetation along the levee alignment will take place in consultation with the Pueblo. The planting of native vegetation will serve to replace the screen of vegetation that will be lost during construction, and will replace invasive species such as tamarisk and Russian olive with willows and cottonwoods, among other native plants. Construction near the TCP will also be suspended at the request of Isleta Pueblo when ceremonies or other activities are taking place in the area. Provided that these measures are implemented, USACE determines there will be no adverse effect to the TCP.

In addition to the TCP, the spoil banks themselves are historic properties and will be impacted by the recommended plan. The spoil banks were constructed beginning in the 1930s by MRGCD and are an important part of the overall flood protection system in the Middle Rio Grande Valley; a system that includes the spoil banks, riverside drains and irrigation canals as well as sediment retention features such as jetty jack fields. This system as a whole is widely considered to be eligible for inclusion in the NRHP, although individual features within the system are rarely recorded as sites. Recognizing the long-term need to improve flood protection in the Middle Rio Grande and the fact that this would result in the reconstruction of many of these historic spoil bank features, USACE completed an intensive documentation of the Middle Rio Grande flood protection works from Corrales to San Marcial (Berry and Lewis 1997), as well as an historical context for MRGCD flood protection in the Middle Rio Grande (Dodge and Santillanes 2007). The documents were produced under a programmatic agreement between the New Mexico SHPO and USACE dated June 7, 1996 as mitigation for adverse effects to the spoil bank features throughout the Middle Rio Grande (see Appendix C). These two documents provide an excellent overview of the historic Middle Rio Grande flood protection system and its individual features and have been widely distributed to the public since publication. Both documents are included in Appendix C. Because adverse effects to the spoil banks were previously mitigated USACE determined that there will be no adverse effects to historic properties through the reconstruction of the spoil banks.

In sum, the entire proposed alignment for levee construction has been previously surveyed and two historic properties, a TCP and the historic spoil banks, are present. While the project will result in the construction of engineered levees to replace the spoil banks, impacts to the historic spoil banks have been mitigated through documentation and thus, USACE has determined that the effect will not be adverse. In addition, the TCP identified by Isleta Pueblo has the potential to be impacted by project construction, but USACE has determined that if a protective fence is installed and maintained throughout the construction period, and native plants are established to replace the vegetative screen along the existing spoil banks, the recommended plan will result in no adverse effect to historic properties.

6.4.1 Indian Trust Assets

Construction of the recommended plan will have no effect on ITAs in the project area. The only ITA of potential concern is the water rights of the Isleta Pueblo; however, because the recommended plan will not alter the flow of water through Isleta Pueblo, there will be no effect to Isleta Pueblo's water rights.

6.5 Socioeconomic Environment*

6.5.1 Demography

Increases in population for Albuquerque and Los Lunas have been due to the diverse economy in the metropolitan areas, including education and research, health care, entertainment, hospitality, and retail. Continued urbanization of Bosque Farms and Belen will contribute to increases in population in those communities as well. These projections are considered accurate for the future, with or without the implementation of a Federal project.

6.5.1.1 *Flood Hazards*

A significant reduction in flood hazard will be realized by implementation of the recommended plan. Positive impacts have been quantified over the 50-yr period of analysis but benefits are expected for a much longer period. Flood depths in the overbanks would increase due to less storage capacity in the floodway. Thus, the hazards due to flooding in the study area would likely increase as the existing capacity of the floodway between levees may decrease by some amount in the future.

6.5.1.2 *Flooding Problems*

Table 39 summarizes the estimated single occurrence damages associated with various flood events for the Mountain View to Belen reach of the Rio Grande. A decrease in total single occurrence damages is shown for the 1% and 0.2% ACE events compared to current flood risk damage estimates shown in Table 39. This results from the decreases in the number of damageable properties within the floodplain, as discussed in the following section.

Table 39 Single occurrence damages – future with-project conditions.

LAND USE CATEGORY	**Single Occurrence Damages per Exceedance Event (x $1,000; August, 2010 Price Level)**			
	10%	**2%**	**1%**	**0.2%**
Residential	$4,572	$7,014	$7,863	$9,945
Resident Contents	$1,451	$2,229	$2,533	$3,187
Commercial	$1,962	$3,924	$4,685	$6,005
Commercial Contents	$15,792	$21,256	$23,998	$29,017
Public	$152	$203	$240	$281
Public Contents	$133	$183	$248	$356
Apartment	$1	$1	$3	$16
Apartment Contents	$0	$1	$1	$5
Outbuildings	$105	$170	$195	$256
Outbuilding Contents	$71	$106	$122	$160
Streets, roads	$10,466	$21,720	$25,021	$36,715
Utilities	$232	$762	$898	$1,317
Railroad	$1,693	$1,839	$1,928	$2,830

Vehicles	$2,703	$3,430	$4,086	$5,075
Agriculture	$704	$1,100	$1,209	$1,493
Irrigation Drains	$210	$396	$440	$798
Recreation	$2,837	$2,837	$2,837	$2,837
East Bank	$286	$373	$401	$482
Flood Emergency Costs	$600	$958	$1,094	$1,448
TOTAL	**$58,379**	**$87,486**	**$98,570**	**$129,520**

6.5.1.3 *Damageable Property*

Future flood damages resulting from basin development or growth in the floodplains is largely from infill of current agriculture lands or subdivision of existing developed parcels and are not expected to be significant. Table 39 shows the number of structures within the various probability events. However, future without-project flood damages to existing properties are expected to increase in parts of the study area. The total value of damages caused by a 1-percent chance event to the study area are estimated at $98.57 million (August, 2010 price level). In addition, without implementation of a Federal project, agricultural lands within the project area continue to receive flood damage.

Table 40 Mean number of structures within the floodplain, future with-project conditions.

Land Use Category	Percent Chance Exceedance Event			
	10%	**2%**	**1%**	**0.2%**
Residential	385	549	583	758
Commercial	110	179	190	214
Public	6	14	14	15
Apartment	2	3	3	6
Outbuilding	274	434	450	492
Total Structures	**777**	**1179**	**1240**	**1485**

6.5.2 Land Ownership

Federal interest in the lands under and adjacent to the spoil bank would remain as they are today. The implementation of a Federal project would not change land ownership within the study area in the future.

6.5.3 Land Use

Since the recommended plan would construct levees along the existing spoil bank alignment, no substantial changes in land use are expected in the future with-project conditions.

6.5.3.1 *Irrigation, Agriculture, and Flood Risk Management*

The MRGCD has maintained the network of diversion dams, storage reservoirs, canal headings, irrigation canals, and rehabilitated old irrigation ditches to provide irrigation water to the study area for over 85 years (Reclamation 2015). Although the MRGCD irrigation infrastructure is susceptible to damage from flooding, repair would be expected to occur almost immediately after a flood to ensure its continued operation. Therefore, it can be concluded that implementation of a Federal project will not affect irrigation facilities or agricultural activities.

MRGCD currently maintains spoil banks as flood fighting structures on either side of the floodway (Reclamation 2015; USFWS 2016). Replacing the spoil banks with engineered levees would reduce the risk of a breach flooding the surrounding communities. The engineered levees would also reduce damages to irrigation infrastructure from seepage.

It is also expected that all additional flood risk management improvements operated by the cities of Los Lunas and Belen, Bernalillo and Valencia counties, would be maintained in the future to their current operating condition. No other flood risk management projects are known to be in the planning stages within the Bernalillo to Belen study area.

6.5.3.2 *Water Conservation and Delivery*

Water conservation and delivery would continue into the future with implementation of the recommended plan. Infiltration of surface water into the local groundwater recharge would not be affected.

6.5.3.3 *Operation and Maintenance of Rio Grande Floodway*

Reclamation would continue maintenance of the floodway for water delivery to support delivery of native water to Elephant Butte Reservoir under the Rio Grande Compact (Reclamation 2015; USFWS 2016).

6.5.3.4 *Valle de Oro National Wildlife Refuge (Refuge)*

The Refuge would continue plans for converting farmland into wildlife habitat with implementation of the recommended plan.

6.5.3.5 *Transportation Facilities*

Transportation facilities would continue to function with regular maintenance with implementation of the recommended plan. The BNSF Railroad recognizes the flood risk but currently considers it to be acceptable. Reclamation intends to maintain the channel such that the current capacity of the bridges is not further reduced. Their maintenance program will continue into the future until the structural integrity of the bridge deteriorates to the point that it must be replaced. However, this is not expected to occur within the next 50 years, which is the period of analysis covered by the evaluations summarized in this report. It can be concluded that with the implementation of the recommended plan, the railroad bridges would continue to function as they do under current conditions or until a large event destroys either or both of the bridges and they are replaced with a bridge elevated above the floodplain.

Similarly, I-25, along with state highways NM 6, NM 147, NM 309, and NM 346 would continue to operate with no expected changes to occur in the future.

6.5.4 Environmental Justice

In the future with-project condition, the probability of flooding will be reduced in the study area. Future development if any would not likely change the demographics in Bernalillo or Valencia Counties and the study area. A reduction in potential losses of property or agricultural production, or eliminating the need to maintain flood insurance could relieve a significant financial burden, especially to low income households.

6.6 Aesthetics*

The future with-project conditions of the aesthetic value of the proposed project area would remain largely unchanged, which is thought to be of moderate to high visual quality. There are no data to indicate that the existing aesthetic characteristics of the study area, including the irrigated fields, riparian forest, woodlands, and river channel, would change significantly in the future with the implementation of a Federal project.

6.7 Cumulative Effects

The environmental baseline excludes the effects of the existing spoil banks that have been in place since the 1930s. Cumulative impacts are those which result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions. Accordingly, discussion of effects of the with-project condition only pertains to the incremental difference between the current spoil banks and the planned engineered levee. This section discusses the project relative to other activities which have affected Rio Grande hydrology and channel morphology. The discussion primarily relies on information presented in this report and other summary reports (e.g., Crawford et al. 1993; Berry and Lewis 1997; Mussetter Engineering, Inc. 2002; Dodge and Santillanes 2007; USACE and Reclamation 2007).

A direct effect of the recommended plan would be the enhanced level of safety and well-being provided to communities located on the 13,495 acres of floodplain on both sides of the Rio Grande. The potential for loss of life, injury, emotional trauma, and economic losses that accompany major flooding would be significantly reduced. Improved flood protection would benefit would the wildlife, education, and recreation provided by Valle de Oro NWR.

The construction footprint of the engineered levee into the floodway converts 305.8 acres of riparian vegetation into herbaceous vegetation, including 87.0 acres for the Vegetation Management Zone. The effects of the recommended plan on riparian vegetation and avian habitat would be mitigated by 219 acres of vegetation management and undetermined area of terrace lowering. Flow conditions within the 7,247 acre floodway up to the failure discharge (4000-7000 cfs) would be the same with or without the recommended plan. The effect of the proposed action is flow greater than 7000 cfs would be safely contained within the floodway.

6.8 Unavoidable Significant Environmental Effects

Potential effects of the project as it was originally authorized in 1948 were not determined in any fashion comparable to current practice. Since no design or footprint of a specific construction project was presented in the authorization, a determination of effects to the environment is not possible. The effects of implementing the project as originally authorized would presumably be very similar to the effects of implementing the recommended plan. Effects of the recommended plan are presented in Table 41.

Primary, long-term impacts identified in the study performed in 1941 prior to the 1948 Congressional authorization entailed the unavoidable loss or degradation of certain resources due to the levee footprint. Short-term effects were related to construction activities, and may have included a qualitative impact assessment for minor resources.

Table 41 Projected effects of the recommended plan.

Resource	Recommended Plan
Riparian vegetation	Reduce riparian forest by 305.8 acres.
Jurisdictional wetland	0 acres (change footprint if necessary).
Upland Grass/Shrub (in borrow areas)	Between 100-250 acres (if enhanced mitigation is not required for endangered species habitat)
Federally listed species	May affect, but not likely to adversely affect the flycatcher, likely to adversely modify its critical habitat. May affect, but not likely to adversely affect the cuckoo, likely to adversely modify its habitat. May affect, but not likely to adversely affect the minnow, likely to adversely modify its critical habitat.
Cultural resources	No adverse effect to historic properties; adverse effect determination to be completed for waste disposal locations.
Recreation	Temporary impairment due to limited access during construction.
Wildlife and Fisheries	Not appreciably affected or appreciably altered.
Water quality; water salvage and conveyance; sediment transport; air quality; land use	Not appreciably affected or appreciably altered.

6.9 Irreversible and Irretrievable Commitment of Resources

In accordance with NEPA, this GRR/SEIS discusses any irreversible and irretrievable commitment of resources that would be involved in the development of the project. Significant irreversible environmental changes are defined as uses of nonrenewable resources during the initial and continued phases of the alternatives that may be irreversible due to the large commitment of these resources.

Implementation of the recommended plan would result in the irretrievable commitment of land within the floodway. Replacing the spoil banks with engineered levees would constitute a change in land use, vegetation and habitat type. The replacement levees would be compatible with the other uses of the surrounding area. In addition, construction of engineered levees would result in the irretrievable commitment of construction materials, fossil fuels, and other energy resources.

While the recommended plan would result in the irretrievable commitment of materials and fossil fuels during the construction phase of the project, operation and maintenance is not expected to increase the use of either construction materials or fossil fuels.

6.10 Relationship between Short-Term Uses of the Environment and Long-Term Productivity

In accordance with NEPA, this section discusses the relationship between local short-term uses of the human environment and maintenance of long-term productivity for the project. Construction of the project would involve short-term alteration in vegetation and wildlife, air quality, and traffic patterns. Construction of any of the project alternatives would temporarily narrow the range of beneficial uses of these resources during construction.

Adverse effects on these resources would be limited to the construction phase of the project. No short-term uses of the environment are expected after the project is placed in operation. The air quality would return to pre-project levels after construction is completed. In the long term, planting to compensate for the loss of specific habitat types would offset the loss of vegetation and ensure the long-term productivity of the Middle Rio Grande.

In addition, several long-term benefits for the environment would result from the project. Improving public safety due to stronger flood risk management measures and reducing flood damage would increase productivity of the surrounding human community. Increasing the floodway capacity for safe conveyance of river flow would also increase the long-term productivity of the bosque.

7. COORDINATION AND CONSULTATION

7.1 Public Involvement under NEPA

Coordination with the public and interested parties has taken place throughout the current study. Table 42 summarizes public involvement to date. The public will be provided a 45-day review period of the draft GRR/SEIS and at least one public meeting will be conducted during that review period.

Table 42 Summary of previous coordination with the public and interested parties.

Location	Audience	Attendees	Date
Village of Los Lunas Office	Village of Los Lunas, Our Tomorrow, MRCOG, public	5	7/21/2008
Mountain View Community Center	MRGCD, Sandoval County, UNM, SWCA, MRCOG	5	7/23/2008
Isleta Pueblo Tribal Offices	Isleta Pueblo Tribal Council, MRGCD, public	9	7/24/2008
Isleta Pueblo Tribal Council	Isleta Pueblo Tribal Council	unknown	10/25/2010
Isleta Pueblo Tribal Offices	Isleta Pueblo staff and residents	6	2/26/2013
Middle Rio Grande Conservancy District Office	MRGCD staff	2	9/5/2013
Isleta Pueblo Tribal Council	Isleta Pueblo Tribal Council	unknown	11/12/2013
Valencia County Commissioner's Chambers - Los Lunas, NM	Los Lunas, public	12	12/3/2013
Mountain View Community Center	USFWS, UNM, MRGCD, City of Albuquerque, Albuquerque Bernalillo County Water Utility Authority, Albuquerque Metropolitan Area Flood Control Authority, Sierra Club, Amigos Bravos	16	12/4/2013
Isleta Pueblo Senior Center	Isleta Pueblo staff and residents, public	5	12/19/2013
US Army Corps of Engineers District Office	Isleta Pueblo staff	3	4/17/2014
US Army Corps of Engineers District Office	MRGCD, Isleta Pueblo, USFWS, USBR, Village of Bosque Farms, Friends Valle de Oro NWR, BikeABQ, Mountain View Neighborhood Association, South Valley Civitan Club, Audubon New Mexico, Hawks Aloft	17	4/21/2014

7.2 Coordination with Other Federal, State, Regional and Local Agencies

7.2.1 SHPO and Isleta Pueblo THPO Consultation

USACE provided a consultation letter to the Isleta Pueblo Tribal Historic Preservation Officer (THPO) on August 27, 2015 regarding USACE's determination that, provided that a protective fence is implemented during construction, and native plants are planted to replace the vegetative screen along the levee, there will be no adverse effect to the TCP on Isleta Pueblo lands. The THPO concurred with USACE's determination on September 28, 2015 (Appendix C).

USACE also consulted with the SHPO and Isleta Pueblo THPO regarding the potential effects of the project on the historic spoil banks. While the project will result in the reconstruction of the spoil banks, impacts to the historic spoil banks have been mitigated through documentation and thus, USACE determined that the effect will not be adverse. The SHPO and the Isleta Pueblo THPO concurred with this determination of effect on January 21, 2014 (HPD Consultation # 98447; Appendix C) and September 28, 2015 (Appendix C), respectively.

7.2.2 Fish and Wildlife Coordination Act

The Draft Fish and Wildlife Coordination Act report was received from the Service on February 12, 2015. Comments on the draft report were provided to the Service on July 5, 2017, with the final coordination report expected to be finalized by October 1, 2017. Draft versions of the report were sent to the New Mexico Department of Game and Fish, and the Forestry Division of the New Mexico Energy, Minerals, and Natural Resources Department. The report was also sent to the Pueblos of Isleta, and Valle de Oro National Wildlife Refuge.

7.2.3 Endangered Species Act Consultation

USACE initiated consultation with the U.S. Fish and Wildlife Service on January 6, 2017. Consultation with the U.S. Fish and Wildlife Service is ongoing. A draft Biological Opinion is anticipated before January 1, 2018.

7.3 Consultation with Native American Tribes

Consistent with the Department of Defense's American Indian and Alaska Native Policy of 1998, and pursuant to 36 CFR 800.2(c)(2)(i), tribal consultation on this project was conducted in 2010 with all Native American tribes that indicated they have concerns in Bernalillo and Valencia Counties. Responses were received from the Hopi Tribe, the Pueblo of Laguna, the White Mountain Apache Tribe and Ysleta del Sur Pueblo; all indicated that there were no cultural resources concerns with the project (Appendix C). In addition to these consultation letters, USACE has worked closely with Isleta Pueblo to identify potential cultural resources concerns on Isleta Pueblo lands. USACE is not aware of any TCPs within the project area for those portions of the project falling outside of Isleta Pueblo property, but a TCP has been identified on Isleta Pueblo lands. Isleta Pueblo has provided USACE with a general location for the TCP, although a specific location was not provided. Should the project go forward to construction, specific measures will need to be implemented to avoid and protect the TCP. Consultation with Isleta Pueblo is ongoing, and will continue throughout the life of the project. The Isleta Pueblo Tribal Council has expressed their formal support of the project

8. COMPLIANCE WITH APPLICABLE LAWS, POLICIES AND PLANS

This GRR/SEIS was prepared by USACE in compliance with all federal and state requirements, and in accordance with the goals and objectives of MRGCD, the local project partner, and other stakeholders within the project area.

8.1 Federal Requirements

This GRR/SEIS was prepared by USACE in compliance with all applicable Federal statutes, regulations, and Executive Orders, as amended, including, but not limited to, the following:

- National Environmental Policy Act (42 U.S.C 4321 *et seq*.)
- CEQ Regulations for Implementing the Procedural Provisions of NEPA (40 CFR Part 1500 *et seq*.)
- U.S. Army Corps of Engineers' Procedures for Implementing NEPA (33 CFR Part 230; ER 200-2-2)
- National Historic Preservation Act (16 U.S.C. 470 *et seq*.)
- Archaeological Resources Protection Act (16 U.S.C. 470aa *et seq*.)
- Native American Graves Protection and Repatriation Act (25 U.S.C. 3001 *et seq*.)
- Protection of Historic and Cultural Properties (36 CFR 800 *et seq*.)
- American Indian Religious Freedom Act (42 U.S.C. 1996)
- Clean Water Act (33 U.S.C 1251 *et seq.*)
- Clean Air Act (42 U.S.C. 7401 *et seq.*)
- Endangered Species Act (16 U.S.C. 1531 *et seq*.)
- Fish and Wildlife Coordination Act (48 Stat. 401; 16 USC 661 *et. seq.*)
- Migratory Bird Treaty Act (16 U.S.C. 703 *et seq.*)
- Federal Noxious Weed Act (7 U.S.C. 2814)
- Farmland Protection Policy Act (7 U.S.C. 4201 *et seq.*)
- Executive Order 11593, Protection and Enhancement of the Cultural Environment
- Executive Order 11990, Protection of Wetlands
- Executive Order 11988, Floodplain Management
- Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations
- Executive Order 13112, Invasive Species
- EO 13653, Preparing the United States for the Impacts of Climate Change
- EO 13514, Federal Leadership in Environmental, Energy, and Economic Performance
- Energy Independence and Security Act of 2007 (P.L. 110-140, Section 438, 121 Stat. 1492, 1620)

8.2 State Requirements

This GRR/SEIS was prepared by USACE in compliance with all applicable state requirements. Appendix E of this GRR/SEIS includes a detailed Section 404(b)(1) guidelines evaluation and a finding of compliance with the requirements of the Clean Water Act. A Section 401 Water Quality Certification shall be obtained from both the NMED and Isleta Pueblo, with the conditions of the permit to be incorporated into pertinent construction contract specifications.

8.3 Local Plans and Policies

The MRGCD has affirmed its intent to participate in the project. The results attained in the additional analyses conducted and presented in this GRR/SEIS have not changed the sponsor's favorable support of this project. The sponsor has the state-chartered responsibility for providing flood risk management to the Middle Rio Grande Valley, and recognizes the importance to its constituents of proceeding with this project. The sponsor has received statements of support from the New Mexico Interstate Stream Commission, which continues to show interest and support for this project. In addition, Isleta Pueblo and various other communities within Valencia County have indicated their support for the project.

9. POST AUTHORIZATION CHANGES

This chapter outlines the changes to the proposed project since it was originally authorized in 1941 and again in 1986. These changes are necessary due to changing construction standards, changing conditions in the floodway, and changing ecosystem restoration priorities.

Prior to the formation of the MRGCD in 1925, site-specific irrigation and flood protection structures, mainly community-specific acequias (irrigation ditches), were already in place. However, the first formal, organized attempt at flood risk management began with the MRGCD.

Since the Flood Control Act of 1941, the objectives of the Rio Grande and tributaries studies, surveys, reports, authorizations, appropriations and projects have been modified as conditions warranted. Events occurred and conditions changed that affected the project and resulted in expanding the scope of the Belen LRR study:

- Endangered Species Status: In 1994, the Southwestern Willow Flycatcher and the Rio Grande silvery minnow, both of which inhabit the study area, were added to the Federal Endangered Species List under the provisions of the Endangered Species Act. Additionally, the study area is within designated critical habitat for both species. Finally, in 2014, the Yellow-billed Cuckoo was listed as threatened and may occur in the study area.

- Middle Rio Grande Basin Hydrologic Computations: USACE recognizes that hydrologic analyses of the Middle Rio Grande Valley must evaluate flood discharges resulting from both the long-duration regulated flows from the upstream reservoirs (which are predominantly snowmelt flood events) and the unregulated short-duration, high intensity flows originating in the contributing watershed downstream of the reservoirs (associated primarily with rainfall events). As a result, alternatives under consideration in the Middle Rio Grande Valley must include features to mitigate against both flood sources. Because the authorized plan addressed only impacts due to the unregulated peak flood discharges, additional analyses and design are required.

- Sponsor Financial Capabilities: In 1998, USACE authored separate limited reevaluation studies for the Belen East and West study units (Belen LRR) and for the Rio Grande Floodway, San Acacia to Bosque del Apache Unit, Socorro County, New Mexico (San Acacia LRR). MRGCD made a decision to proceed with San Acacia spoil bank replacement first. This decision was largely due to their financial capabilities. It therefore became necessary to focus on the completion of the San Acacia LRR and delay the completion of the Belen LRR studies for the Belen Units as described in the 1979 Feasibility Report. The Belen Units are accordingly incorporated into this GRR/SEIS.

- Levee Criteria: The recommended levee design reflects the latest design and construction criteria for levees. Levee design will incorporate modifications to address long duration flows as required by USACE Policy Guidance Letter Number 26 (1991). Any proposed plan must now incorporate design features to prevent seepage through the levee due to prolonged flow against the riverward toe. Additionally, a risk-based approach to assess project performance has been used to identify levee heights that reasonably maximize net benefits and form the basis of the National Economic Development (NED) plan.

- Habitat Mitigation: The 1979 Feasibility Report recommended the creation of 75 acres of wetlands for borrow areas and the acquisition of 200 acres for fish and wildlife mitigation. Though recent USACE policies, procedures and hydrologic studies indicate that the current engineering project may not require the use of borrow and associated mitigation measures, providing borrow from the floodplain for the recommended levee height creates cost effective opportunities for increasing floodplain connectivity for enhanced riparian habitat mitigation.

- The Corps now employs a risk-based approach to assess project performance.

9.1.1 Description of Authorized Project

The Rio Grande and tributaries studies and projects were initiated in response to a series of Congressional actions authorizing studies and projects within the Rio Grande basin and particularly within the study area. Most of those authorities are listed in Section 1.4. The Middle Rio Grande Flood Protection, Bernalillo to Belen, New Mexico, project was originally authorized in 1941, and was reauthorized in 1986 following completion of the 1979 Feasibility Report and the submission of the June 23, 1981 Chief's Report (SUBJECT: Middle Rio Grande Flood Protection, Bernalillo to Belen, New Mexico) to Congress. The recommended plan consisted of the following units:

- Corrales Unit: Levee construction and raising an average of 2.8 feet above existing height. The unit extended from high ground in the vicinity of the Corrales Siphon downstream to immediately upstream of the Oxbow marsh area.
- Mountain View Unit: Levee construction and raising an average of 2.5 feet above existing height. The unit extends from the South outlet of the Albuquerque Diversion Channel to 3,000 feet downstream of the I-25 river crossing on the east side of the river.
- Isleta Unit – West: Proposed levee would be constructed and raised an average of 3.8 feet above existing height. The unit extends from the I-25 bridge and Atchison, Topeka and Santa Fe railroad bridge, to the State Road 147 bridge approach at Isleta.
- Belen Unit – East: Levee construction and raising an average of 2.7 feet above existing height. The unit extends from high ground upstream of State Road 147 bridge crossing, to 3,700 feet downstream from the railroad bridge at Belen.
- Belen Unit – West: Levee construction and raising an average of` 3 feet above existing height. The unit extends from the Santa Fe Railroad track immediately downstream of Isleta Marsh to approximately 7,000 feet downstream of the railroad bridge at Belen.
- Compensation for impacts to fish and wildlife resources: Proposed creation of 75 acres of wetlands from carefully designed borrow areas, and 200 acres of woodland would be acquired in fee or easement.

9.1.2 Authorization

The project is being conducted by authorities contained in the Flood Control Act of 1941, Section 4 (Public Law (P.L.) 228, 77th Congress, 1st Session, H.R. 4911) and the Water Resources Development Act of 1986, Section 401 (P.L. 662, 99th Congress, November 17, 1986).

9.1.3 Funding Since Authorization

Table 43 illustrates the funding history for the current project dating back to 1984.

Table 43 Funding history since 1984.

FY	Federal Funding								Non-Federal Funding	
	General Investigations			ARRA		Construction General				
	Appropriation	Allocation	Expenditures	Allocation	Expenditures	Appropriation	Allocation	Expenditures	Cash	Expenditures
1984	500,000.00	500,000.00	401,747.76							
1985	600,000.00	560,000.00	592,261.97							
Cost Shared 1986										
1986	450,000.00	431,000.00	310,877.64							
1987	475,000.00	346,000.00	519,422.78							
1988	400,000.00	400,000.00	336,989.18							
1989			49,098.78							
1990		10,000.00	25,630.95							
1991			10,970.94			130,000.00	50,000.00	40,696.98		
1992							200,000.00	132,037.05		
1993						400,000.00	422,000.00	416,988.01		
1994						2,125,000.00	1,816,000.00	778,852.25		
1995						3,800,000.00	3,199,000.00	670,703.51		
1996								890,737.50	530,000.00	
1997						3,501,000.00	1,231,000.00	3,842,368.67	1,619,750.00	2,109,494.30
1998						560,000.00	562,000.00	544,143.69		
1999						570,000.00	224,000.00	340,296.74		
2000						600,000.00	515,000.00	448,368.86		
2001						600,000.00	393,000.00	387,135.11		
2002						600,000.00	229,000.00	304,052.80		
2003						800,000.00	371,202.38	377,396.38		

FY	Federal Funding								Non-Federal Funding	
	General Investigations			ARRA		Construction General				
	Appropriation	Allocation	Expenditures	Allocation	Expenditures	Appropriation	Allocation	Expenditures	Cash	Expenditures
2004						600,000.00	353,000.00	364,201.23		
2005						300,000.00	322,000.00	298,368.92		
2006						600,000.00	314,000.00	275,501.84		
2007						350,000.00	350,000.00	268,581.70		
2008						295,000.00	295,000.00	360,979.24		
2009						383,000.00	383,000.00	480,918.62		
2009 ARRA Funding				3,235,930.00	59,075.85					
2010				(1,985,930.00)	1,181,862.34	756,000.00	756,000.00	319,194.75		
2011				(9,061.81)			199,585.00	376,569.60		
2012							49,999.00	311,492.07		
2013							299,400.00	241,796.68	300,000.00	209,076.40
2014							315,000.00	362,788.73	200,000.00	181,683.53
2015	276,000.00	376,000.00	358,495.66					14,105.57		108,348.68
2016										
Totals	**2,701,000.00**	**2,623,000.00**	**2,605,495.66**	**1,240,938.19**	**1,240,938.19**	**16,970,000.00**	**12,849,186.38**	**12,848,276.50**	**2,649,750.00**	**2,608,602.91**
Project/Study Name: MRG, Bernalillo to Belen, NM								PWI No: 012289 (511)		

9.1.4 Changes in Scope of Authorized Project

There have been no changes in scope since the project was authorized.

9.1.5 Changes in Project Purpose

There have been no changes in the project purpose since the project was authorized.

9.1.6 Changes in Local Cooperation Requirements

There have been no changes in the local cooperation requirements. It is expected that an up-to-date Project Partnership Agreement (PPA) will be executed for the recommended plan prior to commencement of construction.

9.1.7 Change in Location of Project

There have been refinements in proposed levee alignments for the recommended plan, but no major changes in project location. For the Belen East and West Units, there have been deletions and additions to the levee alignments (Figure 26). Table 44 below shows changes in length of proposed levees.

Table 44 Comparison of unit extents from 1979 to 2017.

Unit	1979 Length (miles)	2017 Length (miles)	Change (miles)
Corrales	12.6	Constructed 1997	
Mountain View	4.9	4.4	-0.5
Isleta West	3.2	3.2	0
Isleta East	Eliminated from Consideration	Eliminated from Consideration	N/A
Belen East	22.1	18.1	-4.0
Belen West	20.0	22.1	+2.1
Total	62.8*	47.8	

**Includes 12.6 miles for Corrales Unit*

9.1.8 Design Changes

The levee design will reflect the latest design and construction criteria for levees. Levee design will incorporate modifications to address long duration flows as required by USACE Policy Guidance Letter Number 26. Any proposed plan must now incorporate design features to prevent seepage through the levee due to prolonged flow against the riverward toe. Additionally, a risk-based approach to assess project performance will be used.

9.1.9 Changes in Total Project First Costs

Authorized project costs were in 1978 dollars at 6 7/8% interest rate, recommended project costs are presented in 2016 dollars at 3 1/8% interest rate (Table 45).

Table 45 Changes in total project first cost.

Estimated Cost for the Recommended Project	**Estimated Cost for the Project as Authorized by Congress**	**Authorized Project updated to Current Price Level**	**Estimated Cost for Project last presented to Congress**
$247,722,100	$44,900,000	$77,200,000	$77,200,000

9.1.10 Changes in Project Benefits

Authorized project benefits were in 1978 dollars at 6 7/8% interest rate, recommended project benefits are presented in 2016 dollars at 3 1/8% interest rate (Table 46).

Table 46 Changes in project benefits.

Benefits in the project document	**Benefits last reported to Congress**	**Benefits based on reevaluations which have been done to support the recommended changes to the project**
$102,849,800	$23,600,000	$1,622,000 (Corrales Unit [1979])

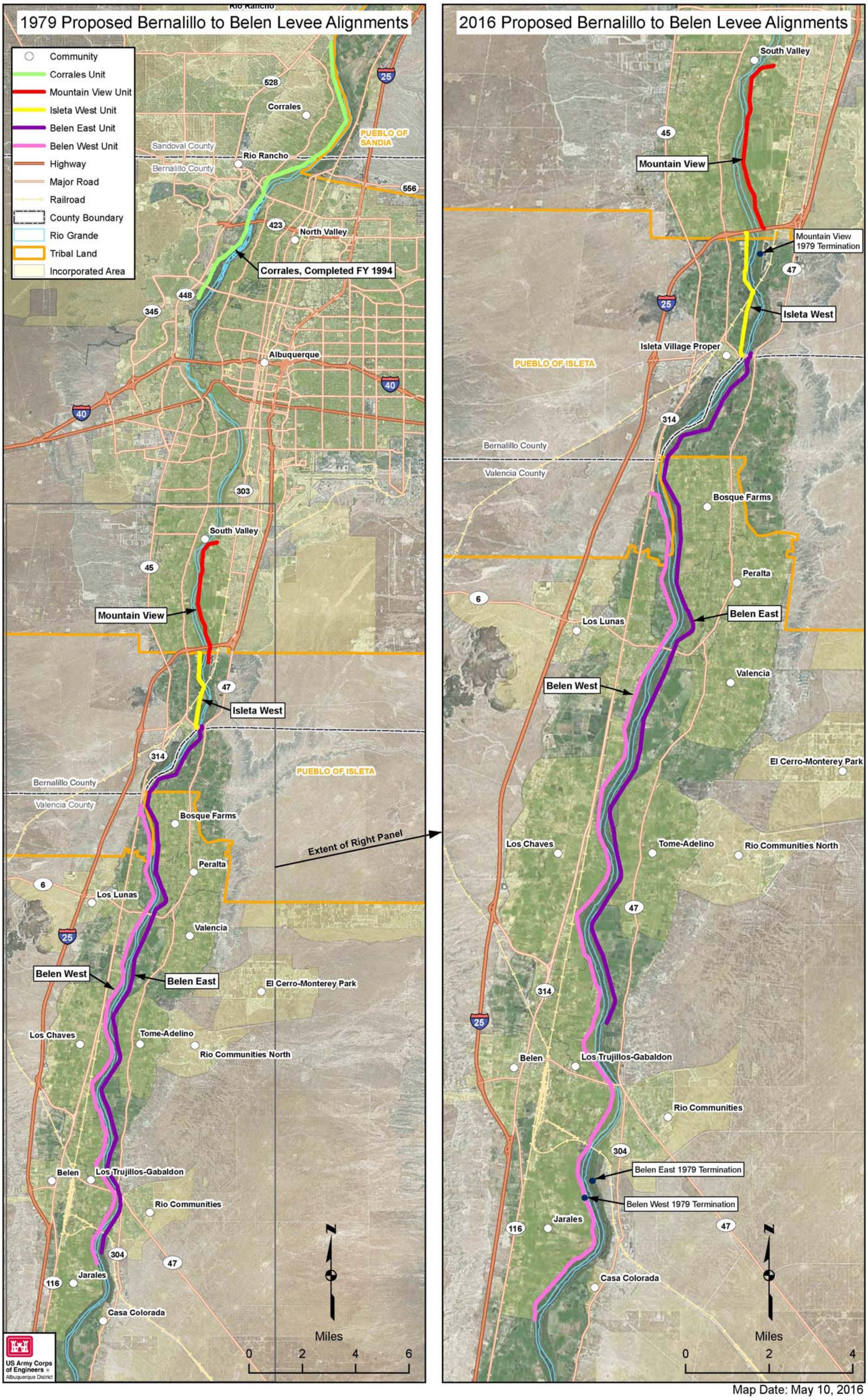


Figure 26 Comparison of 1979 authorized and 2016 recommended project units.

9.1.11 Benefit-Cost Ratio (BCR)

The benefit-cost ratio (BCR) for the authorized project is 1.6:1 at 7% interest rate. The BCR for the recommended project is 6.8:1 at 3 1/8% interest rate. The interest rate used in the authorizing document was 6 7/8 %.

9.1.12 Changes in Cost Allocation

Table 47 Changes in cost allocation.

Project Purpose	**Authorized Project**	**Recommended Project**
Engineered levees	$28,623,000	$247,722,100
Wetland Creation	$500,000	$0
Mitigation	$1,375,000	TBD

9.1.13 Changes in Cost Apportionment

The project as authorized used a proposed cost-share policy which resulted in a cost apportionment of 75% Federal, 25% non-Federal. The current recommended project will be apportioned at 75/25 as well (Table 48).

Table 48 Changes in cost apportionment.

Cost Share	**Authorized Project October 1978 Price Levels**	**Recommended Project**
Non-Federal	$7,474,000	$61,930,525
Federal	$22,418,000	$212,791,575

9.1.14 Environmental Considerations in Recommended Changes

Potential effects of the 1979 Authorized Project were not determined in the same manner as current practice. Effects from the Authorized Plan would be very similar to the effects of the recommended plan and are presented in Chapter 6.

Primary, long-term impacts entailed the unavoidable loss or degradation of certain resources due to the levee footprint. Short-term effects were related to construction activities, and may have included a qualitative impact assessment for minor resources.

Federal, State, and local environmental quality goals and policies are considered in evaluating the long-term effect that the alternatives may have on significant environmental resources. Significant environmental resources are defined by the U.S. Water Resources Council as those components of the ecological, cultural, and aesthetic environments which, if affected by the alternatives, could have a material bearing on the decision-making process. Avoidance of adverse impacts, followed by minimization and then mitigation of unavoidable, significant adverse impacts, is the formulation direction that is called for within NEPA.

The NED plan (also the recommended plan) is the, the plan that maximizes net benefits, will produce the most benefits at the lowest cost. Therefore the added cost of larger levees may be offset by providing more benefits due to the increased assurance of preventing higher flood stages (e.g., less frequent flood event). The evaluation of levee sizes demonstrated that the Base Levee (or 1% ACE WSEL) + 7 feet height most efficiently produced the maximum net benefits for the levee features. A larger levee project would incur substantial borrow costs for material, real estate costs to accommodate the wider footprint, and potentially mitigation costs. A smaller levee does not maximize the economic benefits.

This section summarizes the preliminary effects determinations that were made for the initial array of alternatives and the without-project condition (Appendix E). Relationships for specific ecological resource categories were assessed during the screening of alternatives: aquatic habitat, riparian habitat, minnow, flycatcher, cuckoo, and mouse.

Differences in effects among the various levee heights evaluated are a matter of degree, with increasing protection of the floodplain. Although inundation, scouring, and sediment accretion are natural processes of sand-bed rivers such as the Rio Grande, the recovery of plant and animal communities from the 1% ACE flood event would be slow.

The alternative plans were formulated to avoid and minimize adverse effects to riparian and aquatic habitat from the levee footprint. Permanent disturbance to soil and associated vegetation would occur throughout the project area due to physical constraints, resulting in the new levee toe extending beyond the existing riverward levee toe. Furthermore, permanent removal of vegetation would be required to accommodate a 15-foot-wide vegetation management zone along both sides of the levee, in compliance with ETL 1110-2-571, which requires that no vegetation (except grasses) be allowed to grow within 15 feet of the toe of the new levees. Any adverse effects would be mitigated by revegetation in the floodplain and riparian zone of available area reclaimed into the active floodplain.

10. RECOMMENDATIONS

This chapter presents USACE recommendations based on the information included in the GRR/SEIS. Also included is a description of the Items of Cooperation that will be required from the non-Federal sponsor for a Flood Risk Management (Single Purpose) Project that will be specifically authorized by Congress.

I recommend that the alternative selected in this reevaluation be authorized for implementation, as a Federal project, with such modifications that may be advisable in the discretion of the Commander, Albuquerque District, U.S. Army Corps of Engineers. The estimated first cost (2016 price level) of the Recommended Plan is $253,273,000 with an estimated Federal cost of $190,329,000 and an estimated non-Federal cost of $62,944,000. The estimated annual OMRR&R cost is $275,000 (2016 price levels).

This recommendation is made with the understanding that Federal implementation of the Recommended Plan would be subject to the non-Federal sponsor complying with applicable Federal laws and policies, including but not limited to the following requirements:

a. Provide a minimum of 25 percent, but not to exceed 50 percent of total project costs as further specified below:

    1. Provide 50 percent of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work;
    2. Provide, a cash contribution of funds equal to 5 percent of total project costs during construction;
    3. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the project; and
    4. Provide, during construction, any additional funds necessary to make its total contribution equal to at least 25 percent of total project costs.

b. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

c. Not less than once each year, inform affected interests of the extent of protection afforded by the project;

d. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

e. Comply with Section 402 of the WRDA 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a Project Partnership Agreement, and to implement such plan not later than one year after completion of construction of the project;

f. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for use in adopting regulations, or taking other actions to prevent unwise future development and to ensure compatibility with protection levels provided by the project;

g. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function;

h. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

i. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government in a manner compatible with the project's authorized purposes and in accordance with applicable federal and state laws and regulations, and any specific directions prescribed by the Federal Government;

j. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

k. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

l. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations Section 33.20;

m. Comply with all applicable federal and state laws and regulations, including but not limited to: Section 601 of the Civil Rights Act of 1964 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; the Age Discrimination Act of 1975 (42 U.S.C. 6102); the Rehabilitation Act of 1973, as amended (29 U.S.C. 794) and Army Regulation 600 7 issued pursuant thereto; and 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (labor standards originally enacted as the Davis-Bacon Act, the Contract Work Hours and Safety Standards Act, and the Copeland Anti-Kickback Act);

n. Perform, or ensure performance of, any investigations that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

o. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

p. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

q. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the WRDA 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project, or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to Congress as proposals for authorization and implementation funding. However, prior to transmittal to Congress, the sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Date

James L. Booth
Lieutenant Colonel, U.S. Army
District Engineer

11. LIST OF RECIPIENTS*

[*NOTE: List of Recipients will be supplied immediately prior to circulation for public review*.]

12. REFERENCES

Bargman, Byrd A. 1998. A Cultural Resources Survey of Middle Rio Grande Conservancy District Levees: Isleta to Belen Reach. OCA/UNM Report No. OCA-185-605. NMCRIS Activity No. 59915. Office of Contract Archaeology, University of New Mexico, Albuquerque.

Berry, K. Lynn and Karen Lewis. 1997. Historical Documentation of Middle Rio Grande Flood Protection Projects: Corrales to San Marcial. OCA/UNM Report No. 185-555 (NMCRIS No. 59879). Office of Contract Archeology. University of New Mexico. Prepared for U.S. Army Corps of Engineers. Albuquerque District. Albuquerque, Contract No. DACW47-94-D-0019, Delivery Order No. 0006.

Chang, H.H. 1988. *Fluvial Processes in River Engineering*. San Diego State University, San Diego, California. A Wiley-Interscience Publication, John Wiley & Sons, New York.

Chapin, C.E., and Cather, S. 1994. Tectonic setting of the axial basins of the northern and central Rio Grande rift, in Keller, G.R., and Cather, S.M., eds., Basins of the Rio Grande Rift: Structure, Stratigraphy, and Tectonic Setting: Geological Society of America Special Paper 291, p. 5–23.

Connell, S.D. 1997. Geology of the Alameda 7.5-minute quadrangle, Bernalillo and Sandoval Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources Open-file Digital Map OF-DM 10, scale 1:24,000; printed 25 August 1998.

Connell, S.D. 1998a. Preliminary geologic map of the Albuquerque West 7.5-minute quadrangle, Bernalillo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Open-file Digital Map OF-DM 17, scale 1:24,000; dated 28 October 1998.

Connell, S.D. 1998b. Preliminary geologic map of the Bernalillo 7.5-minute quadrangle, Sandoval County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Open-file Digital Map OF-DM 16, scale 1:24,000; printed 27 August 1998.

Connell, S.D. 2004. Geology of the Albuquerque Basin and tectonic development of the Rio Grande rift, north-central New Mexico, in Mack, G.H., and Giles, K.J., eds., The Geology of New Mexico, A Geologic History: New Mexico Geological Society Special Publication 11, p. 359–388.

Connell, S.D., Cather, S.M., Ilg, B., Karlstrom, K.E., Menne, B., Picha, M., Andronicos, C., Read, A.S., Bauer, P.W., and Johnson, P.S. 1995. (last revised: 17 Feb 2000). Geology of the Bernalillo and Placitas 7.5-min quadrangles, Sandoval County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Geologic Map OF-GM 2 and 16, scale 1:24,000 (mapped at 1:12,000).

Crawford, C.S., A.C. Culley, R. Leutheuser, M.S. Sifuentes, L.H. White, and J.P. Wilber. 1993. Middle Rio Grande ecosystem: bosque biological management plan. U.S. Fish and Wildlife Service Report. 291 pp.

Decker, Jeremy T. 2015. A 63.4-Acre Cultural Resources Inventory of Proposed Levee Alignments for the Bernalillo to Belen Flood Protection Project on Isleta Pueblo, Bernalillo and Valencia Counties, New Mexico. USACE Report No. USACE-ABQ-

2013-012. NMCRIS Activity No. 128666. US Army Corps of Engineers, Albuquerque District.

Dodge, William A., and Abraham Santillanes. 2007. Controlling the Floods: The Role of the U.S. Army Corps of Engineers in the History of the Middle Rio Grande Conservancy District. (NMCRIS NO. 130392). Van Citters: Historic Preservation, LLC. Prepared for the U.S. Army Corps of Engineers, Albuquerque District, Albuquerque, Contract No. W912PP-06-F-0053.

Elias, E. H., A. Rango, C. M. Steele, J. F. Mejia, and R. Smith. 2015. Assessing climate change impacts on water availability of snowmelt-dominated basins of the Upper Rio Grande basin, Journal of Hydrology: Regional Studies, 3, 525-546, doi: http://dx.doi.org/10.1016/j.ejrh.2015.04.004.

Federal Emergency Management Agency (FEMA) 1993. Wet Floodproofing Requirements for Structures Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program. www.fema.gov/media-library/assets/documents/3503

FEMA. 2005 Procedures for Developing Scopes of Work for the Acquisition and Relocation of Floodprone Structures. www.fema.gov/media-library-data/20130726-1516-20490-5325/relocation_sow.pdf

FEMA 2007. Selecting Appropriate Mitigation Measure for Floodprone Structures. www.fema.gov/media-library-data/20130726-1609-20490-5083/fema_551.pdf

Glover, T. G. 1975. Geology of the Central Organ Mountains, Doña Ana County, New Mexico: New Mexico Geological Society Guidebook, 26th Field Conference, Las Cruces Country, p. 157-161.

Grauch, V.J.S. and Connell, S.D. 2013. New perspectives on the geometry of the Albuquerque Basin, Rio Grande rift, New Mexico: Insights from geophysical models of rift-fill thickness, Geological Society of America Special Paper 494.

Hitchcock, C. and Kelson. K. 2007. GIS-based liquefaction potential and effects mapping, Albuquerque-Santa Fe Corridor, New Mexico, National Earthquake Hazards Reduction Program, U.S. Geological Survey Award Number 03-HQ-GR-0067.

Kelson, K.I., Hitchcock, C.S., and Randolph, C.E. 1999. Liquefaction susceptibility in the Inner Rio Grande Valley near Albuquerque, New Mexico: Final Technical Report, U.S. Geological Survey, Award 98-HQ-GR-1009, 40 p. + appendices.

Lozinsky, R.P. 1994. Cenozoic stratigraphy, sandstone petrology, and depositional history of the Albuquerque basin, central New Mexico, in Keller, G.R., and Cather, S.M., eds., Basins of the Rio Grande Rift: Structure, Stratigraphy, and Tectonic Setting: Geological Society of America Special Paper 291, p. 73–82.

Machette, M.N., Personius, S.F., Kelson, K. I., Dart, R.L., and Haller, K.M. 1998. Map and data for Quaternary faults in New Mexico: USGS Open-file Report 98-521, 443 pp.

Marshall, Michael P. and Henry Walt. 2006. A Cultural Resource Survey for the Isleta North Bosque Wildfire Project, Bernalillo County, New Mexico. Cibola Research Consultants Report No. 415 (NMCRIS No. 100494). Cibola Research Consultants, Corrales, New

Mexico. Prepared for the U.S. Army Corps of Engineers, Albuquerque District, Albuquerque.

May, S.J., and Russell, L.R. 1994. Thickness of the syn-rift Santa Fe Group in the Albuquerque Basin and its relation to structural style, in Keller, G.R., and Cather, S.M., eds., Basins of the Rio Grande Rift: Structure, Stratigraphy, and Tectonic Setting: Geological Society of America Special Paper 291, p. 113–123.

McEnany, Timothy G. 1998. A Cultural Resources Inventory of the Mountain View Reach Levee Alignments in and Adjacent to Isleta Pueblo, Bernalillo County, New Mexico. OCA/UNM Report No. OCA-185-666. NMCRIS Activity No. 75870. Office of Contract Archaeology, University of New Mexico, Albuquerque.

Melillo, J. M., T. C. Richmond, and G. W. Yohe, editors. 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program.

Morgan, P., Seager, W.R., and Golombek, M.P. 1986. Cenozoic thermal, mechanical, and tectonic evolution of the Rio Grande rift: Journal of Geophysical Research, v. 91, no. B6, pp. 6263–6276.

Mussetter, R. A., P.F. Lagasse, and M.D. Harvey. 1994. Erosion and Sediment Design Guide. Prepared for Albuquerque Metropolitan Arroyo and Flood Control Authority.

New Mexico Environment Department (NMED). 2009. Water Quality Monitoring of the Middle Rio Grande, Annual Baseline Condition and Trends of Key Water Quality Parameters, October 2006–July 2008, Final Report. Santa Fe, NM. 2009. ftp://ftp.nmenv.state.nm.us/www/swqb/MAS/Surveys/MiddleRioGrande-2009.pdf

NOAA. 1993. *Atlas II, Precipitation-Frequency Atlas of the Western United States, Volume IV – New Mexico.*

NOAA. 2004. *Atlas 14, Precipitation-Frequency Atlas of the United States, Semiarid Southwest*.

Parametrix. 2008. Restoration Analysis and Recommendations for the Isleta Reach of the Middle Rio Grande, NM. Prepared for the Middle Rio Grande Endangered Species Collaborative Program, USBR Contract No. 06CR408146. Prepared by Parametrix, Albuquerque, New Mexico. July 2008.

Personius, S.F., Machette, M.N., and Kelson, K.I. 1999. Quaternary faults in the Albuquerque area -- An update: New Mexico Geological Society Guidebook 50, p. 189-200.

Personius, S.F., Eppes, M.C., Mahan, S.A., Love, D.W., Mitchell, D.K., and Murphy, A. 2001. Log and data from a trench across the Hubbell Spring fault zone, Bernalillo County, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF-2348, v. 1.1.

Roelle, J.E., and W.W. Hagenbuck. 1995. Surface Cover Changes in the Rio Grande Floodplain, 1935-89 in LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, eds. 1995. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, DC. http://biology.usgs.gov/status_trends/static_content/documents/OLR.pdf

Scurlock, D. 1998. An Environmental History of the Middle Rio Grande Basin. USDA Forest Service General Technical Report RMRS-GTR-5. Fort Collins, CO.

Seager, W. R. 1981, *Geology of Organ Mountains and southern San Andres Mountains, New Mexico*. New Mexico Bureau of Geology and Mineral Resources Memoir 36, 97 p.

Spiegel, Z., and Baldwin, B. 1963. Geology and Water Resources of the Santa Fe Area, New Mexico; with Contributions by F.E. Kottlowski and E.L. Barrows and a Section on Geophysics by H.A. Winkler: U.S. Geological Survey Water-Supply Paper 1525, 258 p.

Trieste, D.J. 1992. Evaluation of Supercritical/Subcritical Flows in High-Gradient Channel. *Journal of Hydraulic Engineering*, ASCE, v. 118, no. 8, pp. 1107-1118.

Reclamation, USACE and Sandia National Laboratories. 2013. West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment, U.S. Bureau of Reclamation, Upper Colorado Region, Albuquerque Area Office (December 2013), Albuquerque, NM.

USACE. 1996. EM 1110-1-1906 Soil Sampling.

USACE. 2000. ER 385-1-95 Safety and Occupation Health Requirements for Hazardous, Toxic, and Radioactive Waste Activities.

USACE. 2003. SamWin Hydraulic Design Package. Engineer Research and Development Center, licensed to Musseter Engineering, Inc., License Number 10.03019, February 16, 2003.

USACE 2006. Middle Rio Grande Flow Frequency Study. Report to the Albuquerque District by the Hydrologic Engineering Center (HEC), Davis, CA.

USACE. 2010. ER-200-2-3 Environmental Compliance Policies.

USACE. 2011. Final Detailed Project Report with Integrated Environmental Assessment, Section 1135, Las Cruces Dam Environmental Restoration Project, 147 p.

USACE 2016. Earthquake Design and Evaluation for Civil Works Projects, Engineering Regulation ER-1110-2-1806, US Army Corps of Engineers, Dept. of the Army, Washington DC, 31 May.

USACE 2017. Programmatic Biological Assessment of U.S. Army Corps of Engineers Middle Rio Grande Flood Protection, Bernalillo To Belen, New Mexico: Mountain View, Isleta And Belen Units. Submitted to the U.S. Fish and Wildlife Service January 6, 2017.

USEPA and New Mexico Environment Department. 1998. Water Resources Issues in New Mexico, Vol. 38. November.

USGS 2017. Earthquake Hazards Program, National seismic hazard maps, U.S. Geological Survey, Dept. of Interior, Reston, VA. Retrieved on 22 Feb 2017 from https://geohazards.usgs.gov/hazards/apps/cmaps/.

Wischmeier, W.H. and D.D. Smith. 1978. *Predicting Rainfall Erosion Losses*. Agricultural Handbook 537, Science and Education Administration, USDA.

Wong, I., Olig, S., Dober, M., Silva, W., Wright, D., Thomas, P., Gregor, N., Sanford, A., Lin, K.-W., and Love, D. 2004. Earthquake scenario and probabilistic ground-shaking hazard maps for the Albuquerque–Belen–Santa Fe, New Mexico, corridor: New Mexico Geology, v. 26, p. 3-33.

Wong, CM, Williams, CE, Pittock, J, Collier, U and P Schelle. March 2007. World's top 10 rivers at risk. WWF International. Gland, Switzerland. http://wwf.panda.org/about_our_earth/about_freshwater/freshwater_problems/river_decline/10_rivers_risk/