Rio Grande de Manati Flood Risk Management Study
Integrated Feasibility Report & Environmental Assessment

Municipality of Ciales, Commonwealth of Puerto Rico

U.S. Army Corps of Engineers
Pittsburgh District

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COVER SHEET

Rio Grande de Manati Flood Risk Management Study, Ciales, Puerto Rico Final Integrated Feasibility Report & Environmental Assessment

The U.S. Army Corps of Engineers is the lead federal agency responsible for the planning and design of flood risk management projects, including addressing National Environmental Policy Act (NEPA) requirements. This document represents the final Integrated Feasibility Report—combining the final feasibility report and final environmental assessment—for the Rio Grande de Manati Flood Risk Management Study, Ciales Puerto Rico that complies with requirements of the federal Council on Environmental Quality.

EXECUTIVE SUMMARY

Rio Grande de Manati Flood Risk Management Study, Ciales, Puerto Rico Final Integrated Feasibility Report & Environmental Assessment

1 Purpose & Need

The purpose of the Rio Grande de Manati Flood Risk Management Feasibility Study is to assess and recommend federal actions to reduce risk and damages caused by flooding along the Rio Grande de Manati within the Municipality of Ciales, Puerto Rico. Flood damages have ranged from frequent nuisance flooding to severe and widespread impacts like those sustained during Hurricane Maria in 2017. Flooding has resulted in damages to homes, transportation, public infrastructure (i.e., wastewater treatment facilities), and commercial and industrial facilities.

The Municipality contracted development of plans and specifications for a flood protection works project designed to manage recurring flood risk within the communities of Dos Rios and Alturas de Ciales. Plans and specifications for the original design were completed in 2012. The scope of the current feasibility study was initially limited to the validation of the original flood protection works plan. However, additional flood risks were identified following Hurricane Maria that extended beyond the scope of the original flood protection works, including inundation of structures and roadways outside the original project footprint, as well as extensive bank failure induced by flooding during Hurricane Maria that is threatening transportation infrastructure. The study scope was expanded to include these additional risks. The specific study objectives are to:

- Objective 1: Reduce risks to life safety associated with inundation of structures, as well as transportation routes required for evacuation and post-flood recovery within Dos Rios, Ciales Pueblo, and Alturas de Ciales over the next 50 years.
- Objective 2: Reduce risk of flood damage to structures and public infrastructure within the communities of Dos Rios, Ciales Pueblo, and Alturas de Ciales over the next 50 years.

2 Current and Future Conditions

The study area is located at the confluence of the Rio Grande de Manati—the primary source of flooding within the study area—and Rio Cialitos. The study area includes the Ciales Pueblo and communities of Dos Rios and Alturas de Ciales and has undergone extensive development, which combined with the steep, mountain topography limits the amount of natural floodplain.

A total of 159 structures representing private homes, businesses, and industry and public facilities fall within the 0.002 annual exceedance probability (AEP) floodplain. United States

Geological Survey (USGS) data indicate the Rio Grande de Manati has reached flood stage 35 times in the past 50 years, with flooding caused by Hurricane Maria representing the largest event within the same time period. Trend analysis failed to detect a trend in historic annual peak streamflow. A recent review of existing literature suggests future storm events will be more frequent and intense due to climate change; however, there is no consensus regarding how changes in precipitation translate to altered hydrology. Despite this uncertainty, future increases in the magnitude and/or frequency of extreme storm events will likely increase flood risks associated with inundation of structures and roads, as well as damage to transportation infrastructure resulting from bank failure.

The U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory indicates no wetlands are present in the study area. One federally endangered species—the Puerto Rican Boa (*Chilabothrus inornatus*)—may occur in the study area. Water quality within the Rio Grande de Manati is listed as impaired due to fecal coliform, nitrogen, copper, total phosphorus, and turbidity. The Rio Grande de Manati supports a diverse aquatic community. There are nine known archaeological sites within or adjacent to the study area, as well as numerous structures meeting criteria for treatment as potential historic property.

3 Plan Formulation

Although flood-induced bank failure and bridge scour were identified as distinct problems within the study area, no direct link could be made between bank instability/scour and flood inundation. Consequently, neither the study authority nor USACE policy (USACE, 1999) permit the study, recommendation, or implementation of measures designed to address bank instability and/or bridge scour along the Rio Grande de Manati.

The study team developed a list of 10 structural and non-structural management measures—features or activities implemented at specific locations to address one or more of the planning objectives—that would help meet study objectives. An initial screening of management measures resulted in five measures being retained for further development into alternative plans, including: channelization/channel modification, floodwalls, levees, upstream reservoir, and non-structural relocations. Management measures were combined into an initial array of system-wide alternative plans. Alternatives were screened into the following final array of viable plans that would provide integrated and holistic solutions to flood risk throughout the study area:

- Alternative 0. No Action: The No Action alternative assumes no measures would be implemented by the federal government to achieve the planning objectives.
- Alternative 1. Levee/Floodwall System: This alternative incorporates the original, locally-developed flood protection works plan and a floodwall around the wastewater treatment.
- Alternative 2. Channel Modification: This alternative includes excavation and construction of a meandering low flow channel with increased capacity and improved hydraulic conductivity, as well as a floodwall around the wastewater treatment plant.

- Alternative 3. Non-Structural Relocations: A total of 59 structures within the 0.04 AEP floodplain would be acquired and demolished. Residents would be relocated. Alternative 3 incorporates a floodwall around the wastewater treatment plant.
- Alternative 4. Channelization: This alternative involves construction of a concrete-lined channel designed to increase capacity and improve hydraulic conductivity.

Alternative 3 was the only alternative with positive net economic benefits (i.e., annual benefits that exceed annual costs) and, thus, maximizes national economic development. Alternative 3 was the only alternative to have positive effects and benefits across all four accounts (national economic development, regional economic development, environmental quality, and other social effects) and criteria (i.e., completeness, effectiveness, efficiency, and acceptability) established in the Principles and Guidelines for the purposes of comparing alternatives (USACE, 1983). Alternative 3 also has the least environmental impacts among the four alternatives and the greatest potential environmental benefits. There would be residual current and future risk for structures outside of the 0.04 AEP floodplain and for inundation of roads throughout the study area; however, Alternative 3 has the least amount of uncertainty regarding residual risk and sustained benefits as all risk to relocated structures would be completely and indefinitely removed.

Costs and benefits associated with all elements of Alternative 3 were further analyzed to ensure each was incrementally justified. The floodwall designed to protect the wastewater treatment was not incrementally justified (i.e., annual costs exceeded annual benefits) and was removed from the recommended plan.

4 Recommended Plan

A total of 59 structures located within the 0.04 AEP floodplain would be acquired and demolished (Fig. ES-1). Residents and businesses would be relocated outside of the floodplain to comparable properties that are decent, safe, and sanitary and meet the needs and preferences of the displaced individuals. Participation would be mandatory. Non-structural relocations have a total first cost of $13,860,000, net annual benefits of $368,000, and a benefit cost ratio of 1.7.

5 Environmental Effects & Compliance *

The recommended plan is not anticipated to have significant negative environmental effects. All practical measures to avoid or minimize adverse environmental effects will be employed and are detailed in the integrated feasibility report and environmental assessment. USACE has coordinated with Commonwealth of Puerto Rico and federal agencies to ensure this feasibility study is compliant with all applicable laws, regulations, and executive orders (Table ES-1).

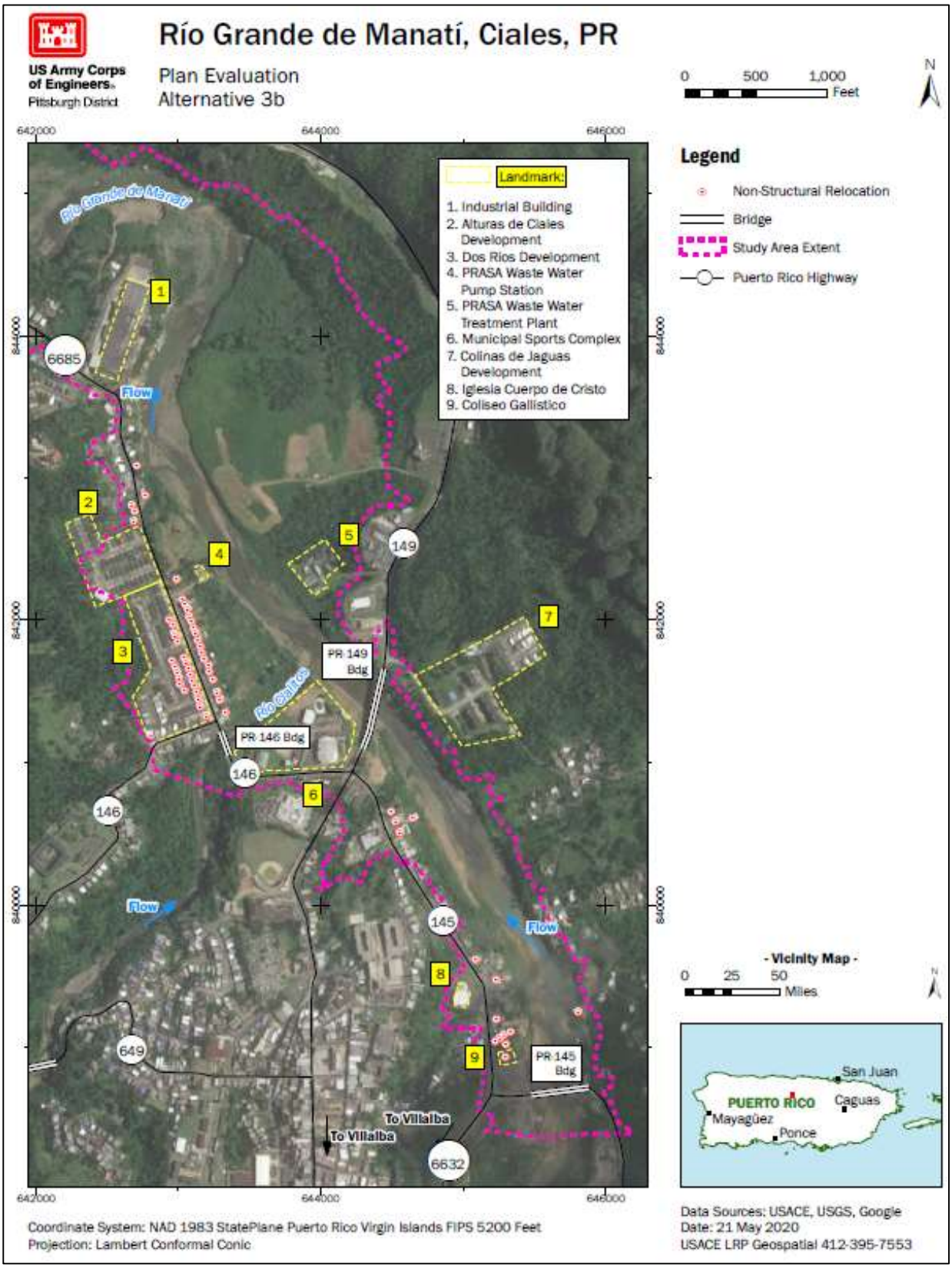

Fig. ES-1. Plan view of the recommended plan.

Table ES-1. Current compliance status with respect to applicable environmental laws and regulations. C = Compliant.

Reference	Environmental Laws/Regulation	Compliance
42 U.S.C. 1996	American Indian Religious Freedom Act of 1978	C
16 U.S.C. 668-668d	Bald and Golden Eagle Protection Act	C
42 U.S.C. 7401	Clean Air Act of 1970, as amended	C
33 U.S.C. 1251, et. seq.	Clean Water Act of 1977, as amended	C*
16 U.S.C. §1451 et. seq.	Coastal Zone Management Act of 1972	C
42 U.S.C. 9601	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980	C*
7 U.S.C. 4201 et. seq.	Farmland Protection Policy Act of 1981	C
16 U.S.C. 1531, et. seq.	Federal Endangered Species Act of 1973, as amended	C*
16 U.S.C. 460(l)(12), et. seq.	Federal Water Project Recreation Act	C
16 U.S.C. 661	Fish and Wildlife Coordination Act, as amended	C*
16 U.S.C. 1801, et. seq.	Magnuson-Stevens Fishery Conservation and Management Act	C
16 U.S.C. §1361 et. seq.	Marine Mammal Protection Act of 1972	C
16 U.S.C. §§715 et. seq.	Migratory Bird Conservation Act	C*
16 U.S.C. 703, et. seq.	Migratory Bird Treaty Act of 1918, as amended	C*
42 U.S.C. 4321 et.seq.	National Environmental Policy Act of 1969	C*
54 U.S.C. 300101	National Historic Preservation Act, as amended	C*
33 U.S.C. 401 et. seq.	Rivers and Harbors Act of 1899, Section 10	C
42 U.S.C. 4601 et. seq.	Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970	C*
16 U.S.C. 1271 et. seq.	Wild and Scenic Rivers Act of 1968	C
E.O. 12898	Federal Actions to Address Environmental Justice in Minority and Low-Income Populations	C
E.O. 11988	Floodplain Management	C
E.O. 13112	Invasive Species	C
E.O. 13186	Migratory Birds	C*
E.O. 13045	Protection of Children from Environmental Health Risks and Safety Risks	C
E.O. 11990	Protection of Wetlands	C*

*Full compliance will be achieved when the Finding of No Significant Impact and 404(b)(1) are signed and the following environmental compliance actions have been completed.

To comply with the Endangered Species Act, the USFWS guidelines for boa conservation will be included in the plans and specifications. To comply with the Migratory Bird Treaty Act and the Migratory Bird Conservation Act, the USFWS nationwide standard conservation measures will be included in the plans and specifications. To comply with the Clean Water Act and E.O. 11990, a wetland delineation will be conducted during project engineering and design. If applicable, the 404(b)(1) analysis will be updated during project engineering and design, and Section 401 Water Quality Certification will be obtained. A Section 402 NPDES permit will be obtained during project engineering and design, if necessary. To comply with Section 106 of the National Historic

Preservation Act, a Programmatic Agreement between USACE and the SHPO has been developed. Consultation with the SHPO will continue during project engineering and design.

6 Preliminary Recommendation

The study team preliminarily recommends moving the non-structural relocation of 59 structures within the 0.04 AEP floodplain forward as the recommended plan. The next likely action will be for the recommended plan to be outlined in a Chief's Report.

HOJA DE COBERTURA

Estudio del Manejo de Riesgo de Inundación del Río Grande de Manatí, Ciales, Puerto Rico
Borrador del Informe Integrado de Viabilidad y Evaluación Ambiental

El Cuerpo de Ingenieros del Ejército de los Estados Unidos (USACE, por sus siglas en inglés) es la principal agencia federal responsable de la planificación y el diseño de proyectos de manejo de riesgos de inundación, incluyendo el cumplimiento de los requisitos de la Ley Nacional de Política Ambiental (NEPA, por sus siglas en inglés). Este documento representa el Informe Integrado de Viabilidad - que incluye el informe de viabilidad y la evaluación ambiental - para el Estudio de Manejo de Riesgos de Inundación del Río Grande de Manatí, Ciales Puerto Rico que cumple con los requisitos del Consejo Federal de Calidad Ambiental.

RESUMEN EJECUTIVO

Estudio del Manejo de Riesgo de Inundación del Río Grande de Manatí, Ciales, Puerto Rico
Informe Integrado de Viabilidad y Evaluación Ambiental (Final)

1 Objetivo y Necesidad

El objetivo de este estudio de viabilidad es evaluar el riesgo de inundación y recomendar medidas federales para reducir los futuros daños causados por las inundaciones a lo largo del Río Grande de Manatí en el Municipio de Ciales, Puerto Rico. Los daños causados por las inundaciones han variado desde frecuentes inundaciones estorbosas a impactos graves y generalizados como los sufridos durante el huracán María en 2017. Las inundaciones han causado daños en viviendas, transportación, infraestructura pública (esto es, las instalaciones de tratamiento de aguas residuales) y edificios comerciales e industriales.

El Municipio contrató la elaboración de planes y especificaciones para un proyecto de obras de protección contra las inundaciones destinado para el manejo del riesgo de inundaciones recurrentes en las comunidades de Dos Ríos y Alturas de Ciales. El enfoque de este estudio se limitó inicialmente a la validación del plan original de obras de protección contra las inundaciones. Sin embargo, tras el huracán María se identificaron riesgos adicionales de inundación que se extendieron más allá del alcance de las obras de protección contra inundaciones originales, como la inundación de estructuras y carreteras fuera de la cobertura original del proyecto, así como la extensa fallas de las riberas inducidas por la inundación durante el huracán María que está amenazando la infraestructura de transportación. El alcance del estudio se amplió para incluir estos riesgos adicionales. Los objetivos específicos del estudio son:

- Objetivo 1: Reducir los riesgos para la seguridad de la vida asociados con la inundación directa y la pérdida de acceso de las rutas de evacuación y recuperación después de la inundación en el Pueblo de Ciales, Dos Ríos y Alturas de Ciales en los próximos 50 años.
- Objetivo 2: Reducir el riesgo de daños por inundaciones a las estructuras, instalaciones públicas e infraestructura de transporte asociados a las inundaciones y a las fallas de las riberas inducidas por las inundaciones en el Pueblo de Ciales, y las comunidades de Dos Ríos, y Alturas de Ciales en los próximos 50 años.

2 Condiciones Actuales y Futuras

El área de estudio está localizada en la confluencia del Río Grande de Manatí - la fuente primaria de inundaciones dentro del área de estudio - y el Río Cialitos. El área de estudio incluye el pueblo de Ciales y las comunidades de Dos Ríos y Alturas de Ciales. Estas comunidades han sido objeto de amplio desarrollo, que combinado con la topografía escarpada y montañosa limita la cantidad de llanura de inundación natural.

Un total de 159 estructuras que incluyen viviendas privadas, empresas, industrias e instalaciones públicas se encuentran dentro de la llanura inundable de 0.002 anual de superación (AEP, por sus siglas en inglés) y corren el riesgo de sufrir inundaciones y daños. Los datos del Servicio Geológico de los Estados Unidos indican que el Río Grande de Manatí ha alcanzado la etapa de inundación 35 veces en los últimos 50 años. Las inundaciones causadas por el huracán María representan el acontecimiento más significativo durante este período de tiempo. El análisis de tendencia no logró detectar una tendencia en el flujo máximo anual histórico de los arroyos. Un examen reciente de los estudios impresos sugiere que los futuros episodios de tormentas serán más frecuentes e intensos debido al cambio climático; sin embargo, no hay consenso sobre la forma en que los cambios en la precipitación se reflejarán en la alteración de las condiciones hidrológicas. A pesar de esta incertidumbre, el aumento futuro en la magnitud y/o frecuencia de fenómenos de tormentas extremas probablemente incrementará los riesgos de inundación asociados a la inundación de estructuras y carreteras, así como los daños a la infraestructura de transporte derivados de la quiebra de los bancos.

El Inventario Nacional de Humedales del Servicio de Pesca y Vida Silvestre de los Estados Unidos (USFWS, por sus siglas en inglés) indica que no hay humedales en la zona de estudio. Una especie en peligro de extinción a nivel federal -la boa puertorriqueña (Chilabothrus inornatus)- puede estar presente en la zona de estudio. La calidad del agua dentro del Río Grande de Manatí está catalogada como deteriorada debido a coliformes fecales, nitrógeno, cobre, fósforo total y turbidez. El Río Grande de Manatí sustenta una comunidad acuática diversa. Hay nueve sitios arqueológicos dentro o adyacentes a la zona de estudio, así como numerosas estructuras que cumplen los criterios para ser tratadas como posibles propiedades históricas.

3 Formulación del Plan

Aunque la falla de los bancos inducida por las inundaciones y la socavación de los puentes se identificaron como problemas distintos dentro de la zona de estudio, no se pudo establecer un vínculo directo entre la inestabilidad/la socavación de los bancos y la inundación por inundación. Por consiguiente, la autoridad encargada del estudio ni la política de la USACE (USACE, 1999) permiten el estudio, la recomendación o la implementación de medidas destinadas a abordar la inestabilidad de los bancos y/o la socavación de los puentes a lo largo del Río Grande de Manatí.

El equipo del estudio elaboró una lista de diez (10) medidas de manejo no estructurales - funciones o actividades aplicadas en lugares específicos para resolver uno o más de los objetivos de planificación- que ayudarían a cumplir los objetivos del estudio. Un examen inicial de las

medidas de manejo resultó en la retención de cinco (5) medidas para su posterior desarrollo en planes alternativos, entre ellas: canalización/modificación de canales, muros de contención, diques, embalse aguas río arriba, y reubicaciones no estructurales. Luego las medidas de manejo se combinaron en una serie inicial de planes alternos para todo el sistema. Las alternativas se examinaron en una serie final de planes viables que ofrecen soluciones integradas y holísticas al riesgo de inundación en toda la zona de estudio. La serie final incluye:

- Alternativa 0. No acción: La alternativa de no acción supone que el Gobierno Federal no aplicará ninguna medida para alcanzar los objetivos de la planificación.
- Alternativa 1. Sistema de diques y muros de contención: Esta alternativa incorpora el plan original de las obras de protección contra inundaciones desarrolladas localmente, y un muro de contención alrededor de la planta de tratamiento de aguas residuales.
- Alternativa 2. Modificación del canal: Esta alternativa incluye la excavación y construcción de un canal de flujo bajo serpenteante con mayor capacidad y mejor conductividad hidráulica, así como la construcción de un muro de contención alrededor de la planta de tratamiento de aguas residuales.
- Alternativa 3. Reubicaciones no estructurales: Un total de 59 estructuras dentro de la llanura de inundación de 0.04 AEP serían adquiridas y demolidas. Los residentes serían reubicados. La alternativa 3 incorpora un muro de contención alrededor de la planta de tratamiento de aguas residuales.
- Alternativa 4. Canalización: La canalización implica la construcción de un canal revestido de hormigón diseñado para aumentar la capacidad y mejorar la conductividad hidráulica.

La alternativa 3 era la única alternativa con beneficios económicos netos positivos (es decir, beneficios anuales superiores a los costos anuales) y, por lo tanto, maximiza el desarrollo económico nacional. La alternativa 3 era la única alternativa que tenía efectos y beneficios positivos en las cuatro cuentas (desarrollo económico nacional, desarrollo económico regional, calidad ambiental y otros efectos sociales) y criterios (es decir, integridad, eficacia, eficiencia y aceptabilidad) establecidos en los Principios y Directrices a los efectos de la comparación de alternativas (USACE, 1983). La alternativa 3 también es la que tiene menos efectos ambientales entre las cuatro alternativas y la que tiene el mayor potencial de beneficios ambientales. Habría un riesgo residual actual y futuro para las estructuras fuera de la llanura de inundación de 0.04 AEP y para la inundación de las carreteras en toda el área de estudio; sin embargo, la Alternativa 3 tiene el menor grado de incertidumbre con respecto al riesgo residual y a los beneficios sostenidos, ya que todo el riesgo para las estructuras reubicadas sería eliminado completamente e indefinidamente.

Se analizaron más a fondo los costos y beneficios asociados a todos los elementos de la Alternativa 3 para asegurar que cada uno de ellos se justificara de manera incremental. El muro de contención diseñado para proteger el tratamiento de las aguas residuales no se justificó de forma incremental (es decir, los costos anuales superaron los beneficios anuales) y se eliminó del plan seleccionado provisionalmente.

4 Plan Recomendado

Un total de 59 estructuras ubicadas dentro de la llanura de inundación de 0.04 AEP serían adquiridas y demolidas (Fig. ES-1). Los residentes y negocios serían reubicados fuera de la llanura de inundación a propiedades comparables que sean decentes, seguras y sanitarias y que satisfagan las necesidades y preferencias de los individuos desplazados. La participación sería obligatoria. Las reubicaciones no estructurales tienen un costo inicial total de $13,777,000 dólares, beneficios anuales netos de $371,000 dólares y una relación costo-beneficio de 1.7.

5 Efectos Ambientales y Cumplimiento *

No se anticipa que el plan recomendado tenga efectos ambientales negativos significativos. Se emplearán todas las medidas prácticas para evitar o reducir al mínimo los efectos ambientales adversos, incluyendo el uso de las mejores prácticas de manejo durante construcción, que se detallan en el informe integrado de viabilidad y la evaluación ambiental. El USACE ha coordinado con las agencias estatales y federales para asegurar que el plan recomendado cumpla con todas las leyes, regulaciones y órdenes ejecutivas pertinentes. Un resumen del estado de cumplimiento actual se muestra en la Tabla ES-1.

Se necesitarán medidas adicionales de cumplimiento ambiental durante la fase de ingeniería y diseño del proyecto. Se completará un estudio de los humedales antes la fase de pre-ingeniería y diseño, y se requerirá la mitigación de cualquier impacto inevitable en los humedales. Se obtendrá una certificación de conformidad con el artículo 401 de la Ley de Agua Limpia antes de la construcción, si es necesario. El USACE ha suscrito un Acuerdo Programático con la Oficina de Preservación Histórica del Estado de Puerto Rico para posponer la identificación y evaluación final de las propiedades históricas hasta que se apruebe el estudio y el proyecto entre en la fase de ingeniería y diseño previos a la construcción en cumplimiento de la Sección 106 de la Ley de Preservación Histórica Nacional (36 CFR § 800.4[b][2]). La adquisición y reubicación será completada por el patrocinador local con la supervisión de la USACE para asegurar el cumplimiento de la Ley de Políticas Uniformes de Asistencia para la Reubicación y Adquisición de Bienes Inmuebles.

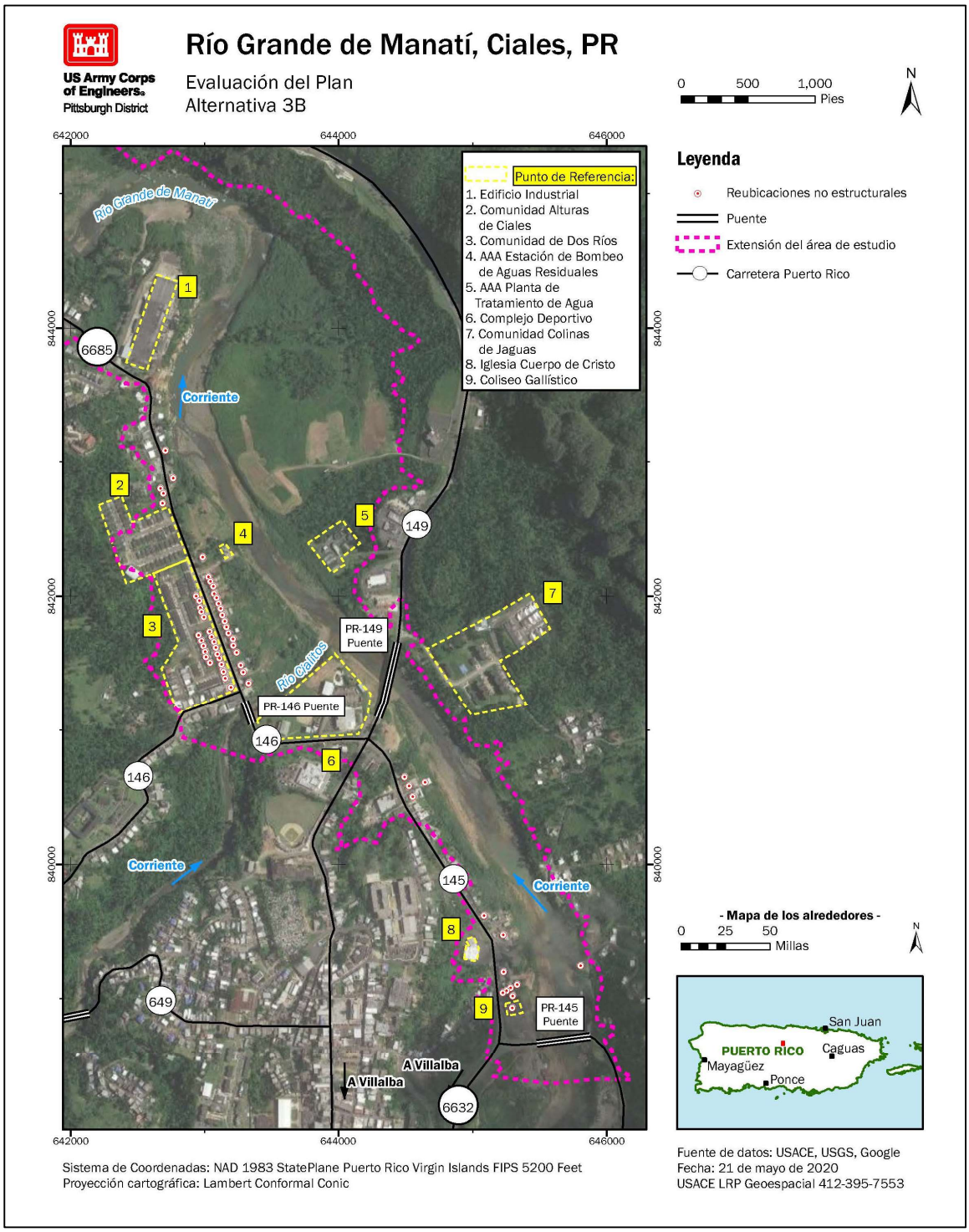

Fig. ES-1. Vista del plan recomendado.

Tabla ES-1. Estado actual de cumplimiento con respecto a las leyes y reglamentos ambientales pertinentes. C = Cumplido.

Referencia	Leyes/reglamentos ambientales	Cumplimiento
42 U.S.C. 1996	Acto de Libertad Religioso Indio Americano de 1978	C
16 U.S.C. 668-668d	Ley de Protección del Águila Calva y Dorada	C
42 U.S.C. 7401	Ley de Aire Limpio de 1970, enmendada	C
33 U.S.C. 1251, et. seq.	Ley de Agua Limpia de 1977, enmendada	C*
16 U.S.C. §1451 et. seq.	Ley de Ordenación de las Zonas Costeras de 1972	C
42 U.S.C. 9601	Ley de Respuesta Ambiental Comprensiva, Compensación y Responsabilidad (CERCLA) de 1980	C*
7 U.S.C. 4201 et. seq.	Acto Normativo de Protección de Tierras Agrícolas	C
16 U.S.C. 1531, et. seq.	Ley Federal de Especies en Peligro de Extinción, enmendada	C*
16 U.S.C. 460(l)(12), et. seq.	Ley de Recreación en Proyectos de Agua Federales	C
16 U.S.C. 661	Ley de Coordinación de Pesca y Vida Silvestre, enmendada	C*
16 U.S.C. 1801, et. seq.	Ley para la Conservación y Administración de la Pesca Magnuson-Stevens	C
16 U.S.C. §1361 et. seq.	Ley de Protección de Mamíferos Marinos de 1972	C
16 U.S.C. §§715 et. seq.	Ley de Conservación de las Aves Migratorias	C*
16 U.S.C. 703, et. seq.	Ley del Tratado de Aves Migratorias de 1918, Enmendada	C*
42 U.S.C. 4321 et.seq.	Ley de Política Ambiental Nacional de 1969	C*
54 U.S.C. 300101	Ley para la Conservación Histórica, enmendada	C*
33 U.S.C. 401 et. seq.	Sección 10 de los Ríos y Puertos Acta de 1899	C
42 U.S.C. 4601 et. seq.	Ley de Política de Uniforme de Asistencia para la Reubicación y Adquisición de Propiedades Inmuebles de 1970	C*
16 U.S.C. 1271 et. seq.	Ley Nacional de Ríos Silvestres y Escénicos	C
E.O. 12898	Medidas Federales para Abordar la Justicia Ambiental en Poblaciones Minoritarias y en Poblaciones de bajos Ingresos	C
E.O. 11988	Manejo de la Llanura Inundable	C
E.O. 13112	Especies Invasivas	C
E.O. 13186	Aves Migratorias	C*
E.O. 13045	Protección ante los Riesgos de Salud Ambiental y Riesgos de Seguridad para los Niños	C
E.O. 11990	Protección de los Humedales	C*

* El pleno cumplimiento se logrará cuando se firmen la Conclusión de no Impacto Significativo y el 404(b)(1) y en tanto las siguientes acciones de cumplimiento ambiental se habrán completado.

Para cumplir con la Ley de Especies en Peligro de Extinción, las directrices del USFWS para la conservación de la boa se incluirán en los planes y especificaciones. Para cumplir con la Ley del Tratado sobre las Aves Migratorias y la Ley de Conservación de las Aves Migratorias, se incluirán

en los planes y especificaciones las medidas de conservación estándar del USFWS en todo el país. Para cumplir con la Ley de Agua Limpia y el E.O. 11990, se llevará a cabo una delineación de los humedales durante la ingeniería y el diseño del proyecto. Si es aplicable, el análisis 404(b)(1) se actualizará durante la ingeniería y el diseño del proyecto, y se obtendrá la Certificación de Calidad del Agua de la Sección 401. Se obtendrá un permiso de la Sección 402 del NPDES durante la ingeniería y el diseño del proyecto, si es necesario. Para cumplir con la Sección 106 de la Ley de Preservación Histórica Nacional, se ha desarrollado un Acuerdo Programático entre el USACE y la SHPO. La consulta con la SHPO continuará durante la ingeniería y el diseño del proyecto.

6 Recomendación Preliminar

El equipo de estudio recomienda preliminarmente que se adelante la reubicación no estructural de 59 estructuras dentro de la llanura inundable de 0.04 AEP como el plan recomendado. La siguiente acción probable será que el plan recomendado se esboce en un Informe del Jefe (Chief's Report).

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Note: Asterisks in the table of contents and report sub-headings denote sections required for NEPA compliance.

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1 PURPOSE AND NEED *

1.1 Introduction

The purpose of this feasibility study is to assess flood risk and recommend federal actions to reduce future damages caused by flooding along the Rio Grande de Manati within the Municipality of Ciales, Puerto Rico. United States Geological Survey data indicate the Rio Grande de Manati has reached flood stage 35 times in the past 50 years. Flood damages have ranged from frequent nuisance flooding to severe and widespread impacts like those sustained during Hurricane Maria in 2017.

Flooding along the Rio Grande de Manati has resulted in damages to privately owned homes, transportation, public infrastructure (i.e., wastewater treatment facilities), and commercial and industrial facilities. This study developed alternatives to address the ongoing flood risk in Ciales and recommends a federal action that provides the greatest net economic benefit to the nation.

1.1.1 Study Authority

The authority for the Rio Grande de Manati (Ciales), Puerto Rico Feasibility Study is Section 204 of the River and Harbor and Flood Control Acts of 1970 (PL 91-611), which states:

> "The Secretary of the Army, acting through the Chief of Engineers, is authorized to cooperate with the Commonwealth of Puerto Rico, political subdivisions thereof, and appropriate agencies and instrumentalities thereof, in the preparation of plans for the development, utilization, and conservation of water and related land resources of drainage basins and coastal areas in the Commonwealth of Puerto Rico, and to submit to Congress reports and recommendations with respect to appropriate participation by the Department of the Army in carrying out such plans…"
>
> "The Secretary of the Army, acting through the Chief of Engineers, shall consider plans to meet the needs of the Commonwealth for protection against floods, wise use of flood plain lands, improvement of navigation facilities, regional water supply, and waste management systems, outdoor recreation facilities, the enhancement and control of water quality, enhancement and conservation of fish and wildlife, beach erosion control, and other measures for environmental enhancement."

Funding for this study was appropriated in the Supplemental Appropriations of the Bipartisan Budget Act of 2018 (Public Law 115-123), dated 9 February 2018, which funded initiation and/or completion of previously authorized flood and storm damage reduction studies within states and territories impacted by Hurricanes Harvey, Irma, and Maria, including Puerto Rico. The Pittsburgh

District is conducting this study for the Jacksonville District. The total authorized study cost is $1.2M and the authorized schedule is 24 months.

This feasibility study conforms to US Army Corps of Engineers (USACE) Policy Guidance on Implementation of Supplemental Appropriations in the Bipartisan Budget Act of 2018, dated 9 August 2018. This study also follows guidance provided in Planning Bulletin 2018-01(S) Feasibility Study Milestones Supplemental Guidance, dated 20 June 2019, which supplements Planning Bulletin 2018-01 and applies to all feasibility studies resulting in a Chief's or Director's Report recommending project authorization.

1.1.2 Study Sponsor

The non-federal sponsor for the Rio Grande de Manati (Ciales), Puerto Rico Feasibility Study is the Puerto Rico Department of Natural and Environmental Resources. A Feasibility Cost Sharing Agreement was executed by USACE Jacksonville District on 09 October 2018.

1.1.3 Study Stakeholders

Other local, commonwealth, and federal entities cooperating with USACE on this study include:

Municipality of Ciales: Municipal representatives worked closely with USACE and the non-federal sponsor to define the study scope and objectives, providing requested data on damages caused by Hurricane Maria, and assisted in facilitating site visits and public outreach efforts.

Puerto Rico Housing Department: The Puerto Rico Housing Department is coordinating with USACE and local and commonwealth stakeholders regarding their Repair, Reconstruction, or Relocation (R3) program. The R3 program is a voluntary program that supports repair, reconstruction, or relocation of eligible single-family homes impacted by hurricanes Irma and/or Maria. The Puerto Rico Housing Department has worked with local and commonwealth representatives to maximize participation under this program, including holding two outreach efforts within Ciales. USACE will continue working with the Puerto Rico Housing Department to identify—once this information is finalized—residents within the study area who will be participating in the R3 program to ensure this information is appropriately incorporated into final analyses. It is anticipated that the majority of private residents within the study area will either not participate or not be eligible to participate in this program.

Puerto Rico Department of Transportation (PRDOT): PRDOT provided data and engineering information for impacted transportation infrastructure within the study area.

Central Office for Recovery, Reconstruction, and Resilience (COR3): COR3 representatives attended initial site visits and remained engaged throughout the study to provide information on

how the current study and any subsequent project would fit within the context of ongoing reconstruction and recovery efforts within the Municipality of Ciales.

Puerto Rico Congressional Representatives: Gabriel Rodriguez Aguilo, the Representative for District 13 and Majority Leader of the Puerto Rico House of Representatives, has been engaged with USACE and other agency stakeholders throughout the study. Mr. Rodriguez Aguilo was instrumental in helping to define the study scope and facilitating and coordinating all public outreach efforts.

Puerto Rico Resident Commissioner: Representative Jenniffer Gonzalez-Colon's office has been engaged throughout the project, attending site visits and participating in discussions with local, commonwealth, and other federal stakeholders regarding the scope of the current study.

Federal Emergency Management Agency (FEMA): Prior to the initiation of the current feasibility study, FEMA initiated an effort to relocate 110 at-risk public housing units from within the communities of Dos Rios and Alturas de Ciales. The FEMA effort does not include relocation of any private homes or businesses within the study area. FEMA and partnering agencies were engaged with USACE and other agency stakeholders to provide information on how the current study and any subsequent project would fit within the context of this relocation effort.

1.2 Study Area & Scope

1.2.1 Geographic Setting

The Municipality of Ciales is located on the northern slopes of the Puerto Rican Central Mountain Range, approximately 25 miles southwest of San Juan and has a population of approximately 19,000 (Fig. 1-1). The study area is generally centered on the community of Dos Rios, which sits at the confluence of the Rio Grande de Manati and Rio Cialitos.

1.2.2 History of the Investigation

The Municipality contracted development of plans and specifications for a flood protection works (henceforth referred to as the 'original flood protection works') project designed to manage recurring flood risk within the communities of Dos Rios and Alturas de Ciales. Plans and specifications for the original flood protection works project were completed in 2012 and included a combined levee and floodwall system, an internal storm water management and drainage system (i.e., storm sewers and retention pond), and river widening (see Appendix A, Attachment 1 for an overview of the existing plan). The original flood protection works plan was never implemented due to limited local funding available for construction and operation of the project.

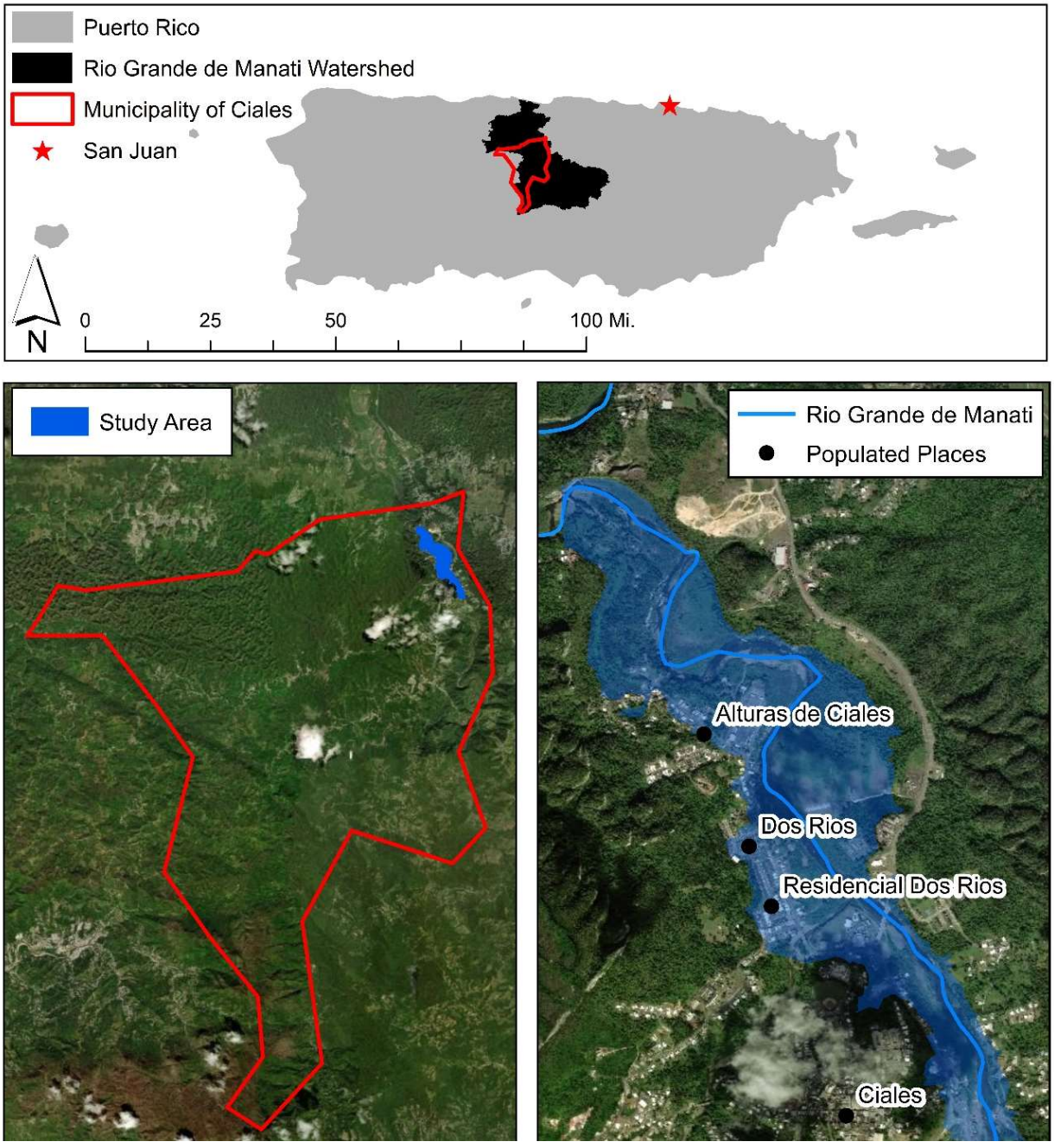

Fig. 1-1. Location of the Rio Grande de Manati watershed, Municipality of Ciales, and study area within Puerto Rico. The Rio Grande de Manati flows northwest through the study area.

1.2.3 Study Scope

The study scope was initially limited to the validation of the original flood protection works plan. During an initial site visit conducted on 26 October 2018, members of the project delivery team

(PDT), with input from the non-federal sponsor and local officials, identified flood-related damages and ongoing flood risk that extend beyond the scope of the original flood protection works. Risks include inundation of structures and roadways, as well as extensive bank failure induced by flooding during Hurricane Maria that is threatening structures and transportation infrastructure along areas of the stream bank. Expansion of the study scope beyond that of the original flood protection works—as discussed with the local sponsor and stakeholders—was agreed upon with the vertical team.

This report analyzes a series of alternatives designed to reduce the on-going flood risks, including a no action plan, as well as various combinations of structural and non-structural measures including an assessment of the original Flood Protection Works plan. Plans were evaluated and compared based on a set of criteria that included effectiveness, cost, and environmental impacts, among others, resulting in the selection of the recommended plan.

1.2.4 Study Area

In order to capture the expanded study scope, the study area was defined as the flood-prone area [i.e., within the 0.002 annual exceedance probability (AEP) floodplain, or area inundated during the 500-year flood] extending approximately 12,500 linear feet along the Rio Grande de Manati from the site of the PR-145 Bridge downstream to the PR-6685 Bridge (Fig. 1-1).

The study area contains the communities of Pueblo Ciales, Dos Rios, and Alturas de Ciales. There are a total of 218 structures within the study area. Fifty-nine (59) structures comprise 110 public housing units that are in the process of being relocated by FEMA and, thus, are not considered further in this feasibility study. A total of 159 structures, including private residences and commercial (retail stores, restaurants, and churches), industrial, and public (wastewater treatment plant and associated pump station, recreational facilities) facilities were include in this feasibility study. Many of the structures analyzed as part of this feasibility study have experienced recurring and severe flooding. Numerous homes within the communities of Dos Rios and Alturas de Ciales are in the 0.1 AEP floodplain and were almost completely inundated during Hurricane Maria. Although there are commercial properties within the study area, most local businesses are located within portions of Pueblo Ciales that are outside of the study area.

The study area also contains roads and bridges that represent critical access and egress routes for people living within and outside of the study area. There are three bridges crossing the Rio Grande de Manati within the study area. The PR-145 Bridge at the most upstream extent of the study area was washed away during Hurricane Maria. A temporary bridge was constructed and is now operational. The PR-6685 Bridge at the downstream extent of the study area, which is listed on the National Register of Historic Places, was also damaged during and temporarily closed following Hurricane Maria. Puerto Rico Highway 149 represents a secondary highway across the island of Puerto Rico. The PR-149 Bridge, which was damaged but remained open following Hurricane Maria, has an average daily traffic count of approximately 10,000. Several major

roadways also become inundated during large flood events, including PR-6685 and PR-145. Inundation of roads results in short-term isolation of residents within the study area during large flood events. Damage to one or more of the bridges within the study area can result in transportation detours and delays both during and after flood events. Loss of all three bridges would result in long-term isolation of residents within the study area. All transportation detours or delays increase life and safety risk to residents that need access to critical services or facilities—the nearest of which are generally located approximately 8 miles north in Manati.

1.3 Problems and Opportunities

1.3.1 Problems

An initial site visit on 26 October 2018 attended by members of the PDT and local, commonwealth, and federal stakeholders resulted in identification of the following problems:

1. Elevated flood risk for structures within the floodplain. There are 159 structures within the study area (i.e., 0.002 AEP floodplain; Fig. 1-2), including private homes, businesses, industrial sites, and public facilities (i.e., sewage treatment plant).

2. Inundation of transportation infrastructure. Several major access and evacuation routes are located within the 0.01- and 0.002-percent AEP floodplains (Fig. 1-2). Inundation of and damage to roadways and bridges increases life safety risk both during (evacuation) and after (recovery) flood events.

3. Extensive flood-induced bank failure. Hurricane Maria resulted in extensive flood-induced bank failure that is currently placing key pieces of transportation infrastructure at elevated risk of failure (i.e., loss of use due to damage or safety) within two zones throughout the study area (Fig. 1-2). Bank failure in zone 1 is threatening the PR-149 Bridge and PR-145, while failure in zone 2 is threatening PR-6685. Transportation infrastructure at elevated risk of failure as a result of flood-induced bank failure are integral to key access and evacuation routes for municipal residents both within and outside of the study area.

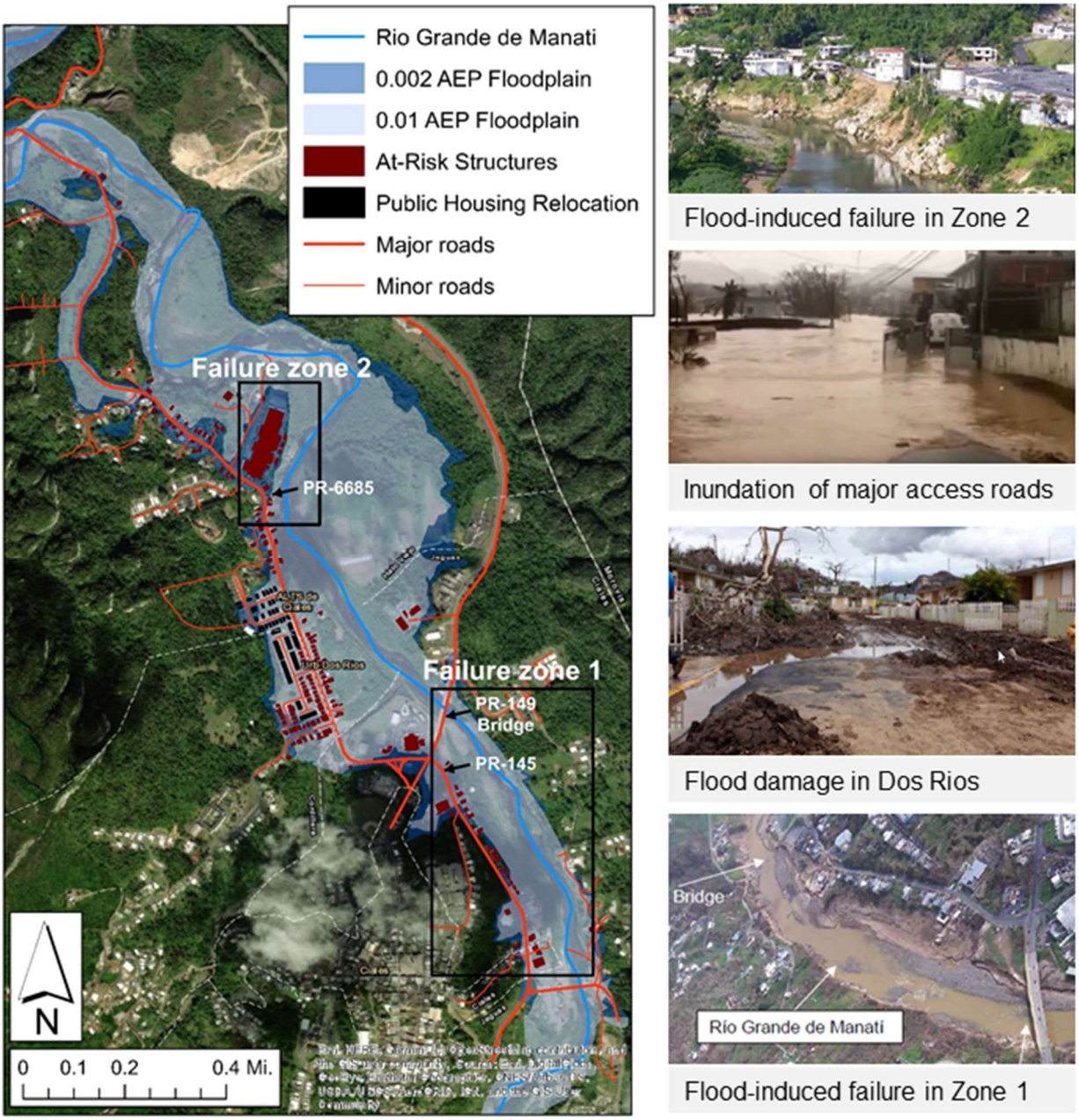

Fig. 1-2. Map depicting at-risk structures within the 0.01 AEP (i.e., 100-year) and 0.002 AEP (i.e., 500-year) floodplains, major and minor roads, and areas where Hurricane Maria resulted in flood-induced bank failure. Images of flood-induced bank failure in two critical zones are also shown.

1.3.2 Opportunities

Successful completion of this study and identification of a federally-justified project would enable USACE to realize the following identified opportunities (i.e., chance to create a future condition that is desirable through project implementation):

- Protection of public infrastructure, homes, and businesses from future flood damage. Reducing flood risk through implementation of structural and/or non-structural measures would reduce recurring flood damages to public infrastructure (e.g., roads and bridges) and works (e.g., wastewater treatment plant), homes, and businesses located within the floodplain and floodway throughout the study area.

- Protection of public infrastructure, homes, and businesses from flood induced bank failure. Reducing the potential for flood induced bank failure would offer homes, businesses, industry, and public transportation infrastructure protection from damage during future flood events.

- Continuity of transportation during and following flood events. Effectively reducing the extent and/or duration of inundation and protecting transportation infrastructure from flood-induced bank failure would help improve access to population centers and associated critical facilities and evacuation from impacted areas during and after future flood events. Such measures could also reduce long-term transportation delays. This is evidenced by the fact that floodwaters associated with Hurricane Maria led to failure of the PR-145 Bridge—the replacement for which is still under construction, impacting transportation 2 years later.

- Improved life safety within the study area. Reducing transportation stoppages and delays will improve life safety by helping to secure sustained: 1- evacuation routes for at-risk families; 2- access to impacted areas following the recession of flood waters; and 3- access to population centers and associated critical facilities both during and following future flood events. Reducing risks associated with inundation would also improve life safety for residents currently located within the floodplain and floodway.

- Restoration of natural floodplain areas along the Rio Grande de Manati. Implementation of certain flood risk management measures can result in removal of structures from the floodplain and/or result in greater floodplain connectivity and associated restoration of natural floodplain habitats.

- Realization of recreational & environmental benefits in areas that will temporarily flood. Potential removal of structures from the floodplain and restoring natural floodplain habitat through various flood risk reduction measures could result in improved recreational opportunities (e.g., wildlife viewing, hiking, improved stream access).

- Improved community awareness of flood risk. Community outreach and engagement throughout the study and resulting project could improve community awareness of flood risk, resulting in greater long-term community resiliency.

1.4 Objectives and Constraints

1.4.1 Objectives

1.4.1.1 Federal Planning Objective

The federal objective is to contribute to the national economic development (NED) consistent with protecting the nation's environmental resources, pursuant to national environmental statutes, applicable executive orders, and other federal planning requirements. Contributions to NED are reflected monetarily as increases in the net value of the national output of goods and services and are the result of direct net economic benefits that accrue in the study and the rest of the nation following project implementation.

1.4.1.2 Federal Environmental Objective

USACE strives to balance the environmental and development needs of the nation in compliance with the National Environmental Policy Act (NEPA) and other authorities provided by Congress and the Executive Branch. Public participation is encouraged early in the study to help define problems and environmental concerns, as well as to identify environmental resources that would likely be favorably or adversely affected by a project alternative. Alternative plans are formulated to avoid adverse impacts to the fullest extent possible. Significant adverse impacts that cannot be avoided are mitigated as required by Section 906(d) of WRDA 1986.

1.4.1.3 Study Objectives

The following study objectives have been developed to provide a means of determining whether project alternatives are capable of addressing identified problems while simultaneously maximizing identified opportunities:

- Objective 1: Reduce risks to life safety associated with inundation of structures, as well as transportation routes required for evacuation and post-flood recovery within Dos Rios, Ciales Pueblo, and Alturas de Ciales over the next 50 years.
- Objective 2: Reduce risk of flood damage to structures and public infrastructure within the communities of Dos Rios, Ciales Pueblo, and Alturas de Ciales over the next 50 years.

1.4.2 Constraints

A constraint is a restriction that limits the extent of the planning process. Successful identification of study constraints helps to avoid undesirable outcomes. This study must adhere to general planning constraints that affect all USACE studies, including restrictions established by USACE policy and legal authority. No study-specific constraints were identified.

1.4.3 Planning Considerations

There are several other local considerations that need to be taken into account during the planning process. These additional planning considerations include:

- Endangered species: The Puerto Rican boa is an endangered species potentially occurring within the study area. Alternatives should seek to avoid impacts to this species.

- Cultural resources: There are previously identified cultural resources within the study area. Many of the structures within the study area were also constructed over 50 years ago, making them eligible for consideration as historic properties.

- Local site conditions: Local geology (i.e., steep, mountains with limited floodplain area) and extensive development limit capacity to store water within the floodplain.

2 EXISITING AND FUTURE WITHOUT PROJECT CONDITIONS

This chapter describes the relevant environmental resources and socioeconomic conditions that may affect or be affected by the project alternatives if implemented. The future without project (FWOP) condition reflects the expected condition in absence of federal action. The information provided in this chapter serves as the baseline for alternative evaluation.

2.1 Planning Horizon

The planning horizon encompasses the planning study period, project implementation, period of economic analysis, and the effective life of the project. The planning study period for the current feasibility study is two years and started on October 9, 2018 (Fig. 2-1). Project implementation assumes an unconstrained timeline for project authorization, design, and construction and is anticipated to be three years (Fig. 2-1). The period of economic analysis represents the time frame used when forecasting and quantifying benefits associated with the future with- and without-project conditions. The period of economic analysis for flood risk management projects is 50 years. The project may last longer (i.e., project life) than the period of economic analysis. The assumed project life for flood risk management projects is 100 years (Fig. 2-1).

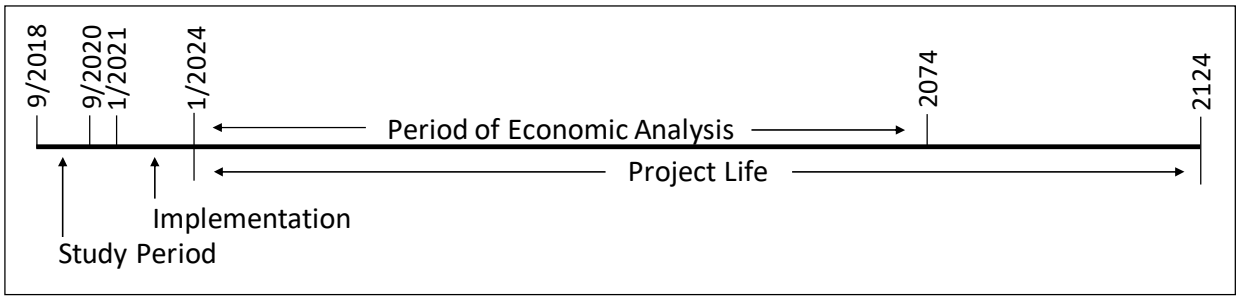

Fig. 2-1. Planning horizon for the Rio Grande de Manati Feasibility Study.

2.2 Existing Conditions *

2.2.1 General Setting

The Municipality of Ciales is located on the northern slopes of the Puerto Rican Central Mountain Range and is surrounded by karst geology. The study area is located at the confluence of the Rio Grande de Manati and Rio Cialitos. The Rio Grande de Manati—the source of flooding within the study area—flows through the study area in a northwesterly direction and joins the North Atlantic Ocean in Barceloneta, approximately 15 miles north of Ciales. Communities in the study area have undergone extensive development, which combined with the steep, mountainous topography limits the amount of natural floodplain. See the Phase I Environmental Site Assessment (Appendix B) for more detailed information on regional geology and topography.

The study area has sustained recurring damages from flood events, with Hurricane Maria in 2017 resulting in the most recent major flood event. Flood inundation along the Rio Grande de Manati has caused extensive failure of stream banks that is currently threatening transportation infrastructure associated with critical access and evacuation routes for the Municipality of Ciales, as well as damages to residential housing, businesses and public infrastructure.

2.2.2 Climate & Weather

Climate in Ciales is tropical. Daily temperatures generally range from 68-87 °F. Average annual precipitation is approximately 70 inches; however, annual rainfall in the headwaters of the Rio Grande de Manati watershed exceeds 90 inches (Fig. 2-2). Rainfall throughout Puerto Rico varies strongly by season, with the wet season spanning from April through November and the dry season from December through March (National Weather Service Forecast Office, (https://w2.weather.gov/climate/local_data.php?wfo=sju).

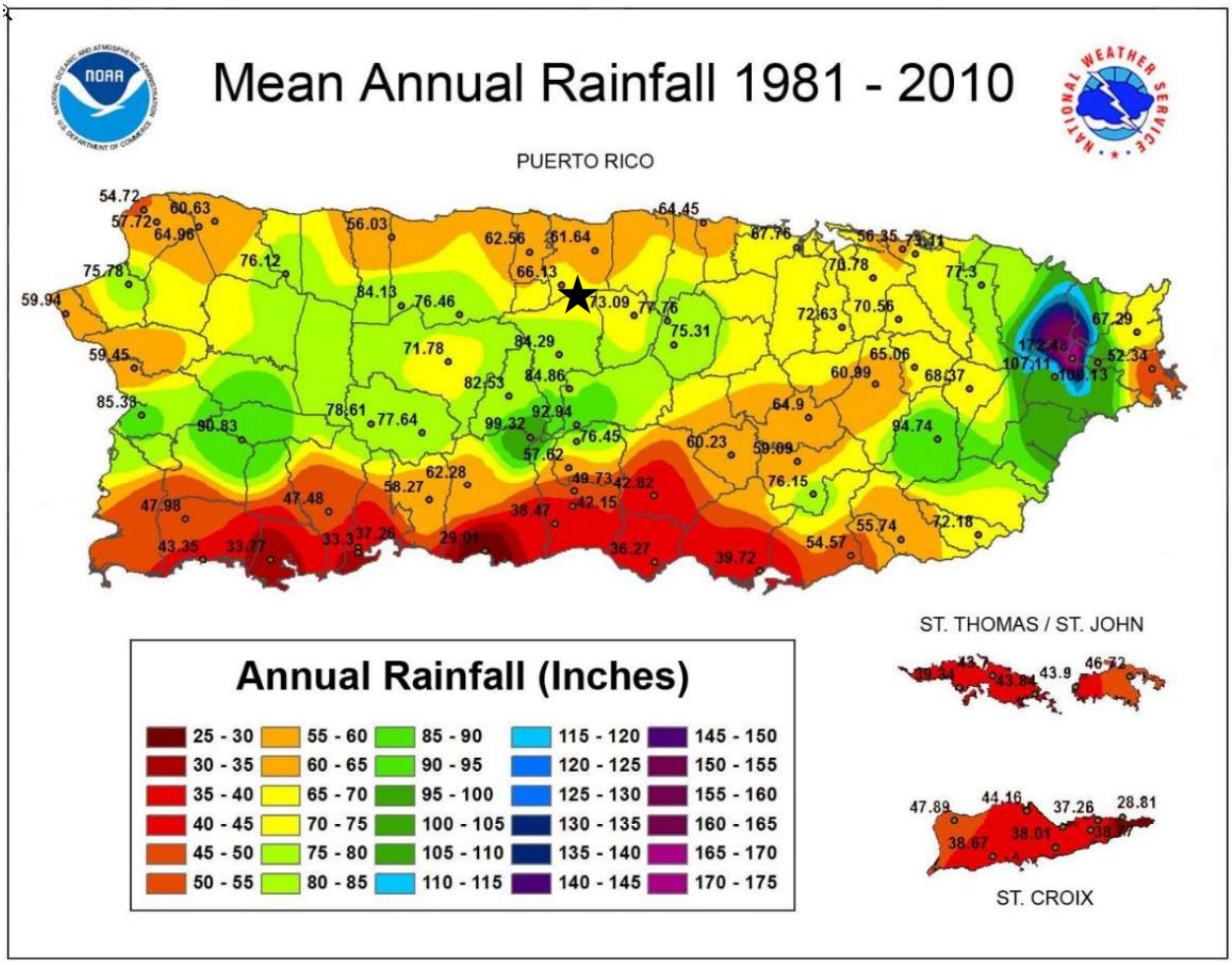

Fig. 2-2. Mean annual rainfall for Puerto Rico and the Virgin Islands. The black star indicates the approximate location of the study area.

Puerto Rico also experiences the Atlantic Hurricane season, which runs from June 1st to November 30th. On average, one quarter of the island's annual precipitation is contributed by tropical cyclones (Rodgers et al. 2001). However, total rainfall during large hurricanes has been recorded in excess of 40 inches in certain locations. Within a 48 hour period during Hurricane Maria, an estimated total of 12 inches of rain fell on the study area, while estimated total rainfall was in excess of 20 inches in parts of the Rio Grande de Manati watershed (Fig. 2-3).

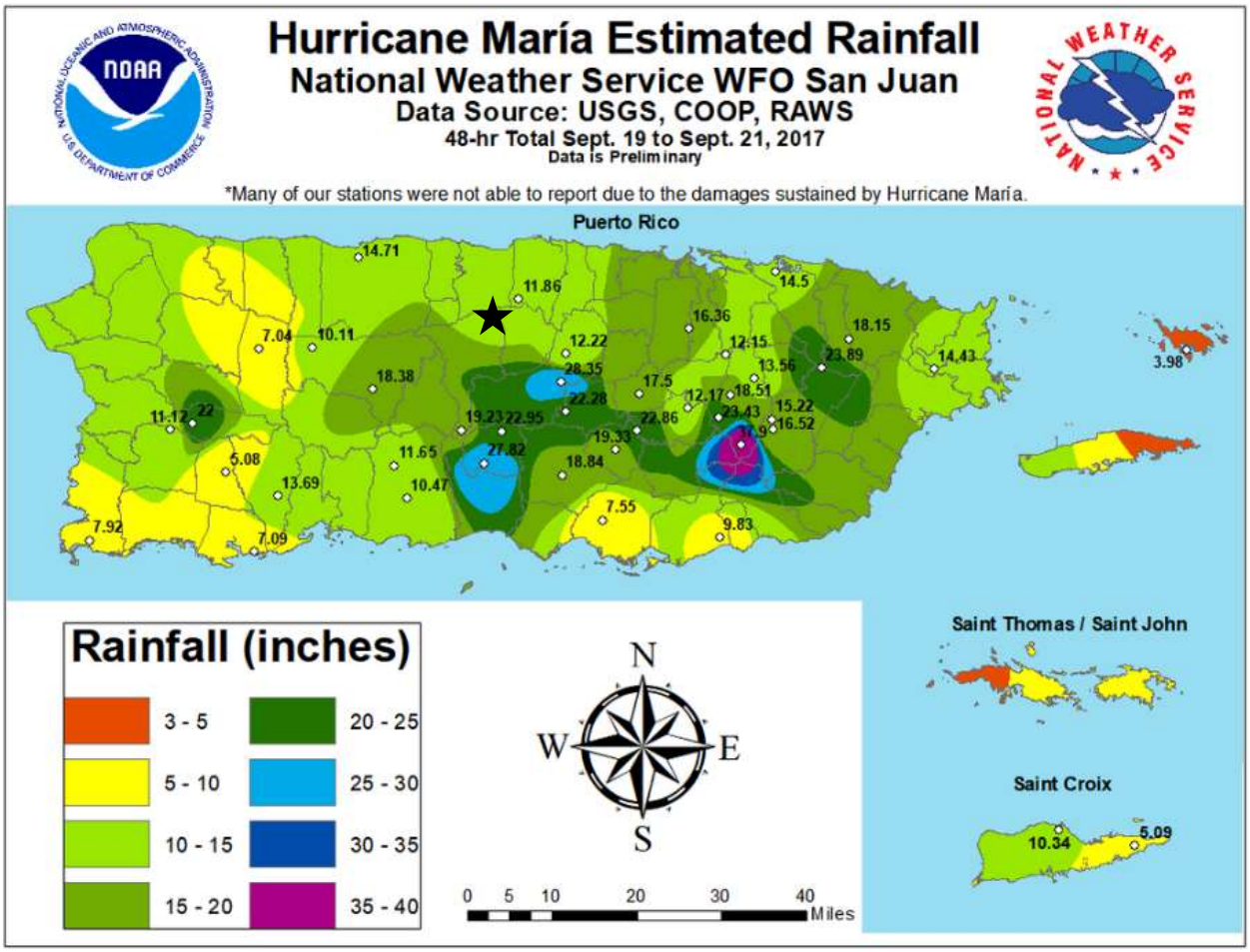

Fig. 2-3. Estimated rainfall for Puerto Rico and the Virgin Islands. The black star indicates the approximate location of the study area.

2.2.3 Flood Risk

2.2.3.1 Hydrologic Characteristics and Tidal Influences

The study area is located at the confluence of the Rio Grande de Manati and Rio Cialitos (Fig. 2-4). The Rio Grande de Manati—the source of flooding within the study area—flows through the study area in a northwesterly direction and joins the North Atlantic Ocean in Barceloneta, approximately 15 miles north of Ciales. Hydrology within the study area is a function of rainfall runoff and groundwater processes throughout the watershed. An assessment of potential tidal influences on inundation within the study area was conducted by combining the current low, intermediate, and high high-tide scenarios (as determined by the Sea Level Change calculator), the NOAA 0.01 AEP estimated extreme water level, and mean higher high water to estimate possible downstream boundary conditions. These boundary conditions were then input into the

hydraulic model, which indicated sea level has no influence on water surface elevations within the study area (see Appendix A for a detailed description of this analysis).

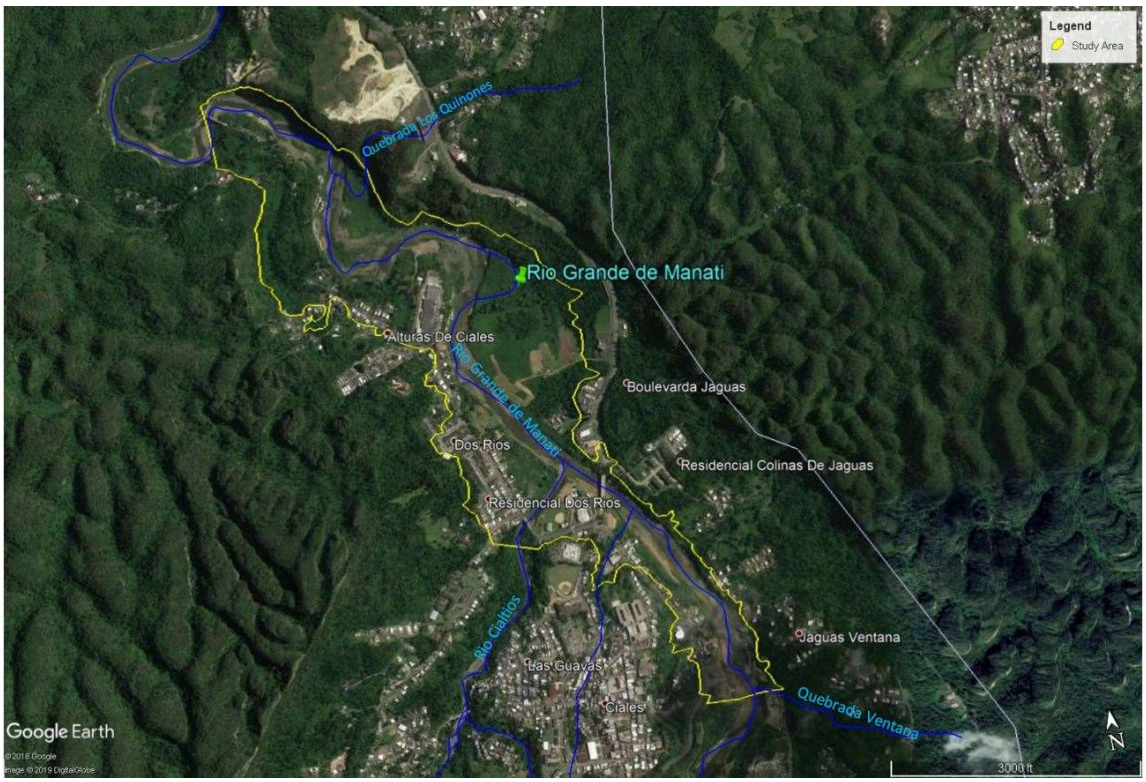

Fig. 2-4. Rio Grande de Manati and tributaries in the study area.

2.2.3.2 Flood Damages

The Municipality of Ciales, Puerto Rico has a long history of flooding. A United States Geological Survey (USGS) gauge (# 50035000) located just upstream of the study area indicates the Rio Grande de Manati has exceeded flood stage 35 times within the past 50 years [10 major floods (stage height greater than 16 feet), 15 moderate floods (stage height greater than 12 feet), and 10 minor floods (stage height greater than 10 feet)]. Flooding caused by Hurricane Maria (estimated stage height = 43.36 feet, estimated discharge = 284,000 cfs) represented the largest event within this time period and had a duration of 5 to 6 days. Based on the peak flow frequency analysis from the most recent FEMA Flood Insurance Study, the Hurricane Maria flood event was estimated to have an AEP between 0.005 (193,500 cfs) and 0.002 (364,800 cfs).

A total of 159 structures including residences, commercial (retail stores, restaurants, and churches) and industrial facilities, and public facilities (wastewater treatment plant and associated pump station, recreational facilities) exist within the study area (Table 2-1). Many of these structures have experienced recurring and severe flooding. Flooding of the waste water treatment plant results in discharges of raw sewage to the Rio Grande de Manati. The discharge

of untreated wastewater impacts the health of communities within the study area, as well as the health of all communities downstream of the study area.

Table 2-1. Inventory of structures within the study area.

Structure Type	**Number**
Residential	135
Commercial	16
Public	5
Industrial/Utility	3
Total	*159*

The federal government is in the process of relocating 110 public housing units from the communities of Dos Rios and Alturas de Ciales, which are not included in our structure inventory.

Historic flooding has also resulted in the inundation of several major roads located within the floodplain (i.e., PR-145, PR-146, PR-149 and PR-6685) and damage to bridges (PR-145, PR-149, and PR-6685) that connect the study area to major population centers and associated critical facilities (i.e., hospitals).

2.2.3.3 Life Safety Risk

The majority of residents living within the Municipality of Ciales live in the mountains outside of the floodplain—many of whom become isolated due to inundation of roads. These residents may have the greatest life safety risk within the study area associated with individual medical emergencies and lack of access to city centers and the associated critical facilities (e.g., medical facilities and police station). Flooding in this area is generally associated with large precipitation and/or hurricane events that are forecast well in advance of subsequent flooding, providing ample warning time for residents to prepare for potential evacuation. For example, evacuation orders were issued and evacuation shelters were opened across Puerto Rico on the afternoon of 18 September 2017, nearly 48 hours ahead of landfall for Hurricane Maria. The Rio Grande de Manati also has a relatively slow rate of rise, providing additional evacuation time for residents that may not receive or heed initial warnings. It took approximately 5 hours for the Rio Grande de Manati to reach flood stage once it started to consistently rise and an additional 5 hours to reach peak stage height during Hurricane Maria. The duration of flooding is also closely tied to the length of precipitation. Therefore, residents who lose access during flooding events regain access relatively quickly after the storm has passed.

A much smaller proportion of residents live within the floodplain. Residents within the floodplain also receive ample warning to evacuate prior to structures and evacuation routes being inundated due to the timing and notification of major hurricane-driven flood events. Water velocities are generally not high enough to destroy or wash away structures. Therefore, if residents do not see the forecast or do not receive a warning, a large portion of the population at risk could vertically evacuate to either the second floor or the roof of their structure.

2.2.4 Earth Resources

2.2.4.1 Geology & Topography

Geology of the study area is primarily of the Cretaceous to middle Tertiary age (upper and middle Oligocene and lower Miocene) and Quaternary period (Fig. 2-5). Cretaceous and Tertiary age rocks include stratified limestone and marly limestone containing lenses of calcareous sand and gravel and terrigneous clastics (Berryhill, 1965). The northern end of the study area includes Quaternary period (Holocene-Pleistocene) landslide deposits and unconsolidated alluvium. The alluvium is comprised of unconsolidated silt, sand, gravel, cobbles, and boulders along the stream and stream valley and angular rock debris and rock-slide debris on and at the base of steep slopes and are the most recent geological deposits in the Ciales region (Berryhill, 1965). The San Sebastian Formation (middle-upper Oligocene) is also identified in the northern part of the study area and includes clay, sand, gravel, and sandy limestone, shaley clay, sandstone, and conglomerate. The southern end of the study area includes the intrusive mass (Morovis and Ciales stocks) of plutonic granodiorite and unconsolidated alluvium. A small portion of the southern end of the study area includes the Los Negros Formation composed of basaltic hyaloclastite-breccia with basaltic lava, volcanic sandstone, and siltstone (USGS, 1998).

The topography of Puerto Rico is extremely varied. The interior of the island—of which the study area is part—is generally characterized by very steep slopes and narrow valleys (Kay, 1959).

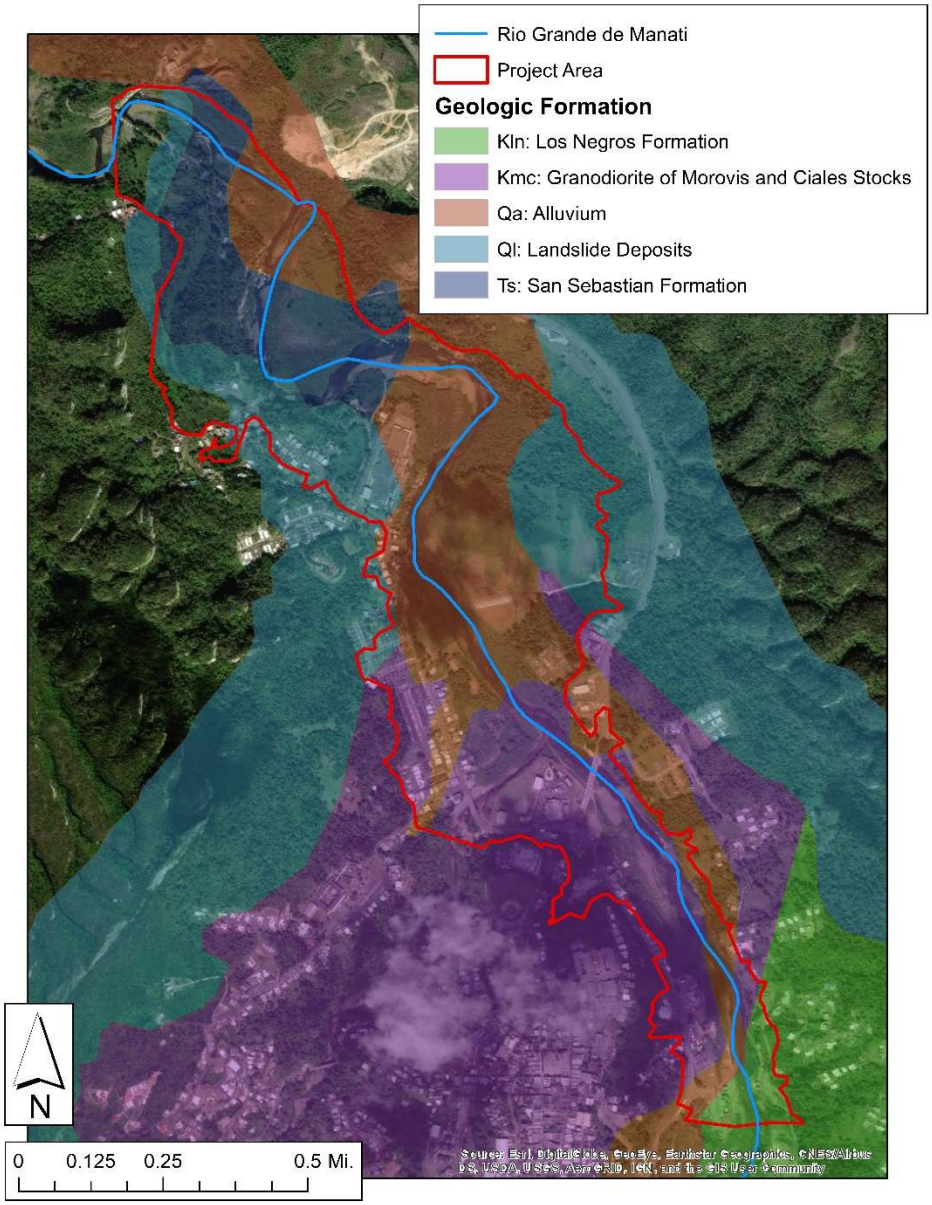

Fig. 2-5. Underlying geology associated with the study area.

2.2.4.2 Soils

Soil borings collected as part of the original flood protection works project indicate a high percentage of sand and clayey silt, particularly at depths up to approximately 15 feet. None of the soil series found in the study area are classified as hydric; however, several soil types [Toa silty clay loam (To), Vivi loam (Vm), Reilly gravelly silt loam (Re), riverwash (Rm), Moca clay (MoC2), Lirios clay loam (LcF2)] have hydric inclusions (USDA, 2019). The study area also contains soils classified as prime farmland soils (Ingenio clay loam (InD), Moca clay (MoC2), Toa silty clay

loam (To), and Vivi loam (Vm)] and farmland of statewide importance (Colinas clay loam). See Fig. 2-6 for location of the referenced soil types within the study area.

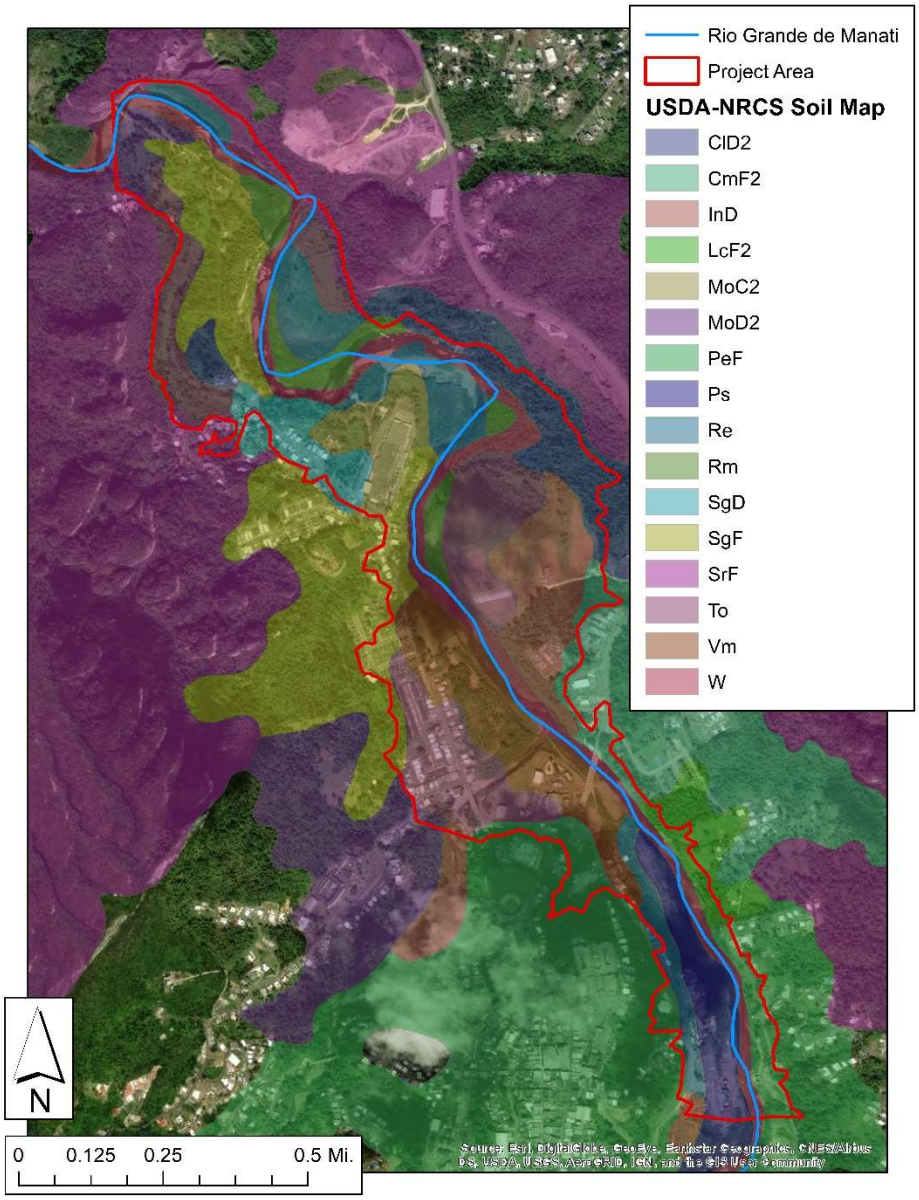

Fig. 2-6. U.S. Department of Agriculture-Natural Resource Conservation Service (USDA-NRCS) soil mapping for the study area. Soil symbols correspond to those presented in the text.

The soil profile (high proportion of sand and clayey silt) indicates elevated potential for erosion and bank failure during large-scale flood events, such as that observed during Hurricane Maria. Hurricane Maria resulted in the lateral/landward loss of up to 115 feet of stream bank in the vicinity of the PR-149 Bridge and PR-145 (Figs. 2-7). Bank failure resulted in steeper banks that are more exposed to and at risk of failure during more frequent flood events.

Fig. 2-7. Google images taken prior to Hurricane Maria (2016, left image) and post-Hurricane Maria (2017, right image) depicting flood-induced bank failure upstream of the PR-149 Bridge.

Similarly, Hurricane Maria resulted in the loss of approximately 35 feet of top of bank adjacent to PR-6685, which is now only 25 feet from the edge of bank (Figs. 2-8).

Fig. 2-8. Google images taken prior to Hurricane Maria (2016, left image) and post-Hurricane Maria (2018, right image) depicting flood-induced bank failure adjacent to PR-6685. Red oval denotes area of 35 lateral feet of bank loss adjacent to PR-6685.

The PR-149 Bridge, PR-145, and PR-6685 are all integral to critical access and evacuation routes for residents of Ciales during and after flood events and their failure would result in increased life and safety risk. Puerto Rico Highway 149, PR-6685, and PR-145 are the only direct routes out of the study area to the towns of Manati (north) and Morovis (east)—the nearest location of certain critical facilities (e.g., hospitals).

2.2.4.3 Air Quality

The Clean Air Act requires the United States Environmental Protection Agency (USEPA) to set national ambient air quality standards for six common air pollutants, known as criteria air pollutants. These pollutants include lead, sulfur dioxide, particulate matter (PM-2.5 and PM-10), ozone, carbon monoxide, and nitrogen dioxide (USEPA, 2019). Areas that persistently exceed the standards are designated as nonattainment areas. Federal actions must not cause or contribute to new violations, worsen existing violations, or delay attainment of national ambient air quality standards.

The study area is located in the Puerto Rico Air Quality Control Region (40 CFR 81.77) and is in attainment for all the national ambient air quality standards. The study area is located within an urban environment and *de minimis* emissions likely occur from vehicle traffic, lawn care equipment, and construction equipment on a regular basis.

2.2.5 Water Resources

2.2.5.1 Water Quality

The Rio Grande de Manati and Rio Cialitos are listed as impaired waters under Section 303(d) of the Clean Water Act. Impaired waters are those that are polluted or degraded and do not meet water quality standards. Portions of both streams are listed as impaired for coliform bacteria, which poses a human health hazard. In 2010, a Total Maximum Daily Load (TMDL)—the maximum amount of a given pollutant that a body of water can receive while still meeting water quality standards—was developed for fecal coliform bacteria in the Rio Grande de Manati (USEPA, 2010). TMDL reports provide a pollution reduction plan with the goal of removing the water body from the impaired waters list. One of the recommendations in the 2010 Rio Grande de Manati TMDL report was to reduce bacterial discharges from urban areas that occur during rainfall and events as a result of pollution sources being located too proximate to drainage areas. The wastewater treatment plant within the study area has been inundated during past flood events, resulting in release of untreated sewage into the Rio Grande de Manati.

The TMDL report also identified increased turbidity as a source of impairment. Turbidity relates to the cloudiness (or clarity) of water. When a stream or river has high turbidity levels, suspended materials like sediments, silts, clays, and organic material cloud the water. Sedimentation in streams and rivers increases when stream banks become destabilized and erosion occurs. Suspended sediments in rivers and streams can negatively impact fish, aquatic invertebrates, and reduce light levels for aquatic vegetation. Suspended materials also provide surfaces where toxic chemicals and bacteria can attach, exacerbating chemical and bacterial impairments.

A recent report also listed portions of both the Rio Grande de Manati and Rio Cialitos as impaired due to total nitrogen, copper, total phosphorus, and turbidity (USEPA, 2018).

2.2.5.2 Riverine Habitat

The Rio Grande de Manati is a perennial river with alternating sequences of shallow riffles composed of cobbles/boulders and deep pools consisting of varying substrate sizes (Fig. 2-9).

Fig. 2-9. Photos of typical riffle (left) and pool (right) habitats within the Rio Grande de Manati.

High erodibility of banks throughout the watershed results in transient fine sediments (Fig. 2-10).

Fig. 2-10. Photo showing fine sediments covering the stream bed.

2.2.5.3 Wetlands

The main stem of the Rio Grande de Manati is classified as an R2UBH (riverine, lower perennial, unconsolidated bottom, permanently flooded) wetland (USFWS, 2018). The U.S. Fish and Wildlife Service's (USFWS) National Wetlands Inventory map does not indicate the presence of any non-riverine wetlands in the study area (see Fig. 2-11). A review of the soil survey data in the study area indicates that although none of the soils found are classified as hydric, some soil types have hydric inclusions (see Section 2.2.4.2 Soils; USDA, 2019). Thus, it is possible that wetlands are

present within the floodplain. One potential wetland area was identified during a site visit adjacent to the Rio Grande de Manati near the existing wastewater treatment facility. Due to funding and schedule limitations, a wetland survey was not possible during the feasibility study. A wetland delineation will be conducted during the Preconstruction Engineering and Design (PED) phase to verify the presence or absence of wetlands within the project footprint.

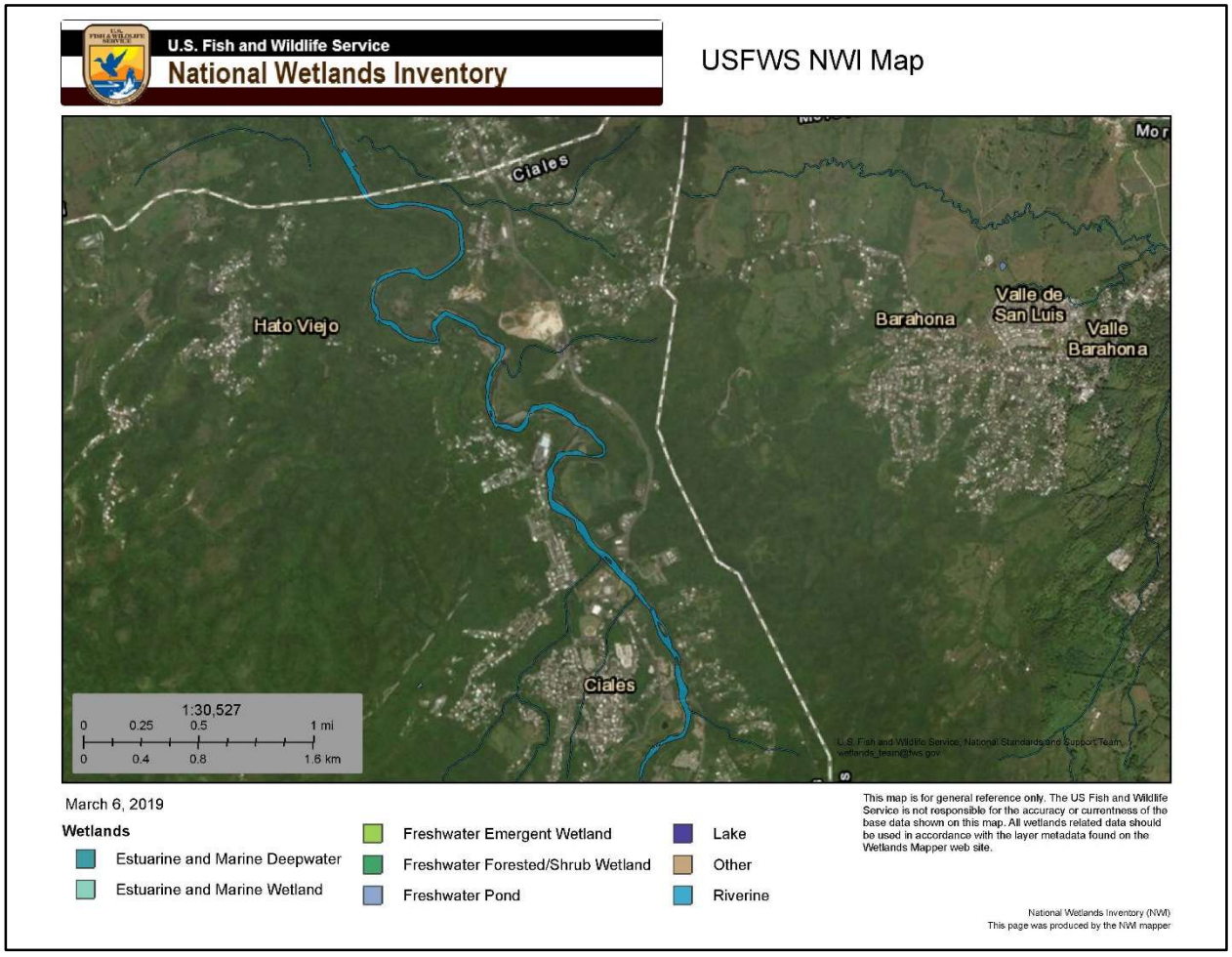

Fig. 2-11. National Wetlands Inventory Map.

2.2.6 Biological Resources

2.2.6.1 Vegetation

Vegetation in the study area is comprised of various grasses, epiphytes, vines, shrubs and trees. A flora inventory was completed in 2004 for the EA completed as part of the original flood protection works plan (see Environmental Appendix, Appendix B). The resulting report indicated that no endangered or rare plant species were found in the project area. No federally listed

threatened or endangered plant species are present in the study area (USFWS Coordination Letter, 24 June 2019).

2.2.6.2 Fish & Wildlife Resources (Other than Threatened & Endangered Species)

The Rio Grande de Manati represents one of the only undammed and unimpeded rivers within the region and is important habitat for a diverse aquatic community. The Rio Grande de Manati supports populations of native fish, shrimp, freshwater crabs, and other invertebrates. Native fish species include American eel, mountain mullet, river goby, and sirajo goby (Kwak, 2007). Some species are amphidromous, where adults spend their lives in the freshwater river, but release eggs which travel to estuarine habitat near the mouth of the river. The eggs metamorphose in salt water and larvae remain in the estuary for a period of time until the juveniles and sub adults then migrate back upstream. The free flowing Rio Grande de Manati provides the habitat that allows these migratory and amphidromous species to flourish.

A wildlife inventory of the area was completed in 2004 as part of the EA completed as part of the original flood protection works plan (see Environmental Appendix, Appendix B). Wildlife found in the study area include reptiles and amphibians (snakes, frogs, toads, anoles, geckos, and iguanas), small mammals, and birds. A USFWS Information for Planning and Consultation System search noted seven species of migratory birds listed as birds of conservation concern under the Migratory Bird Treaty Act that may occur within the study area (Table 2-2).

Table 2-2. Migratory bird species that may occur in the study area.

Common Name	**Scientific Name**	**Breeding period**
Antilean Mango	*Anthracothorax dominicus*	Mar 1 to Aug 20
Cape May Warbler	*Setophaga tigrina*	Breeds elsewhere
Lesser Yellowlegs	*Tringa flavipes*	Breeds elsewhere
Mangrove Cuckoo	*Coccyzus minor*	Apr 20 to Aug 20
Puerto Rican Screech-owl	*Megascops nudipes newtoni*	Apr 1 to Jun 30
Puerto Rican Vireo	*Vireo latimeri*	Apr 8 to Aug 1
White-crowned Pigeon	*Patagioenas leucocephala*	May 1 to Sep 30

2.2.6.3 Threatened & Endangered Species

Based on the results of an initial USFWS Information for Planning and Consultation System search conducted on 21 March 2019 and consultation with the USFWS Caribbean Ecological Service Field Office, one federally listed endangered species may occur in the study area, the Puerto Rican boa (*Chilabothrus (*formerly *Epicrates) inornatus*). An updated USFWS Information for Planning and Consultation System search conducted on 16 June 2020 indicated no changes to the species list.

The Puerto Rican boa (*Chilabothrus inornatus*) belongs to the family Boidae and order Squamata and is classified as endangered under the Endangered Species Act. It is endemic to Puerto Rico

and is the largest snake inhabiting the island, reaching a length of up to seven feet. Its color and pattern markings are highly variable. Adult coloring can range from tan to dark brown, gray or black, while juveniles may be reddish brown in color with many markings. Boas are most frequently found in northern Puerto Rico's karst areas. They have been observed occupying a variety of habitats, ranging from virgin forests to areas with high levels of human disturbance, and have been found at elevations ranging from sea level to approximately 1300 feet.

It is non-venomous and generally prefers to avoid humans, only biting if provoked. The boa is more active at night and may be found during the day hiding (including in machinery) or basking in the sun. Boas consume a variety of birds, lizards, and small mammals, including bats. It has been documented that boas hang near cave openings inhabited by bats and capture them when the bats leave in the evening to feed (USFWS, 2019).

2.2.7 Land Use & Associated Impacts

2.2.7.1 Land Use

The study area encompasses approximately 345 acres of land area. Herbaceous (39%) and forest (30%) represent the dominant land cover classes within the study area (Table 2-3; Fig. 2-12). Much of the herbaceous land area has been historically used for small-scale agricultural operations. Residential and urban development (28%) represents the dominant contemporary land use activity within the study area (Table 2-3; Fig. 2-12). Land use and cover information was derived from the 2001 National Land Cover Database. Assessment of aerial imagery indicate land cover and use have remained relatively stable since 2001.

Table 2-3. Land cover and use within the study area as defined by the 2001 National Land Cover Database (Multi-Resolution Land Characteristics Consortium, 2001).

Land Cover Class	**Area (acres)**	**Area (%)**
Herbaceous	135	39
Forest	104	30
Developed	97	28
Shrub/Scrub	6	2
Open Water	3	1

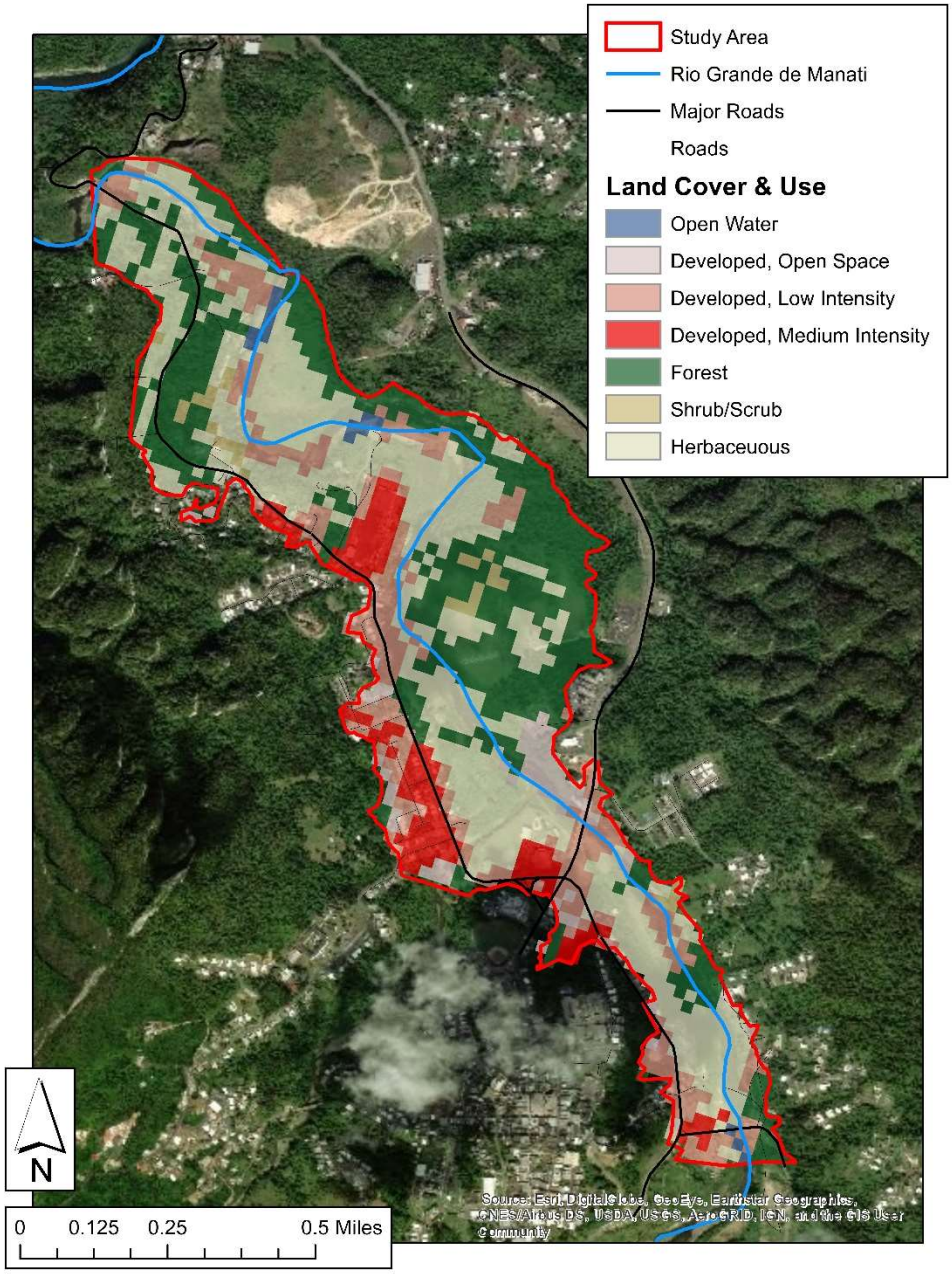

Fig. 2-12. Land cover and use classes within the study area as defined by the 2001 National Land Cover Database.

2.2.7.2 Hazardous, Toxic, & Radioactive Wastes

A Phase I Environmental Site Assessment was conducted to evaluate the potential for hazardous, toxic and radioactive waste (HTRW) within the study area. The Phase I Environmental Site Assessment did not identify any recognized environmental conditions that would indicate contamination within the study area, or areas offsite that could potentially impact the study area (see Environmental Appendix, Appendix B).

No indication of any noxious odors, or lagoons/ponds containing hazardous substances or petroleum products, containers of hazardous substances, or stressed vegetation was noted during the site reconnaissance within or adjacent to the study area. However, a former gasoline station with underground storage tanks was identified adjacent to Rio Cialitos Creek. There was no evidence of petroleum releases from this site and the gasoline station did not have documented releases or violations.

Review of environmental records online and through a database search indicate that there are no known current releases of petroleum/hazardous material within the study area that would potentially affect soil, sediment, groundwater or surface water, nor are there any known properties undergoing remediation due to contamination within the study area. Based on review of environmental records provided, any environmental conditions noted at adjacent and/or nearby properties are unlikely to have affected the study area.

2.2.7.3 Noise

The study area is located within an urban community, which typically consists of high noise levels. Noise levels are measured in units of sound pressure levels called decibels (USDL, 2019). A-weighted sound levels, abbreviated as dBA, describe how the human ear perceives relative loudness. Typical noises in the study area such as those described in Table 2-4, would include commercial and residential vehicle traffic, lawn care, residential activities, other ongoing construction projects, and noise generated from ongoing mining activities occurring in the area. Noise levels above 85 decibels can damage hearing depending upon the length of time that someone is exposed to the noise.

Table 2-4. Typical noise levels (USDL, 2019 and CDC, 2019)

Noise Source/Activity	**Typical Noise Level (dBA)**
Silent Room	20
Urban Residence	50
Normal Conversation	60
City Traffic	85
Lawn Mower	85
Car Horn (at 16 feet)	100
Construction Activities (Operating Heavy Equipment)	120

2.2.8 Socioeconomic Environment

2.2.8.1 Socioeconomic Setting

As of July 2018, the Municipality of Ciales had an estimated population of 15,918 (USCB, Quick Facts). This represents a 15.2% decrease in population size from April 2010 when the population was an estimated 18,782 people. The entire island of Puerto Rico experienced a similar magnitude of decline in population of 14.3%. The percentage of persons over the age of 65 is similar in Ciales (20.5%) as compared to the entire island of Puerto Rico (20.7%). The median household income in the Municipality of Ciales is $14,432 (in 2017 dollars) (USCB, 2013-2017 US Census Bureau American Community Survey). The proportion of persons living below the poverty line is greater in Ciales (58.2%) as compared to the entire island of Puerto Rico (44.4%) (USCB, 2013-2017 US Census Bureau American Community Survey). Poverty thresholds are set by the Office of Management and Budget and are minimum dollar amounts needed to purchase basic needs, such as shelter, food and clothing. The average minority population in the study area is 100% of the total population. The low-income and minority population status within the study area necessitates consideration of environmental justice impacts associated with the recommended federal action (see 5.4.20 E.O. 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations for a full assessment of environmental justice considerations).

2.2.8.2 Aesthetic & Recreation Resources

A public park with various recreational facilities (i.e., baseball field, walking trail) is located adjacent to the Rio Cialitos where the tributary joins the Rio Grande de Manati. The Rio Grande de Manati and Rio Cialitos may be used recreationally for swimming, fishing, and boating. The Manati Bridge at Mata de Platano along PR-6685 is listed on the National Register of Historic Places and represents a popular scenic and tourist destination (NPS, National Register Information System).

2.2.9 Cultural Resources

Cultural resources are prehistoric and historic sites, structures, districts, artifacts, or any other physical evidence of human activity considered important to a culture, subculture, or community for scientific, traditional, religious, or any other reason. Several federal laws and regulations protect these resources, including the National Historic Preservation Act (54 U.S.C. §300101 et. seq.) (NHPA), the Archaeological and Historic Preservation Act of 1974 (54 U.S.C. §§312501-312508), and the Archaeological Resources Protection Act of 1979 (16 U.S.C. §§470aa-470mm). These federal laws, specifically Section 106 of the NHPA (54 U.S.C. §306108), require federal agencies to consider the effects of their actions on cultural resources and historic properties, including districts, sites, buildings, structures, and objects included or eligible for inclusion in the National Register of Historic Places (NRHP).

Section 106 of the NHPA and its implementing regulations (36 CFR 800) requires an assessment of the potential impact of an undertaking on historic properties that are within the proposed

project's area of potential effects (APE). The APE is defined as the geographic area(s) "within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist" (36 CFR 800.16(d)). The APE for impacts of the proposed project includes the areas where ground disturbing activities, including disposal, access, and construction staging would occur. The APE also includes the viewshed of adjacent historic properties that may be affected by the construction of proposed project features thereby causing a change in the historic landscape. For the purposes of this report, the preliminary APE is the study area shown in Fig. 1-1.

The Council on Environmental Quality's regulations implementing NEPA also requires that Federal agencies consider the "unique characteristics of the geographic area such as proximity to historic or cultural resources, and the degree to which the [proposed] action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places" (40 CFR §1508.27(b) (3)). Documentation of historic/cultural resources is important for this project because the area surrounding Ciales provides an environment that is rich in prehistoric and historic human activity and has a high potential for containing intact cultural resources.

2.2.9.1 Previously Identified Cultural Resources

The PR State Historic Preservation Officer (SHPO) noted the lack of systematic surveys for cultural resources in the study area in a letter to USACE on January 22, 2019 (SHPO 12-27-18-01). A review of studies on file at SHPO found no cultural resources surveys conducted within the study area. Despite the lack of systematic surveys on record, ten cultural resources have been identified within or immediately adjacent to the study area. All but one of the recorded cultural resources are archaeological sites. The SHPO site files include significant cultural resources representing prehistoric, Spanish Colonial, and twentieth-century periods in the study area. The previously-recorded cultural resources are provided in Table 2-5. Due to the sensitive nature of these resources, no map is provided.

Table 2-5. Cultural resources recorded within or immediately adjacent to the study area in the SHPO database.

Site	Name	Barrio	Site Description	Reported elements
CI0100006	Ciales 6; Doña Caro	Cordillera	caves (2)	pottery, axes, stone pounders, cemi, stone collar
CI0100008	Ciales 8; Bateyes I	Hato Viejo	village/possible ceremonial plaza; hacienda	cemis, beads, lithics, pottery
CI0100009	Ciales 9; Bateyes II	Hato Viejo	village/possible ceremonial plaza	cemis, pottery, shell, lithics, and petroglyphs
CI0100010	Ciales 10; Ventana I	Jaguas	two caves with possible ceremonial plaza	pottery, possible batey

Site	Name	Barrio	Site Description	Reported elements
CI0100011	Ciales 11; Cueva de Sapo	Hato Viejo	cave	shell, pottery, shell
CI0100012	Ciales 12; Cueva Coco	Hato Viejo	cave	pottery
CI0100019	Ciales 19; Pueblo II Ciba # 19	Jaguas	habitation	pottery and stone tools
CI0100020	Ventana II; CIBA # 20	Jaguas	village/possible ceremonial plaza	dujos, pottery, lithics, and a batey
CI0100027	CIBA 27; Bateyes III	Hato Viejo	habitation	Pottery and ground stone
CI0200001	Puente 321; Juan José Jiménez	Hato Viejo	bridge	truss bridge

The nine archaeological sites within or immediately adjacent to the study area include the remnants of a historic hacienda, prehistoric villages with plazas, archaeological deposits in caves, and petroglyphs. Four of the sites on the eastern side of the Río Grande de Manatí are noted in the site file as including plazas, with at least two reporting stone-lined plazas. Artifacts recovered from these four sites (CI0100008, CI0100009, CI0100010, and CI0100020) include duhos, cemis, and other artifacts consistent with locations of ceremonial and political importance.

Other sites include caves with petroglyphs and associated archaeological deposits and prehistoric habitations. In the site files database, all of the archaeological sites are listed as potentially eligible or not evaluated for the NRHP. On the northern end of the study area, the Juan José Jiménez Bridge (Puente 321, CI0200001) was listed in the NRHP in 1995 as the "Manatí Bridge at Mata de Plátano" (NRHP Reference Number 95000847). This bridge was purchased by the Spanish government for use in Carolina, but not constructed before the end of the Spanish-American War. The U.S. military government of Puerto Rico moved the raw materials to Ciales and installed the bridge over the Río Grande de Manatí. This is the first truss bridge constructed while Puerto Rico has been under the control of the United States of America.

The previously-recorded archaeological sites occur both within and outside of the area FEMA classifies as the Floodway. On a Light Detection and Ranging (LiDAR) digital terrain model, the prehistoric habitations are located on terraces or hills in and on the edge of the flood zones. Based on a review of the study area topography, the terraces and hills at edge of the study area have a high probability for containing intact cultural deposits.

In August 2019, the USACE Project archaeologist conducted a visual reconnaissance and limited pedestrian survey of the study area to supplement remote sensing data. The archaeologist examined exposed ground surfaces, photographed buildings, and compared conditions to the LiDAR and historic aerial photography. Area informants indicated some of the structures were constructed prior to 1970, meeting the 50-year threshold for treatment as a potential historic

property. Though much of the study area is previously disturbed by development, sections were identified with potential for archaeological deposits. The unrecorded historic buildings and high density of surrounding archaeological sites indicate there are potential unrecorded historic properties within the areas of potential effects of the project alternatives.

2.3 Forecasted Setting *

This section describes likely future conditions in the absence of any additional federal action. This is also referred to as the future without project condition (FWOP).

2.3.1 Climate

A recent review of existing literature regarding climate change within Puerto Rico found general consensus that average temperatures across Puerto Rico are increasing and that large storm events in the region will become more frequent and intense (USACE, 2015).

2.3.2 Flood Risk

2.3.2.1 Hydrologic Characteristics & Tidal Influence

A climate change assessment was conducted per USACE policy and guidance (USACE, 2018). Results of the climate assessment are summarized here. Detailed results of the climate assessment can be found in Appendix A, Engineering.

Historic trends in instantaneous annual peak flow at the U.S. Geological Survey gauge number 50035000 were assessed using the USACE Nonstationarity Detection (NSD) Tool (USACE, 2017). The NSD Tool failed to detect a significant increasing or decreasing trends in observed historic annual peak flow. The NSD Tool also failed to detect significant nonstationarities—changes in the statistical characteristics of the hydrologic time series. A recent review of existing literature regarding climate change within Puerto Rico found general consensus that future storm events in the region will be more frequent and intense (USACE, 2015); however, there is currently no consensus regarding how changes in precipitation translate to altered hydrologic conditions. Despite this lack of consensus, projected future increases in extreme storm events will likely increase flood risk in the future (USACE, 2015). Thus, future changes in flood risk are qualitatively considered during the plan formulation process.

A sea level rise analysis was conducted per USACE policy and guidance (USACE, 2013 and USACE, 2014). The most conservative boundary condition projected for the end of the 100 year project life was 10.07 feet. These represents the highest downstream boundary condition used for the

analysis and was compared with the mean higher high water initially incorporated in the existing conditions hydraulic model. There was no increase in water surface elevation in the study area extents for the future without project condition under the most conservative scenario. Therefore, sea level rise was not considered further in the plan formulation process (see Appendix A, Engineering for a detailed description of this analyses).

2.3.2.2 Flood Damages

A total of 159 structures representing private homes, businesses, and industry and public facilities remain in the study area and are included in the assessment of FWOP flood and inundation risk (see Table 2-1). The 110 public housing units included in the federal relocation effort were not included in the FWOP analysis. Annual damages under the FWOP condition are estimated to be $1,643,000 (see Appendix C, Economic Appendix). Increased magnitude and frequency of flood events would also increase inundation of and damage to transportation infrastructure, resulting in increased costs to residents (i.e., transportation delays) and local and commonwealth governments (i.e., repair and rehabilitation).

2.3.2.3 Life Safety Risk

Increased magnitude and frequency of flood events would increase life safety risks for residents living within the floodplain as a result of increased inundation depths that affect their ability to vertically evacuate. Flooding of the waste water treatment plant will continue to cause discharges of raw sewage to the watershed. Risks to human health and safety will increase under the FWOP condition. Increased magnitude and frequency of flood events would also increase life and safety risk associated with inundation of and damage to transportation infrastructure, increasing the frequency and length of isolation and resulting in decreased access to population centers and associated critical facilities. Continued and worsening Inundation of and damage to transportation infrastructure will also result in increased costs to residents (i.e., transportation delays) and local and commonwealth governments (i.e., repair and rehabilitation).

2.3.3 Earth Resources

2.3.3.1 Geology & Topography

It is likely that future floods will continue to result in loss of bank material, migration of the channel, and/or changes in channel morphology and topography.

2.3.3.2 Soils

Soils throughout much of the study area would continue to be disturbed as a result of land use activities (i.e., agriculture, development, and gravel mining). High erodibility of soils along the Rio Grande de Manati coupled with exacerbated erosive conditions (i.e., steeper stream banks and reduced vegetative stabilization) following Hurricane Maria result in elevated probability of future flood-induced bank failure and associated failure of at-risk transportation infrastructure over the period of analysis. Failure of major transportation routes would increase life safety risk due to loss of access to population centers and associated critical facilities, as well as the inability to receive or delayed receipt of recovery aid. Continued and worsening erosion of the river banks would also increase the risk of damages to homes and businesses adjacent to the stream. Soils in undisturbed, upland areas would remain relatively unchanged should these lands not be developed in the future.

2.3.3.3 Air Quality

No change to air quality conditions is expected under the FWOP condition.

2.3.4 Water Resources

2.3.4.1 Water Quality

Continued flooding of the wastewater treatment plant may cause untreated wastewater discharges containing fecal coliform bacteria and other pollutants to enter the Rio Grande de Manati exacerbating the current water quality impairments and increasing human health risks. Continued erosion of stream banks would likely further contribute to turbidity impairment.

2.3.4.2 Riverine & Floodplain Habitats

An increase in the magnitude and frequency of large storm and flood events could result in destabilization and disturbance of riverine, riparian, and undeveloped floodplain habitats throughout the study area.

2.3.4.3 Wetland Habitat

Destabilization and disturbance of floodplains during future flood events could affect any existing floodplain wetlands.

2.3.5 Biological Resources

2.3.5.1 Vegetation

Vegetation along the river banks would likely continue to be temporarily impacted as a result of scour during large flood events.

2.3.5.2 Fish & Wildlife Resources (Other than Threatened and Endangered Species)

Flooding would continue to scour and temporarily disturb riparian and floodplain habitats. Turbidity and sedimentation resulting from scour and erosion of stream banks may impact fish and aquatic invertebrate populations. Both fish and wildlife species would be expected to relocate to similar habitats in the area and likely no significant impacts would occur, although there may be negative localized impacts to fish and wildlife species.

2.3.5.3 Threatened & Endangered Species

No significant impact on the presence of threatened and endangered species is anticipated under the FWOP condition. Boas impacted by the disturbance of riparian and floodplain habitats would be expected to relocate to similar habitats in the area.

2.3.6 Land Use & Associated Impacts

2.3.6.1 Land use

Limited additional urban development is expected within the study area due to the surrounding mountainous topography and known flood risk. Undeveloped lands will likely continue to be used for small-scale agricultural operations. Developed floodplain areas will continue to be at risk for flooding during heavy rain events with continuing damage to property and infrastructure.

2.3.6.2 Hazardous, Toxic, & Radioactive Waste

No change is expected with respect to HTRW under the FWOP condition.

2.3.6.3 Noise

No change is expected to noise levels under the FWOP condition.

2.3.7 Socioeconomic Environment

2.3.7.1 Socioeconomic Setting

Although Puerto Rico experienced a decrease in population from 2010 to 2018, the population within the study area is not expected to decrease over the period of analysis. Specifically, the majority of residents within the study area are living below the poverty line and would therefore likely not have the financial means to relocate on their own.

2.3.7.2 Aesthetic & Recreation Resources

Stream bank destabilization and erosion will continue and contribute to a degradation of aesthetics. Recreation may be impacted if flooding and erosion occur in the area of the ball field.

2.3.8 Cultural Resources

In the absence of a federal project, cultural resources conditions would largely remain the same. Continued disturbance and destabilization of stream banks and floodplain habitats could result in a loss of cultural resources potentially located within the study area; however, continued sedimentation within the floodplain could further bury and protect floodplain cultural resources. Continued flooding and sedimentation could negatively impact the "Manatí Bridge at Mata de Plátano" (NRHP Reference Number 95000847), which was damaged and closed to traffic following Hurricane Maria. Flood inundation would also continue to negatively impact any structures that may classify as historic properties within the study area. Historic properties would continue to be protected under federal and commonwealth laws.

2.4 Summary of Existing and FWOP Conditions

Table 2-6 provides a summary of the FWOP conditions that have a direct effect on the formulation and evaluation of alternative plans and compares the FWOP directly back to existing conditions.

Table 2-6. Summary of existing and FWOP conditions that affect the formulation and evaluation of alternative plans.

Consideration	Current Conditions	FWOP Conditions
Climate	The climate is tropical. Average temperatures range from 68-87 °F. Average annual rainfall is 70 inches across PR and 90 inches within the headwaters of the Rio Grande de Manati River. About 25% of precipitation is hurricane driven.	Average temperatures are expected to increase within the study area. The frequency and intensity of large storm events is also expected to increase.
Flood Risk	The Rio Grande de Manati has reached flood stage 35 times in the last 50 years. Flooding during Hurricane Maria was the largest event within the same time period and was estimated to have an AEP of between 0.01 and 0.002. The study area contains a total of 159 structures, including private homes, commercial and industrial properties, and public facilities. Many structures experience severe and recurring flood damages. However, residents within the floodplain generally have ample warning time to evacuate and can vertically evacuate within or on top of their home, or to adjacent upland areas. Flooding inundates major roadways and damages bridges, resulting in isolation of communities and decreased access to population centers, critical services, and recovery aid.	There is no consensus on how changes in precipitation will translate into altered hydrology. However, projected future increases in the frequency and intensity of large storm events will likely increase the frequency and intensity of flood events. Annual damages to the 159 structures are estimated to be $1,643,000. An increase in the magnitude and frequency of large flood events will likely result in an increase in flood damages, as well as an increase in life safety risk associated with inundation of structures and reduced ability to vertically evacuate within the floodplain. Inundation of and damage to transportation infrastructure will also become more severe, resulting in greater transportation delays and increased costs to local and commonwealth governments, as well as increased life safety risk due to increased frequency and length of isolation and degraded access to critical facilities, and recovery aid.
Earth Resources	Topography is characterized by steep slopes and narrow valleys. Soils have high percentages of sand and clayey silt, particularly at depths less than 15 feet. Soil characteristics contribute to elevated potential for erosion and bank failure during flood events. Several key pieces of transportation infrastructure are at risk due to flood-induced bank failure	Large flood events would continue to result in migration of the channel and changes in channel morphology and topography that could impact private (e.g., homes and businesses) and public (e.g., roads) infrastructure adjacent to the stream. Increased susceptibility of banks following Hurricane Maria (altered vegetation, steeper banks) and the potential

Consideration	Current Conditions	FWOP Conditions
		increase in the frequency and intensity of large storm events would likely exacerbate these changes.
Water Resources	The Rio Grande de Manati is characterized by alternating riffle and pool sequences, with varying substrate sizes. High erodibility of banks result in transient fine sediments within the stream bed. Portions of the Rio Grande de Manati are listed as impaired due to coliform bacteria, turbidity, total nitrogen, copper, and total phosphorus. The USFWS National Wetlands Inventory does not indicate the presence of any non-riverine wetlands in the study area. Soil survey data indicate some hydric inclusions. Therefore, a wetland delineation will be conducted during PED to verify the absence of floodplain wetlands.	Continued and exacerbated erosion of stream banks throughout the watershed will likely result in elevated turbidity and sedimentation, impacting both water and habitat quality. The wastewater treatment plant may continue to flood and release untreated wastewater into the Rio Grande de Manati, maintaining and exacerbating existing problems with coliform bacteria, nitrogen, and phosphorus. Continued flooding would likely result in destabilization and disturbance of riverine, riparian, and floodplain habitats, including any existing floodplain wetlands.
Biological Resources	Vegetation consists of grasses, epiphytes, vines, shrubs, and trees. The Rio Grande de Manati supports a diverse aquatic community of native fish, shrimp, freshwater crabs, and other invertebrates. Wildlife within the study area include reptiles, amphibians, small mammals, and birds. Seven migratory bird species of conservation concern are known to utilize habitats within the study area. One federally-listed endangered species—the Puerto Rican Boa—may occur in the study area.	Vegetation along the river banks would likely continue to be temporarily impacted as a result of scour during large flood events. Sedimentation would continue to impact fish and aquatic invertebrate populations. Both fish and wildlife species, including the Puerto Rican Boa, would be expected to relocate to similar habitats in the area. No significant impacts are expected.
Socioeconomic conditions	Residential/urban development represents the dominant land use (28% of study area). Floodplain lands are also used for small-scale agriculture. Ciales experienced a 15% decline in population from 2010 (18,800) to 2018 (15,900). Approximately 20% of residents are over age 65, and 58% of residents live below the poverty line.	Limited additional development is expected due to the mountainous topography and known flood risk. The population within the study area is not expected to decrease over the period of analysis. The majority of residents within the study area are living below the poverty line and would therefore likely not have the financial means to relocate on their own.

Consideration	Current Conditions	FWOP Conditions
Cultural Resources	There are several known cultural resources sites within or adjacent to the study area. The PR-6685 Bridge is listed on the NRHP. Historic aerial imagery indicates that the age of many structures within the study area make them potentially eligible for listing as historic properties.	Inundation would continue to damage properties currently listed on the NRHP (e.g., PR-6685 Bridge), as well as those properties eligible for listing. Continued destabilization and disturbance of stream banks and floodplain habitats have the potential to impact known cultural resources within the study area.

3 PLAN FORMULATION *

This chapter describes the development of alternative plans that address the study objectives, comparison of those plans, and the selection of a final recommended plan.

3.1 Planning Strategy

The plan formulation strategy consisted of multiple formulation phases and was conducted from a spatial perspective. The study area was divided into four focal areas (Fig. 3-1) recognizing that physical boundaries and environmental conditions create distinctive water management issues in each focal area, as summarized below:

Focal Area 1: Focal Area 1 extends approximately 0.58 miles from the site of the PR-145 Bridge downstream to the PR-149 Bridge. Flooding-related problems in Focal Area 1 include elevated flood risk for structures in the floodplain, inundation of major access roads (i.e., PR-145 and PR-149), and extensive flood-induced bank failure threatening structures and transportation infrastructure (i.e., PR-145 and PR-149 Bridge). The PR-149 Bridge at the downstream extent of Focal Area 1 may act as a pinch point, causing upstream water back-up and inundation.

Focal Area 2: Focal Area 2 extends approximately 0.42 miles downstream of the PR-149 Bridge and includes the communities of Dos Rios and Alturas de Ciales. The original flood protection works plan was entirely within Focal Area 2. Flooding-related problems in Focal Area 2 include elevated flood risk for structures in the floodplain and inundation of major access roads (i.e., PR-146, PR-6685). Focal Area 2 contains a sewage treatment plant with a history of flooding.

Focal Area 3: Focal Area 3 extends approximately 0.44 miles and includes a large industrial facility. Flooding-related problems include increased flood risk for structures within the floodplain, inundation of major access roads (i.e., PR-6685), and extensive flood-induced bank failure threatening PR-6685, as well as residential structures and the industrial facilities. The large river bend in Focal Area 3 may be causing water backup and increased inundation upstream.

Focal Area 4: Extends approximately 0.87 miles to the PR-6685 Bridge. Flooding-related problems include elevated flood risk for structures within the floodplain and inundation of PR-6685, which results in the isolation of communities outside of the floodplain.

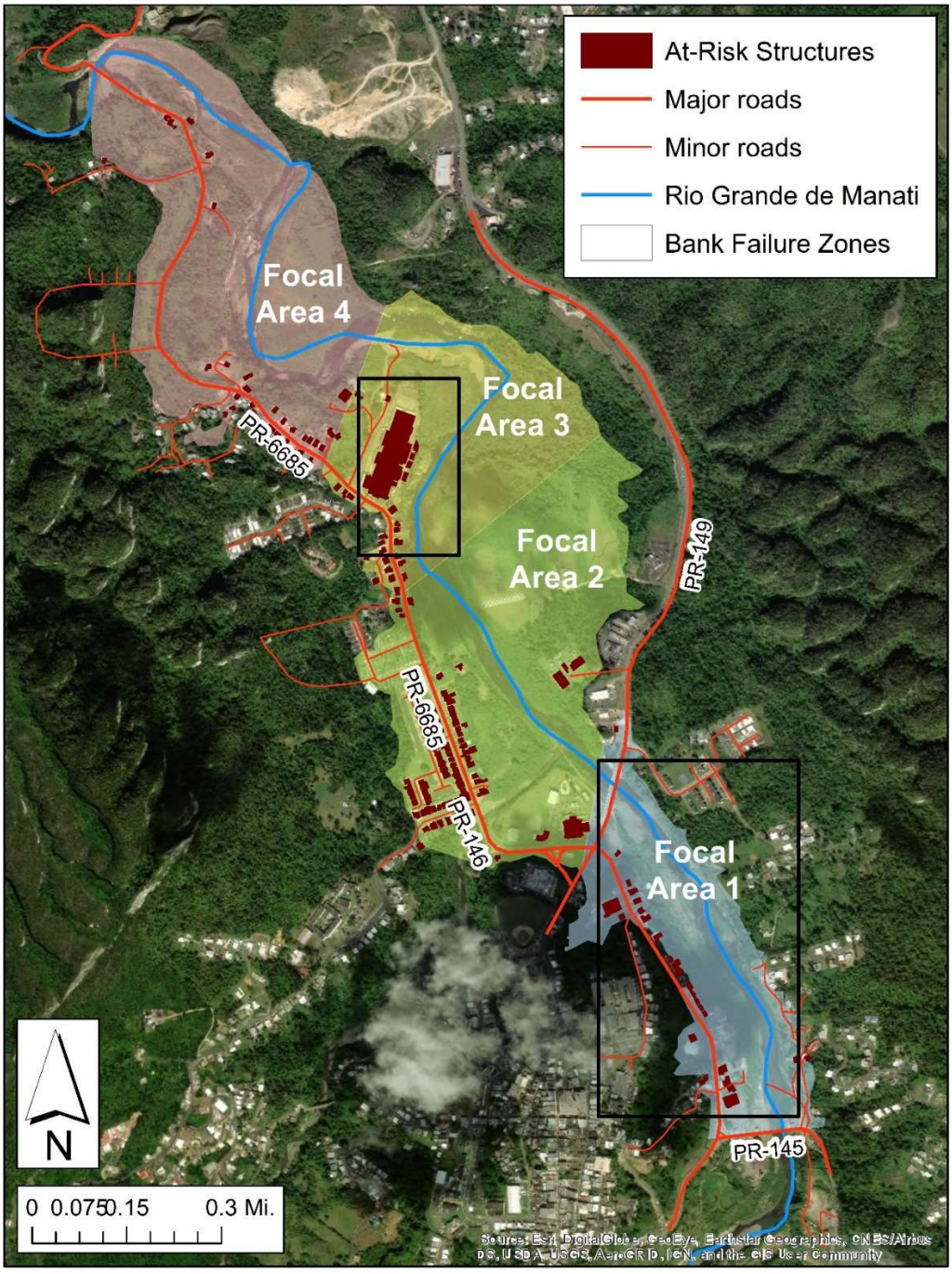

Fig. 3-1. At-risk structures, roadways, and bank failure zones within each focal area.

The PDT first developed and screened a list of management measures that would work to address one or more of the problems and study objectives within each of the four focal areas. Individual management measures were then combined into a series of 'options' for each focal area. Options for each focal area were then combined into an initial array of system-wide alternative plans. Alternatives were assessed to ensure proper functioning and compatibility across focal areas and screened into a final array of viable plans that provided integrated and holistic solutions to flood

risk throughout the study area. Alternatives within the final array were evaluated based on a series of criteria and then compared to one another, enabling identification of the recommended plan. The planning strategy is shown in Fig. 3-2.

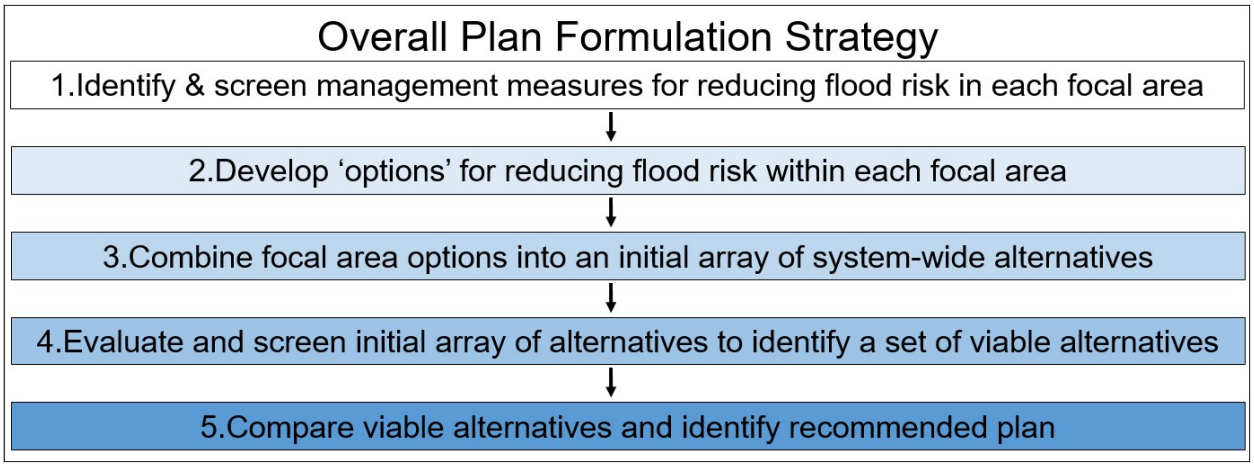

Fig. 3-2. Plan formulation strategy.

3.2 Authority & Policy Constraint

Although flood-induced bank failure and bridge scour were identified as distinct problems within the study area, no direct link could be made between bank instability/scour and flood inundation. Consequently, neither the study authority nor USACE policy (USACE, 1999) permit the study, recommendation, or implementation of measures designed to address bank instability and/or bridge scour along the Rio Grande de Manati. Initial analyses conducted to assess bank failure and bridge scour have been provided in Appendix G, Bank Stabilization & Bridge Scour.

3.3 Management Measure Identification and Screening

3.3.1 Summary of Management Measures

Management measures are features or activities implemented at specific locations to address one or more of the planning objectives. A total of 10 distinct structural, non-structural, and nature-based management measures were identified as having the potential to address one or more of the study objectives. Descriptions of all management measures considered for each focal area are provided in Table 3-1.

Table 3-1. Categories (i.e., structural, non-structural, and nature-based) and descriptions for all management measures considered to manage flood risk associated with inundation and flood-caused bank failure along the Rio Grande de Manati within Ciales.

Management Measure	Category	Description
Channelization/Channel Modification	Structural	Channelization and channel modification can include channel widening, deepening straightening, and/or relocating, as well as channel lining to maintain the desired geometry and decrease roughness, expediting water movement through the system.
Floodwalls	Structural	Construction of a concrete wall along the watercourse or around critical infrastructure to exclude temporary flood waters from protected areas.
Levees	Structural	Construction of an earthen embankment along the watercourse or around critical infrastructure (ring levee) to exclude temporary flood waters from protected areas.
Detention Basins	Structural	Detention basins located upstream of the study area can reduce peak discharge and associated flood damages downstream by temporarily storing flood water throughout the watershed and releasing it slowly.
Upstream Retention	Structural	Upstream retention (i.e., reservoir) can be used to store large quantities of flood water, reducing peak discharges downstream.
Flood-Proofing	Non-structural	Combination of dry (i.e., keeping the water out of the structures) and wet (i.e., allowing water to flow through structures) flood-proofing to reduce damages to individual structures.
Structure Elevation	Non-structural	Raise structures such that the main living area will be above a design flood elevations.
Acquisition/Relocation	Non-structural	Acquisition and demolition of existing structures located within the floodplain. Residents would be relocated outside of the floodplain. Participation in the relocation would be mandatory. The floodplain would be planted with native vegetation. The local sponsor would retain ownership of the acquired property and must ensure no future development or fill would occur; however, the acquired area could be deeded to the local government and/or converted to undeveloped public space.
Flood Warning & Planning	Non-structural	Develop and expand flood warning system and emergency planning (e.g., evacuation routes).
Off-Channel Detention	Nature-based	Off-channel detention areas (which may be part of the floodplain, including wetlands or marshes) would temporarily store water diverted from the river channel. Off-channel detention could be implemented throughout the watershed, including within the study area, to reduce the magnitude of flooding.

3.3.2 Management Measure Screening

All management measures were initially screened based on the four criteria outlined in the Principals and Guidelines (USACE, 1983):

1 Completeness: The extent to which the measure provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.
2 Effectiveness: The extent to which each measure would alleviate the specified problems and achieves the specified opportunities.
3 Efficiency: The extent to which the measure is the most cost effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment.
4 Acceptability: The workability and viability of the measure with respect to acceptance by commonwealth and local entities and the public and compatibility with existing laws, regulations, and public policies.

Results of the initial screening evaluation are presented in Table 3-2. The screening resulted in the removal of five measures from further consideration. The five remaining measures include: channelization/channel modification, floodwalls, levees, upstream reservoir, and non-structural relocations. The applicability of each measure varied among the four focal areas (Table 3-2).

Table 3-2. Summary of management measure screening. Each measure was assessed based on the four P&G criteria to determine whether they should be retained in or removed from (decision) the plan formulation process within and across focal areas.

Management Measure	Narrative	Decision	Focal Areas
Channelization/Channel Modification	Channel straightening, widening, deepening, relocation, and lining could be effective at reducing flood risk by increasing capacity and hydraulic conductivity. These measures would be complete in that they would not require any additional investments or actions to achieve the planned reductions in flood risk. Channelization and channel modification would likely be acceptable to local and commonwealth entities and would comply with laws, regulations, and policies. FEMA relocation of public housing from Dos Rios and Alturas de Ciales will result in decreased benefits, reducing the overall efficiency of this and other structural measures.	Retain	1, 2, 3, 4
Floodwalls	Floodwalls would be effective at protecting populated areas and large, high-value structures. Floodwalls would be complete in that they would not require any additional investments or actions to achieve the planned reductions in flood risk. Floodwalls were included in the original flood protection works study to protect the communities of Dos Rios and Alturas de Ciales and would, thus, likely be accepted by local and commonwealth entities. Floodwalls would comply with laws, regulations, and policies. FEMA relocation of public housing from Dos Rios and Alturas de Ciales will result in decreased benefits, reducing the overall efficiency of this and other structural measures.	Retain	2
Levees	Levees would be effective at protecting populated areas and large, high-value structures. Levees would be complete in that they would not require any additional investments or actions to achieve the planned reductions in flood risk. Levees were included in the original flood protection works study to protect the communities of Dos Rios and Alturas de Ciales and would, thus, likely be accepted by local and commonwealth entities. Levees would comply with laws, regulations, and policies. FEMA relocation of public housing from Dos Rios and Alturas de Ciales will result in decreased benefits, reducing the efficiency of this and other structural measures.	Retain	2
Detention Basins	Watershed (i.e., size, geology) and flood (i.e., volume) characteristics preclude a network of detention basins from being an effective solution to flood risk.	Remove	NA
Upstream Retention	Upstream retention would be effective at decreasing peak discharge and flow velocity, alleviating risk of inundation and flood-induced bank failure. An upstream reservoir would be complete in that it would not require any additional investments or actions	Retain	Outside of study area

Management Measure	Narrative	Decision	Focal Areas
	to achieve the planned reductions in flood risk. An upstream reservoir would likely be acceptable to local and commonwealth entities and would comply with laws, regulations, and policies. High cost to construct a reservoir large enough to effectively reduce flood risk within the study area may reduce efficiency of this measure; however, further evaluation is warranted.		
Flood-Proofing	Wet and dry flood-proofing would provide little benefit to most at-risk structures given the extent to which they are below base flood elevation. Therefore, flood-proofing was deemed to be ineffective at managing flood risk within the study area.	Remove	NA
Structure elevation	Elevation would be difficult or not appropriate for many structures due to the extent they are below base flood elevation. Moreover, most structures are slab-on-grade, which are more difficult and expensive to raise.	Remove	NA
Acquisition/Relocation	Removing all structures and residents from the floodplain would effectively eliminate flood risk and associated damages. Relocation would be complete in that it would not require any additional investments or actions to achieve the planned reductions in flood risk for relocated structures. Feedback received during the public scoping meeting indicated that relocation is locally-preferred over implementation of structural measures. Relocations would comply with laws, regulations, and policies. Relocation of public housing from Dos Rios and Alturas de Ciales would make this a more efficient solution in that fewer structures would need to be relocated.	Retain	1, 2, 3, 4
Flood Warning & Planning	Flooding is generally associated with large storm/hurricane events, which are forecasted far in advance. The non-federal sponsor would be responsible for developing a floodplain management plan within one year of the signing of the project partnership agreement and implementing the plan no later than one year following completion of project construction as specified in Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12). Thus, additional warning and planning would have little benefit and would not be effective at further reducing flood risk.	Remove	NA
Off-Channel Detention	Steep mountainous topography throughout the watershed limits floodplain area available for off-channel detention, rendering this measure ineffective.	Remove	NA

3.4 Alternative Formulation

3.4.1 Summary of Focal Area Options

The PDT first developed options (i.e., combinations of management measures) to address identified problems within each focal area (see Fig. 3-1) as presented below. The PDT also developed a series of comprehensive options that would work to address identified problems across all focal areas.

3.4.1.1 Focal Area 1

Option 1.1. Channel Modification: Channel modifications would include widening and deepening throughout the focal area and at the PR-149 Bridge to increase capacity and decrease water backup and inundation.

Option 1.2. Non-Structural Relocations: High-risk structures within the floodplain would be acquired and residents relocated outside of the floodplain. Participation in the acquisition and relocation project would be mandatory. The floodplain would be planted with native vegetation. The local sponsor would retain ownership of the acquired property and must ensure no future development or fill would occur; however, the acquired area could be deeded to the local government and/or converted to undeveloped public space.

3.4.1.2 Focal Area 2

Option 2.1. Channel Modification & Protection of Wastewater Treatment Plant: Channel modifications would include channel realignment through the field opposite of Dos Rios to improve hydraulic conductivity. The channel would be designed to increase capacity and create improved floodplain connection. This option would include a floodwall or ring levee around the wastewater treatment plant to protect this critical infrastructure that also serves areas outside of Dos Rios and Alturas de Ciales (e.g., Ciales Pueblo).

Option 2.2. Levee/Floodwall System & Protection of Wastewater Treatment Plant: This option would include construction of a floodwall/levee system similar to that proposed under the original Flood Protection Works plan. This option would include a floodwall or ring levee around the wastewater treatment plant to protect this critical infrastructure that also serves areas outside of Dos Rios and Alturas de Ciales (e.g., Ciales Pueblo).

Option 2.3. Non-Structural Relocations & Protection of Wastewater Treatment Plant: High-risk structures within the Dos Rios and Alturas de Ciales communities would be bought out and residents relocated outside of the floodplain. Participation in the acquisition and relocation

project would be mandatory. The floodplain would be planted with native vegetation. The local sponsor would retain ownership of the acquired property and must ensure no future development or fill would occur; however, the acquired area could be deeded to the local government and/or converted to undeveloped public space. This option would include a floodwall or ring levee around the wastewater treatment plant to protect this critical infrastructure that also serves areas outside of Dos Rios and Alturas de Ciales (e.g., Ciales Pueblo).

3.4.1.3 Focal Area 3

Option 3.1. Channel Modification: Channel modifications would include channel widening to increase capacity and realignment to improve hydraulic conductivity and prevent water backup upstream of the existing river bend. A floodplain bench would also be constructed to restore natural floodplain processes.

Option 3.2. Non-Structural Relocations: High-risk structures within the floodplain would be bought out and residents relocated outside of the floodplain. Participation in the acquisition and relocation project would be mandatory. The floodplain would be planted with native vegetation. The local sponsor would retain ownership of the acquired property and must ensure no future development or fill would occur. The acquired area could be deeded to the local government and/or converted to undeveloped public space.

3.4.1.4 Focal Area 4

Option 4.1. Channel Modification: Channel modifications would include channel realignment and widening to increase capacity and improve hydraulic conductivity. A floodplain bench would also be constructed to restore natural floodplain processes.

Option 4.2. Non-Structural Relocations: High-risk structures within the floodplain would be bought out and residents relocated outside of the floodplain. Participation in the acquisition and relocation project would be mandatory. The floodplain would be planted with native vegetation. The local sponsor would retain ownership of the acquired property and must ensure no future development or fill would occur; however, the acquired area could be deeded to the local government and/or converted to undeveloped public space.

3.4.2 Summary of Comprehensive Options

The PDT also developed a series of comprehensive options that would work to address identified problems across all focal areas.

Option C1. Channelization: Channelization would involve channel improvements (i.e., widening and deepening) to increase capacity. The channel would be lined with concrete to decrease roughness, increase hydraulic conductivity, and maintain desired channel geometry and location. Channelization would be designed to reduce inundation of structures, infrastructure (i.e., roadways), and public facilities (i.e., wastewater treatment plant).

Option C2. Upstream Reservoir: Construction of an upstream reservoir would decrease peak discharge and water velocity throughout the study area, alleviating flood risk and damages.

3.4.3 Summary of Alternatives

Focal area-specific and comprehensive options were combined into five distinct alternatives to the FWOP, or 'No Action' plan (Fig. 3-3). Alternatives are named for the primary flood risk management measure included in each; however, other flood risk management measures are generally also included in each alternative.

The Levee/Floodwall system designed during the original flood protection works study to reduce risk of inundation in Focal Area 2 (Option 2.2) was combined with non-structural relocation options to reduce residual risk in Focal Area 1 (Option 1.2), Focal Area 3 (Option 3.2), and Focal Area 4 (Option 4.2) (Alternative 1). Channel modification options were combined across all four focal areas (Options 1.1, 2.1, 3.1, and 4.1) into an alternative (Alternative 2). Non-structural relocation options identified as a viable option for reducing risk of inundation in all focal areas (Options 1.2, 2.3, 3.2, and 4.2) were combined into a single alternative (Alternative 3). Channelization (Alternative 4) and the upstream reservoir (Alternative 5) represent comprehensive options and stand-alone alternatives.

Unless stated otherwise, measures and associated alternatives were developed in an attempt to reduce risks associated with the 0.04 AEP event. During the initial analysis of the FWOP condition, a much greater incremental change in inundation depth and area was observed between the 0.1 and 0.04 AEP events as compared to the 0.04 to 0.02 or the 0.02 to 0.01 AEP events. Thus, the 0.04 AEP event results in the greatest relative increase in damages and associated risk. Consequently, developing, evaluating, and comparing the initial array of alternatives based on the 0.04 event was determined to be an effective way to assess their ability to reduce risk.

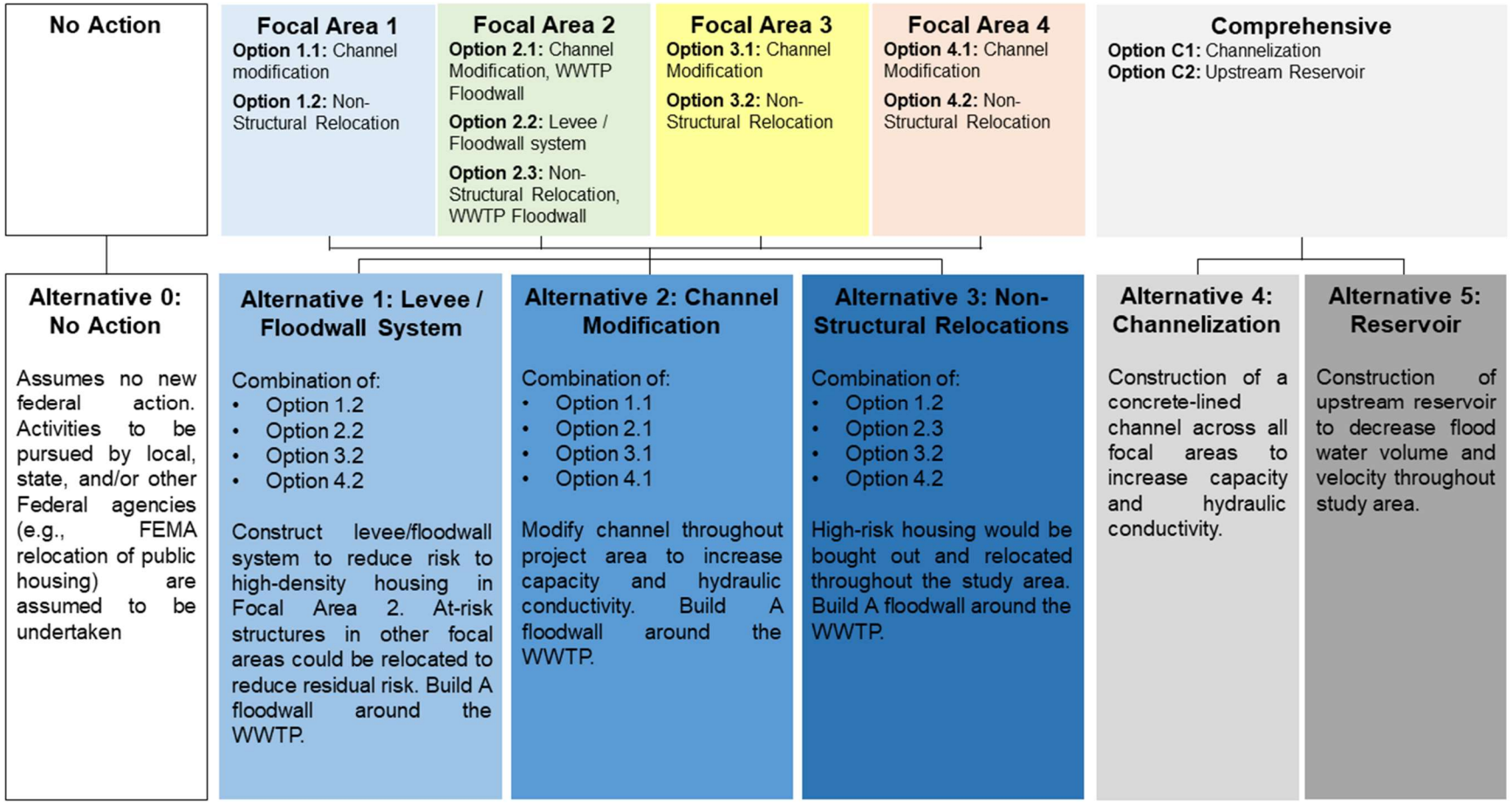

Fig. 3-3. Initial array of alternatives, including a description of the focal area-specific and comprehensive options included in each. WWTP = wastewater treatment plant; FEMA = Federal Emergency Management Agency.

Alternative 0. No Action: USACE planning policy (Engineering Regulation 1105-2-100) and the National Environmental Policy Act (NEPA) require consideration of 'No Action'. The No Action alternative is synonymous with the 'Future without Project Condition' and assumes no measures would be implemented by the federal government to achieve the planning objectives. Any activities to be pursued by local, commonwealth, and/or other federal agencies (e.g., FEMA relocation of public housing) are assumed to be undertaken.

Alternative 1. Levee/Floodwall System: This alternative incorporates the original, locally-developed flood protection works plan and specifications, which included a combined levee/floodwall system, a drainage system and retention pond, as well as channel improvements to reduce flood risk within the community of Dos Rios (Fig. 3-4; see Appendix A, Attachment 1 for an overview of the existing plan). The levee/floodwall system was originally designed to reduce risk up to the 0.01 AEP, as defined by the analyses and modeling completed at the time. High-risk structures in other focal areas not protected by the levee/floodwall system may be relocated to reduce residual risk if incrementally justified. Alternative 1 also incorporates a 1,200-foot concrete capped I-wall (Type I-2) around the wastewater treatment plant (Fig. 3-4). Height of the floodwall would vary to maintain a constant elevation that reduces risk up to the 0.04 AEP event. The maximum height of the floodwall needed to reduce risk associated with the 0.04 AEP would be 8 feet. Stone and concrete material would be sourced from commercial quarries located within the region. Excavated material would be reused on site as fill and construction material to the extent possible. Fill may need to be sourced from an off-site location depending on suitability of on-site material. Any remaining material would be disposed of at a commercial landfill.

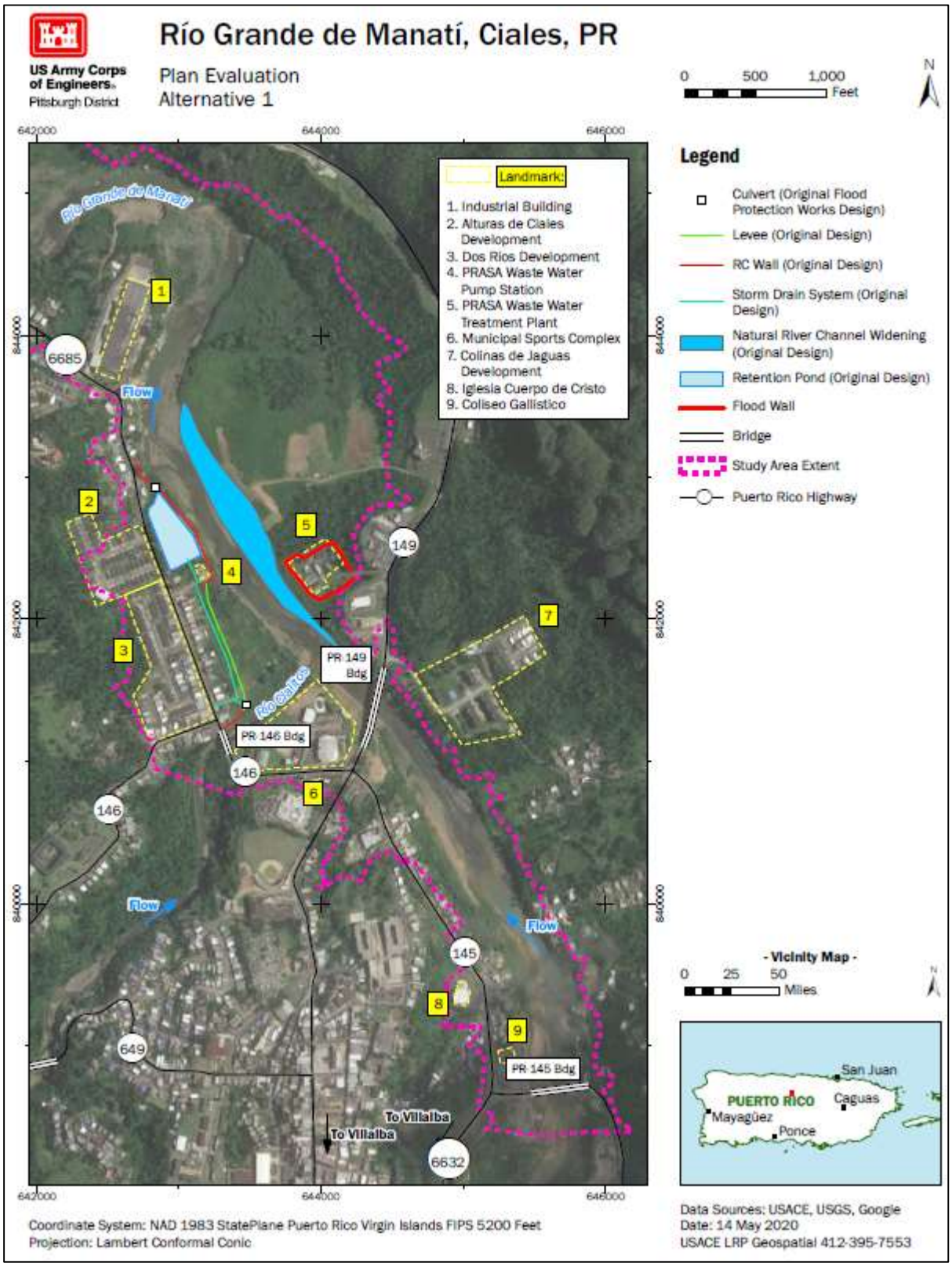

Fig. 3-4. Conceptual plan view of Alternative 1 (Levee/Floodwall System).

Alternative 2. Channel Modification: This alternative includes excavation and construction of approximately 7,800 feet of new, meandering low flow channel (Fig. 3-5). The bottom of the trapezoidal channel would be 200 feet wide and lined with natural river material. Natural river material would be reused from excavated material on site to the extent possible. Channel slopes would be rock-lined at a 3:1 angle to a height of 6 feet. Material would be removed from the area adjacent to the constructed channel to flatten the floodplain and tie into existing grade. The newly constructed low flow channel and widening of the channel within the existing floodplain would increase channel capacity and improve floodplain connection. The channel would be aligned to improve hydraulic conductivity by avoiding large bends in order to prevent water backup and associated flood inundation (Fig. 3-5). To the extent possible, the channel was designed to reduce damages and risk associated with the 0.04 AEP event. However, the design was constrained in certain areas by channel morphology and existing public (e.g., bridges) and private (e.g., homes) infrastructure. Alternative 2 also incorporates a floodwall around the wastewater treatment plant as described under Alternative 1 (Fig. 3-5). Stone and concrete material would be sourced from a commercial quarry located within the region. Excavated material would be reused on site as fill and construction material to the extent possible. Fill may need to be sourced from an off-site location depending on suitability of on-site material. Any remaining material would be disposed of at a commercial landfill.

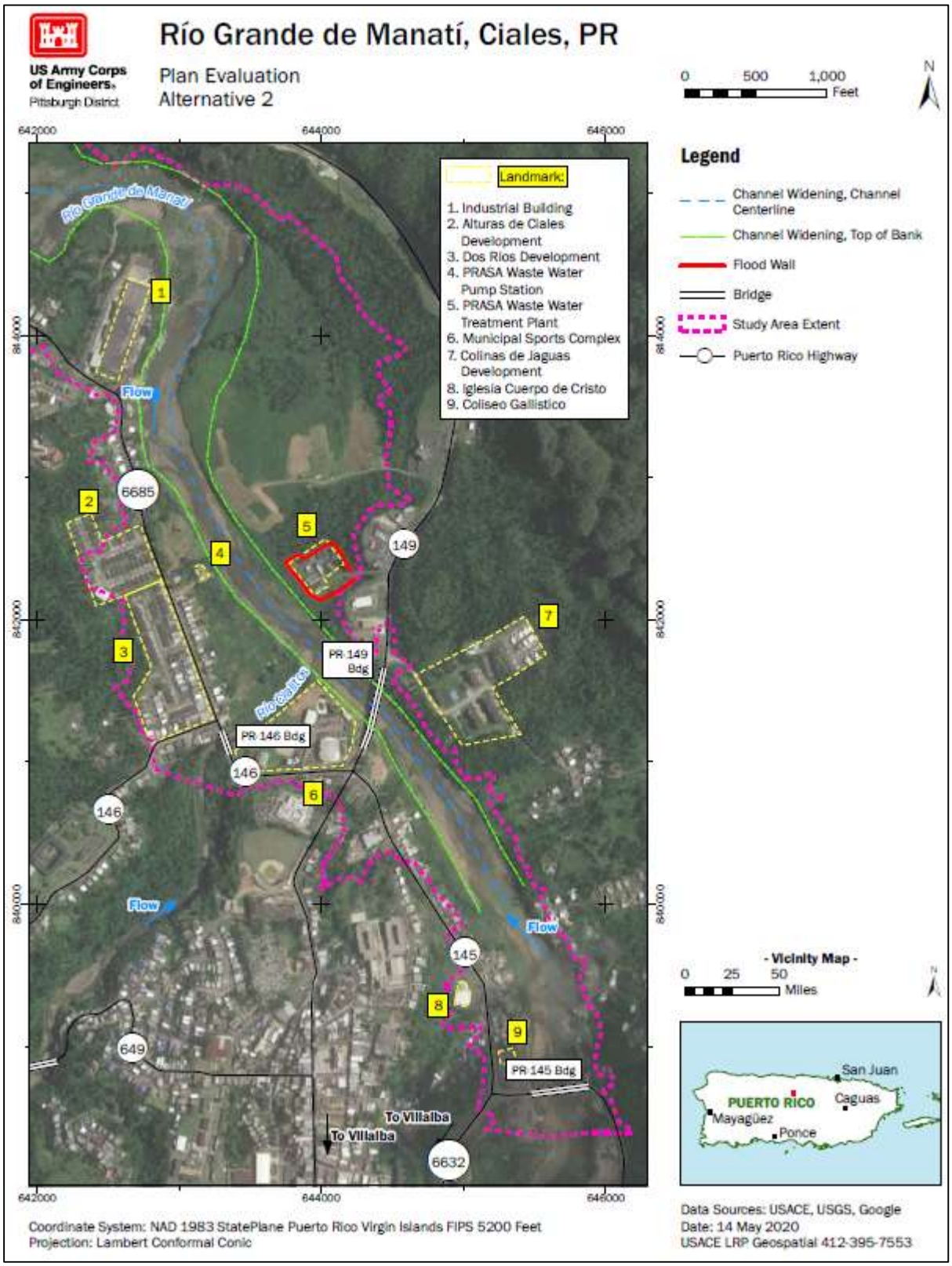

Fig. 3-5. Conceptual plan view of Alternative 2 (Channel Modification).

Alternative 3. Non-Structural Relocations: All 59 structures located within the 0.04 AEP floodplain would be acquired and demolished. Residents would be relocated outside of the floodplain (Fig. 3-6). The floodplain would be planted with native vegetation. The local sponsor would retain ownership of the acquired property and must ensure no future development or fill would occur; however, the acquired area could be deeded to the local government and/or converted to undeveloped public space (e.g., recreational/sports fields).

The 0.04 AEP floodplain contains those structures with the majority of recurring flood damages, as well as those with the greatest life and safety risk during major flood events. Under this alternative, the average inundation depth during the 0.01 AEP event for structures included in the relocation is 15.7 feet. In contrast, the inundation depth for structures within the 0.01 AEP floodplain that are not included in the relocation project is 2.7 feet. Although there is some residual risk to structures not included in the relocation effort, there are other relocation programs these residents can take advantage of to eliminate their risk.

Alternative 3 also incorporates a floodwall around the wastewater treatment plant as described under Alternatives 1 and 2 (Fig. 3-6). Stone and concrete material would be sourced from a commercial quarry located within the region. Excavated material would be reused on site as fill and construction material to the extent possible. Fill may need to be sourced from an off-site location depending on suitability of on-site material. Any remaining material would be disposed of at a commercial landfill.

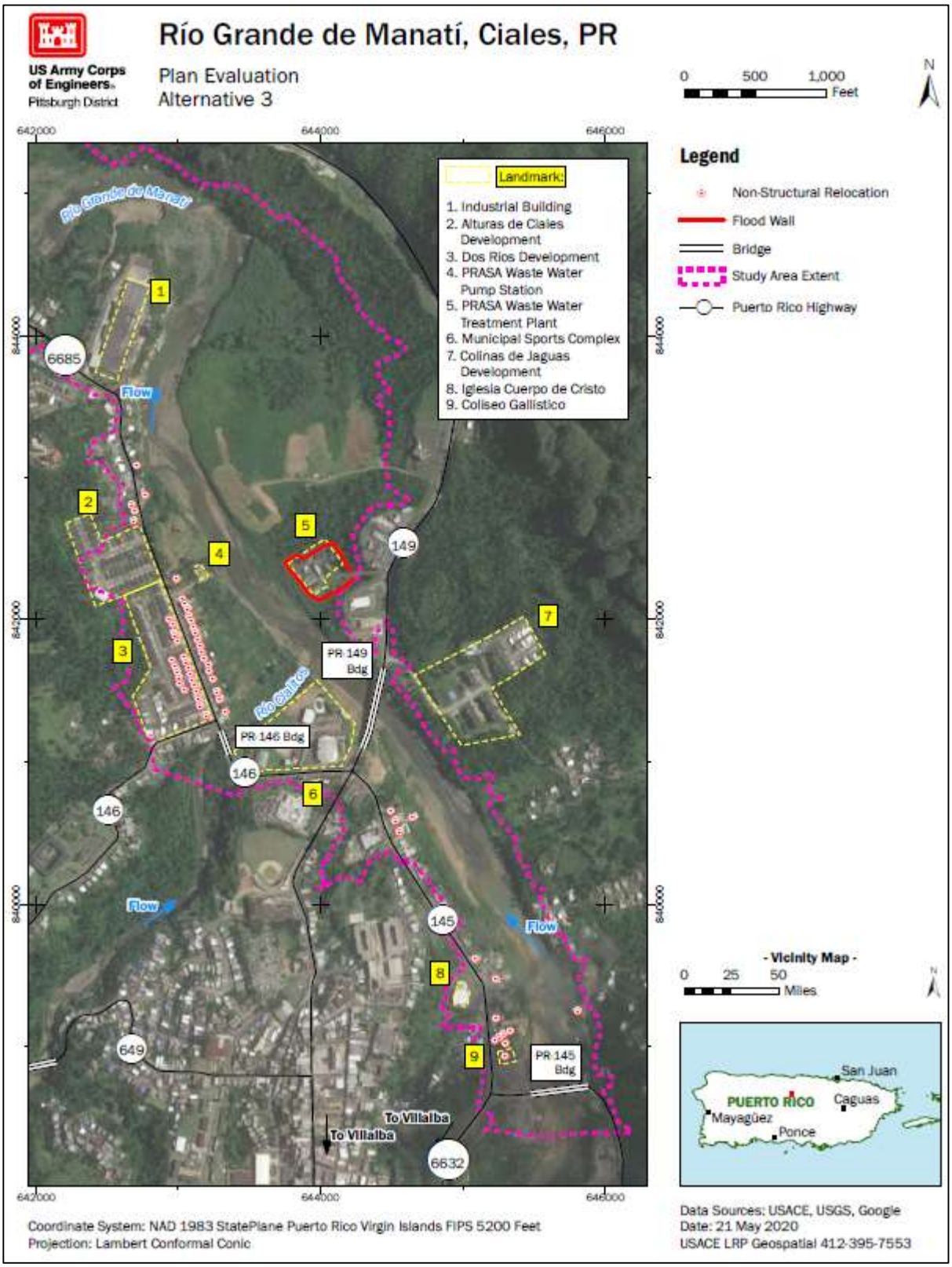

Fig. 3-6. Conceptual plan view of Alternative 3 (Non-Structural Relocations).

Alternative 4. Channelization: Channelization involves construction of approximately 9,000 linear feet of concrete-lined channel within existing riverbank limits (Fig. 3-7). Alternative 4 would require excavating the existing channel to a depth of 17 feet and width of 300 feet. The bottom of the trapezoidal channel would be 100 feet wide, and the slopes would extend to a height of 15 feet at a 3:1 angle. The entire channel would be concrete lined. The channel would be aligned to improve hydraulic conductivity (Fig. 3-7). Channelization would reduce flood risk by increasing capacity and expediting water movement through the study area. The channel was designed to contain a 0.04 AEP event. Designing the channel to contain larger storm events was not feasible given existing channel dimensions and without the need to significantly alter existing public and private infrastructure. Stone and concrete material would be sourced from a commercial quarry located within the region. Excavated material would be reused on site as fill and construction material to the extent possible. Fill may need to be sourced from an off-site location depending on suitability of on-site material. Any remaining material would be disposed of at a commercial landfill.

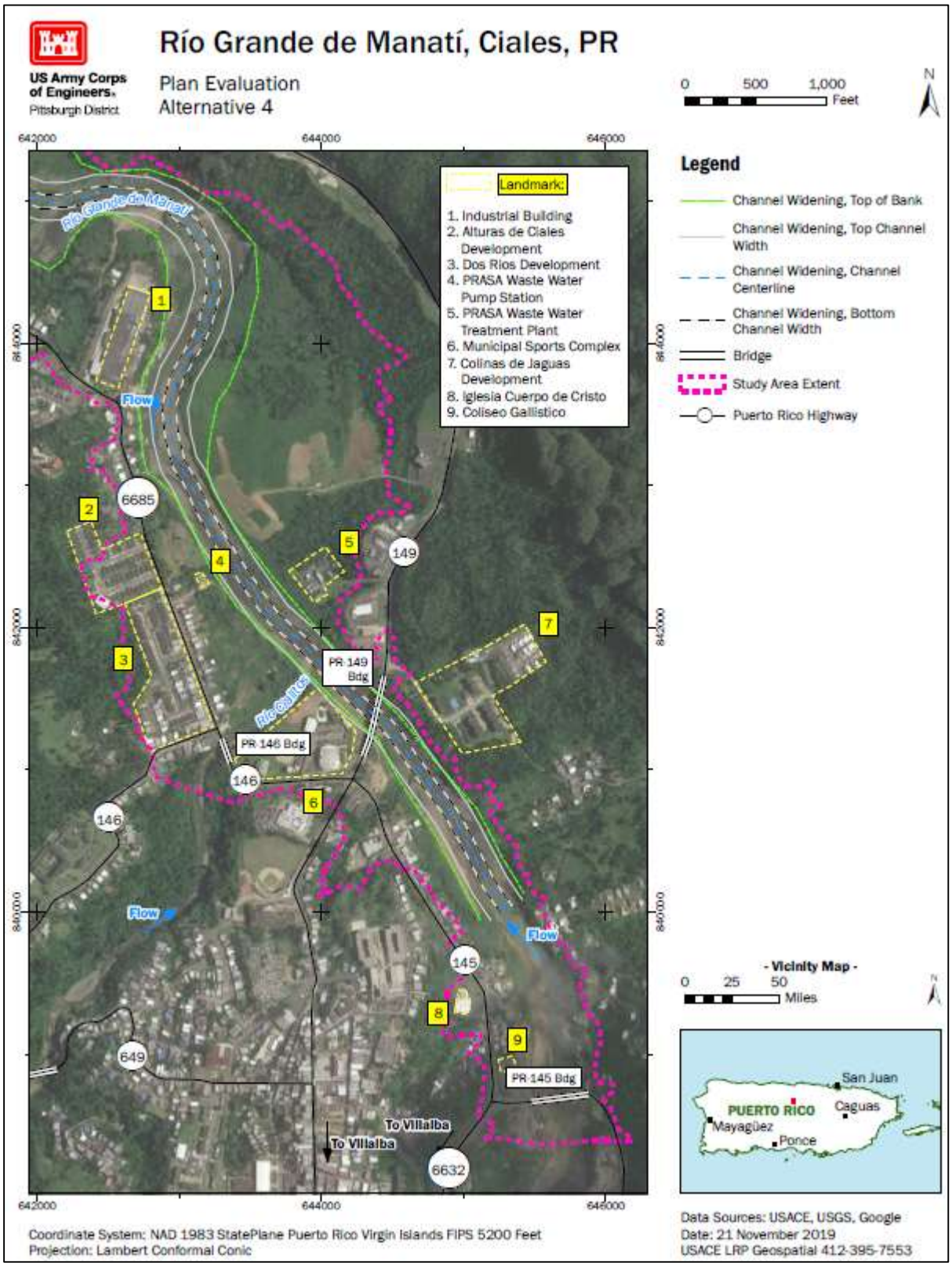

Fig. 3-7. Conceptual plan view of Alternative 4 (Channelization).

Alternative 5. Upstream Reservoir: Construction of an upstream reservoir could alleviate flood risk downstream, including throughout the study area. However, steep topography upstream of the study area would limit the ability to construct a reservoir large enough to effectively reduce flood risk and damages within Ciales. Steep topography also limits development along the river upstream of the study area, and highly developed areas downstream of the study area are protected by existing levees. Consequently, Ciales would account for the majority of benefits associated with reservoir construction, and these benefits would not be enough to offset the large anticipated cost. The Rio Grande de Manati represents one of only a few undammed and unimpeded large river systems within the region and is important habitat for a diverse aquatic community, including a number of amphidromous species that migrate between estuarine and inland aquatic habitats. Construction of a reservoir would result in significant impacts to hydrology, aquatic habitats, and associated aquatic communities. For these reasons, the PDT—in coordination with the vertical team—removed Alternative 5 from further consideration.

The final array of alternatives includes: Alternative 0 (No Action), Alternative 1 (Levee/Floodwall System), Alternative 2 (Channel Modification), Alternative 3 (Non-Structural Relocations), and Alternative 4 (Channelization).

3.5 Alternative Evaluation & Comparison *

3.5.1 Economic Assessment

Alternatives were first evaluated and compared via an economic assessment of costs and benefits. A general overview of project costs and benefits are presented here. See the economic (Appendix C) and cost engineering (Appendix D) appendices for a detailed discussion of methodologies and results associated with calculation of costs and economic benefits. Total project costs and resulting benefits were calculated for each alternative. Costs and benefits were then annualized to enable calculation of net benefits and benefit-cost ratios (BCRs) for each alternative. All costs include estimated project first costs, interest during construction, and operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs. The cost of lands, easements, rights-of-way, relocations, and disposal areas (LERRDs) was only estimated and included for alternatives that were economically justified (i.e., BCR > 1) based on project first costs and OMRR&R costs.

Alternative 3 (Non-Structural Relocations) had the lowest total project cost ($19.5M) and greatest annual benefits ($947K), as well as the greatest annual net benefits ($217,000) and BCR (1.3) (Tables 3-3). All other alternatives have negative annual net benefits and BCRs less than 1.

Table 3-3. Total project benefits and costs, along with benefits and costs computed to an annual equivalent basis and associated net benefits and BCRs for each alternative. Contingencies for project first costs are based on an abbreviated risk analysis (see Appendix D, Cost Engineering).

Measure	**Alt 1: Levee & Floodwall**	**Alt 2: Channel Modification**	**Alt 3: Non-Structural Relocations**	**Alt 4: Chan-nelization**
Total Cost ($1,000s)[a]	$30,834[b]	$107,850[c]	$19,531[d]	$129,355[e]
Annual Benefit ($1,000s)[f]	$703	$406	$947	$848
Annualized Cost ($1,000s)[f]	$1,142	$3,995	$730	$4,791
Annual Net Benefits ($1,000s)	($454)	($3,884)	$217	($4,036)
BCR	0.6	0.1	1.3	0.2

[a] All costs and benefits are in FY20 price levels.
[b] Includes first costs with 40% contingency, OMRR&R, and interest during construction.
[c] Includes first costs with 41% contingency, OMRR&R, and interest during construction.
[d] Includes first costs with 39% contingency, OMRR&R, LERRDs, and interest during construction.
[e] Includes first costs with 42% contingency, OMRR&R, and interest during construction.
[f] Calculated with federal discount rate of 2.75% over a 50-year period of analysis

3.5.2 Principles and Guidelines Accounts

Alternatives were evaluated and compared based on the four accounts established by the Principles and Guidelines (USACE 1983) to assist with evaluation and display of the effects of each alternative. The four accounts are listed and described below:

- National Economic Development (NED): The NED account represents the change in the economic value of the national output of goods and services that results from each plan.
- Regional Economic Development (RED): The RED account characterizes changes in the distribution of regional economic activity that result from each plan.
- Environmental Quality (EQ): The EQ account characterizes non-monetary effects (positive or negative) on significant natural and cultural resources that result from each plan.
- Other Social Effects (OSE): The OSE account characterizes effects of each plan that are relevant to the planning process but not reflected in the other three accounts (e.g., life and safety risk).

The following section evaluates each alternative with respect to the four accounts.

3.5.2.1 NED

The NED account was evaluated using net economic benefits (see Table 3-3).

Alternative 0. No Action: No action would have no effect on NED.

Alternative 1. Levee/Floodwall System: Alternative 1 results in negative net economic benefits ($-454,000) and, thus, would have an overall negative effect on NED.

Alternative 2. Channel Modification: Alternative 2 results in negative net economic benefits ($-3,884,000) and, thus, would have an overall negative effect on NED.

Alternative 3. Non-Structural Relocations: Alternative 3 results in positive net benefits ($217,000) and, thus, would have an overall positive effect on NED.

Alternative 4. Channelization: Alternative 4 results in negative net economic benefits ($-4,036,000) and, thus, would have an overall negative effect on NED.

3.5.2.2 RED

The RED account is a measure of the effect of each alternative on the regional economy and is a function of net changes to the regional income and regional employment under each alternative as compared to the No Action plan. A formal RED analysis was not completed for this study; however, the following changes to RED are expected:

Alternative 0. No Action: No Action would have a negative impact on RED, as local and regional resources would continue to be put toward recovery spending. Continued flooding could also impact the regional economy through a loss of regional businesses and increased unemployment.

Alternative 1. Levee/Floodwall System: Alternative 1 is expected to have a net negative effect on RED. Although there would be a reduction in recovery spending as compared to the No Action alternative, the project costs—much of which will be borne by regional entities—exceed the project benefits. Minimal transfer of income or employment from outside the region is expected.

Alternative 2. Channel Modification: Alternative 2 is expected to have a net negative effect on RED. Although there would be a reduction in recovery spending as compared to the No Action alternative, the project costs—much of which will be borne by regional entities—exceed the project benefits. Minimal transfer of income or employment from outside the region is expected.

Alternative 3. Non-Structural Relocations: Alternative 3 would have a net positive effect on RED. The net reduction in annual recovery spending would outweigh the annual costs of project implementation. Benefits would occur primarily through induced effects on regional income that result in changes in consumption expenditures generated by reduced recovery spending. Minimal transfer of income or employment from outside the region is expected.

Alternative 4. Channelization: Alternative 4 is expected to have a net negative effect on RED. Although there would be a reduction in recovery spending as compared to the No Action

alternative, the project costs—much of which will be borne by regional entities—exceed the project benefits. Minimal transfer of income or employment from outside the region is expected.

3.5.2.3 EQ

Environmental quality was assessed based on whether or not each alternative would have significant effects on environmental (i.e., riverine, wetland, and riparian habitats, biological resources) and cultural resources. See section 3.6 Environmental Effects for a more thorough discussion of potential impacts to environmental and cultural resources associated with each alternative. All alternatives have the potential to impact wetlands, cultural resources, and historic properties. Cultural resources and wetlands surveys would be conducted during PED to determine likely impacts.

Alternative 0. No Action: In the absence of federal action, periodic inundation of the wastewater treatment plant would impact water quality. Flood inundation would also continue to negatively impact any structures that may classify as historic properties.

Alternative 1. Levee/Floodwall System: The levee and floodwall system would is not expected to have significant impacts on any environmental or cultural resources. Minor and temporary impacts to riverine and riparian habitats, as well as associated biological resources, are expected during construction. There would be minor but permanent loss of floodplain connectivity, as well as a permanent loss of vegetation in the footprint off the floodwall, retention pond, and channel widening areas. The floodwall constructed around the wastewater treatment plant would result in permanent improvements to water quality.

Alternative 2. Channel Modification: Channel modification is not expected to have significant impacts on any environmental or cultural resources. Minor temporary impacts to riverine and riparian habitats, as well as associated biological resources, are expected during construction. There would be minor, permanent impacts to riverine habitats as a result of construction of the low-flow channel. A permanent loss of riparian and wildlife habitat are expected in areas where the low-flow channel and wastewater treatment plan floodwall are constructed. The floodwall constructed around the wastewater treatment plant would result in permanent improvements to water quality.

Alternative 3. Non-Structural Relocations: Non-structural relocation would result in permanent benefits to floodplain habitat and associated biological resources. Properties included in the relocation would be permanently cleared and planted with native floodplain vegetation, improving wildlife habitat. All future development would be prohibited. Restoration of natural floodplains would reduce runoff, improving water quality. The floodwall constructed around the wastewater treatment plant would result in permanent improvements to water quality.

Alternative 4. Channelization: Channelization would result in significant, permanent impacts to riverine habitats and associated biological resources. There would be a permanent loss and reduction in quality of riverine habitats through straightening (i.e., physical loss of stream and associated habitat length) and concrete lining (i.e., loss of natural substrate, increases in water temperature). This would negatively impact all aquatic species inhabiting the study area. Temporary and minor impacts to riparian habitat and associated vegetation would occur during construction.

3.5.2.4 OSE

Other social effects include life and safety and public health factors. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) was used to determine the AEP flood event that resulted in inundation depths for roads and structures in excess of 2 feet. Inundation depths greater than two feet were considered to result in increased life and safety risk for occupants of inundated structures and as a result of impassability of inundated roadways. In general, ample warning times associated with the most extreme flood (i.e., hurricane-induced floods) lessens life and safety risk to some extent.

Alternative 0. No Action: No Action would result in continued life safety risks associated with inundation of structures and roadways. Inundation for the most at-risk structures is nearly 20 feet under the No Action plan. Inundation depths on roads exceeding 2 feet occurs during the 0.1 AEP event under the No Action plan.

Alternative 1. Levee/Floodwall System: The floodwall and levee system would reduce life safety risk for structures within the communities of Dos Rios and Alturas de Ciales up to the 0.01 AEP event. However, there is transformed risk and remaining life safety (e.g., less perceived need to evacuate, altered flood risk behind the floodwall and levee) during extreme flood events. For example, this system would have been overtopped during Hurricane Maria. There would be no change in inundation risk for structures outside of the project footprint. The floodwall/levee system would ensure continuity of transportation (i.e., Inundation depths on roads less than 2 feet) up to the 0.02 AEP.

Alternative 2. Channel Modification: Channel modification would reduce life safety risk for structures within the communities of Dos Rios and Alturas de Ciales up to the 0.1 AEP event. There would be no change in inundation risk for structures outside of the Dos Rios area. Channel modification would ensure continuity of transportation (i.e., Inundation depths on roads less than 2 feet) up to the 0.1 AEP.

Alternative 3. Non-Structural Relocations: Non-structural relocations would effectively eliminate inundation for all structures within the 0.04 AEP floodplain throughout the entire study area. Non-structural relocations would not affect life and safety risk associated with inundation of

access and evacuation routes. Inundation depths on roads would exceed 2 feet during the 0.1 AEP event.

Alternative 4. Channelization: Channelization would reduce life safety risk for structures within the 0.04 AEP floodplain throughout the entire study area. There would be residual risk to structures outside of the 0.04 AEP floodplain. Channelization would ensure continuity of transportation (i.e., Inundation depths on roads less than 2 feet) up to the 0.04 AEP.

3.5.2.5 Account Summary & Comparison

This section summarizes and compares alternatives with respect to the four accounts.

NED: Alternative 3 (Non-Structural Relocations) is the only alternative to have positive NED benefits (Table 3-4). Thus, Alternative 3 represents the NED plan. Alternatives 1 (Levee/Floodwall System), 2 (Channel Modification), and 4 (Channelization) all have a negative effect on NED (Table 3-4). Alternative 0 (No Action) would have no effect on NED.

RED: Alternative 3 (Non-Structural Relocations) is the only alternative to have positive RED benefits (Table 3-4). Alternatives 0 (No Action), 1 (Levee/Floodwall System), 2 (Channel Modification), and 4 (Channelization) all have a negative effect on RED (Table 3-4).

EQ: Alternative 3 (Non-Structural Relocations) is expected to have a positive effect on the environment (Table 3-4). Alternative 4 (Channelization) is expected to have significant negative environmental effects, while Alternatives 0 (No Action), 1 (Levee/Floodwall System) and 2 (Channel Modification) have minor negative effects (Table 3-4).

OSE: Alternatives 1 (Levee/Floodwall System), 2 (Channel Relocation), 3 (Non-Structural Relocations), and 4 (Channelization) all have positive OSE through reduced life and safety risk (Table 3-4). Alternative 0 (No Action) would have a negative effect on OSE, as life and safety risk would remain or worsen (see Section 3.5.5.2 Residual Risk Due to Climate Change).

Table 3-4. Comparison of alternatives with respect to the four accounts established in the Principles and Guidelines (USACE 1983). Green = positive effect on each account; yellow = no effect; red = negative effect.

Account	Alt 0: No Action	Alt 1: Levee & Floodwall	Alt 2: Channel Modification	Alt. 3: Relocation	Alt. 4: Channelization
NED	No effect	Negative effect	Negative effect	Positive effect	Negative effect
RED	Negative effect	Negative effect	Negative effect	Positive effect	Negative effect
EQ	Negative effect	Negative effect	Negative effect	Positive effect	Negative effect
OSE	Negative effect	Positive effect	Positive effect	Positive effect	Positive effect

3.5.3 Principles and Guidelines Criteria

Alternatives were also evaluated and compared based on the four criteria established by the Principles and Guidelines (i.e., completeness, effectiveness, efficiency, and acceptability) (USACE 1983). The criteria are listed and defined below:

- Completeness: 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: The extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.
- Efficiency: 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: The workability and viability of the alternative plan with respect to acceptance by commonwealth and local entities and the public and compatibility with existing laws, regulations, and public policies.

The following section evaluates each alternative based on the above criteria.

3.5.3.1 Completeness

Alternative 0. No Action: This alternative relies fully on external flood risk reduction actions, including federal relocation of public housing. There is considerable risk that no non-federal flood risk reduction actions would be taken given the lack of available funds for such efforts. Thus, No Action does not represent a complete plan.

Alternative 1. Levee/Floodwall System: This plan would account for all necessary investments or other actions to ensure the realization of the planned effects. Thus, Alternative 1 represents a complete plan.

Alternative 2. Channel Modification: This plan would account for all necessary investments or other actions to ensure the realization of the planned effects. Thus, Alternative 2 represents a complete plan.

Alternative 3. Non-Structural Relocations: Complete removal of all structures within the 0.04 AEP floodplain is dependent upon completion of the FEMA relocation of all public housing from the communities of Dos Rios and Alturas de Ciales. The FEMA relocation effort has been approved and is underway and would be complete prior to implementation of Alternative 3 (Non-Structural Relocations). Thus, Alternative 3 represents a complete plan.

Alternative 4. Channelization: This plan would account for all necessary investments or other actions to ensure the realization of the planned effects. Thus, Alternative 4 represents a complete plan.

3.5.3.2 Effectiveness

Alternative 0. No Action: No Action would not reduce inundation—and thus would not reduce risks or damages to—structures within the floodplain. No Action would not reduce inundation of transportation infrastructure. Inundation depths greater than two feet affect both structures and roads during the 0.1 AEP flood event under the No Action alternative. There would be no reduction in life safety risks associated with inundation of structures or roads under the No Action alternative. The No Action alternative would not benefit recreational or environmental resources, including floodplain areas. Through the course of the feasibility study, however, there would be improved community awareness of flood risk under the No Action alternative.

Alternative 1. Levee/Floodwall System: Alternative 1 would reduce inundation risk to both structures and roads within the communities of Dos Rios and Alturas de Ciales. Structures and roads within the project footprint experience inundation depths of greater than two feet during the 0.01 AEP event. However, there would be no change in the risk of inundation to structures and roads outside of the project footprint. Structures and roads outside of the project footprint experience inundation depths of greater than two feet at the 0.1 AEP and 0.04 AEP, events respectively. Thus, Alternative 1 would reduce both damages and life safety risk associated with inundation of structures and would improve continuity of transportation during and following flood events. Alternative 1 would not restore natural floodplains and would disconnect the river from its floodplain in the project footprint. Reducing inundation of the wastewater treatment plant up to the 0.04 AEP would provide some environmental benefit through improved water quality. This alternative would not result in realized recreational benefits. The study and construction of Alternative 1, as well as the development and implementation of the associated floodplain management plan would improve community awareness of flood risk.

Alternative 2. Channel Modification: Alternative 2 would reduce inundation risk to both structures and roads. Inundation depths for structures within the communities of Dos Rios and Alturas de Ciales remain below two feet during the 0.1 AEP event. Several structures throughout the remainder of the study area would be inundated prior to the 0.1 AEP event. Inundation depths for roads throughout the study area would remain below two feet during the 0.1 AEP event. Thus, Alternative 2 would reduce both damages and life safety risk associated with inundation of structures and would improve continuity of transportation during and following flood events. Alternative 2 would improve floodplain connectivity and would thus restore natural floodplain structure and processes; however, the newly constructed channel would result in impacts to aquatic habitat. Reducing inundation of the wastewater treatment plant up to the 0.04 AEP would provide some environmental benefit through improved water quality. This alternative would not result in realized recreational benefits. The study and construction of

Alternative 2, as well as the development and implementation of the associated floodplain management plan would improve community awareness of flood risk.

Alternative 3. Non-Structural Relocations: Alternative 3 would effectively eliminate all inundation risk for all 59 structures located within the 0.04 AEP floodplain throughout the entire study area. Alternative 3 would not alter inundation of roads, which would continue to experience inundation depths great than two feet prior to the 0.1 AEP event. Thus, Alternative 3 would reduce both damages and life safety risk associated with inundation of structures. Relocation of structures from and replanting vegetation within the 0.04 AEP floodplain would result in restoration of natural floodplain structure and processes and potentially offer recreational opportunities. Reducing inundation of the wastewater treatment plant up to the 0.04 AEP would provide further environmental benefit through improved water quality. The study and construction of Alternative 3, as well as the development and implementation of the associated floodplain management plan would improve community awareness of flood risk.

Alternative 4. Channelization: Alternative 4 would reduce inundation risk to both structures and roads. Inundation depths for structures within the communities of Dos Rios and Alturas de Ciales remain below two feet during the 0.04 AEP event. Several structures throughout the remainder of the study area flood prior to the 0.04 AEP event. Inundation depths for roads throughout the study area would remain below two feet during the 0.04 AEP event. Thus, Alternative 4 would reduce both damages and life safety risk associated with inundation of structures and would ensure continuity of transportation during and following flood events. Alternative 4 would not improve floodplain structure or function. Reducing inundation of the wastewater treatment plant up to the 0.04 AEP would provide some environmental benefit through improved water quality; however, the construction of a concrete channel would result in permanent loss of aquatic and riparian habitat and impact water quality (e.g., warming). This alternative would not result in realized recreational benefits. The study and construction of Alternative 4, as well as the development and implementation of the associated floodplain management plan would improve community awareness of flood risk.

A summary of the effectiveness of each alternative with respect to addressing the specified problems and realizing the opportunities is provided below in Table 3-5.

Table 3-5. The effectiveness of each alternative with respect to addressing the specified problems and realizing the specified opportunities. Green = positive effect in terms of addressing the problem and realizing the opportunity; yellow = no effect; red = negative effect.

Problem/ Opportunity	Alt 0: No Action	Alt 1: Levee/ Floodwall	Alt 2: Channel Modification	Alt. 3 Relocation	Alt. 4: Channel-ization
Problem					
Elevated risk to structures	No effect	Positive effect	Positive effect	Positive effect	Positive effect
Inundation of roads	No effect	Positive effect	Positive effect	No effect	Positive effect

Problem/ Opportunity	Alt 0: No Action	Alt 1: Levee/ Floodwall	Alt 2: Channel Modification	Alt. 3 Relocation	Alt. 4: Channel-ization
Opportunity					
Reduced risk of inundation	No effect	Positive effect	Positive effect	Positive effect	Positive effect
Continuity of transportation	No effect	Positive effect	Positive effect	No effect	Positive effect
Improved life safety	No effect	Positive effect	Positive effect	Positive effect	Positive effect
Floodplain restoration	No effect	Negative effect	Positive effect	Positive effect	Negative effect
Environmental improvement (Water Quality)	No effect	Positive effect	Positive effect	Positive effect	Negative effect
Environmental Improvement (Habitat)	No effect	Negative effect	Negative effect	Positive effect	Negative effect
Recreational opportunities	No effect	No effect	No effect	Positive effect	No effect
Community awareness	Positive effect	Positive effect	Positive effect	Positive effect	Positive effect

3.5.3.3 Efficiency

Alternative 0. No Action: No Action would not produce any benefits associated with damages to structures or transportation infrastructure.

Alternative 1. Levee/Floodwall System: Alternative 1 results in approximately in negative net annual benefits ($-454,000) and is, thus, not economically justified.

Alternative 2. Channel Modification: Alternative 2 results in approximately in negative net annual benefits ($-3,884,000) and is, thus, not economically justified.

Alternative 3. Non-Structural Relocations: Alternative 3 results in positive net annual benefits ($217,000) and is, thus, economically justified.

Alternative 4. Channelization: Alternative 4 results in approximately in negative net annual benefits ($-4,036,000) and is, thus, not economically justified.

3.5.3.4 Acceptability

Alternative 0. No Action: No Action would not violate any existing laws, regulations, and public policies. However, No Action would not be preferred by local and commonwealth stakeholders. Despite local preferences, No Action would be an acceptable alternative per the definition provided in Section 3.5.3.

Alternative 1. Levee/Floodwall System: Alternative 1 would not violate any existing laws, regulations, and public policies. The original flood protection works plan was accepted by the Municipality and local residents. However, following Hurricane Maria and subsequent relocation of all public housing within the study area, the majority of private homeowners would prefer to relocate rather than implement a structural option such as the floodwall/levee system. Despite local preferences, Alternative 1 would be an acceptable alternative per the definition provided in Section 3.5.3.

Alternative 2. Channel Modification: Alternative 2 would not violate any existing laws, regulations, and public policies. The relatively limited level of protection (i.e., reduced inundation and loss of access/evacuation up to 0.1 AEP) would likely limit local acceptance of this plan. Moreover, following Hurricane Maria and subsequent relocation of all public housing within the study area, more private homeowners would prefer to relocate rather than implement a structural option such as the floodwall/levee system. Despite local preferences, Alternative 2 would be an acceptable alternative per the definition provided in Section 3.5.3.

Alternative 3. Non-Structural Relocations: Alternative 3 would not violate any existing laws, regulations, and public policies. Feedback and input received during the public scoping meeting indicated that relocation is the action preferred by the majority of local residents. Alternative 3 would be an acceptable alternative per the definition provided in Section 3.5.3.

Alternative 4. Channelization: Alternative 4 would not violate any existing laws, regulations, and public policies. Following Hurricane Maria and subsequent relocation of all public housing within the study area, more private homeowners would prefer to relocate rather than implement a structural option such as channelization. Despite local preferences, Alternative 4 would be an acceptable alternative per the definition provided in Section 3.5.3.

3.5.3.5 Criteria Summary & Comparison

This section summarizes and compares alternatives with respect to the four criteria.

Completeness: Alternatives 1 (Levee/Floodwall System), 2 (Channel Modification), 3 (Non-Structural Relocations), and 4 (Channelization) are complete in that they account for all necessary investments or other actions to ensure the realization of the planned effects (Table 3-6). Alternative 0 (No Action) is incomplete because it would rely completely on local action, which is unlikely (Table 3-6).

Effectiveness: Alternatives 1 (Levee/Floodwall System), 2 (Channel Modification), 3 (Non-Structural Relocations), and 4 (Channelization) are all effective in that they would—to some extent—address one or more of the problems while achieving one or more of the objectives (Table 3-6). Alternative 0 (No Action) would not be effective because it would not address any of the specified problems (Table 3-6).

Efficiency: Alternative 3 (Non-Structural Relocations) is the only alternative to have positive net benefits and, thus, is the only economically justifiable alternative (Table 3-6). Alternatives 1 (Levee/Floodwall System), 2 (Channel Modification), and 4 (Channelization) all have negative net benefits and are not economically justified (Table 3-6).

Acceptability: All alternatives would be compliant with existing laws, regulations, and public policies. Based on feedback received during public outreach meetings, Alternative 3 (Non-Structural Relocations) is preferred by the local community over No Action (Alternative 0) and all structural alternatives (Alternatives 1, 2, and 4; yellow). Despite local preferences, all alternatives would be acceptable.

Table 3-6. Comparison of alternatives with respect to the four criteria established in the Principles and Guidelines (USACE 1983). Green = meeting the criteria; yellow = no effect or mixed effects; red = not meeting criteria.

Criteria	Alt 0: No Action	Alt 1: Levee & Floodwall	Alt 2: Channel Modification	Alt. 3: Relocation	Alt. 4: Channelization
Completeness	Incomplete	Complete	Complete	Complete	Complete
Effectiveness	Ineffective	Effective	Effective	Effective	Effective
Efficiency	No net benefits	Negative net benefits	Negative net benefits	Positive net benefits	Negative net benefits
Acceptability	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

3.5.4 Ability to Meet Planning Objectives

This section describes how, and the extent to which, each alternative meets the two planning objectives.

3.5.4.1 Objective 1: Reduce risks to life safety associated with inundation of structures, as well as transportation routes required for evacuation and post-flood recovery within Dos Rios, Ciales Pueblo, and Alturas de Ciales over the next 50 years

The extent to which life and safety risk is reduced varies among alternatives as described below:

Alternative 0. No Action: Life safety risk would not be reduced under the No Action alternative.

Alternative 1. Levee/Floodwall System: The floodwall/levee system would reduce inundation and associated life and safety risk to structures within the communities of Dos Rios and Alturas de Ciales up to the 0.01 AEP flood event. There would be no change in inundation risk for at-risk structures outside of the project footprint. The floodwall/levee system would ensure continuity of transportation (i.e., Inundation depths on roads less than two feet) throughout the study area up to the 0.04 AEP event.

Alternative 2. Channel Modification: Channel modification would reduce inundation and associated life and safety risk up to the 0.1 AEP event. However, considerable residual risk remains for floods exceeding the 0.1 AEP event. Channel modification would ensure continuity of transportation (i.e., Inundation depths on roads less than 2 feet) up to the 0.1 AEP.

Alternative 3. Non-Structural Relocations: Non-structural relocations would eliminate inundation and associated life and safety risk associated with the 59 structures in the 0.04 AEP floodplain within the communities of Dos Rios, Ciales Pueblo, and Alturas de Ciales. There would be residual risk to structures outside of the 0.04 AEP floodplain. Non-structural relocations would not affect life and safety risk associated with inundation of access and evacuation routes.

Alternative 4. Channelization: Channelization would reduce inundation and associated life and safety risk within the communities of Dos Rios, Ciales Pueblo, and Alturas de Ciales up to the 0.04 AEP flood event. There would be residual risk to structures outside of the 0.04 AEP floodplain. Channelization would ensure continuity of transportation (i.e., Inundation depths on roads less than 2 feet) up to the 0.04 AEP.

3.5.4.2 Objective 2: Reduce risk of flood damage to structures and public infrastructure within the communities of Dos Rios, Ciales Pueblo, and Alturas de Ciales over the next 50 years

The extent to which damages are reduced varies among alternatives as described below:

Alternative 0. No Action: Flood damages would not be reduced under the No Action alternative.

Alternative 1. Levee/Floodwall System: The floodwall/levee system would reduce annual flood damages by an estimated $703,000. This includes a reduction in damages to private homes and businesses, as well as the wastewater treatment plant.

Alternative 2. Channel Modification: Channel modification would reduce annual flood damages by an estimated $406,000. This includes a reduction in damages to private homes and businesses, as well as the wastewater treatment plant.

Alternative 3. Non-Structural Relocations: Non-structural relocations would reduce annual flood damages by an estimated $947,000. This includes a reduction in damages to private homes and businesses, as well as the wastewater treatment plant.

Alternative 4. Channelization: Channelization would reduce annual flood damages by an estimated $848,000. This includes a reduction in damages to private homes and businesses, as well as the wastewater treatment plant.

3.5.4.3 Ability to Meeting Planning Objectives Summary & Comparison

Objective 1: All four action alternatives would result in decreased life safety risk associated with inundation of structures and/or roadways and, thus, would meet objective 1.

Objective 2: All four action alternatives would result in reduced damages associated with both inundation of structures and/or roadways and, thus, would meet objective 2.

3.5.5 Risk & Uncertainty

Authority and policy constraints prohibit the study, recommendation, and implementation of measures designed to reduce damages to transportation infrastructure and associated life safety risk resulting from flood-induced bank failure and bridge scour along the Rio Grande de Manati. Thus, there would be risk of economic damages and reduced life safety associated with bank/bridge failure under all alternatives, both now and into the future. There is also a great deal of uncertainty regarding whether or not such measures would be implemented by another local, commonwealth, or federal entity. Loss of transportation due to bank/bridge failure could impact the realization of expected benefits under each alternative (e.g., life safety benefits resulting from a reduction in roadway inundation could be negated if a bridge or road would fail).

3.5.5.1 Residual Risk

Residual risk represents existing, future, or historical risk that remains or might remain after a plan has been implemented. The following residual risks have been identified for each alternative:

Alternative 0. No Action: Risk would be unchanged under the No Action alternative.

Alternative 1. Levee/Floodwall System: There would be residual inundation and associated life and safety risks for structures within the communities of Dos Rios and Alturas de Ciales during floods that exceed 0.01 AEP event. Risk to structures outside of the project footprint would be unchanged. Transportation infrastructure would continue to be inundated during floods that exceed the 0.04 AEP event, resulting in residual risk to residents and communities both inside and outside of the project footprint that rely on potentially inundated roadways for evacuation and access to critical services. The timing of flood inundation and warnings associated with the

most extreme hurricane-induced flood events lessens life and safety risk to some extent. However, the project could result in transformed risk (i.e., the nature of or exposure to the flood hazard has been altered) during flood events that exceed the 0.01 AEP event due to a perception of increased security that causes residents to delay or completely forego evacuation. For example, this system would have been overtopped during Hurricane Maria.

Alternative 2. Channel Modification: There would be residual inundation and associated life and safety risks for all structures during floods that exceed 0.1 AEP event. Transportation infrastructure would continue to be inundated during floods that exceed the 0.1 AEP event, resulting in residual risk to residents and communities both inside and outside of the project footprint that rely on potentially inundated roadways for evacuation and access to critical services. The timing of flood inundation and warnings associated with the most extreme hurricane-induced flood events lessens life and safety risk to some extent. However, the project could result in transformed risk and associated increased life safety risks during flood events that exceed the 0.1 AEP event due to a perception of increased security that causes residents to delay or completely forego evacuation.

Alternative 3. Non-Structural Relocations: Alternative 3 would completely eliminate flood risk for properties within the 0.04 AEP floodplain. There would be no change in flood risk for residents outside of the 0.04 AEP floodplain. Thus, there would be residual inundation and life safety risks to structures outside of the 0.04 AEP floodplain. This alternative would not alter inundation of transportation infrastructure—which occurs during the 0.1 AEP flood event—resulting in residual risk to residents and communities both inside and outside of the project footprint that rely on potentially inundated roadways for evacuation and access to critical services. The timing of flood inundation and warnings associated with the most extreme hurricane-induced flood events lessens life and safety risk to some extent.

Alternative 4. Channelization: There would be residual inundation and associated life and safety risks for all structures during floods that exceed 0.04 AEP event. There would also be residual risk associated with inundation of transportation infrastructure during floods that exceed the 0.04 AEP event. The timing of flood inundation and warnings associated with the most extreme hurricane-induced flood events lessens life and safety risk to some extent. However, the project could result in transformed risk and associated increased life safety risks during flood events that exceed the 0.04 AEP event due to a perception of increased security that causes residents to delay or completely forego evacuation.

3.5.5.2 Residual Risk Due to Climate Change

In accordance with USACE policy and guidance (USACE 2018), potential effects of and uncertainty associated with climate change were assessed over a 100-year period. Changes in flood risk over that timeframe may impact the performance, operation, and maintenance of each alternative.

Alternative 0. No Action: Increases in extreme precipitation projected to occur throughout the 21st century (USACE, 2015) would result in increased flood damages and life safety risk associated with inundation under the No Action plan. Similarly, the frequency with which roadways become inundated under this alternative—the 0.1 AEP as currently characterized—could increase, elevating life and safety risk for individuals both within and outside of the project area that depend on inundated roads for evacuation and access to critical facilities.

Alternative 1. Levee/Floodwall System: Increases in frequency and/or magnitude of extreme precipitation events projected to occur throughout the 100-year project life could increase residual inundation and life and safety risks for structures within the project footprint by increasing the frequency and extent to which the 0.01 AEP flood event as currently characterized is exceeded. The frequency and extent to which the floodwall around the wastewater treatment plant is overtopped could also increase, resulting in elevated residual risk to environmental resources and public health. Structures outside of the project footprint would see increases in residual risk similar to those expected under the No Action alternative. Similarly, the frequency with which roadways become inundated under this alternative—the 0.04 AEP as currently characterized—could increase, elevating life and safety risk for individuals both within and outside of the project area that depend on inundated roads for evacuation and access to critical facilities. Increased water volume and/or velocities could increase OMRR&R requirements for all project components.

Alternative 2. Channel Modification: Increases in frequency and/or magnitude of extreme precipitation events projected to occur throughout the 100-year project life could increase residual inundation and life and safety risks for structures throughout the study area by increasing the frequency and extent to which the 0.1 AEP flood event as currently characterized is exceeded. The frequency and extent to which the floodwall around the wastewater treatment plant is overtopped could also increase, resulting in elevated residual risk to environmental resources and public health. Similarly, the frequency with which roadways become inundated under this alternative—the 0.1 AEP as currently characterized—could increase, elevating life and safety risk for individuals both within and outside of the project area that depend on inundated roads for evacuation and access to critical facilities. Changing hydrology could alter erosion and sedimentation rates, affecting project performance (i.e., decreased capacity) and OMRR&R requirements. Increased water volume and/or velocities could increase OMRR&R requirements for the wastewater treatment plant floodwall.

Alternative 3. Non-Structural Relocations: Relocations would continue to have zero risk under a changing climate. Increases in extreme precipitation projected to occur throughout the 100-year project life would increase residual risk associated with inundation of structures not included in the relocation. Similarly, the frequency with which roadways become inundated under this alternative—the 0.1 AEP as currently characterized—could increase, elevating life and safety risk for individuals both within and outside of the project area that depend on inundated roads for evacuation and access to critical facilities. The frequency and extent to which the floodwall

around the wastewater treatment plant is overtopped could also increase, resulting in elevated residual risk to environmental resources and public health.

Alternative 4. Channelization: Increases in frequency and/or magnitude of extreme precipitation events projected to occur throughout the 100-year project life could increase residual inundation and life and safety risks for structures throughout the study area by increasing the frequency and extent to which the 0.04 AEP flood event as currently characterized is exceeded. Similarly, the frequency with which roadways become inundated under this alternative—the 0.4 AEP as currently characterized—could increase, elevating life and safety risk for individuals both within and outside of the project area that depend on inundated roads for evacuation and access too critical facilities. Changing hydrology could alter erosion and sedimentation rates, affecting project performance (i.e., decreased capacity) and OMRR&R requirements.

3.5.5.3 Uncertainty

Identifying and managing risk is critical to making informed planning decisions in the face of uncertainty. However, some level of uncertainty will remain following any decision. Understanding and characterizing this remaining uncertainty is also critical as it can affect the outcome of any decision. This section characterizes uncertainty under each alternative.

Alternative 0. No Action: Alternative 0 (No Action) has large uncertainty as it completely relies on action by other entities.

Alternative 1. Levee/Floodwall System: Long-term sustainability of risk reduction is dependent on sustained OMRR&R throughout the life of the project. Current local and regional economic conditions limit the Sponsor's ability to conduct necessary OMRR&R requirements. Limited time (i.e., 24-month study), resources (i.e., $1.2M in total study costs), and data (e.g., post-Maria LiDAR and geotechnical data) limit capacity for feasibility-level design and increase uncertainty in estimated costs. Increased cost could be realized during pre-construction engineering and design.

Alternative 2. Channel Modification: Long-term sustainability of risk reduction is dependent on sustained OMRR&R throughout the life of the project. Current local and regional economic conditions limit the Sponsor's ability to conduct necessary OMRR&R requirements. There is elevated potential for cultural resources and/or wetland impacts due to construction of the low-flow channel. Limited time (i.e., 24-month study), resources (i.e., $1.2M in total study costs), and data (e.g., post-Maria LiDAR and geotechnical data) precluded full cultural resources and wetlands surveys from being conducted. If wetland or cultural resources are significantly impacted, mitigation may be required in order to be compliant with environmental laws and regulations. Limited time and funding also limited the capacity for feasibility-level design during the feasibility study, resulting in increased uncertainty in the study costs. Increased cost could be realized during pre-construction engineering and design.

Alternative 3. Non-Structural Relocations: Many of the structures being considered for relocation were constructed over 50 years ago, making them eligible for consideration as historical properties. Limited time (i.e., 24-month study) and resources (i.e., $1.2M in total study costs) precluded a full cultural resource survey. Mitigation may be required to offset impacts to potentially historic properties being relocated.

Alternative 4. Channelization: Long-term sustainability of risk reduction is dependent on sustained OMRR&R throughout the life of the project. Current local and regional economic conditions limit the Sponsor's ability to conduct necessary OMRR&R requirements. There is elevated potential for cultural resources and/or wetland impacts due to construction of the low-flow channel. Limited time (i.e., 24-month study), resources (i.e., $1.2M in total study costs), and data (e.g., post-Maria LiDAR and geotechnical data) precluded full cultural resources and wetlands surveys from being conducted. If wetland or cultural resources are significantly impacted, mitigation may be required in order to be compliant with environmental laws and regulations. Limited time and funding also limited the capacity for feasibility-level design during the feasibility study, resulting in increased uncertainty in the study costs. Increased cost could be realized during pre-construction engineering and design.

3.5.5.4 Risk & Uncertainty Summary & Comparison

Residual Risk: The level of residual risk varies across all alternatives. Alternative 1 (Levee/Floodwall System) results in the least residual risk to structures and roadways within the Dos Rios and Alturas de Ciales; however, it only reduces risk in the project footprint and would result in transformed risk behind the floodwall/levee system. Alternative 2 (Channel Modification) results in the greatest residual risk throughout the study area. Alternatives 3 (Non-Structural Relocation) results in consistent residual risk to structures throughout the study area outside of the 0.04 AEP floodplain and results in the most residual risk of roadway inundation. Alternative 4 (Channelization) results in a consistent level of residual risk to structures throughout the study area that is similar to Alternative 3. Alternatives 1 (Levee/Floodwall System), 2 (Channel Modification), and 4 (Channelization) could provide a sense of security that causes residents to forgo or delay evacuation, thereby increasing residual life and safety risk.

Residual Risk Due to Climate Change: All alternatives will experience changes to residual risk resulting from projected increases in large rain and flood events (USACE, 2015). Climate change could increase the magnitude and frequency of events that exceed the capacity of individual management measures, including the levee/floodwall system (0.01 AEP event; Alternative 1), channel modification (0.1 AEP; Alternative 2), channelization (0.04 AEP; Alternative 4), and non-structural relocations (0.04 AEP; Alternative 3). Increased magnitude and frequency of flood events could increase the need for OMRR&R for structural measures, resulting from increased water velocities and debris and/or sedimentation and decreased capacity.

Uncertainty: Alternative 0 has the greatest overall uncertainty because it relies completely on non-federal action to reduce flood risk. Alternatives 2 (Channel Modification), 3 (Non-Structural Relocations), and 4 (Channelization) have the greatest uncertainty regarding potential impacts to unknown wetland and cultural resources. Alternatives 1 (Floodwall/Levee System), 2 (Channel Modification), and 4 (Channelization) have the greatest uncertainty regarding the sponsor's ability to complete OMRR&R required to ensure sustained project benefits. Alternative 3 has the least amount of uncertainty regarding sustained benefits of flood risk reduction measures as risk to relocated structures is permanently removed and requires no future action.

3.6 Environmental Effects *

This section presents effects on environmental resource categories associated with implementing each of the alternatives included in the final array. The evaluation of effects is based on a comparison of anticipated status of each resource category under the with- and without-project (see Section 2 for description of resources under the without project condition) conditions and distinguishes between adverse and beneficial effects. The presentation of resource categories within this section matches those presented in Section 2. The terms "impact", and "effect" are used interchangeably in this chapter. Effects may be direct, indirect, and/or cumulative. Direct effects result from an action and occur at the same time and place. Indirect effects result from an action, are reasonably foreseeable, and may occur at a later time or a distance away from the action. Cumulative effects result from the collection of federal and non-federal actions taking place over the same period of time (See Section 5.3.1 for discussions on cumulative effects). Effects may be temporary (occurring during the period of construction) or permanent (remaining for years into the future). Effects may be beneficial (positive) or adverse (negative). The term "significant" means that the effects would result in a substantial change to the environment or resource. Minor effects do not substantially change the environment or resource. Direct and indirect effects were considered for each of the environmental resource categories. Effects described below are direct effects unless specifically indicated otherwise.

3.6.1 Climate

None of the alternatives have implications for affecting the current or future climate.

3.6.2 Flood Risk

3.6.2.1 Hydrologic Characteristics and Tidal Influences

Alternative 1. Levee/Floodwall System: Temporary, minor effects to hydrology would be expected during construction activities resulting from cofferdam placement (or other stream

diversion method) with this alternative. Portions of the Rio Grande de Manati may need to be diverted away from work areas with cofferdams or by other means, which would slightly impact hydrology in the area during construction. Permanent, minor changes in hydrology would occur with the widening of the channel resulting from the increase in channel capacity. No significant impacts to hydrology are expected.

Alternative 2. Channel Modification: With this alternative, temporary effects to hydrology would be expected during construction activities. Portions of the Rio Grande de Manati may need to be diverted away from work areas with cofferdams or by other means, which would slightly impact hydrology in the area during construction. Permanent effects would include an increase in channel capacity resulting from the widening and deepening of the existing channel and the construction of the low flow channel. Permanent changes to surface water velocities would be expected within the channel improvement and realignment sections. Direct and indirect effects downstream would result from changes in hydrology in the study area. Minor localized impacts to hydrology may occur; however, there would be no significant impact at the regional- or watershed-scale.

Alternative 3. Non-Structural Relocations: With this alternative, minor and localized effects to hydrology in the Rio Grande de Manati would be expected. Demolition and removal of homes would result in a reduction in impervious surface and increase in infiltration. Demolition and removal of homes would also have minor effects on flood inundation depths and water velocities. Minor localized impacts to hydrology may occur; however, there would be no significant impact at the regional- or watershed-scale.

Alternative 4. Channelization: The channelization alternative would widen and deepen the existing channel increasing channel capacity and surface water velocities. The concrete lined channel would reduce groundwater contributions to the Rio Grande de Manati along the 9,000 linear foot reach of trapezoidal channel. An increase in surface water velocities would extend downstream of the study area impacting hydrology outside of the study area. This change could significantly cause direct and indirect impacts to resources immediately downstream of the study area.

3.6.2.2 Flood Damage

Alternative 1. Levee/Floodwall System: The HEC-RAS and HEC-FDA model output indicates this alternative would reduce flood risk for homes, businesses, and public facilities (i.e., wastewater treatment plant) up to the 0.01 AEP event. Businesses and public facilities would continue to be strongly impacted during larger flood events.

Alternative 2. Channel Modification: The HEC-RAS and HEC-FDA model output indicates this alternative, as currently developed, would reduce flood risk up to the 0.1 AEP event. Residual risk

would exist for homes, businesses, and public facilities (i.e., wastewater treatment plant) during floods that exceed the 0.1AEP event.

Alternative 3. Non-Structural Relocations: The HEC-RAS and HEC-FDA model output indicates this alternative would effectively eliminate flood risk for homes and businesses within the 0.04 AEP event—providing these individuals the opportunity to relocate to areas with zero flood risk. There would be no change in risk for homes, businesses, and public facilities (i.e., wastewater treatment plant) outside of the 0.04 AEP floodplain.

Alternative 4. Channelization: The HEC-RAS and HEC-FDA model output indicates this alternative would reduce flood risk up to the 0.04 AEP event. Residual risk would remain for homes, businesses, and public facilities (i.e., wastewater treatment plant) during floods that exceed the 0.04 AEP event. Increased stream velocities could increase scour at the downstream PR-6685 Bridge resulting in further deterioration of bridge structure.

3.6.2.3 Life Safety Risk

Each of the four alternatives would result in reduced life and safety risk associated with both direct inundation and loss of key access and evacuation routes.

Alternative 1. Levee/Floodwall System: This alternative would reduce life and safety risk associated with direct inundation of structures and major access (e.g., post-flood recovery) and evacuation (e.g., evacuation and/or access to critical facilities) routes within the communities of Dos Rios and Alturas de Ciales up to the 0.01 AEP event. There would be transformed risk as a result of altered flood risk behind the floodwall and levee system.

Alternative 2. Channel Modification: This alternative would reduce life and safety risk associated with direct inundation of structures and major access (e.g., post-flood recovery) and evacuation (e.g., evacuation and/or access to critical facilities) routes up to the 0.01 AEP event throughout the study area.

Alternative 3. Non-Structural Relocations: This alternative would effectively eliminate life and safety risk associated with direct inundation of structures located within the 0.04 AEP event floodplain throughout the study area.

Alternative 4. Channelization: This alternative would reduce life and safety risk associated with direct inundation of structures and major access (e.g., post-flood recovery) and evacuation (e.g., access to critical facilities) routes up to the 0.04 AEP event throughout the study area.

3.6.3 Earth Resources

3.6.3.1 Geology & Topography

Alternative 1. Levee/Floodwall System: Alternative 1 (Levee/Floodwall System) would not significantly alter the local geology or topography.

Alternative 2. Channel Modification: Alternative 2 (Channel Modification) would alter the topography in the affected area. A portion of the excavated material would remain on site to form the new channel. However, this change would not significantly alter the local geology or topography.

Alternative 3. Non-Structural Relocations: Alternative 3 (Non-Structural Relocations) would not significantly alter the local geology or topography.

Alternative 4. Channelization: Channelization would alter the channel geometry and associated topography throughout the study area. However, this change would not significantly alter the local geology or topography.

3.6.3.2 Soils

Alternative 1. Levee/Floodwall System: Permanent removal of soils in the area of the retention pond, for the floodwall footer, and in the portion of channel proposed for channel widening would occur with this alternative. The area of channel widening may impact approximately six acres of soils classified as prime farmland adjacent to the existing Rio Grande de Manati riverbanks, which is approximately 4% of the area of prime farmland located within the study area. Temporary impacts to soil during construction activities would also be expected. No significant impacts to soils or prime farmland are expected.

Alternative 2. Channel Modification: Permanent removal of soils in areas of channel widening and deepening would occur with this alternative. There would be a permanent loss of soil in the area of channel realignment. The channel realignment would impact approximately 8 acres of soils classified as prime farmland, which is approximately 5% of the area of prime farmland located within the study area. Minor permanent impacts to soil would occur in the area of floodwall. No significant impacts to soils or prime farmland are expected.

Alternative 3. Non-Structural Relocations: Some excavation of soils would occur in the area of the floodwall around the wastewater treatment plant. Disturbed areas would be restored upon completion of construction. Minor temporary impacts to soil may occur during removal of homes proposed for buyouts. While homes do not have basements, removal of foundation pads may temporarily impact the soil surface; however soils in these areas would be restored and replanted. No significant impacts to soils are expected.

Alternative 4. Channelization: Channelization would reduce soil erosion in the areas of the concrete lined channel with this alternative. Increased soil erosion and stream bank destabilization downstream of the concrete channel would occur resulting from increased velocities of stream flow. Permanent removal of soils within the channel would occur with the channel deepening and widening. No significant impacts to soils are expected.

3.6.3.3 Air Quality

Alternative 1. Levee/Floodwall System: This alternative would result in temporary minor increases in emissions from construction equipment during construction. Emissions would be *de minimis*. Air quality would be expected to return to pre-construction conditions following completion of construction activities. No adverse impacts to air quality are expected with this alternative.

Alternative 2. Channel Modification: This alternative would result in temporary minor increases in emissions from construction equipment during construction. Emissions would be *de minimis*. Air quality would be expected to return to pre-construction conditions following completion of construction activities. No adverse impacts to air quality are expected with this alternative.

Alternative 3. Non-Structural Relocations: This alternative would result in temporary minor increases in emissions from construction equipment during construction. Emissions would be *de minimis*. Temporary impacts to air quality may occur during building demolitions. Air quality would be expected to return to pre-construction conditions following completion of construction and demolition activities. Testing and appropriate abatement measures would be implemented as necessary to avoid any adverse impacts to air quality (see Section 3.6.6.2, Hazardous, Toxic, & Radioactive Wastes for further detail). No adverse impacts to air quality are expected with this alternative.

Alternative 4. Channelization: This alternative would result in temporary minor increases in emissions from construction equipment during construction. Emissions would be *de minimis*. Air quality would be expected to return to pre-construction conditions following completion of construction activities. No adverse impacts to air quality are expected with this alternative.

3.6.4 Water Resources

3.6.4.1 Water Quality

Alternative 1. Levee/Floodwall System: Section 401 water quality certification would be obtained from the Puerto Rico Department of Natural and Environmental Resources. Temporary increases in sedimentation and turbidity are expected during construction. Best management practices would be employed to minimize impacts. The floodwall around the wastewater treatment plant

would provide a long-term benefit to water quality by reducing or eliminating raw sewage discharges to the river that occur during flooding events. No significant impacts to water quality are expected with this alternative.

Alternative 2. Channel Modification: Section 401 water quality certification would be obtained from the Puerto Rico Department of Natural and Environmental Resources. Temporary increases in sedimentation and turbidity are expected during construction. Best management practices would be employed to minimize impacts. The floodwall around the wastewater treatment plant would provide a long-term benefit to water quality by reducing or eliminating raw sewage discharges to the river that occur during flooding events. No significant impacts to water quality are expected with this alternative.

Alternative 3. Non-Structural Relocations: Section 401 water quality certification would be obtained from the Puerto Rico Department of Natural and Environmental Resources. Temporary increases in sedimentation and turbidity are expected during construction. Best management practices would be employed to minimize impacts. The floodwall around the wastewater treatment plant would provide a long-term benefit to water quality by reducing or eliminating raw sewage discharges to the river that occur during flooding events. Removal of structures and planting of native vegetation within the floodplain would reduce runoff and increase infiltration, improving downstream water quality. No significant impacts to water quality are expected with this alternative.

Alternative 4. Channelization: Section 401 water quality certification would be obtained from the Puerto Rico Department of Natural and Environmental Resources. Permanent temperature changes are expected from the construction of the concrete lined channel. Decreased sedimentation and turbidity are expected within the area of the concrete lined channel; however, increased sedimentation and turbidity would occur downstream of channelization resulting in both direct and indirect effects. Channelization would result in a reduction in residence time where excess nutrients may be processed, which may exacerbate current water quality impairments for nutrients (nitrogen and phosphorus). No significant impacts to water quality are expected with this alternative.

3.6.4.2 Riverine & Floodplain Habitats

Alternative 1. Levee/Floodwall System: The levee/floodwall system would permanently disconnect floodplain habitat from the river. No significant impacts to riverine habitat are expected.

Alternative 2. Channel Modification: Temporary impacts to riverine habitat would occur during construction activities with conditions in the main stem of the Rio Grande de Manati expected to return to pre-construction levels once construction activities are complete. Permanent impacts

to riverine habitats would occur within the Rio Grande de Manati due to the construction of the new low flow channel. No significant impacts to riverine habitat are expected.

Alternative 3. Non-Structural Relocations: No significant impacts to riverine habitat are expected. Alternative 3 would result in permanent benefits to floodplain habitat. Properties included in the relocation would be permanently cleared and planted with native floodplain vegetation. All future development would be prohibited.

Alternative 4. Channelization: The change from natural riverbed to a concrete lined channel would result in the permanent loss of 9,000 linear feet of aquatic habitat. Channelization also negatively impacts aquatic resources both upstream and downstream of the channelized area and permanent adverse impacts both upstream and downstream of the study area are expected with this alternative. Channelization would result in significant adverse impacts to aquatic resources within and outside (i.e., upstream and downstream) of the study area. Direct and indirect effects to aquatic resources would be expected with this alternative. Mitigation for permanent impacts would be required.

3.6.4.3 Wetland Habitat

Alternative 1. Levee/Floodwall System: A wetland delineation would be completed in PED. If wetlands are present in any of the areas where earth disturbance or fills are proposed (levee, retention pond, channel widening, floodwall), temporary and/or permanent impacts may occur. If wetlands were to be impacted, supplemental NEPA documentation that includes a mitigation plan would be developed. Mitigation for permanent wetland impacts would be required. Restoration of any temporary wetland impacts would be required and would include best management practices of separating and stockpiling hydric soils and reseeding wetland areas with native wetland seed mix to restore wetlands to pre-construction conditions. No significant impacts to wetlands are expected.

Alternative 2. Channel Modification: A wetland delineation would be completed in PED. If wetlands are present in any of the areas where earth disturbance or fills are proposed (channel widening, new channel construction, floodwall), temporary and/or permanent impacts may occur. If wetlands were to be impacted, supplemental NEPA documentation that includes a mitigation plan would be developed. Mitigation for permanent wetland impacts would be required. Restoration of any temporary wetland impacts would be required and would include best management practices of separating and stockpiling hydric soils and reseeding wetland areas with native wetland seed mix to restore wetlands to pre-construction conditions. No significant impacts to wetlands are expected.

Alternative 3. Non-Structural Relocations: A wetland delineation would be completed in PED. If wetlands are present in any of the areas where earth disturbance or fills are proposed (floodwall), temporary and/or permanent impacts may occur. If wetlands were to be impacted, supplemental

NEPA documentation that includes a mitigation plan would be developed. Mitigation for permanent wetland impacts would be required. Restoration of any temporary wetland impacts would be required and would include best management practices of separating and stockpiling hydric soils and reseeding wetland areas with native wetland seed mix to restore wetlands to pre-construction conditions. No significant impacts to wetlands are expected.

Alternative 4. Channelization: A wetland delineation would be completed in PED. If wetlands are present along the Rio Grande de Manati in the area where the channelization is proposed, permanent wetland loss would occur. If wetlands were to be impacted, supplemental NEPA documentation that includes a mitigation plan would be developed. Mitigation for permanent wetland impacts would be required.

3.6.5 Biological Resources

3.6.5.1 Vegetation

Alternative 1. Levee/Floodwall System: A permanent loss of vegetation in the channel widening, floodwall, and retention pond areas would occur. Effects to vegetation are expected to be minor and not significant.

Alternative 2. Channel Modification: With this alternative, a temporary loss of some stream bank vegetation during construction activities is expected, although most stream bank areas are devoid of vegetation due ongoing bank erosion. Vegetation would be restored along stream bank after construction activities are complete. A permanent loss of vegetation in the channel widening and floodwall areas would occur. Effects to vegetation are expected to be minor and not significant.

Alternative 3. Non-Structural Relocations: A permanent loss of vegetation in the floodwall area is expected, although effects would be minor. There would be an increase in vegetation in the areas of buyouts after structures are removed and the area is replanted with native floodplain plants. Minor vegetation benefits are expected to occur in these replanted floodplain areas. Effects to vegetation are expected to be minor and not significant.

Alternative 4. Channelization: With this alternative, a temporary loss of some stream bank vegetation during construction activities is expected, although most stream bank areas are devoid of vegetation due ongoing bank erosion. Vegetation would be restored after construction activities are complete. Effects to vegetation are expected to be minor and not significant.

3.6.5.2 Fish & Wildlife Resources (Other than Threatened and Endangered Species)

Alternative 1. Levee/Floodwall System: This alternative would result in some permanent loss of wildlife habitat in the area of channel widening and in the retention pond construction area. Construction activities and noise could disturb and displace fish and wildlife temporarily but effects are expected to be minor and would cease once construction activities are complete. These impacts are not expected to be significant.

Alternative 2. Channel Modification: With this alternative, construction activities and noise could disturb and displace fish and wildlife temporarily but effects are expected to be minor and would cease once construction activities are complete. Wildlife habitat in area of channel realignment would be permanently lost but it would be expected that wildlife would relocate to other habitat in the vicinity. Fish and aquatic invertebrate habitat may increase in area of low flow channel construction. These impacts are not expected to be significant.

Alternative 3. Non-Structural Relocations: With this alternative, temporary impacts to fish and wildlife resources would occur during construction activities as fish and wildlife are displaced due to the increased noise, activity and presence of construction equipment. An increase in wildlife habitat is expected in the areas of the non-structural relocations as the areas would be converted to natural floodplain habitat. These impacts are not expected to be significant.

Alternative 4. Channelization: A complete loss of 9,000 linear feet of natural fish habitat would occur as a result of the concrete lined channel. Permanent elimination of riffle/pool habitats within the area of the proposed channel would also occur. The construction of the concrete channel would result in water temperature changes displacing fish and other aquatic organisms. Direct and indirect impacts to fish resources downstream of the study area are also expected with increased surface water velocities, increased sediment deposits, and increased erosion downstream of the concrete channel. Construction activities and noise would temporarily impact wildlife but it is expected that any wildlife displaced by construction activities would return to the area once activities are complete. Significant, permanent, and adverse impacts to fish resources would occur with this alternative.

3.6.5.3 Threatened & Endangered Species

All alternatives may affect but are not likely to adversely affect the federally listed (endangered) Puerto Rican boa (*Chilabothrus inornatus*). Habitat loss and modification is the largest overall threat to the species. Karst formations are present near Ciales; however no impacts to these areas would be proposed with this project. It is not expected that the proposed project would alter habitat currently occupied by the boa. The greatest potential for impact to the boa would likely occur during construction activities. To avoid and/or minimize impacts to the boa, the USFWS has developed guidelines for boa conservation at construction sites and these conservation measures would be included in the plans and specifications and the contractor would be required to abide by them (see Environmental Appendix, Appendix B). Consultation with the USFWS service is ongoing. No significant impact is expected.

3.6.6 Land Use & Associated Impacts

3.6.6.1 Land Use

Alternative 1. Levee/Floodwall System: Minor effects to land use would occur with construction of floodwall and levee, widening of channel, and construction of retention pond. Channel widening would impact the agricultural field located near the wastewater treatment plant.

Alternative 2. Channel Modification: Moderate effects to land use with construction of low flow channel, as the channel would be constructed through an existing undeveloped agricultural field.

Alternative 3. Non-Structural Relocations: Minor effects to land use with the construction of the floodwall around the waste water treatment plant. Land use in the area of buyouts would change from residential housing to floodplain, which would provide a benefit in flood risk reduction.

Alternative 4. Channelization: Minor effects to land use would occur with the construction of the concrete-lined channel, including to the agricultural field located near the wastewater treatment plant.

3.6.6.2 Hazardous, Toxic, & Radioactive Waste

Alternative 1. Levee/Floodwall System: Permanent removal of soils in the area of the retention pond, for the floodwall footer, and in the portion of channel proposed for channel widening would occur with this alternative. Although the Phase I Environmental Site Assessment did not identify recognized environmental conditions, any soil disturbance could result in inadvertent discovery of HTRW during construction, and soil removed from the site could potentially require testing for contamination prior to placement offsite. In addition, a levee is proposed to be placed adjacent to a former gas station with underground storage tanks identified during the Phase I Environmental Site Assessment. Disturbance of soil in this area during construction could result in inadvertent discovery of petroleum contamination and impacts could be significant. Appropriate guidance and regulations should be followed for any potential hazardous material or petroleum cleanup activities.

Alternative 2. Channel Modification: Permanent removal of soils in areas of channel widening and deepening would occur with this alternative. In addition, minor soil disturbance would occur in the area of floodwall. As with Alternative 1, any soil disturbance could result in an inadvertent discovery of HTRW and/or petroleum contamination during construction and the impacts could be significant. In addition, soil removed from the site may require testing for contamination prior to placement. Appropriate guidance and regulations should be followed for any potential hazardous material or petroleum cleanup activities.

Alternative 3. Non-Structural Relocations: Some excavation of soils would occur in the area of the floodwall around the wastewater treatment plant with soil reuse onsite. Disturbed areas would be restored upon completion of construction. Temporary minor soil disturbance is also expected during removal of the above ground portion of the former gasoline station structure and homes proposed for buy-outs. The underground petroleum storage tanks would remain in place and be backfilled. Soil disturbance is minimal under this alternative. Some of the buildings proposed to be demolished may contain asbestos or lead-based paint. Prior to demolition, the contractor would be required to test for asbestos and lead-based paint and/or appropriate abatement procedures would be required. The contractor would be responsible for obtaining any applicable air quality permits prior to demolition. Therefore, no significant impacts to HTRW are expected.

Alternative 4. Channelization: Permanent removal of soils within the channel would occur with the channel deepening and widening. Any significant soil disturbance or permanent removal of soils could result in the inadvertent discovery of HTRW or petroleum contamination during construction and the impacts could be significant. In addition, soil removed from the site may require testing for contaminants prior to placement offsite. Appropriate guidance and regulations should be followed for any potential hazardous material or petroleum cleanup activities.

3.6.6.3 Noise

For all alternatives, temporary increases in noise levels would be expected during construction activities. Noise levels would be expected to return to pre-construction conditions once construction activities are complete. No adverse impacts resulting from noise are expected with any of the alternatives.

3.6.7 Socioeconomic Environment

3.6.7.1 Socioeconomic Setting

Temporary socioeconomic benefits may occur as a result of increased jobs and local revenue during construction activities associated with all four alternatives. Reduced flood risk and damages associated with all alternatives would result in decreased spending on flood recovery—money that could be diverted to the local and regional economies. The extent of socioeconomic effects vary among alternatives:

Alternative 1. Levee/Floodwall System: This alternative reduces flood damages and associated recovery costs for homes, businesses, and public facilities (i.e., wastewater treatment plant) within the communities of Dos Rios and Alturas de Ciales up to the 0.01 AEP event. Reduced

recovery spending would enable additional money to enter other sectors of the local (e.g., retail) and regional (e.g., recreation and tourism) economies. Temporary socioeconomic benefits may occur as a result of increased jobs and local revenue during construction. There is a potential for lost agricultural revenue due to a reduction in cultivatable land due to channel widening.

Alternative 2. Channel Modification: This alternative reduces flood damages and associated recovery costs up to the 0.1 AEP event throughout the study area. Reduced recovery spending would enable additional money to enter other sectors of the local (e.g., retail) and regional (e.g., recreation and tourism) economies. Temporary socioeconomic benefits may occur as a result of increased jobs and local revenue during construction. There is a potential for lost agricultural revenue due to a reduction in cultivatable land due to channel modification.

Alternative 3. Non-Structural Relocations: This alternative effectively eliminates damages and associated recovery costs for homes and businesses within the 0.04 AEP event floodplain throughout the study area. Reduced recovery spending would enable additional money to enter other sectors of the local (e.g., retail) and regional (e.g., recreation and tourism) economies. Temporary socioeconomic benefits may occur as a result of increased jobs and local revenue during the relocation effort. A portion of the residents could be relocated outside of Ciales; however, this is not expected to significantly impact the local economy. Negative social impacts may occur if individuals do not want to relocate. Feedback received during the initial public scoping meeting indicated non-structural relocations are the preferred alternative. Therefore, significant social impacts are not anticipated.

Alternative 4. Channelization: This alternative reduces flood risk and damages up to the 0.04 AEP event throughout the study area. Reduced recovery spending would enable additional money to enter other sectors of the local (e.g., retail) and regional (e.g., recreation and tourism) economies. Temporary socioeconomic benefits may occur as a result of increased jobs and local revenue during construction. There is a potential for lost agricultural revenue due to a reduction in cultivatable land due to channelization.

3.6.7.2 Aesthetic & Recreation Resources

Alternative 1. Levee/Floodwall System: With this alternative, temporary impacts to aesthetics during construction activities would occur. Permanent minor benefits to recreation with reduced damage risk to an adjacent park (Parque Samuel Rosario Rivera) would also be expected. No significant impacts to aesthetic or recreation resources are expected.

Alternative 2. Channel Modification: With this alternative, temporary impacts to aesthetics during construction activities would occur. Permanent minor benefits to recreation with reduced damage risk to an adjacent park (Parque Samuel Rosario Rivera) would also be expected. No significant impacts to aesthetic or recreation resources are expected.

Alternative 3. Non-Structural Relocations: With this alternative, temporary impacts to aesthetics during construction activities would occur. Permanent changes in aesthetics would occur after structure relocation and floodplain plantings are complete. Additional possible benefits to recreation may be realized if non-structural relocation areas are used as a community green space. No significant impacts to aesthetic or recreation resources are expected.

Alternative 4. Channelization: With this alternative, changes to aesthetics would occur with the construction of concrete lined channel (temporary and permanent). A permanent reduction in recreation (fishing) resulting from loss of fish habitat in concrete lined channel is expected. Minor changes to aesthetics would occur with the reduction of stream bank erosion and minor improvements in recreation would occur with reduced damage risk to an adjacent park (Parque Samuel Rosario Rivera). No significant impacts to aesthetic or recreation resources are expected.

3.6.8 Cultural Resources

Analysis of potential impacts to historic and cultural resources considered both direct and indirect effects. Direct effects may result from physically altering, damaging, or destroying all or part of a historic or cultural property, or changing the character of physical features within the property's setting that contribute to its historic significance. An effects analysis focuses on the characteristics of a historic property that qualify it for inclusion in the NRHP, and assesses the potential to alter historically significant characteristics and diminish the integrity of a historic property. There may also be cultural resources of value which are not eligible for inclusion in the NRHP. The Area of Potential Effect (APE) for direct affects was defined as being within and adjacent to the proposed construction footprint of structural measures where ground disturbing activities, including disposal, access, and construction staging would occur. The APE also includes the viewshed of adjacent historic properties that may be affected by the construction of proposed project features thereby causing a change in the historic landscape.

Indirect effects are reasonably foreseeable effects caused by an undertaking that may occur later in time, be farther removed in distance or be cumulative. Cumulative effects result from the collection of federal and non-federal actions taking place over the same period of time. Implementation of any of the federal action alternatives could induce growth; however, none of the Action Alternatives propose to construct housing or extend infrastructure, such as new roads or utilities that would support the future construction of housing. Additionally, construction of infrastructure that may result from flood-risk reduction must comply with local, commonwealth, and federal historic preservation laws, thereby negating any reasonable and foreseeable indirect or cumulative effects of the Action Alternatives as outline in 36 CFR § 800.5(a)(1).

Consultation with the Puerto Rico State Historic Preservation Office (SHPO) pursuant to Section 106 of the NHPA was initiated by letter on December 17, 2018 (SHPO No.: 12-27-18-01). Additional consultation with SHPO was conducted regarding the APE, sent by letter September

30, 2019. All correspondence relevant to cultural resources is provided in the Environmental Appendix, Appendix B.

All alternatives have the potential to impact cultural resources and historic properties. USACE has not completed all identification measures of the areas of potential effects for the alternatives; the following is based on the existing data from the SHPO database.

Alternative 1. Levee/Floodwall System: The construction of a levee and floodwall system may impact cultural resources in the direct construction footprint, staging areas, and access areas. The natural river widening may adversely impact the recorded archaeological site Ciales 8/Bateyes I (CI0100008), the remains of a historic hacienda and prehistoric village site. The SHPO has determined this site may be eligible for listing on the NRHP. The construction of a floodwall around the water treatment plant may adversely impact the archaeological site Ciales 10/Ventana 1 (CI0100010), mapped in this general vicinity. The SHPO has determined this site may be eligible for listing on the NRHP. The relocation of structures may impact unrecorded historic structures and historic districts, as well as underlying archaeological sites. Additional unrecorded historic properties may be present elsewhere in the construction, staging, and access zones. The impacts to unrecorded historic properties would be adverse.

Alternative 2. Channel Modification: The construction of a new channel in the floodplain may adversely impact the recorded archaeological site Ciales 8/Bateyes I (CI0100008), the remains of historic hacienda and prehistoric village site. The SHPO has determined this site may be eligible for listing on the NRHP. The construction of a floodwall around the water treatment plant may adversely impact the archaeological site Ciales 10/Ventana 1 (CI0100010), mapped in this general vicinity. The SHPO has determined this site may be eligible for listing on the NRHP. Additional unrecorded historic properties may be present elsewhere in the construction, staging, and access zones. The impacts to unrecorded historic properties would be adverse.

Alternative 3. Non-Structural Relocations: The construction of a floodwall around the water treatment plant may adversely impact the archaeological site Ciales 10/Ventana 1 (CI0100010), mapped in this general vicinity. The SHPO has determined this site may be eligible for listing on the NRHP. Additional unrecorded historic properties may be present elsewhere in the construction, staging, and access zones. The impacts to unrecorded historic properties would be adverse. The relocation of structures may impact unrecorded historic structures and historic districts, as well as underlying archaeological sites. Additional unrecorded historic properties may be present elsewhere in the construction, staging, and access zones. The impacts to unrecorded historic properties would be adverse. Pursuant to 36 CFR 800.14, USACE would prepare a Programmatic Agreement to detail the timeline and methods for identifying, avoiding, minimizing, and mitigating effects to historic properties under Section 106 of the National Historic Preservation Act.

Alternative 4. Channelization: The construction of a new channel in the floodplain may adversely impact the recorded archaeological site Ciales 8/Bateyes I (CI0100008), the remains of historic

hacienda and prehistoric village site. The SHPO has determined this site may be eligible for listing on the NRHP. Additional unrecorded historic properties may be present elsewhere in the construction, staging, and access zones. The impacts to unrecorded historic properties would be adverse.

3.7 Plan Selection & Optimization

Alternative 3 is the only alternative with positive net economic benefits and, thus, represents the NED plan. Alternative 3 is also the only alternative to have positive effects and benefits across all four accounts (Table 3-4) and criteria (Table 3-6). Alternative 3 would reduce both flood damages and life and safety risk, meeting both planning objectives. Although Alternative 3 does not reduce risks associated with inundation of roadways and there would be residual current and increased future risk for structures outside of the 0.04 AEP floodplain, Alternative 3 has the least amount of uncertainty regarding current and future residual risk and sustained benefits (see section 3.4.5). All current and future risk for structures relocated under Alternative 3 will be completely and indefinitely removed. Alternative 3 has the least environmental impacts among the four alternatives and has the greatest potential environmental benefits.

Alternative 3 (Non-Structural Relocations) was optimized to ensure that the national economic development plan (i.e., plan that optimizes project costs and benefits) was identified. Costs and benefits of the floodwall and non-structural relocations were analyzed to ensure each was incrementally justified. All costs include estimated project first costs and OMRR&R costs. Cost of LERRDs was estimated and included for measures with incrementally justified first and OMRR&R costs (i.e., BCR > 1) to ensure they were incrementally justified after all costs were accounted for. These additional analyses indicated that the benefit-cost-ratio for the floodwall was 0.3 (Table 3-7). Further analysis by the technical team determined that additional costs associated with altering the height and type of floodwall would not be justified by the minimal increases in benefits. For these reasons, the floodwall was not carried forward and was removed from the recommended plan. The benefit-cost-ratio for non-structural relocations was 1.7 (Table 3-7). Therefore, non-structural relocations were incrementally justified and retained in the recommended plan.

Table 3-7. Economic analysis to determine whether each measure included in Alternative 3 was incrementally justified.

		Estimated Costs and Benefits ($1,000s)	
Item		**NS Relocations**	**Floodwall**
Investment Cost			
	Total Project First Cost [a]	$13,771	$5,760
	Interest During Construction	$47[b]	$39[c]
	Total Investment Cost	$13,817	$5,799
Annual Cost			
	Annualized first cost [d]	$512	$215

	Estimated Costs and Benefits ($1,000s)	
Item	**NS Relocations**	**Floodwall**
Estimated Annual OMRR&R	$0	$2
Total Average Annual Cost	$512	$217
Annual Benefits	$891	$55
Net Annual Benefits	$380	($161)
Benefit-Cost Ratio	1.7	0.3

[a] Includes 39% contingency as determined by an abbreviated risk analysis.
[b] Interest during construction is calculated at 2.75% over a 3 month construction period.
[c] Interest during construction is calculated at 2.75% over a 6 month construction period.
[d] Costs were annualized over a 50-year period of analysis.

The 0.04 AEP floodplain was selected for the non-structural relocations to include those structures with the majority of recurring flood damages, as well as those with the greatest life and safety risk during major flood events. Under this alternative, the average inundation depth during the 0.01 AEP event for structures included in the relocation is 15.7 feet. In contrast, the average inundation depth for structures within the 0.01 AEP floodplain that are not included in the relocation project is 2.7 feet. Although there is residual risk to structures outside the 0.04 AEP floodplain, there are other relocation programs through which these residents can reduce their remaining risk. Therefore, no optimization of the non-structural relocations was pursued.

4 RECOMMENDED PLAN *

This section describes the recommended plan, which represents the optimized version of Alternative 3 (Non-Structural Relocations) and is referred to in the associated appendices as Alternative 3B: Optimized Plan. Optimization resulted in removal of the floodwall around the wastewater treatment plant.

4.1 Plan Details

A total of 59 structures within the 0.04 AEP floodplain would be acquired and demolished. Residents would be relocated outside of the floodplain (Fig. 4-1). Relocation would be mandatory. If necessary, the local sponsor would acquire property through eminent domain to ensure relocation of all 59 structures. The floodplain would be planted with native vegetation. The local sponsor would retain ownership of the acquired property and must ensure no future development or fill would occur; however, the acquired area could be deeded to the local government and/or converted to undeveloped public space (e.g., recreational fields).

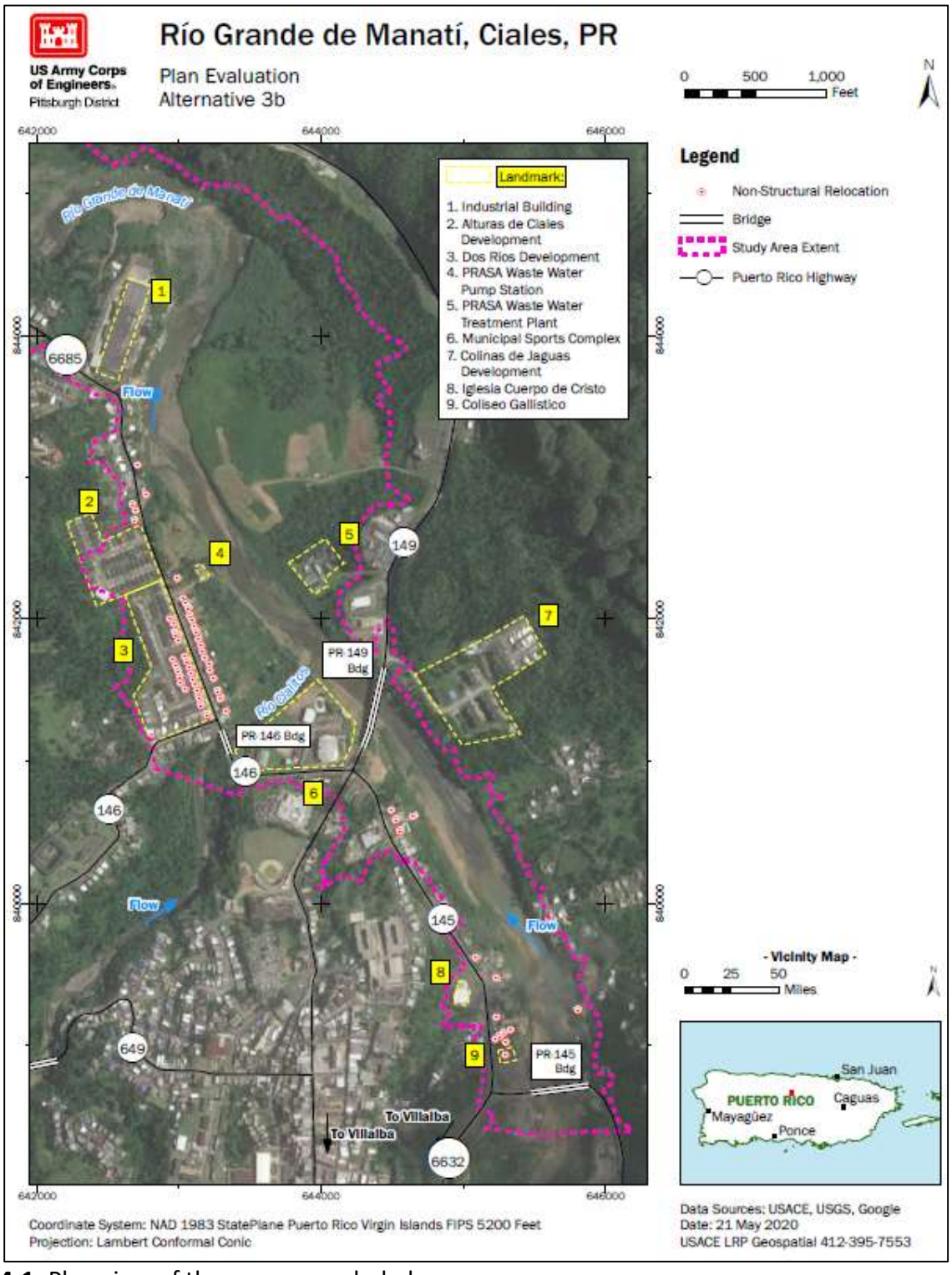

Fig. 4-1. Plan view of the recommended plan.

All acquisition and relocation efforts would comply with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended. A relocation counselor would work with all residents and business owners to identify comparable replacement housing or

commercial property that meet their individual needs and desires. All replacement housing must be decent, safe, and sanitary and functionally equivalent to the residents' present dwelling. Replacement housing can be located within or outside of the community from which the resident is being relocated. The goal for relocating businesses is relocation back into the community from which they are relocated. All residents and business owners would have the freedom of choice in the selection of a replacement home or commercial property.

Residents and business owners would be given fair market value for their property and may qualify for supplemental payments to offset differences in cost between the acquired and identified comparable replacement properties, as well as any increase in mortgage interest. Residents occupying rental properties would be relocated to a comparable rental property. Any price difference in rent between the acquired and comparable rental properties would be multiplied by 42 and given to the renter as one lump sum payment. Relocation benefits include reimbursement of moving costs and expenses. Businesses may also be eligible for payment to cover costs required to reestablish the business at the replacement site, such as necessary modifications to the new property and advertising.

4.2 Economic Analysis

4.2.1 Project Costs

The estimated total project first cost for the recommended plan is $13,860,000 (Table 4-1). Project costs include construction costs, costs for construction management, costs of lands, easements, rights of way, relocations, and disposal areas (LERRDs), and costs associated with pre-construction engineering and design. A thorough description of methodologies and results associated with the cost estimation can be found in the Cost Engineering Appendix, Appendix D).

Table 4-1. Estimated project first costs for the recommended plan.

Construction Item	**Costs ($1,000s)**
LEERDs	$11,293
Project Elements	
Demolition & Removal Costs [a]	$2,053
Pre-Construction Engineering & Design	$349
Construction Management	$164
Total First Cost	$13,860
[a] Includes 44% contingency as determined by an abbreviated risk analysis.	

4.2.2 Cost-Benefit Analysis

In addition to the total project first cost, the economic analysis considers interest during construction to obtain a total investment cost. The total investment cost is then annualized over a 50-year period and added to the anticipated annual operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) cost to establish a total average annual cost. The average annual cost is then compared to average annual benefits (e.g., reduced flood damages) to determine the benefit-cost-ratio. A detailed summary of economic methodologies and results are presented in the Economics Appendix, Appendix C.

The recommended plan has an estimated annualized cost of $515,000 and an estimated annual benefit of $883,000, resulting in a net annual benefit of $368,000 and a benefit-cost-ratio of 1.7 (Table 4-2).

Table 4-2. Estimated costs and benefits associated with the recommended plan.

Construction Item	**Value ($1,000s)**
Investment Cost	
Total Project First Cost	$13,860
Interest During Construction [a]	$47
Total Investment Cost	$13,907
Annual Cost	
Annualized first cost [b]	$515
Estimated Annual OMRR&R	$0
Total Average Annual Cost	$515
Annual Benefits	$883
Net Annual Benefits	$368
Benefit-Cost Ratio	1.7
[a] Interest during construction is calculated at 2.75% over a 3 month construction period. [b] Costs were annualized over a 50-year period of analysis.	

4.3 Cost Sharing

All estimates are at the 2019 price level and may change due to inflation prior to construction. The non-federal sponsor must provide self-certification of financial capability as required by USACE policy. Use of funds from other federal programs, including any non-federal contribution required as a matching share, to meet financial obligations of the non-federal sponsor is not permitted unless USACE authorizes use of those funds in writing.

Project design and implementation costs are shared 65 percent federal and 35 percent non-federal. The non-federal sponsor is required to provide all land, easements, rights-of-way, relocations, and disposal areas (LERRDs). If the LERRD costs exceed 35 percent of the total project cost the difference will be reimbursed by the federal government. Demolition and removal of structures are considered construction costs and are typically performed by the federal government. Based on these requirements, the estimated non-federal contribution for the

recommended plan is $4,850,000, which includes $4,728,000 in LERRD costs after a $6,565,000 reimbursement by the federal government and $122,000 for pre-construction engineering and design (Table 4-3).

Table 4-3. Estimated federal and non-federal cost share for the recommended plan.

	Estimated Costs ($1,000s)		
Construction Item	**Federal Cost**	**Non-Federal Cost**	**Total Cost**
Pre-Construction Engineering & Design	$227 (65%)	$122 (35%)	$349
LERRDs	$0	$11,293	$11,293
Construction (Demolition & Removal) [a]	$2,217	$0	$2,217
Reimbursement	$6,565	($6,565)	
Subtotal	$8,782 (65%)	$4,728 (35%)	$13,510
Total Project	$9,009 (65%)	$4,850 (35%)	$13,860
[a] Construction costs include costs associated with construction and construction management.			

4.4 Design, Construction & Environmental Considerations

Construction activities for the non-structural relocations include demolition and removal of the 59 structures included in the non-structural relocation effort. An allowance was included for disconnecting utilities (e.g., water, electric). All material would be hauled to a commercial landfill. Some of the structures proposed to be demolished may contain asbestos or lead-based paint. Prior to demolition, the contractor would be required to test for asbestos or lead-based paint and/or appropriate abatement procedures would be required.

To comply with the Endangered Species Act, the USFWS guidelines for boa conservation at construction sites will be included in the plans and specifications, which the contractor will be required to implement (see Environmental Appendix, Appendix B). To comply with the Migratory Bird Treaty Act and the Migratory Bird Conservation Act, the USFWS nationwide standard conservation measures will be included in the plans and specifications, which the contractor will be required to implement (see Environmental Appendix, Appendix B). To comply with the Clean Water Act, a wetland delineation will be conducted in PED. If applicable, the 404(b)(1) analysis will be updated in PED, and Section 401 Water Quality Certification will be obtained. A Section 402 NPDES permit will be obtained during PED, if necessary. To comply with Section 106 of the National Historic Preservation Act, a Programmatic Agreement between USACE and the SHPO has been developed. Consultation with the SHPO will continue during PED.

4.5 Lands, Easements, Rights-of-Way, Relocations, & Disposal Areas

This section provides a general description of LERRDs required for the recommended plan. Complete details regarding real estate considerations are presented in the Real Estate Appendix, Appendix E. Fee simple acquisition would be required for 59 structures (Fig. 4-2). The total estimated real estate costs associated with non-structural relocations is $11,293,050, which includes real estate administration ($171,000), real estate costs (i.e., structures and associated land tracts; $7,603,050), additional acquisition costs (e.g., surveys appraisals, administration, title, and condemnation; $1,333,800), and relocation costs ($2,815,200) (Table 4-4).

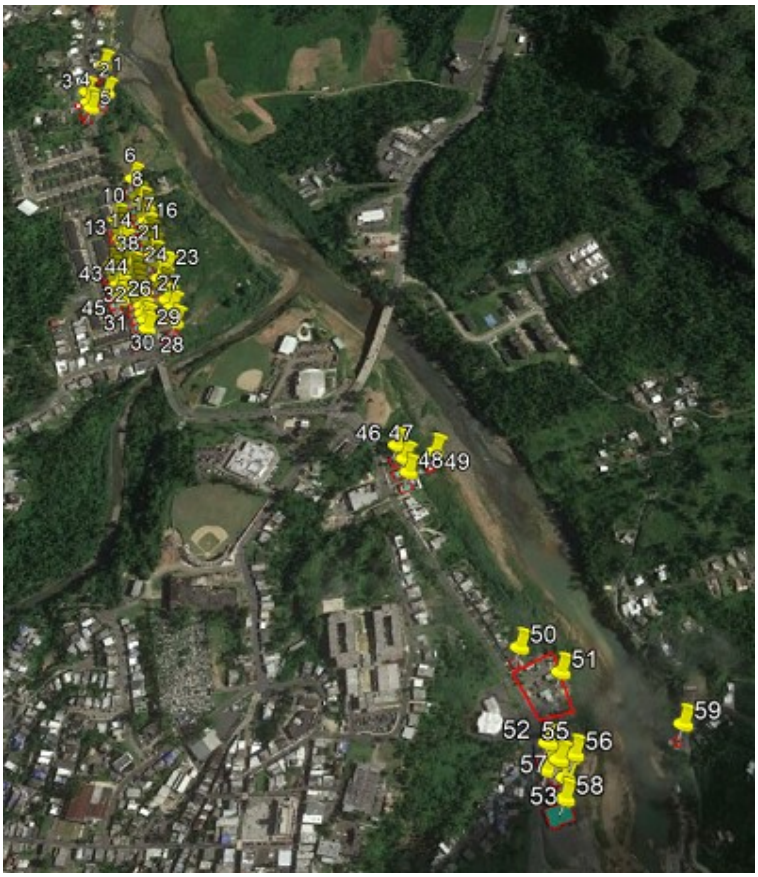

Fig. 4-2. Real estate requirements for the recommended plan, including location of the 59 structures (yellow markers) and associated parcels (red outlines) included in non-structural relocations. Detailed maps can be found in the Real Estate Appendix, Appendix E.

Table 4-4. Estimated real estate costs for the recommended plan.

Item	**Estimated Cost**
Real Estate Administration [a]	$171,000
Acquisition Costs (Survey, Appraisal, Administration, Title, Condemnation) [a]	$1,333,800
LERRDs [b]	$7,603,050
Relocation costs [ac]	$2,815,200
Total	*$11,293,050*

[a] Includes 20% contingency.
[b] Includes acquisition of land and associated structures. Includes 30% in incremental costs.
[c] Relocation costs assume $31,000 per residential structure or $40,000 per commercial structure.

4.6 Operation, Maintenance, Repair, Rehabilitation, and Replacement

There are no anticipated OMRR&R requirements or costs for the recommended plan.

4.7 Risk & Uncertainty

Authority and policy constraints prohibited the study and recommendation of measures designed to reduce damages to transportation infrastructure and associated life safety risk resulting from flood-induced bank failure and bridge scour along the Rio Grande de Manati. Thus, there would be residual risk of economic damages and reduced life safety associated with bank/bridge failure under the recommended plan—both now and into the future. It is uncertain if measures designed to reduce the risk of bank/bridge failure would be implemented by another local, commonwealth, or federal entity.

Residual Risk: There would be no change in flood risk for residents outside of the 0.04 AEP floodplain. Thus, there would be residual inundation and life safety risks to structures outside of the 0.04 AEP floodplain. This alternative would not alter inundation of transportation infrastructure—which occurs prior to the 0.1 AEP flood event—resulting in residual risk to residents and communities both inside and outside of the project footprint that rely on potentially inundated roadways for evacuation and access to critical services. The recommended plan would not reduce inundation of the wastewater treatment plant, resulting in residual risk of inundation, damage, and impacts to the environment and public health.

Residual Risk Due to Climate Change: Increases in extreme precipitation projected to occur throughout the 100-year project life would increase residual risk associated with inundation of structures not included in the relocation. Similarly, the frequency with which roadways become inundated could increase, elevating life and safety risk for individuals both within and outside of the project area that depend on inundated roads for evacuation and access too critical facilities. Ample warning times and associated evacuation notices associated with the most extreme flood events (i.e., hurricane-induced floods) lessens life and safety risk to some extent. The frequency and extent to which the wastewater treatment plant is inundated could also increase, resulting in elevated residual risk to environmental resources and public health. Potential risks to project features are included in Table 4-5.

Table 4-5. Climate risks identified for measures included in the recommended plan.

Feature	Trigger	Hazard	Harm	Qualitative Likelihood
Non-Structural Relocations	Increased magnitude and frequency of large storm and flood events.	Future flood volumes and velocities may be larger and more frequent than present.	Increased inundation risk for structures outside of the 0.04 AEP floodplain not included in the project.	Likely

Uncertainty: Many of the structures being considered for relocation were constructed over 50 years ago, making them eligible for consideration as historical properties. Limited time (i.e., $1.2M in total study costs) and resources (i.e., $1.2M in total study costs) precluded a full cultural resource survey. Mitigation may be required to offset impacts to potentially historic properties being relocated.

4.8 Project Implementation

4.8.1 Views of the Non-Federal Sponsor

The Commonwealth of Puerto Rico's Department of Natural and Environmental Resources (DNER) is supportive of the study and the feasibility-level findings included in this report. There has been coordination with the DNER, relevant federal agencies, the Commonwealth of Puerto Rico, and the municipality of Ciales throughout the development of this feasibility report.

4.8.2 Schedule

A summary of the study schedule is provided in Table 4-6. The Pittsburgh District will finalize and transmit the integrated feasibility report. After its review of the final integrated feasibility report and environmental assessment, HQUSACE will prepare the Chief of Engineers' Report (Chief's Report). Once signed, the Chief's Report will be submitted to the Assistance Secretary of the Army (Civil Works) [ASA (CW)]. The ASA (CW) will transmit the final integrated feasibility report and environmental assessment to the Office of Management and Budget, who will review and then submit the document to Congress for Authorization.

Table 4-6. Schedule for completion of the Rio Grande de Manati, Ciales (PR) Feasibility Study.

Activity/Milestone	Date
Feasibility Cost Sharing Agreement Signed	09 OCT 2018 **Actual**
Alternatives Milestone	12 JAN 2019 **Actual**
Tentatively Selected Plan Milestone	06 SEP 2019 **Actual**
Release Report for Public/Concurrent Review	24 FEB 2020 **Actual**
Agency Decision Milestone	08 MAY 2020 **Actual**

Activity/Milestone	Date
Submit Final Report	25 JUN 2020
Policy & Legal Compliance Review Complete	27 JUL 2020
Senior Leader Brief	03 AUG 2020
State & Agency Review	03 SEP 2020
Chief of Engineer's Report Signed	09 OCT 2020

Once authorized, it may be possible to use remaining 2018 Supplemental Appropriation funds for project implementation. If there are no 2018 Supplemental Appropriation funds available for implementation, the project will need specific appropriations prior to implementation. Acquisition and relocation, along with design, solicitation, and award of the construction (i.e., demolition and removal) contract are expected to occur over 36-months. Demolition and removal is expected to take an additional 3 months. A detailed implementation schedule is included in Appendix D, Cost Engineering Appendix.

4.8.3 Non-Federal Sponsor Responsibilities

In accordance with the cost share provisions in Section 103 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 2213), project design and implementation are cost shared 65 percent federal and 35 percent non-federal as described in Section 4.3 of this report. There are no anticipated OMRR&R requirements for the recommended plan.

4.8.4 Project Agreements

A Design Agreement that details cost share requirements associated with the development of detailed plans and specifications must be executed between USACE and the non-federal sponsor prior to pre-construction engineering. USACE and the non-federal sponsor must then enter into a project partnership agreement prior to start of construction. The project partnership agreement defines responsibilities of the non-federal sponsor during and following project implementation, including cost-share responsibilities for project implementation.

4.8.5 Project-Specific Considerations

The floodwall around the wastewater treatment plant was not incrementally justified (i.e., no net economic benefits and a BCR less than 1) and could not be included within the recommended plan per USACE policy (USACE, ER 1105-2-100, Planning Guidance Notebook, 2000). However, the floodwall would provide public health, economic, and environmental benefits. Thus, USACE recommends considering local implementation of the floodwall to further reduce flood risk.

Federal implementation of the recommended plan would also be subject to non-federal sponsor compliance with the following applicable federal laws and policies:

- Inform affected interests of the extent of protection afforded by the project no less than once each year.
- Agree to participate in and comply with applicable federal floodplain management and flood insurance programs.
- Prepare a floodplain management plan within one year of the signing of the project partnership agreement and implement the plan no later than one year following completion of project constructions as specified in Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12).
- Prevent obstructions or encroachments on the project, including prescribing and enforcing regulations to prevent obstructions or encroachments, such as new developments on project lands, easements, and rights-of-way or the addition of facilities that may reduce the level of protection the project affords, hinder project OMRR&R, or interfere with project function.
- Publicize floodplain information and provide this information to zoning and other regulatory agencies for use in adopting regulations, taking other actions to prevent unwise future development, and ensuring compatibility with protection levels provided by the project.
- 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 and OMRR&R of the project, including those necessary for relocations, borrowing of material, or disposal of dredged or excavated material. Inform all affected persons of applicable benefits, policies, and procedures in connection with these laws and regulations.
- For so long as the project remains authorized, complete OMRR&R requirements on the project at no cost to the federal Government in a manner compatible with the project's authorized purposes and in accordance with applicable federal and commonwealth laws, regulations, and any specific directions prescribed by the federal government. There are no anticipated OMRR&R requirements or costs for the recommended plan.
- 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 purposes of completing, inspecting, or conducting OMRR&R on the project.
- Hold and save the U.S. free from all damages arising from the construction or OMRR&R of the project and any betterments, except for damages due to the fault or negligence of the U.S. or its contractors.
- Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project for a minimum of three years after final accounting.
- Comply with all applicable federal and commonwealth 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 6007 issued pursuant thereto; 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).

- 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) and Public Law 96-510, as amended (42 U.S.C. 9601-9665) that may exist in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for construction and completion of OMRR&R of the project. However, for lands that the federal government determines to be subject to the navigation servitude, only the federal government shall perform such investigations unless the federal government provides the non-federal sponsor with prior specific written direction, in which case the non-federal sponsor shall perform such investigations in accordance with such written direction.
- Assume, as between the federal government and the non-federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the federal government determines to be required for construction and completion of OMRR&R of the project.
- Agree, as between the federal government and the non-federal sponsor, that the non-federal sponsor shall be considered the operator of the project for the purposes of CERCLA liability, and to the maximum extent practicable, OMRR&R the project in a manner that will not cause liability to arise under CERCLA.
- Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project, or separable element thereof, until each non-federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

5 ENVIRONMENTAL EFFECTS & COMPLIANCE *

5.1 Environmental Effects of Recommended Plan

This section details potential environmental effects of the recommended plan. As detailed in Section 3.5, direct and indirect effects were considered for each of the environmental resource categories. Effects described below are direct effects unless specifically indicated otherwise.

5.1.1 Climate

The recommended plan would not affect the current or future climate.

5.1.2 Flood Risk

5.1.2.1 Hydraulic Characteristics & Tidal Influences

No changes to hydrology would be expected with these measures. These measures effectively eliminate flood risk for structures within the 0.04 AEP event—providing these individuals the opportunity to relocate to areas with zero flood risk. Residual risk remains for structures (i.e., wastewater treatment plant) outside of the 0.04 AEP floodplain. Removal of structures within the 0.04 AEP floodplain could reduce inundation depths for structures not included in the relocation due to restoring natural hydraulic conditions.

5.1.2.2 Flood Damages

Non-structural relocations would effectively eliminate damages and associated recovery costs for structures within the 0.04 AEP event floodplain.

5.1.2.3 Life Safety Risk

The recommended plan would eliminate life and safety risk associated with direct inundation for all structures within the 0.04 AEP floodplain.

5.1.3 Earth Resources

5.1.3.1 Geology & Topography

Relocation of structures currently within the 0.04 AEP floodplain would not affect local geology or topography.

5.1.3.2 Soils

Minor temporary impacts to soil may occur during demolition and removal of structures from the 0.04 AEP floodplain. While structures generally do not have basements, removal of foundation pads may temporarily impact the soil surface; however soils in these areas would be restored and replanted. No significant impacts to soils are expected. No impacts to prime farmland are expected.

5.1.3.3 Air Quality

Temporary minor increases in emissions from construction equipment would be expected. Emissions would be *de minimis* (i.e., minor impacts resulting in no adverse effect). Temporary air quality disturbances may occur during demolition. The contractor would be responsible for obtaining all applicable air quality permits related to the demolition activities. No significant impacts to air quality are expected.

5.1.4 Water Resources

5.1.4.1 Water Quality

The removal of structures and planting of native vegetation within the floodplain would reduce runoff and increase infiltration, improving downstream water quality. No significant impacts to water quality are expected.

5.1.4.2 Riverine & Floodplain Habitats

No impacts to riverine habitats would be expected with these measures. The removal of structures would increase natural floodplain habitat. No significant impacts to riverine or floodplain habitat are expected.

5.1.4.3 Wetland Habitat

Demolition and removal of structures from the 0.04 AEP floodplain would not affect wetland habitats.

5.1.5 Biological Resources

5.1.5.1 Vegetation

There would be an increase in vegetation after structures are removed and the area is replanted with native floodplain plants. Minor vegetation benefits would be expected to occur in these replanted floodplain areas. No significant impacts to vegetation are expected.

5.1.5.2 Fish & Wildlife Resources (Other than Threatened and Endangered Species)

An increase in wildlife habitat would be expected under the recommended plan as much of the 0.04 AEP floodplain would be converted from developed area to natural floodplain. No significant impacts to fish & wildlife resources are expected.

5.1.5.3 Threatened & Endangered Species

Demolition and removal of structures within the 0.04 AEP floodplain may affect, but is not likely to adversely affect, the federally listed (endangered) Puerto Rican boa. Habitat loss and modification is the largest overall threat to the species. Karst formations—habitats frequently occupied by the Puerto Rican boa—are present near Ciales; however, no impacts to these areas are proposed with this project. Furthermore, implementation of the recommended plan is not expected to alter habitat currently occupied by the boa. To avoid and/or minimize impacts to the boa during demolition and removal activities, the USFWS has developed guidelines for boa conservation at construction sites and these conservation measures would be included in the plans and specifications and the contractor would be required to abide by them (see Environmental Appendix, Appendix B). Consultation with the USFWS service is ongoing. No significant impacts to threatened and endangered species are expected.

5.1.6 Land Use & Associated Impacts

5.1.6.1 Land Use

Land use in the area of buyouts would change from residential housing to floodplain, which would reduce overall flood risk within the area. No significant impacts are expected.

5.1.6.2 Hazardous, Toxic, & Radioactive Waste

Temporary minor soil disturbance is expected during removal of the above ground portion of the former gasoline station and other structures proposed for non-structural relocation. The underground petroleum storage tanks would remain in place and be backfilled. Soil disturbance is minimal under this alternative. Some of the structures proposed to be demolished may contain asbestos or lead-based paint. Prior to demolition, the contractor would be required to test for asbestos or lead-based paint and/or appropriate abatement procedures would be required. No significant impacts from HTRW are expected.

5.1.6.3 Noise

Temporary increases in noise levels would be expected during construction activities. Noise levels would be expected to return to pre-construction conditions once construction activities are complete. No adverse impacts resulting from noise are expected.

5.1.7 Socioeconomic Environment

5.1.7.1 Socioeconomic Setting

Reduced recovery spending would enable additional money to enter other sectors of the local (e.g., retail) and regional (e.g., recreation and tourism) economies. Temporary socioeconomic benefits may occur as a result of increased jobs and local revenue during the relocation effort. A portion of the residents could be relocated outside of Ciales; however, this is not expected to significantly impact the local economy. Negative social impacts could occur if individuals do not want to relocate. Feedback received during the initial public scoping meeting indicated non-structural relocations are the preferred alternative. Therefore, significant social impacts are not anticipated.

5.1.7.2 Aesthetic & Recreation Resources

Permanent changes in aesthetics would occur after structure relocation and floodplain plantings are complete. Additional possible benefits to recreation may be realized if non-structural relocation areas are used as a community green space. No significant impacts to aesthetic and recreation resources are expected.

5.1.8 Cultural Resources

Consultation with the State Historic Preservation Office (SHPO) pursuant to Section 106 of the National Historic Preservation Act was initiated by letter on December 17, 2018. Additional consultation with SHPO was conducted regarding the Area of Potential Effects (APE) and the need for a Programmatic Agreement, sent by letter September 30, 2019. The SHPO concurred with the preliminary APE and agreed to develop a Programmatic Agreement by letter on October 17, 2019. The Programmatic Agreement details how USACE will defer evaluation of historic properties and assessment of effects due to budgetary, access, and schedule constraints until the study is approved and the project enters Preconstruction Engineering and Design Phase in compliance with Section 106 of the National Historic Preservation Act (36 CFR § 800.4[b][2]). A draft Programmatic Agreement was provided by USACE on October 29, 2019, with SHPO comment returned on December 5, 2019. The Programmatic Agreement has been signed by the

Jacksonville District Commander and is awaiting final signature by the SHPO. All correspondence relevant to cultural resources is also provided in the Environmental Appendix, Appendix B.

The recommended plan has the potential to impact cultural resources and historic properties. USACE has not completed all identification measures of the areas of potential effects for the alternatives; the following is based on the existing data from the SHPO database.

The relocation of structures may impact unrecorded historic structures and historic districts, as well as underlying archaeological sites. Additional unrecorded historic properties may be present elsewhere in the construction zones. The impacts to unrecorded historic properties would be adverse. Pursuant to 36 CFR 800.14, USACE developed a Programmatic Agreement to detail the timeline and methods for identifying, avoiding, minimizing, and mitigating effects to historic properties under Section 106 of the National Historic Preservation Act. The Programmatic Agreement has been signed by the Jacksonville District Commander and is currently awaiting final signature by the SHPO.

5.1.9 Summary of the Environmental Effects of the Recommended Plan

A summary of anticipated environmental effects resulting from implementation of the recommended plan is provided below in Table 5-1.

Table 5-1. Summary of anticipated environmental effects resulting from implementation of the recommended plan.

Environmental Resource	**Minor Effect**	**No Effect**
Aesthetics	☒	☐
Air quality	☒	☐
Aquatic resources/wetlands	☐	☒
Fish and wildlife habitat	☒	☐
Threatened/Endangered species	☒	☐
Historic properties	☒	☐
Other cultural resources	☒	☐
Floodplains	☒	☐
Hazardous, toxic & radioactive waste	☐	☒
Hydrology	☐	☒
Land use	☒	☐
Noise levels	☒	☐
Public infrastructure	☐	☒
Socio-economics	☒	☐
Environmental justice	☐	☒
Soils	☒	☐
Water quality	☒	☐
Climate change	☐	☒

5.2 Environmental Operating Principles

This study and the associated recommended plan maintain the USACE commitment to environmental stewardship by conforming to the following USACE Environmental Operating Principles:

- Foster sustainability as a way of life throughout the organization. The recommended plan fosters environmental sustainability by representing the plan with the least environmental impacts and provides environmental benefits via floodplain restoration.
- Proactively consider environmental consequences of all USACE activities and act accordingly. The PDT coordinated with appropriate environmental agencies to identify all possible environmental impacts and sought avenues to minimize those impacts.
- Create mutually supporting economic and environmentally sustainable solutions. The recommended plan maximally reduces flood risk by removing residences and businesses from the floodplain, which simultaneously improves riparian habitats, connectivity, and functioning.
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by USACE, which may impact human and natural environments. The PDT is engaged in the activities necessary to assess and minimize cumulative impacts to the environment through the National Environmental Policy Act via necessary surveys and agency coordination. It is expected that the recommended plan will be compliant with all applicable laws and policies.
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs. Environmental risks were identified early in the study process and used to inform plan formulation decisions.
- Leverage scientific, economic, and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner. The PDT worked with local and regional stakeholders and held a scoping meeting with the general public to obtain all existing scientific, economic, and social knowledge regarding environmental context and used this information during the plan formulation process.
- Employ an open, transparent process that respects views of individuals and groups interested in USACE activities. The PDT was open and transparent regarding the study process and possible outcomes during site visits and the public scoping meeting. All feedback obtained during these outreach activities was incorporated into the planning process.

The recommended plan will be reviewed and potentially modified during the PED phase. If changes to the project result in effects that have not been previously evaluated, then pursuant to the National Environmental Policy Act (NEPA), USACE will prepare a separate NEPA document to address the changes and evaluate the associated effects. USACE and its contractors commit to avoiding, minimizing, and mitigating for adverse effects during construction activities.

5.3 Impacts Assessment

5.3.1 Cumulative Impacts & Effects Determination

Cumulative effects are defined in 40 C.F.R. §1508.7 as those effects that result from "...the incremental effect of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time."

No significant cumulative effects would be expected under the recommended plan. Past actions include general land use development and transportation infrastructure. Current actions include general land use development, construction of transportation infrastructure (the PR-145 Bridge is currently being re-constructed following failure during Hurricane Maria), and ongoing gravel mining operations occurring just upstream of the PR-6685 Bridge. Future actions include the federal relocation of 110 public housing units from the communities of Dos Rios and Alturas de Ciales. It is also expected that general land use development, updates to transportation infrastructure, and mining operations would continue. The recommended plan would have temporary, minor effects during construction activities; however, once construction activities are complete it is expected that areas would return to pre-construction conditions. Taking into account all of these factors, the recommended plan is not expected to have significant cumulative effects.

5.3.2 Unavoidable Adverse Impacts

Temporary minor adverse effects aesthetics, air quality, wildlife, and noise levels may occur during construction. None of the unavoidable adverse impacts were deemed significant.

5.3.3 Irreversible and Irretrievable Commitments of Resources

Irreversible and irretrievable commitment of resources represent the permanent loss of resources for future or alternative purposes—resources that cannot be recovered or recycled or those that are consumed or reduced to unrecoverable forms. Implementation of the recommended plan would result in the irreversible and irretrievable commitment of the following resources:

- Oil and gasoline consumed and energy expended during project construction.

The use of these nonrenewable resources are expected to represent a small proportion of the region's resources and would not affect the availability of these resources for other purposes.

5.3.4 Growth Inducing Effects

Growth-inducing effects are defined in 40 C.F.R. §1508.8 as those that induce changes in population density or growth rate. Actions are considered growth-inducing when they:

- Directly or indirectly foster economic growth, population growth, or the construction of additional housing in the affected environment.
- Removes obstacles to population growth.
- Results in additional taxes to existing community service facilities.
- Encourages or facilitates other activities that could significantly affect the environment, either individually or cumulatively.

The recommended plan is not anticipated to result in population growth or construction of additional housing. Local geology (i.e., steep mountains with limited floodplain area) and extensive existing development have resulted in minimal developable land that is not already developed. Properties included in the relocation would be permanently cleared and all future development would be prohibited.

5.3.5 Systems & Watershed Context

The Rio Grande de Manati represents one of few major rivers along Puerto Rico's north coast that remains unimpeded. As a result, the Rio Grande de Manati has a full complement of native stream fauna, including many species that migrate between the coast and upstream habitats. The recommended plan would maintain existing in-stream habitats, helping to preserve aquatic biota and support their life history requirements (e.g., reproduction, dispersal, and foraging). The recommended plan would restore natural floodplain area and associated wildlife habitats. The recommended plan is also consistent with the relocation of public housing within the study area.

5.4 Compliance with Applicable Laws & Policies

A summary of completed and anticipated environmental compliance activities completed to-date is presented in Table 5-2.

Table 5-2. Environmental coordination and compliance activities completed. All relevant documentation regarding environmental coordination and compliance can be found in the Environmental Appendix, Appendix B.

Statute	Actions
NEPA	• Scoping letters sent: 17 DEC 2018 • Environmental Assessment and Finding of No Significant Impact integrated into feasibility report

Statute	Actions

	• Public comment period held from 26 FEB 2020–27 MAR 2020
	  • Public scoping meeting held on 8 MAR 2020
	  • Public comments integrated into final report

ESA	• USFWS letter of concurrence was received on 28 February 2020
FWCA	• FWCA Planning Aid Letter Received: 24 June 2019 • MOU drafted and signed 9 Oct 2019 enabling feasibility report/EA to complete FWCA requirements • USFWS comment letter received on 28 February 2020 (comments to be addressed during PED)
CWA	• Section 404(b)(1) analysis integrated into feasibility report (analysis will be updated in PED) • Section 401 Water Quality Certification obtained during PED • Section 402 NPDES permit obtained during PED
CERCLA	• HTWR Phase 1 Report included in Environmental Appendix, Appendix B
NHPA	• Programmatic Agreement developed with SHPO to conduct survey during PED. The Programmatic Agreement has been signed by the Jacksonville District Commander and awaiting final signature by the SHPO

A detailed description of compliance with all applicable laws and policies is provided in the following sections.

5.4.1 National Environmental Policy Act of 1969 (42 U.S.C. §4321 *et.seq.*)

The National Environmental Policy Act (NEPA) requires that federal agencies consider the environmental effects of their actions. It requires that an Environmental Impact Statement (EIS) be included in every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment. The EIS must provide detailed information regarding the proposed action and alternatives, the environmental effects of the alternatives, appropriate mitigation measures, and any adverse environmental effects that cannot be avoided if the proposal is implemented. Agencies are required to demonstrate that these factors have been considered by decision makers prior to undertaking actions. Major federal actions determined not to have a significant adverse effect on the quality of the human environment may be evaluated through an Environmental Assessment (EA).

This integrated feasibility report and environmental assessment evaluates the environmental effects of the recommended plan and alternatives. This integrated feasibility report and environmental assessment has been prepared pursuant to NEPA Sec. 102(C). Effects on the quality of the human environment as a result of the recommended plan are anticipated to be less than significant. The integrated feasibility report and environmental assessment has incorporated any necessary and applicable modifications to the scope and/or nature of the project, any effects to the human environment resulting from these modifications, the

procedures and practices used to implement the project, and/or the type and extent of compensatory mitigation associated with the project. Accompanying this integrated feasibility report and environmental assessment is a Finding of No Significant Impact.

5.4.2 Endangered Species Act of 1973 (16 U.S.C. §1531 *et.seq.*)

The Endangered Species Act, amended in 1988, establishes a national program for the conservation of threatened and endangered species of fish, wildlife, and plants and the habitat upon which they depend. Section 7(a) of the Endangered Species Act requires that federal agencies consult with USFWS and the National Marine Fisheries Service (NMFS), as appropriate, to ensure that proposed actions are not likely to jeopardize the continued existence of endangered or threatened species or to adversely modify or destroy designated critical habitats. Only species under the jurisdiction of the USFWS are present in the study area; therefore consultation with NMFS is not required.

For species under the jurisdiction of the USFWS, USACE initiated consultation in accordance with Section 7 of the Endangered Species Act in February 2020. Using the USFWS' online database and information received from the USFWS Caribbean field office, one species, the Puerto Rican boa (*Chilabothrus inornatus*), was identified as occurring within the study area. The USFWS has developed conservation measures to avoid or minimize impacts on the boa during project development in areas where the boa may occur (see Environmental Appendix, Appendix B). These conservation measures would be implemented during project construction.

A concurrence letter was received from the USFWS for a May Affect, Not Likely to Adversely Affect (MANLAA) determination for the Puerto Rican boa on 28 February 2020, completing USFWS consultation under the Endangered Species Act. The study is compliant with the Endangered Species Act.

5.4.3 Fish and Wildlife Coordination Act of 1958 (16 U.S.C. §661 *et.seq.*)

USACE requested technical assistance in accordance with the Fish and Wildlife Coordination Act (FWCA) on 5 June 2019 for the proposed alternatives. The USFWS provided comments via letter dated 24 June 2019. USACE submitted further information, including the recommended plan, to the USFWS via letter dated 23 September 2019. A memorandum for the record has been submitted to USFWS to document an agreement between USACE and USFWS to use the NEPA review and Endangered Species Act consultation processes to complete coordination responsibilities under the Fish and Wildlife Coordination Act. This agreement will avoid duplicate analysis and documentation as authorized under 40 CFR section 1500.4 (k), 1502.25, 1506.4, and is consistent with the Presidential Executive Order for Improving Regulation and Regulatory Review, released January 18, 2011. A concurrence letter was received from the USFWS noting the completion of consultation. Thus, the study is compliant with the FWCA.

5.4.4 National Historic Preservation Act of 1966 (16 U.S.C. §470(a), *et.seq.*)

Section 106 of the National Historic Preservation Act of 1966 and its implementing regulations (36 CFR 800) require federal agencies to identify and resolve adverse effects to historic properties within the Area of Potential Effects (APE) of projects, activities, or programs funded in whole or in part under direct or indirect jurisdiction of a federal agency. Historic properties include buildings, structures, objects, sites, objects, and historic districts worthy of preservation due to historic significance. This process is carried out in consultation with Advisory Council on Historic Preservation, State Historic Preservation Offices (SHPO), Certified Local Governments, Indian Tribes, and the interested public. The Puerto Rico SHPO has been identified as the appropriate SHPO for all proposed alternatives. The National Park Service database of Certified Local Governments does not include any in Puerto Rico. There are no federally-recognized Indian Tribes in Puerto Rico. Due to budgetary constraints for this study, USACE has developed a Programmatic Agreement in coordination with the Puerto Rico SHPO to defer final identification and evaluation of historic properties until the study is approved and the project enters the Preconstruction Engineering and Design phase in compliance with Section 106 of the National Historic Preservation Act (36 CFR § 800.4[b][2]). The Programmatic Agreement has been signed by the Jacksonville District Commander and is awaiting final signature by the SHPO.

5.4.5 Clean Water Act of 1972 (33 U.S.C. §1251 *et.seq.*)

The Clean Water Act (CWA) is the primary legislative vehicle for federal water pollution control programs and the basic structure for regulating discharges of pollutants into waters of the United States (WOTUS), which includes streams, rivers and wetlands among other waters. The CWA was established to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." The CWA sets goals to eliminate discharges of pollutants into navigable waters, protect fish and wildlife, and prohibit the discharge of toxic pollutants in quantities that could adversely affect the environment.

The discharge of fill material into WOTUS is regulated by the Clean Water Act, sections 404 and 401. USACE does not issue permits for its own civil works activities, including the discharge of fill into WOTUS. Nevertheless, USACE has accepted responsibility for the compliance of its civil works projects with Section 404, as well as the obligation to seek water quality certification under Section 401. The recommended plan may include discharge of fill into wetlands, if present. Once plans, impacts, and potential staging areas are finalized during PED, and prior to construction, a wetland delineation will be conducted to determine if wetlands are present in the areas where construction, earth disturbance, and staging are proposed. It is expected that if wetlands are present, impacts can either be avoided or minimized. Compliance with Section 404 of the Clean Water Act will be completed prior to construction for impacts to any wetlands (if present and impacted). After the wetland delineation is completed during PED, a 404(b)(1) analysis will be

completed if there will be a discharge of fill into WOTUS as a result of the recommended plan. USACE will coordinate the project with the Commonwealth of Puerto Rico to obtain Section 401 Water Quality Certification (WQC), if required. Compliance with Section 401 of the Clean Water Act will be complete once a 401 WQC is issued to USACE, if required.

A National Pollutant Discharge Elimination System (NPDES) permit would be required under Section 402 of the CWA, as the project would disturb greater than one acre of land. A Stormwater Pollution Prevention Plan (SWPPP) would be developed and a Notice of Intent (NOI) submitted to the USEPA prior to construction activities to obtain coverage under the NPDES Construction General Permit. Compliance with Section 402 of the Clean Water Act will be complete once USACE obtains coverage under the NPDES permit.

5.4.6 Clean Air Act of 1970 (42 U.S.C. §7401 *et. seq.*)

USEPA's General Conformity Rule was promulgated to implement Section 176(c) of the Clean Air Act. The purpose of the rule is to ensure that federal actions do not cause or contribute to new violations, worsen existing violations, or delay attainment of the national ambient air quality standards (USEPA, 2019).

Ciales is designated as an attainment area for federal air quality standards under the Clean Air Act (40 CFR 81.355). USEPA's General Conformity Rule applies to those areas that are designated as nonattainment and maintenance areas; therefore a conformity determination is not required for this project.

Temporary air quality effects from construction equipment may occur during construction activities; however these effects would be considered *de minimis* and are not expected to be significant. Temporary air quality disturbances may occur during demolition. The contractor would be responsible for obtaining all applicable air quality permits related to the demolition activities. No significant impacts to air quality are expected. If air quality permits are required, the project will be in compliance with this Act once permits are obtained.

5.4.7 Coastal Zone Management Act of 1972 (16 U.S.C. §1451 *et. seq.*)

The study area is located outside of Puerto Rico's coastal zone management program jurisdiction (Fig. 5-1). The recommended plan would have no effect on the coastal zone.

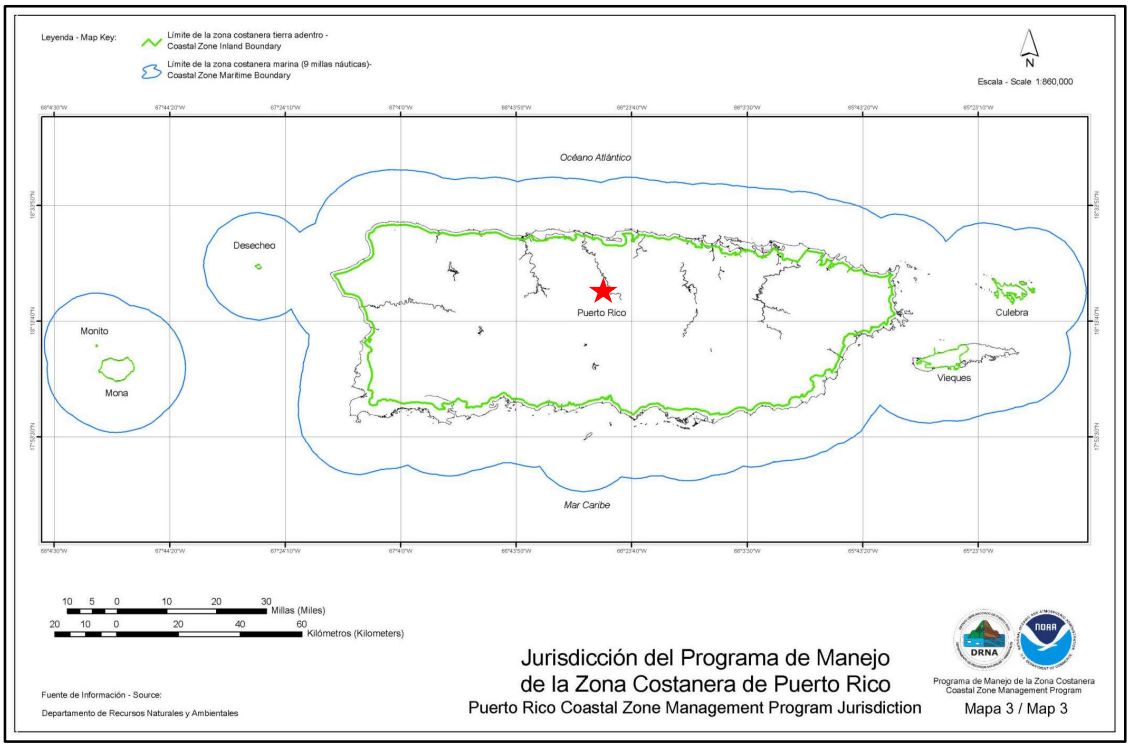

Fig. 5-1. Puerto Rico Coastal Zone Management Map. Red star denotes approximate location of study area.

5.4.8 Farmland Protection Policy Act of 1981 (7 U.S.C. §4201 *et.seq.*)

The study area contains soils classified as prime farmland and farmland of statewide importance in the soil survey for the Arecibo Area, Puerto Rico Northern Part. The project footprint is limited to the developed areas where demolition and removal of structures within the 0.04 AEP floodplain is proposed. No impacts to farmland or pastureland are proposed. No prime or unique farmland will be impacted by implementation of this project. If the conceptual plans change during PED to include impacts that may extend into prime farmland areas, then coordination with the National Resources Conservation Service (NRCS) will be conducted and an AD1006 (farmland conversion impact rating form) will be completed.

5.4.9 Wild and Scenic Rivers Act of 1968 (16 U.S.C. §1271 *et. seq.*)

The recommended plan will not affect any designated wild and scenic river reaches (Fig. 5-2).

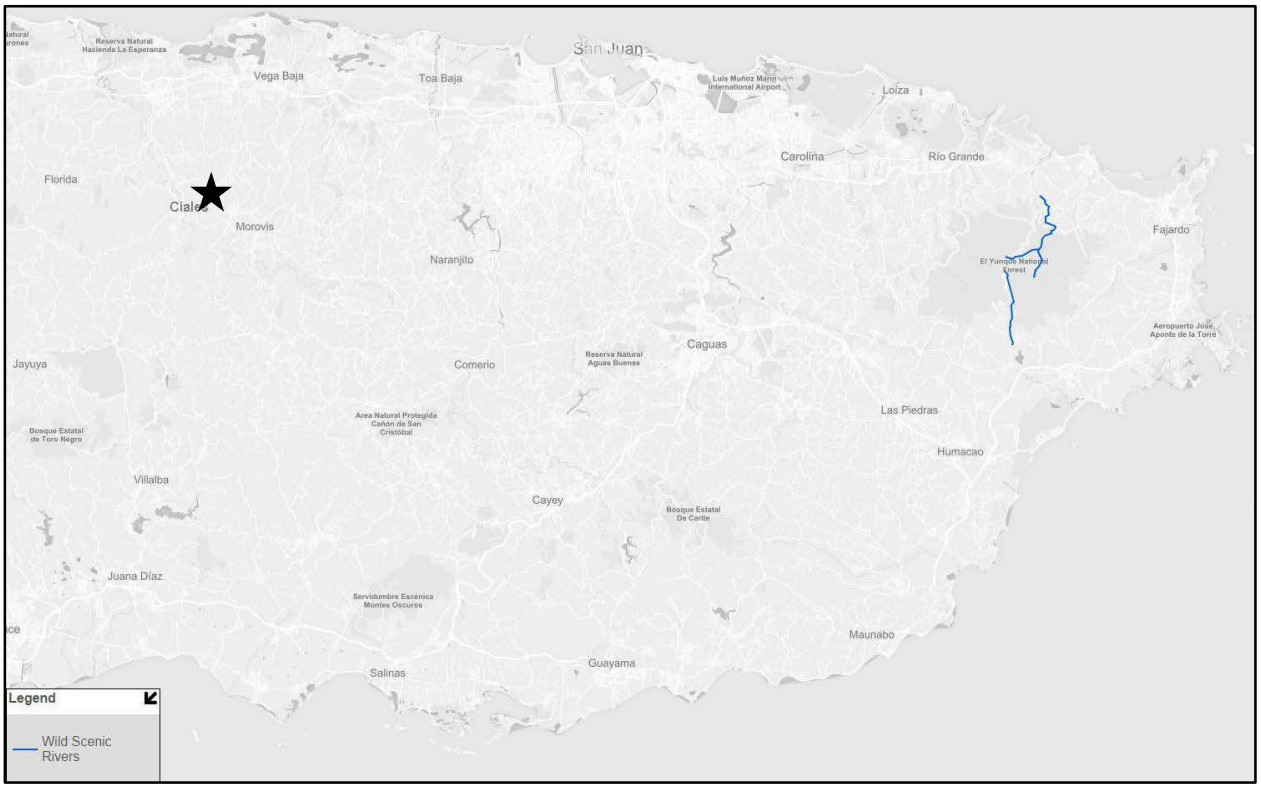

Fig. 5-2. Puerto Rico Wild and Scenic River Map. The black star indicates the approximate location of the study area. Map obtained from https://www.rivers.gov/puerto-rico.php.

5.4.10 Marine Mammal Protection Act of 1972 (16 U.S.C. §1361 *et. seq.*)

The proposed work will occur in a freshwater river and will have no effects on marine mammals. This project is in compliance with the Act.

5.4.11 Federal Water Project Recreation Act (16 U.S.C. 460(l)(12), *et. seq.*)

In the planning of any federal navigation, flood control, reclamation, or water resources project, the Federal Water Project Recreation Act, as amended, requires that full consideration be given to opportunities that the project affords for outdoor recreation and fish and wildlife enhancement. The Act requires planning with respect to development of recreation potential. Projects must be constructed, maintained, and operated in such a manner if recreational opportunities are consistent with the purpose of the project. Recreational resources and opportunities are considered and discussed in previous sections of this report. This project is in compliance with the Act.

5.4.12 Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §1801 *et. seq.*)

The proposed work will occur in a freshwater river. The recommended plan will have no effects on essential fish habitat nor marine fisheries and does not require coordination with National Marine Fisheries Service. This project is in compliance with the Act.

5.4.13 Rivers and Harbors Act of 1899, Section 10 (33 U.S.C. §401 *et. seq.*)

The proposed work will not obstruct navigable waters of the U.S. This project is in compliance with the Act.

5.4.14 Migratory Bird Treaty Act (16 U.S.C. §§703-712) & Migratory Bird Conservation Act (16 U.S.C. §§715-715D, 715E, 715F-715R)

The USFWS has developed nationwide standard conservation measures to reduce impacts to migratory birds and their habitats (see Environmental Appendix, Appendix B). The project plans and specifications will include these migratory bird protection measures for construction activities. If construction activities are proposed to occur during nesting season, a nesting survey will be completed prior to the commencement of construction activities. If nesting activities occur within the construction area, appropriate buffers will be placed around nests to ensure their protection. The project will be coordinated with USFWS and will comply with these acts.

5.4.15 Uniform Relocation Assistance and Real Property Acquisition Policies Act Of 1970 (42 U.S.C. §4601 *et. seq.*)

The purpose of the Uniform Relocation Assistance and Real Property Acquisition Act is to ensure that owners of real property to be acquired for federal and federally assisted projects are treated fairly and consistently and that persons displaced as a direct result of such acquisition will not suffer disproportionate injuries as a result of projects designed for the benefit of the public as a whole. The non-federal sponsor will be responsible for acquiring any real estate interests for the project. USACE will work with the non-federal sponsor to ensure compliance with this Act. The project will comply with this Act.

5.4.16 Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d)

The Bald and Golden Eagle Protection Act prohibits the taking, possession or commerce of bald and golden eagles, except under certain circumstances. Amendments in 1972 added penalties

for violations of the Act or related regulations. Bald and golden eagles are not typically found in Puerto Rico and it is not expected that a take of either bald or golden eagles is likely through any of the actions discussed in this EA. This project is in compliance with the Act.

5.4.17 American Indian Religious Freedom Act of 1978 (42 U.S.C. 1996)

The American Indian Religious Freedom Act of 1978, establishes protection and preservation of Native Americans' rights of freedom, belief, expression, and exercise of traditional religions. Courts have interpreted the American Indian Religious Freedom Act to mean that public officials must consider Native Americans' interests before undertaking actions that might impact their religious practices, including impact on sacred sites.

The recommended plan is not expected to have any effect upon Native Americans' rights of freedom of belief, expression, and exercise of traditional religions.

5.4.18 Executive Order (E.O.) 11988, Floodplain Management

Executive Order 11988 requires federal agencies to avoid, to the extent possible, the long and short-term adverse impacts associated with the occupancy of the floodplain, and to avoid direct and indirect support of floodplain development where there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by flood plains."

The purpose of the proposed project is to reduce the risk of flood loss and minimize the impact of floods on human safety, health and welfare. Floodplain area will increase as a result of this project. USACE has determined that the project is in the public interest and is in compliance with this order.

5.4.19 E.O. 11990, Protection of Wetlands

Executive Order 11990 encourages federal agencies to take actions to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands when undertaking federal activities and programs. The recommended plan should not cause any adverse impacts to wetlands. If permanent wetland impacts are proposed once plans are finalized during PED, wetland impacts will be mitigated for. If proposed, temporary wetland impacts will be restored once project construction activities have been completed. The recommended plan is in compliance with this order.

5.4.20 E.O. 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations

5.4.20.1 Background & Definitions

Executive Order 12898, dated February 11, 1994, mandates that "each federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations."

The Council on Environmental Quality (CEQ) has oversight of the federal government's compliance with EO 12898 and NEPA. CEQ, in consultation with the US Environmental Protection Agency (EPA) and other affected agencies, developed NEPA guidance for addressing requirements of the EO (CEQ, 1997). This guidance was developed to further assist federal agencies with their NEPA procedures so that environmental justice (EJ) concerns are effectively identified and addressed.

The CEQ has also identified six general principles for consideration in identifying and addressing EJ in the NEPA process which include: (1) area composition (demographics); (2) data (concerning cumulative exposure to human health or environmental hazards); (3) interrelated factors (recognize the interrelated cultural, social, occupational, or economic factors); (4) public participation; (5) community representation; and (6) tribal representation.

The following definitions are used by the CEQ in guidance on key terms of the EO:

- Low-income population: Low-income populations in an affected area should be identified with the annual statistical poverty thresholds from the Bureau of the Census' Current Population Reports, Series P-60 on Income and Poverty. In identifying low income populations, agencies may consider as a community either a group of individuals living in geographic proximity to one another, or a set of individuals (such as migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect.

- Minority: Individual(s) who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.

- Minority population: Minority populations should be identified where either: (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In identifying minority communities, agencies may consider as a community either a group of individuals living in geographic proximity to one another, or a geographically dispersed/transient set of

individuals (such as migrant workers or Native American), where either type of group experiences common conditions of environmental exposure or effect. The selection of the appropriate unit of geographic analysis may be a governing body's jurisdiction, a neighborhood, census tract, or other similar unit that is to be chosen so as to not artificially dilute or inflate the affected minority population. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds.

- Disproportionately high and adverse human health effects: When determining whether human health effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable:

    - Whether the health effects, which may be measured in risks and rates, are significant (as employed by NEPA), or above generally accepted norms. Adverse health effects may include bodily impairment, infirmity, illness, or death.
    - Whether the risk or rate of hazard exposure by a minority population, low-income population, or Indian tribe to an environmental hazard is significant (as employed by NEPA) and appreciably exceeds or is likely to appreciably exceed the risk or rate to the general population or other appropriate comparison group.
    - Whether health effects occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environmental hazards.

- Disproportionally high and adverse environmental effects: When determining whether environmental effects are disproportionately high and adverse, agencies are to consider the following three factors to the extent practicable:

    - Whether there is or will be an impact on the natural or physical environment that significantly (as employed by NEPA) and adversely affects a minority population, low-income population, or Indian tribe. Such effects may include ecological, cultural, human health, economic, or social impacts on minority communities, low-income communities, or Indian tribes when those impacts are interrelated tribes when those impacts are interrelated to impacts on the natural or physical environment.
    - Whether environmental effects are significant (as employed by NEPA) and are or may be having an adverse impact on minority populations, low-income populations, or Indian tribes that appreciably exceeds or is likely to appreciably exceed those on the general population or other appropriate comparison group.
    - Whether the environmental effects occur or would occur in a minority population, low-income population, or Indian tribe affected by cumulative or multiple adverse exposures from environmental hazards. (Ibid. Appendix A, pp. 25-27).

5.4.20.2 Analysis & Conclusions

USACE conducted an EJ analysis by first determining whether EJ populations are present and second by determining whether the proposed action would result in a disproportionately high and/or adverse effect on these populations.

For purposes of the EJ analysis, the area of effect is the study area. Using the USEPA EJSCREEN Tool, the project boundaries were defined and the average percentages for minority and low-income populations were compared for the study area and Puerto Rico (Table 5-3). No data was available to compare to overall EPA region or U.S. averages.

Table 5-3. USEPA EJSCREEN environmental justice criteria percentages.

	Study area (%)	**Puerto Rico (%)**
Minority Population	100	99
Low Income Population	88	73

Based on the information provided by the USEPA EJSCREEN tool, the average minority population in the study area is 100% of the total population, and 88% of the total population is low income. The study area qualifies as an EJ community for both minority and low income populations.

Impacts of the recommended plan on EJ communities are expected to be temporary, primarily during construction activities. Temporary impacts related to noise and air quality will occur, but are expected to cease once construction is completed with the area returning to pre-construction conditions. The recommended plan will not cause any significant impacts, nor will it cause either disproportionately high and adverse human health or environmental effects. The recommended plan is expected to provide long-term benefits to the EJ communities by reducing flood risk. Individuals included in the relocation would be provided all necessary assistance and equitable housing. Therefore, impacts to EJ communities would not be expected.

5.4.21 E.O. 13045, Protection of Children from Environmental Health Risks & Safety Risks (62 FR 19885; April 21, 1997)

Executive Order 13045 mandates that each federal agency: “shall make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children; and shall ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks.”

The recommended plan does not affect children disproportionately from other members of the population and will not increase any environmental health or safety risks to children. While schools and daycares are present within the study area, they are not located in the areas where construction activities are proposed. This project is in compliance with the order.

5.4.22 E.O. 13112, Invasive Species

No new or invasive species will be introduced to the area as a result of the recommended plan. Re-vegetation of disturbed areas and floodplain areas with native seeds and plants will reduce the areas where existing invasive species could spread. This project is in compliance with the order.

5.4.23 E.O. 13186, Migratory Birds

Executive Order 13186 mandates that federal agencies that take actions that have, or are likely to have, a measurable negative effect on migratory bird populations enter into a Memorandum of Understanding (MOU) with the USFWS. The existing Department of Defense MOU does not address migratory birds on lands not owned by USACE. Real estate for the proposed project will be owned by the non-federal sponsor. USACE will include the USFWS' Nationwide Standard Conservation Measures in the project plans and specifications and will require the contractor to abide by those requirements. This project is in compliance with the order.

5.5 Public & Agency Coordination *

This section summarizes public and agency coordination undertaken by USACE to satisfy NEPA requirements for public involvement and agency consultation and coordination.

5.5.1 Scoping

5.5.1.1 Agency Coordination

Site visits held on 26 October 2018 and 17 December 2018 and attended by members of the Pittsburgh District PDT, the non-federal sponsor, and key stakeholders (e.g., local, commonwealth, and federal representatives) resulted in consensus on the problems to be addressed by and overall scope of the feasibility study.

5.5.1.2 Study Scoping Letters

Commonwealth and federal agencies were notified via letter dated 17 December 2018 of the intent by USACE to prepare an Environmental Assessment to evaluate the potential effects of alternatives to reduce flood risk within the Municipality of Ciales, Puerto Rico (Environmental Appendix, Appendix B). Management measures considered included structural measures such as channel improvement (widening, deepening, straightening), flood walls, levees, rip rap, gabion baskets/mattresses, concrete/stone revetments, channel relocation, and transportation-related recommendations; non-structural measures such as flood-proofing, home acquisition and

relocation, and emergency planning; and environmental measures such as wetland retention, riparian restoration, channel diversions, and plantings. Comments were requested within 30 days of letter receipt.

Three comment letters were received from the Puerto Rico State Historic Preservation Office (SHPO) dated 22 January 2019, the Puerto Rico Department of Economic Development and Commerce Permits Management Office (OGPe) dated 23 January 2019, and the Puerto Rico Planning Board dated 30 January 2019 (Environmental Appendix, Appendix B). The Puerto Rico SHPO letter stated that multiple archaeological sites are located in the area and Bridge No. 321 (the PR-6885 Bridge) is listed in the NRHP. The OGPe letter did not contain comments on the proposed alternatives. The letter from the Puerto Rico Planning Board requested information on the selected alternative, and hydrologic and hydraulic studies for the project once available.

5.5.1.3 Public and Agency Scoping Meeting

A public scoping meeting was held on 24 March 2019 during which a general presentation of potential flood risk reduction measures and alternatives was presented. This meeting was attended by over 100 local community members and stakeholders. There was a general consensus among participants that relocation of private at-risk structures—similar to the effort to relocate the 110 public housing units from Dos Rios—was the preferred action. There was also general lack of support for a structural action that would result in some level of residual risk to those residents in the floodplain.

5.5.2 Draft Integrated Feasibility Report and Environmental Assessment

A Notice of Availability for the draft integrated feasibility report and environmental assessment, including an unsigned, draft Finding of No Significant Impact were published on 26 February 2020 and circulated to all pertinent commonwealth and federal agencies and interested stakeholders for a 30-day public review and comment period.

Consistent with NEPA regulations and guidance, A Notice of Availability for the draft integrated feasibility report and environmental assessment and associated unsigned, draft Finding of No Significant Impact, was distributed to the following list of recipients:

- Federal Agencies: USFWS, FEMA, USACE Antilles Regulatory, NOAA Marine Fisheries Service, USEPA, USDA, USGS

- Commonwealth Agencies: Puerto Rico Department of Natural and Environmental Resources, Puerto Rico State Historic Preservation Office, Puerto Rico Environmental Quality Board, Puerto Rico Planning Board, Institute of Puerto Rican Culture, Puerto Rico Office of Permit Management, Puerto Rico Department of Agriculture, Puerto Rico Agency for Emergency

Management and Disaster Management, Puerto Rico DNER Protected Species Program, Puerto Rico Department of Health, Puerto Rico Public Housing Administration, Puerto Rico Department of Transportation and Public Works, Puerto Rico Department of Economic and Trade Development, Puerto Rico Water and Sewage Authority, Puerto Rico Public Buildings Authority, Puerto Rico Electric Power Authority, Puerto Rico Department of Public Security, Puerto Rico Firefighters Corps, Puerto Rico Land Authority, Puerto Rico Police Bureau

- Others: Puerto Rico Tourism Company, Puerto Rico College of Engineers and Land Surveyors, Puerto Rico Land Administration, Puerto Rico Para la Naturaleza, Federal and Commonwealth Representatives and Senators, Mayor of Ciales, Municipal Library of Ciales

Letters notifying local residents of the Notice of Availability and the 8 March 2020 public meeting were prepared and sent to Representative Gabriel Rodrigues Aguilo's office to be hand delivered to those individuals potentially affected by the proposed non-structural relocations. The Notice of Availability was also mailed to resident addresses in the non-structural relocation areas. A public meeting was also held during review period on 8 March 2020.

A total of 9 public review comments were received—none of which resulted in substantial changes to the recommended plan. All comments received during the public review and comment period were considered and incorporated into the final report, as appropriate. All comments and associated responses can be found within the Environmental Appendix, Appendix B, Public and Agency Project Comments.

6 RECOMMENDATIONS *

The study team recommends outlining the recommended plan—non-structural relocation of 59 homes within the 0.04 AEP floodplain—in a Chief's Report. The recommended plan reasonably maximizes contribution to the national economic development consistent with protecting the nation's environmental resources, pursuant to national environmental statutes, applicable executive orders, and other federal planning requirements.

The floodwall around the wastewater treatment plant was not incrementally justified (i.e., negative net economic benefits and a BCR less than 1) and could not be included within the recommended plan per USACE policy (USACE, ER 1105-2-100, Planning Guidance Notebook, 2000). However, the floodwall would provide public health, economic, and environmental benefits. Thus, USACE recommends considering local implementation of the floodwall to further reduce flood risk.

The recommendations contained herein are based on the information available at the current time and reflect 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 U.S. Army Corps of

Engineers or Executive Branch. Consequently, the recommendations may be modified before they are transmitted to Congress as proposals for authorization and implementation funding. However, the sponsor, Commonwealth of Puerto Rico, interested federal agencies, and other parties will be advised of any modification and afforded the opportunity to provide comments on the updated document.

Date

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