RÍO GUAYANILLA FLOOD RISK MANAGEMENT STUDY

INTEGRATED FEASIBILITY REPORT

& ENVIRONMENTAL ASSESSMENT

MUNICIPALITY OF GUAYANILLA

the COMMONWEALTH OF PUERTO RICO

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ABSTRACT*
Río Guayanilla Flood Risk Management Study, Guayanilla, Puerto Rico
Final Integrated Feasibility Report & Environmental Assessment

The lead federal agency responsible for the planning and design of a flood risk management project, including addressing National Environmental Policy Act (NEPA) requirements is the U.S. Army Corps of Engineers (USACE). This report is an Integrated Feasibility Report (IFR), combining a feasibility report and Environmental Assessment (EA) complying with requirements of the federal Council on Environmental Quality (CEQ). An asterisk in the table of contents notes sections that are required for NEPA compliance.

Abstract

This Final Integrated Feasibility Report (IFR) presents a feasibility study for addressing flood risks to the communities within the Rio Guayanilla floodplain. Documentation includes the development and assessment of various measures and alternatives to address specific study objectives while considering the effects to the human and natural environments. Documentation and analyses were developed to a feasibility level of detail sufficient to identify the most cost effective and environmentally compliant plan which is termed the Recommended Plan.

The study area is located in Guayanilla, Puerto Rico beginning north of highway PR-2 and extending southward to the river's outlet at the Caribbean Sea. The study area includes the whole floodplain of the lower Rio Guayanilla, where the Municipality of Guayanilla is located, portions of the mountains to the west, and to a lesser degree, the marine/estuarine coastline. Analyses show that flooding overtops the existing natural river channel of Rio Guayanilla in the study area at the 0.5 Annual Exceedance Probability (AEP) storm event (which corresponds to a 2-year flood event). In the study area, there are approximately 8,800 residents and 1,665 public, commercial and residential structures at risk of inundation. There are also approximately 400 acres of agricultural land at risk of inundation. Analysis shows that the 0.002 AEP (500-year flood event) would cause an estimated $278 million in structural and other damages. Study analyses focused on alternatives, including a diversion channel, to convey flood waters greater than the 0.5 AEP flow around the Municipality of Guayanilla.

Of the three action alternatives, Alternative #3 Diversion Channel South w/ Single Line Protection is the Recommended Plan. The Recommended Plan includes the construction of an engineered diversion channel with a bottom width of 100-feet and 2:1 side slopes. The 9,000 foot engineered channel will extend from a new diversion structure, constructed across the existing river approximately 2,000 feet downstream of PR-127. The diversion structure will direct the majority of flood waters to the trapezoidal diversion channel while maintaining a bank-full flow to the Rio Guayanilla. The diversion structure will maintain riverine connectivity for sediment transport and fish passage. The diversion channel and existing channel will be reconnected upstream of the Phase I project with an additional diversion structure. Relocation of three local roads will be required.

The diversion channel will also include a levee along the eastern side of the channel. The riverside slope of the levee will be lined with riprap to prevent erosion. Upstream of the diversion channel, a combination of levees and floodwalls will be constructed on the east side of the river channel at designated locations. The levees will be constructed from local limestone sourced from an abandoned quarry within the project area. A 2,750 foot long earthen levee will be constructed to reduce flood risk for El Faro community from overbank riverine flooding. Other plan features include the development of a flood warning/response

plan, and conservation measures for connectivity, flow and habitat. Due to impacts associated with the El Faro levee, wetland mitigation of 6.0 acres is also included in the Recommended Plan. Conservations measures for two special status species will be implemented during quarrying to minimize potential impacts to less than significant.

The Recommended Plan has an estimated first cost of $154 million and a benefit-to-cost ratio (BCR) of 3.3 to 1 at the current Fiscal Year 2020 (FY20) discount rate of 2.75%. The Recommended Plan would reduce average annual damages by $19.8 million.

HOJA DE CUBIERTA *
Estudio de Gestión de Riesgos de Inundaciones del Río Guayanilla, Guayanilla, Puerto Rico
Informe Final Integrado de Viabilidad y Evaluación Ambiental

El organismo federal principalmente responsable por la planificación y diseño de un proyecto de gestión de riesgo de inundaciones es el Cuerpo de Ingenieros del Ejército de los EE.UU. (USACE, por sus siglas en inglés) en cumplimiento con los requisitos de la Ley Nacional de Política Pública Ambiental (NEPA, por sus siglas en inglés). Este reporte es un Informe Integrado de Viabilidad (IFR, por sus siglas en inglés) que incluye un Informe de Viabilidad y Evaluación Ambiental (EA) en cumplimiento con los requisitos del Consejo Federal de Calidad Ambiental (CEQ, por sus siglas en inglés). Los asteriscos que se encuentran en la tabla de contenido indican las secciones que se requieren para cumplir con el NEPA.

Resumen

El Informe Final de Viabilidad Integrado (IFR) presenta un estudio de viabilidad para atender los riesgos de inundación que enfrentan las comunidades que ubican en la llanura inundable del Río Guayanilla. La documentación incluye el desarrollo y la evaluación de diversas medidas y alternativas para abordar objetivos específicos del estudio teniendo en cuenta los efectos al entorno humano y natural. La documentación se desarrolló a un nivel de viabilidad lo suficientemente detallada para identificar el plan más costo efectivo y compatible con el medio ambiente. A este plan se le denomina como el Plan Recomendado.

El área de estudio se encuentra en Guayanilla, Puerto Rico, cerca de la carretera PR-2 y se extiende hasta la confluencia del río con el Mar Caribe. El área de estudio incluye toda la llanura inundable río abajo del Río Guayanilla, donde se encuentra el Municipio de Guayanilla, porciones de las montañas al oeste y, en menor grado, la línea costera marina/estuarina. Los análisis muestran que las inundaciones sobrepasan el cauce natural del Río Guayanilla en el área de estudio a una probabilidad anual de excedencia (AEP, por sus siglas en inglés) de 0.5 (que corresponde a inundaciones de recurrencia de 2-años). En el área de estudio, hay aproximadamente 8,800 residentes y 1,665 estructuras públicas, comerciales y residenciales en riesgo de inundación. También hay aproximadamente 400 cuerdas de terreno agrícolas en riesgo de inundación. El análisis muestra que el 0.002 AEP (evento de inundación de 500 años) causaría un estimado de $278 millones en daños estructurales y de otro tipo. Los análisis del estudio se centraron en las alternativas, incluyendo un canal de desviación, para transportar las aguas de inundación superiores al flujo de 0.5 AEP alrededor del municipio de Guayanilla.

De las tres alternativas de acción, la Alternativa #3 Canal de Desvío al Sur con Una Línea de Protección es el Recomendado Plan. El Plan Recomendado incluye la construcción de un canal de desvío de 100 pies de ancho al fondo y una pendiente lateral de 2:1. El canal de 9,000 pies de largo se extenderá desde una nueva estructura de desviación, construida a través del río existente aproximadamente 2,000 pies aguas abajo de la PR-127. La estructura de desviación dirigirá la mayoría de las aguas de inundación al canal de desvío trapezoidal mientras mantiene un flujo de banco lleno al Río Guayanilla. Las estructuras de desvío mantendrán la conectividad fluvial para el transporte de sedimentos y el paso de peces. El canal de desvío y el canal existente se reconectarán aguas arriba del Fase I del Proyecto con una estructura de desviación adicional. Se requerirá la reubicación de tres carreteras locales.

El canal de desviación también incluirá un dique a lo largo del lado este del canal. La ladera del río del dique estará revestida de escollera ("rip-rap") para evitar la erosión. Aguas arriba del canal de desviación, se construirá una combinación de diques y muros de contención en el lado oriental del canal del río en lugares designados. Los diques se construirán con piedra caliza local procedente de una cantera abandonada dentro del área del proyecto. Se construirá un dique de tierra de 2,750 pies de largo para reducir el riesgo de inundación a la comunidad de El Faro de las inundaciones fluviales. Otras características del plan incluyen la elaboración de un plan de alerta/respuesta a las inundaciones y medidas de conservación de la conectividad, el flujo y el hábitat. Debido a los impactos asociados al dique de El Faro, en el plan recomendado también se incluye la mitigación de humedales de 6.0 acres. Las medidas de conservación para dos especies de estatus especial se aplicarán durante la extracción de piedra para minimizar los impactos potenciales a menos que significativos.

El primer costo estimado del Plan Recomendado es de $154 millones y tiene una relación beneficio-costo (BCR por sus siglas en inglés) de 3.3 a 1 en el actual año fiscal 2020 (FY20) a una tasa de descuento de 2.75%. El Plan Recomendado reduciría los daños anuales en un promedio de $19.8 millones.

EXECUTIVE SUMMARY

Río Guayanilla Flood Risk Management Study, Guayanilla, Puerto Rico Final Integrated Feasibility Report & Environmental Assessment

PURPOSE & NEED

The Municipality of Guayanilla, Puerto Rico is located in the active floodplain of the Rio Guayanilla with the natural river channel bisecting the community. Heavy rainfall combined with very steep slopes in the upper catchment can produce high peak discharges in a relatively short period of time. The 1% AEP (100-year) flood event can inundate over 8 square kilometers of land within the study area.

Significant flood events occurred in the Rio Guayanilla floodplain in: 1975, 1979, 1982, 1985, 1996, 1998, 2004, 2008, 2012 and 2017. This history of significant flood events established the need for action. The 1975 flood caused by Hurricane Eloise resulted in damages. Several hundred residents were forced from their homes as 99 houses were destroyed and 276 additional houses were damaged. Fatalities were reported in the 1975, 1979, 1985, and 1998 and 2012 floods. In addition to the damaged structures and lives lost, floodwaters and sediment (rock and silt) deposition resulted in closures of major area roadways and impeded access to critical facilities. These facilities include a regional hospital and the local fire, emergency services and police stations. In 2017 Hurricane Maria caused significant flooding in the community. During the storm overbank flooding from the Rio Guayanilla washed out a major bridge and caused significant damage to 106 homes and numerous commercial establishments including the community supermarket, the local pharmacy, and the local bakery. Several other critical public structures were inundated, banana and coffee harvests were destroyed and the area was left without electricity and telecommunications for months.

As established by the Flood Control Act of 1936, flood risk management projects are in the Federal Interest if the benefits over the period of analysis exceed estimated costs and if the lives, safety and property within the project area would be adversely affected. The 1990 Reconnaissance Study concluded that there was a Federal Interest in a project based on the potential benefits derived from five different structural alternatives. The 1990 Recommended Plan included 4 miles (6.5 kilometers) of earthen levee, 2.25 miles (3.6 kilometers) of trapezoidal channel improvements (stream channelization), 0.8 miles (1.3 kilometers) of trapezoidal channel diversion, 984 feet (300 meters) of rectangular concrete channels and the replacement of three vehicular bridges.

The total first cost of the 1990 Recommended Plan was $12.5 million. Average annual costs were estimated at $1.2 million; average annual benefits were $2.5 million. The 1990 Recommended Plan had a benefit-to-cost ratio of 2.1. The non-Federal sponsor for the Reconnaissance Study, the Department of Natural & Environmental Resources of Puerto Rico (DNER), elected to construct the Recommended Plan instead of proceeding to a feasibility study. The DNER constructed the most downstream reach of the Recommended Plan (Phase I) in the early 2000s.

The purpose of a flood risk evaluation includes identifying the measures necessary to reduce the consequences of flooding, such as those measures that reduce risks to life safety, damages to residential and commercial structures and public infrastructure and lost economic output due to recovery efforts.

DEVELOPMENT OF ALTERNATIVE PLANS

Plan formulation is an iterative process resulting in the development, evaluation and comparison of alternative plans to address identified study problems by achieving the outlined objectives. Problems considered for this study are high hazard flash flooding that results in risks to life safety and significant economic losses. Heavy rainfall combined with very steep slopes in the upper mountain catchment can produce high peak discharges on the magnitude of 30,000-40,000 cfs in a relatively short period of time (hours). High rates of runoff are driven by the topography and naturally impervious ground surfaces. This natural flooding regime once helped create a diverse ecosystem within the coastal floodplain and estuary. Since the area was developed, flooding has become a significant problem for citizens in the community, other local homesteads and the agriculture lands situated within the floodplain. The risks associated with flooding are high based on the resources at risk in the community and the frequency of overbank flooding. The 100-year flood can inundate over 8-square kilometers within the municipality and rural areas of Guayanilla, but damages occur and residents are put at risk during more frequent events.

The planning objectives presented below are directly related to the flood problems introduced above and discussed in more detail in Chapter 1 of the feasibility study.

Reduce Risk of Flood Damages to Structures and Infrastructure – To lower the risk of damages induced by flooding and associated effects, this objective seeks to reduce the depth, duration and likelihood of flooding. Evaluation of how successfully an alternative meets this objective will be measured by the reduction in estimated average annual damages for the with-project condition versus the without project condition. Within the study area, flood risk reduction was specifically focused on residential, public and commercial structures, utilities, transportation infrastructure and agricultural fields in production. Benefits associated with the project begin at completion of project implementation and continue for project design life.

Reduce Risks to Life Safety – To lower the risks to life safety from flash flooding and associated effects this objective seeks to properly inform the public of pending floods, and reduce the depth, duration and likelihood of flooding. Success would be measured by the reduction in flooding within the community which significantly affect life safety. Measures formulated to satisfy this objective include appropriate warning and flood response. Within the study area, flood risk reduction was specifically focused on the population at risk and the risk to commercial structures, utilities, transportation infrastructure and agricultural fields in production. Benefits associated with the project begin at completion of the project implementation and continue for project design life.

Management measures are features or activities that can be implemented at a specific geographic location to address all or a portion of the problems and achieve objectives. Measures can directly address the hazards (flooding), the way the hazards behave (performance) or indirectly address them through eliminating or reducing the consequences (monetary damages, risk to life safety). Measures considered for this study are either non-structural or structural. A suite of six (6) non-structural measures and eleven (11) structural measures were developed to address study needs. Measure screening was conducted by consideration of technical efficacy, environmental effects, policies and guidelines. Two (2) non-structural and seven (7) structural measures were retained for further development into alternative plans. Six (6) action alternative plans were developed and evaluated using the following screening criteria: life safety, environmental effects, real estate requirements, utilities and sustainability. Based on the screening process one (1) no action and three (3) action alternatives were recommended for further detailed economic and environmental analyses:

- No Action Plan
- Alternative #1 Non-Structural Measures

- Alternative #3 Diversion Channel South w/ Single Line Protection
- Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Detailed analyses of the three action alternatives resulted in the identification of an alternative that maximized net benefits or the NED Plan. Alternative #3 is the NED Plan.

AFFECTED ENVIRONMENT

The Island of Puerto Rico is located in the Caribbean Sea and has a relatively stable annual climate (75-85°F year round/subtropical). This type of climate allows for high biological productivity that drives biodiversity and valued human resources. Its collocation along the Puerto Rico Trench and within the Atlantic Hurricane zone makes it susceptible to drastic environmental disturbance regimes that include earthquakes, tsunamis, hurricanes and distinct wet/dry periods. The Rio Guayanilla watershed itself is located in the southwest of the island, which typically receives a much less consistent rainfall than the north side; with storms being more intense but notably less frequent. The Rio Guayanilla is naturally an ephemeral river with two distinct segments (for the purposes of this study) – the upper montane and the lower coastal floodplain. The upper segment flows through mountain parent material, which is typically impervious bed rock. The riparian zone is dense with Subtropical Dry Forest community and although some deforestation has occurred, it adds beneficial large woody debris and organic materials to an otherwise nutrient deficient mountain stream. Sparsely arranged homesteads occur here, as well where the topography allows, roads and pathways; utilities span up the mountain side to reach some of these structures. Water quality may be affected by mountain homestead inputs.

As the river flows into the coastal plain near PR-379 the land use and topography reflect modifications for agriculture, residential, commercial and to a much lesser degree light industry. The natural riparian zone hydrology, soils, native plant communities, and in some cases the geology, have been modified from their natural state for these purposes. The confining valley wall to the west is a mountain range primarily of karstic limestone, which is generally undisturbed and considered an area of high biodiversity. This area provides habitat for several federally endangered species and is contiguous with the Guánica National Forest Preserve. The confining valley wall to the east is similar, but smaller, more developed and less biologically diverse. The valley walls serve as a watershed divide between the Rio Guayanilla and the Rio Macaná.

High hazard montane discharges into the coastal plain created a thick alluvial deposition of gravel and sand between the two confining valley walls. The river channel has maintained connectivity, substrate sorting, sediment transport and active meandering; although evidence of channel modification in certain reaches is apparent. Observed modifications to the channel include induced channel incision (minor) from confinement, channelization and bank armoring/stabilization projects. Aside from these modifications, sufficient ephemeral riverine habitat is created and sustained for a small suite of migratory, amphidromous (fresh or saltwater tolerant) fishes recorded by Kwak (2007) at PR-127.

The Municipality of Guayanilla itself is nestled in the upper portion of the coastal floodplain valley where the valley is narrower. This location makes the municipality susceptible to both riverine flooding and gully/ravine washes from the eastern hilly and mountainous valley wall. The river generally flows to the west of and through the middle of municipality, maintaining a meandering pattern before turning southward towards the outlet at Guayanilla Bay. The floodplain is semi-connected at small rain events and fully connected at larger events when widespread flood damages occur. There are several major bridge over-road crossings and a variety of structures located alongside the banks. Within the 100-year event floodplain there are over 1,500 structures and utilities. Water quality is affected by agricultural drainage and waste water discharged to the river during flood events.

The land use to the south of PR-3337 is primarily agricultural, with the exception of the small coastal neighborhoods of El Faro and Playa de Guayanilla. The river in this reach was channelized and leveed as part of the Phase I DNER project in 2006. Based on the calculated flows entering the coastal alluvial plain at PR-379, large floods inundated the entire valley in the past, inducing many braided and overland flowages that would temporally flush and maintain estuarine habitats along the coastline at the Bay of Guayanilla.

Based on the natural deep depth of the bay and the flat coastal plain, shallow estuary wetland habitat is limited along the coastline. Outside of the deep natural bay there are several coral reefs of the true marine environment, which are considered adjacent to the study area.

ENVIRONMENTAL CONSEQUENCES AND MITIGATION

All practicable and appropriate means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. Best management practices (BMPs) as detailed in the IFR/EA will be implemented, if appropriate, to minimize impacts. For all alternatives the potential effects to significant nature resources were evaluated, as appropriate. A summary assessment of the potential effects of the Recommended Plan are contained in the following table:

Summary of Environmental Impacts Assessment

	Insignificant effects	Insignificant effects as a result of mitigation*	Resource unaffected by action
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	☒	☐	☐
Socio-economics	☒	☐	☐
Environmental Justice	☒	☐	☐
Soils	☒	☐	☐
Water Quality	☒	☐	☐
Climate Change	☒	☐	☐

It was determined that compensatory mitigation (40 C.F.R. § 230.93) would be implemented for the loss of 5.8 acres of perennial estuarine interior basin mangrove wetland/habitat and associated fauna as described for Clean Water Act compliance in the 404(b)(1) Analysis (*Appendix A2*) and USFWS Final Coordination Act Report (*Appendix A4*). The effects under NEPA are considered to be lowered to less than significant by the application of the conservation measures for flow, habitat and connectivity as well as 6 acres of compensatory mitigation. Planning analyses were completed to identify the least

environmentally damaging alternative. These elements of the Recommended Plan are described in *Appendix A3 Mitigation, Monitoring and Adaptive Management Plan*.

Based upon avoidance and minimization during the planning process, as well as the incorporation of USFWS prescribed conservation measures (*Appendix A4 ESA Consultation-CAR*), the USACE has concluded that a "May Affect, but not likely to Adversely Affect" determination for the Puerto Rican Boa and Puerto Rican Nightjar is appropriate for the Recommended Plan. The effects under Section 7 of the ESA are considered to be lowered to less than significant by the application of the USFWS prescribed conservation measures during quarrying operations for levee materials for these two species. The USFWS concurrence with the USACE determination is included in *Appendix A4-ESA Consultation-CAR*.

COMPLIANCE WITH APPLICABLE LAWS, REGULATIONS, POLICIES AND PLANS

The proposed alternatives are in compliance with appropriate statutes, executive orders, memoranda and USACE regulations. Applicable laws, statutes and executive orders are provided in Appendix A. Applicable federal compliance components include the Natural Historic Preservation Act of 1966; the Endangered Species Act of 1973; the Fish and Wildlife Coordination Act; EO 12898 (environmental justice); EO 11990 (protection of wetlands); EO 11988 (floodplain management); and the Rivers and Harbors Act of 1899. The potential project is in compliance with the Clean Air Act; the Clean Water Act, and the National Environmental Policy Act of 1969. Mitigation and conservation measures are included in the Recommended Plan to address impacts to significant aquatic habitat that could not be avoided. Conservation measures will be implemented during quarrying operations to reduce impacts to special status species to less than significant. There were no additional adverse environmental effects identified which cannot be minimized or avoided should the proposal be implemented. The proposed alternatives would have localized and short-term effects to uses of the study area coastal zone environment. There are no irreversible and irretrievable commitments of resources identified resulting from the proposed action should it be implemented.

Applicable Federal, State & Local Legal Compliance Summary

Reference	Environmental Statutes/Regulations	Project Compliance
Federal		
42 U.S.C. 7401, et seq.	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, as amended	C
42 U.S.C. 9601, et seq.	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980	C
16 U.S.C. 1531, et seq.	Federal Endangered Species Act of 1973, as amended	C
16 U.S.C. 661, et seq.	Fish and Wildlife Coordination Act, as amended	C
EO 11990	Protection of Wetlands	C
EO 11988	Floodplain Management	C
EO 12898	Federal Actions to Address Environmental Justice in Minority and Low-Income Populations	C
EO 13045	Protection of Children from Environmental Health Risks and Safety Risks	C
16 U.S.C. 1801, et seq.	Magnuson-Stevens Fish Conservation and Management Act	C
16 U.S.C. 703, et seq.	Migratory Bird Treaty Act of 1918, as amended	C
54 U.S.C. 300101, et seq.	National Historic Preservation Act, as amended	C
42 U.S.C. 6901, et seq.	Resource Conservation and Recovery Act of 1976, as amended	C
Commonwealth		
12 L.P.R.A. 8001 et seq.	Environmental Public Policy Act of 2004, as amended	C

[a] NA = not applicable, C = Compliance, P = Pending, and NC = Non-Compliant

THE RECOMMEDED PLAN

Alternative #3 is the Recommended Plan. The Recommended Plan includes the construction of an engineered diversion channel with a bottom width of 100-feet and 2:1 side slopes. The 9,000 foot engineered channel will extend from a new diversion structure, constructed across the existing river approximately 2,000 feet downstream of PR-127. The diversion structure will direct the majority of flood waters to the trapezoidal diversion channel while maintaining a bank-full flow to the Rio Guayanilla. The diversion channel and existing channel will be reconnected upstream of the Phase I project with an additional diversion structure. The diversion structures will maintain riverine connectivity for sediment transport and fish passage. Relocation of three local roads will be required.

The diversion channel will also include a levee along the eastern side of the channel. The riverside slope of the levee will be lined with riprap to prevent erosion. Upstream of the diversion channel, a combination of levees and floodwalls will be constructed on the east side of the river channel at designated locations. The levees will be constructed from local limestone sourced from an abandoned quarry within the project area. A 2,750 foot long earthen levee will be constructed to reduce flood risk for El Faro community from overbank riverine flooding. Other plan features include the development of a flood warning/response plan, and conservation measures for connectivity, flow and habitat. Due to impacts associated with the El Faro levee, wetland mitigation of 6.0 acres is also included in the Recommended Plan. Conservations measures for two special status species will be implemented during quarrying to minimize potential impacts to less than significant.

The Recommended Plan has an estimated first cost of $154 million and a benefit-to-cost ratio (BCR) of 3.3 to 1 at the current Fiscal Year 2020 (FY20) discount rate of 2.75%. The Recommended Plan would reduce average annual damages by $19.8 million.

Resumen Ejecutivo

Estudio de Gestión de Riesgos Inundaciones del Río Guayanilla, Guayanilla, Puerto Rico
Informe Final Integrado de Viabilidad y Evaluación Ambiental

PROPÓSITO Y NECESIDAD

El Municipio de Guayanilla, Puerto Rico se encuentra en la llanura de inundación del Río Guayanilla y el cauce natural del río atraviesa la ciudad. Las fuertes lluvias combinadas con las laderas empinadas en la cuenca superior pueden producir altos niveles de descargas en un período relativamente corto de tiempo. El 1% AEP (100 años) de un evento de inundación puede inundar más de 8 kilómetros cuadrados de tierra dentro del área de estudio.

En los años 1975, 1979, 1982, 1985, 1996, 1998, 2004, 2008, 2012 y 2017 se dieron inundaciones significativas en la llanura inundable del Río Guayanilla. El acontecimiento de estas inundaciones significativas estableció claramente una necesidad de acción. La inundación de 1975 causada por el Huracán Eloisa causó daños. Varios cientos de residentes fueron obligados a abandonar sus hogares, ya que 99 viviendas fueron destruidas y otras 276 viviendas sufrieron daños. Se registraron muertes en las inundaciones de: 1975, 1979, 1985, 1998 y 2017. Además de las estructuras dañadas y las vidas perdidas, la deposición de aguas de inundación y sedimentos (roca y limo) provocó el cierre de las principales carreteras de la zona e impidió el acceso a instalaciones críticas. Estas instalaciones incluyen un hospital regional y las estaciones de bomberos, servicios de emergencia y policía. En 2017 el Huracán María causó inundaciones significativas en la comunidad. Durante la tormenta, la crecida del Río Guayanilla arrastró un puente de mayor importancia y causó daños significativos a 106 casas y numerosos establecimientos comerciales entre ellos el supermercado de la comunidad, la farmacia y panadería local. Varias otras estructuras públicas críticas fueron inundadas, las cosechas de guineo y café fueron destruidas y la zona se quedó sin electricidad y telecomunicaciones por meses.

Según se estableció en la Ley de Control de Inundaciones de 1936, los proyectos de gestión del riesgo de inundaciones son de interés Federal si los beneficios durante el período de análisis superan los costos estimados y si las vidas, seguridad de las personas y los bienes dentro del área del proyecto se verían adversamente afectados. El estudio "Reconnaissance" de 1990 concluyó que el Interés Federal estaba justificado basado en los beneficios potenciales derivados de cinco alternativas estructurales distintas. El Plan Recomendado de 1990 incluía 4 millas (6.5 kilómetros) de dique de tierra, 2.25 millas (3.6 kilómetros) de mejoras de canal trapezoidal (canalización de la corriente), 0.8 millas (1.3 kilómetros) de desviación de canal trapezoidal, 984 pies (300 metros) de canales rectangulares de hormigón y el reemplazo de tres puentes vehiculares.

El primer costo total del Plan Recomendado de 1990 fue de $12.5 millones. Los costos anuales promedio se estimaron en $1.2 millones; los beneficios anuales promedio fueron de $2.5 millones. El Plan Recomendado de 1990 tenía una relación beneficio/costo de 2.1. El

patrocinador no federal del Estudio "Reconnaissance", el Departamento de Recursos Naturales y Ambientales de Puerto Rico (DRNA), eligió construir el Plan Recomendado en lugar de proceder a un estudio de viabilidad. El DRNA construyó río abajo el Plan Recomendado (Fase I) a principios de la década de 2000.

El propósito de la evaluación del riesgo de inundación incluye identificar las medidas necesarias para reducir las consecuencias de las inundaciones, tales como las medidas que reducen el riesgo a la seguridad, vida humana, daños a las estructuras residenciales y comerciales y a la infraestructura pública, y pérdida de producción económica debido a los esfuerzos de recuperación.

DESARROLLO DE PLANES ALTERNATIVOS

La formulación de plan es un proceso iterativo que da lugar a la elaboración, evaluación y comparación de planes alternativos para abordar los problemas de estudio identificados mediante el logro de los objetivos esbozados. Los problemas considerados para este estudio son las inundaciones repentinas de alta peligrosidad que resultan en riesgos a la seguridad de la vida y pérdidas económicas significativas. Las lluvias fuertes combinadas con laderas empinadas en la cuenca de la montaña superior pueden producir altas descargas en una magnitud de 30,000-40,000 pies cúbicos por segundo (cfs, por sus siglas en inglés) en un período de tiempo relativamente corto (horas). Las altas tasas de escorrentía son impulsadas por la topografía y las superficies del suelo naturalmente impermeables. Este régimen de inundación natural ayudó en su día a crear un ecosistema diverso dentro de la llanura de inundación costera y el estuario. Desde que se desarrolló la zona, las inundaciones se han convertido en un problema significativo para los ciudadanos de la comunidad, estructuras y terrenos agrícolas ubicados dentro de la llanura de inundación. Los riesgos asociados a las inundaciones son elevados si se tienen en cuenta los recursos de la comunidad que corren peligro y la frecuencia de las inundaciones en las bancos. Un evento de inundación de 100 años puede inundar más de 8 kilómetros cuadrados dentro del municipio y las zonas rurales de Guayanilla, pero los daños se producen y los residentes corren peligro durante eventos más frecuentes.

Los objetivos de planificación que se presentan a continuación están directamente relacionados con los problemas identificados en las secciones anteriores y se examinan con más detalle en el Capítulo 1 del estudio de viabilidad.

Reducir el Riesgo de Daños por Inundación a Estructuras e Infraestructuras – Para reducir el riesgo de daños provocado por inundaciones y los efectos asociados, este objetivo busca reducir la profundidad, duración y probabilidad de inundación. La evaluación del éxito de una alternativa en cumplimiento con este objetivo se mediría por la reducción en el promedios de los daños anuales estimados para la condición con-proyecto versus la condición sin proyecto. Dentro del área de estudio, la reducción del riesgo de inundación se centró específicamente en las estructuras residenciales, públicas y comerciales, los servicios públicos, la infraestructura de transporte y los campos agrícolas en producción. Los beneficios asociados con el proyecto comienzan al finalizar la ejecución del mismo y continúan a lo largo del ciclo de vida del proyecto.

Reducir el Riesgo a la Vida Humana – Para reducir los riesgos a la vida humana provocados por las inundaciones repentinas y los efectos asociados, este objetivo busca informar adecuadamente al público sobre las inundaciones pendientes y reducir la profundidad, duración y probabilidad de las inundaciones. El éxito se medirá por la reducción de las inundaciones dentro de la comunidad que afecten significativamente la seguridad de la vida. Entre las medidas formuladas para cumplir este objetivo figuran la alerta y la respuesta adecuada a las inundaciones. En la zona de estudio, la reducción de los riesgos de inundación se centró específicamente en la población en riesgo y en el riesgo a las estructuras comerciales, los servicios públicos, la infraestructura de transporte y los terrenos agrícolas en producción. Los beneficios asociados con el proyecto comienzan al finalizar la ejecución del mismo y continúan a lo largo del ciclo de vida del proyecto.

Las medidas de gestión son características o actividades que pueden aplicarse en un área geográfica específica para abordar la totalidad o una parte de los problemas y alcanzar los objetivos. Las medidas pueden atender directamente los peligros (inundaciones), la forma en que los peligros se comportan (rendimiento), o indirectamente abordarlos mediante la eliminación o reducción de las consecuencias (daños monetarios, riesgo a la vida). Las medidas consideradas para este estudio son no-estructurales o estructurales. Se desarrolló un conjunto de seis (6) medidas no-estructurales y once (11) medidas estructurales para atender las necesidades del estudio. El examen de las medidas se llevó a cabo teniendo en cuenta la eficacia técnica, los efectos ambientales, las políticas y las directrices. Se continuo con dos (2) medidas no estructurales y siete (7) estructurales para seguir desarrollando en planes alternativos. Se elaboraron y evaluaron seis (6) planes alternativos de acción utilizando los siguientes criterios de selección: seguridad de la vida, efectos ambientales, requisitos inmobiliarios, servicios públicos y sostenibilidad. Sobre la base del proceso de selección se recomendó un (1) plan de no acción y tres (3) alternativas de acción para realizar análisis económicos y ambientales más detallados:

Plan de No-Acción
Alternativa #1 Medidas No-Estructurales
Alternativa #3 Canal de Desvío al Sur con una Línea de Protección
Alternativa #6 Montaje de Vía Verde con una Línea de Protección

Los análisis detallados de las tres alternativas de acción dieron como resultado la identificación de una alternativa que maximizara los beneficios netos o el Plan NED. La alternativa 3 es el Plan NED.

AMBIENTE AFECTADO

La Isla de Puerto Rico se encuentra en el Mar Caribe y tiene un clima anual relativamente estable (75-85 °F todo el año/subtropical). Este tipo de clima permite una alta productividad biológica que impulsa la biodiversidad y recursos humanos valiosos. Su ubicación a lo largo de la Trinchera de Puerto Rico y dentro de la zona de Huracanes del Atlántico la hace susceptible a regímenes drásticos de perturbación ambiental que incluyen terremotos, tsunamis, huracanes y diferentes períodos húmedos y secos. La cuenca del Río Guayanilla se encuentra en el suroeste de la isla, que por lo general recibe una lluvia mucho menos consistente que el lado norte y las tormentas son más intensas pero notablemente menos frecuentes. Naturalmente el Río Guayanilla es un río efímero con dos segmentos distintos (para los fines de este estudio) – la zona montañosa alta y la llanura de inundación costera baja. El sector alto fluye a través del material primario de la montaña, que es típicamente roca de lecho impermeable. La zona ribereña es densa con una comunidad de Bosque Subtropical Seco y aunque se ha producido cierta

deforestación, añade el beneficio de grandes escombros leñosos y de materiales orgánicos que de lo contrario la montaña tendría un riachuelo con una deficiencia de nutrientes. En esta área hallan estructuras esparcidas, y donde la topografía lo permite hay carreteras y caminos, y los servicios públicos se extienden a la orilla de la montaña para llegar a algunas de estas estructuras. La calidad del agua puede verse afectada por los insumos de las estructuras ubicadas en la montaña.

A medida que el río fluye hacia la planicie costera cerca de la PR-379, el uso de la tierra y la topografía reflejan modificaciones para la agricultura, la vivienda, el comercio y, en mucho menor grado, la industria ligera. La hidrología de la zona ribereña natural, los suelos, las comunidades de plantas nativas y en algunos casos la geología han sido modificadas de su estado natural para estos fines. La pared fronteriza hacia el oeste del valle es una cordillera principalmente de piedra caliza kárstica, que generalmente no se perturba ya que se considera un área de alta biodiversidad; incluyendo varias especies en peligro de extinción federal. Esta zona es contigua con la Reserva Forestal Nacional de Guánica. La pared fronteriza hacia el este del valle es similar, pero más pequeña, más desarrollada y menos biológicamente diversa. Las paredes fronterizas sirven como una línea divisora de la cuenca entre el Río Guayanilla y el Río Macaná.

Descargas montañosas de alto riesgo en la llanura costera crearon una gruesa deposición aluvial de grava y arena entre las dos paredes fronterizas del valle. El propio canal fluvial ha mantenido en su mayor parte la conectividad, la clasificación de sustratos, el transporte de sedimentos y los meandros activos; aunque hay indicios de modificación en ciertos tramos. Las modificaciones observadas en el canal incluyen una incisión menor provocada por el confinamiento, canalización y acorazamiento/estabilización del banco. Aparte de estas deficiencias, se crea y mantiene un hábitat fluvial efímero suficiente para un pequeño conjunto de peces migratorios, anfídroma (tolerantes al agua dulce o salada) registrados por Kwak (2007) en la carretera PR-127.

El Municipio de Guayanilla se encuentra en la parte superior del valle costero de la llanura de inundación, donde el valle es más estrecho. Esta ubicación hace que el municipio sea susceptible tanto a las inundaciones fluviales como a los desbordamientos de los barrancos y las cañadas de la pared oriental del valle montañoso. El río generalmente fluye hacia el oeste y a través del centro del municipio, manteniendo un patrón serpenteante antes de girar hacia el sur, hacia la desembocadura en la Bahía de Guayanilla. La llanura de inundación está semi-conectada en pequeños eventos de lluvia, y totalmente conectada en eventos más grandes, ya que los daños por inundación son evidentes. Hay varios puentes principales por cruce de carreteras y una variedad de estructuras ubicadas a lo largo del banco. Dentro de la llanura de inundación de eventos de 100 años hay más de 1,500 estructuras y utilidades. La calidad del agua se ve afectada por el drenaje agrícola y la descarga de aguas negras al río durante los eventos de inundación.

El uso de la tierra al sur de la PR-3337 es principalmente agrícola, con la excepción de los pequeños barrios costeros de El Faro y Playa de Guayanilla. El río en este tramo fue canalizado y represado como parte de la Fase I del proyecto DRNA en el 2006. Sobre la base de los flujos calculados que entran en la llanura aluvial costera en la PR-379, inundaciones en el pasado han llenado el valle entero, causando turbidez en el agua y flujos mayores que temporalmente barren y mantienen hábitat estuario a lo largo de la costa de la Bahía de Guayanilla.

Basándose en la profundidad natural de la bahía y la llanura costera plana, el hábitat de los humedales de estuario poco profundos está limitado a lo largo de la costa. Fuera de la profundidad natural de la bahía hay varios arrecifes de coral del verdadero medio marino, que se consideran adyacentes a la zona de estudio.

CONSEQUENCIAS AMBIENTALES Y MITIGACIÓN

Se analizaron e incorporaron al Plan Recomendado todos los medios viables y apropiados para evitar o minimizar los efectos ambientales adversos. Si procede, se aplicarán las Mejores Prácticas de Gestión (BMP, por sus siglas en inglés) detalladas en el IFR/EA para minimizar los impactos. Para todas las alternativas se evaluaron, según procediera, los posibles efectos sobre los recursos naturales significativos. En el cuadro siguiente figura una evaluación resumida de los posibles efectos del Plan Recomendado:

Summary of Environmental Impacts Assessment

	Efectos Insignificantes	Efectos Insignificantes Como Resultado de la Mitigación*	Recursos No Afectados por la Acción
Estética	☒	☐	☐
Calidad del Aire	☒	☐	☐
Recursos Acuáticos/Humedales	☐	☒	☐
Habitat de Pesca y Vida Silvestre	☐	☒	☐
Especies Amenazadas/En Peligro de Extinción	☐	☒	☐
Propiedades Históricas	☒	☐	☐
Otros Recursos Culturales	☒	☐	☐
Llanura Inundabe	☒	☐	☐
Residuos Peligrosos, Tóxicos y Radiactivos	☒	☐	☐
Hidrología	☒	☐	☐
Uso de Terreno	☒	☐	☐
Niveles de Ruido	☒	☐	☐
Socio-económico	☒	☐	☐
Justicia Ambiental	☒	☐	☐
Suelos	☒	☐	☐
Calidad del Agua	☒	☐	☐
Cambio Climático	☒	☐	☐

Se determinó que se aplicaría una mitigación compensatoria (40 C.F.R. § 230.93) por la pérdida de 5.8 acres de humedales/hábitat de manglares perennes de la cuenca interior del estuario y la fauna asociada, tal como se describe para el cumplimiento de la Ley de Agua Limpia en el Análisis 404(b)(1) (*Apéndice A2*) y el Informe del Proyecto de Ley de Coordinación del USFWS (*Apéndice A4*). Se considera que los efectos en el marco de la NEPA se reducen a menos que significativos mediante la aplicación de las medidas de conservación del caudal, el hábitat y la conectividad, así como de 6 acres de mitigación compensatoria. Se completaron los análisis de planificación para identificar la alternativa menos perjudicial para el medio ambiente. Estos elementos del Plan Recomendado se describen en el Plan de *Mitigación, Monitoreo y Manejo Adaptativo del Apéndice A3*.

Basándose en la evitación y minimización durante el proceso de planificación, así como en la incorporación de las medidas de conservación prescritas por el USFWS (*Apéndice A4 ESA*), el USACE ha llegado a la conclusión de que una determinación de "Puede afectar, pero no es probable que afecte negativamente" a la Boa Puertorriqueña y al Guabairo Puertorriqueño es apropiada para el Plan

Recomendado. Se considera que los efectos en virtud de la Sección 7 del ESA se reducen a menos que significativos mediante la aplicación de las medidas de conservación prescritas por el USFWS durante las operaciones de extracción de materiales de los diques para estas dos especies. La concurrencia del USFWS con la determinación del USACE se incluye en el *Apéndice A4-ESA*.

CUMPLIMIENTO CON LAS LEYES, REGLAMENTOS, POLITICAS Y PLANES

Las alternativas propuestas cumplen con los estatutos, órdenes ejecutivas, memorandos y reglamentos de USACE. Las leyes, los estatutos y los decretos ejecutivos aplicables figuran en el Apéndice A. Los componentes de cumplimiento federal aplicables incluyen la Ley de Preservación Histórica Natural de 1966; la Ley de Especies en Peligro de Extinción de 1973; la Ley de Coordinación de la Pesca y la Vida Silvestre; la OE 12898 (justicia ambiental); la OE 11990 (protección de los humedales); la OE 11988 (gestión de las llanuras de inundación); y la Ley de Ríos y Puertos de 1899. El posible proyecto se ajusta a la Ley de Aire Limpio, la Ley de Aguas Limpias y la Ley Nacional de Política Pública Ambiental de 1969. En el Plan Recomendado se incluyen medidas de mitigación y conservación para hacer frente a los impactos significativos en el hábitat acuático que no pudieron evitarse. Se aplicarán medidas de conservación durante las operaciones de extracción para reducir los impactos a las especies en situación especial a menos que significativos. No se han identificado efectos ambientales adversos adicionales que no puedan minimizarse o evitarse si se aplica la propuesta. Las alternativas propuestas tendrían efectos localizados y a corto plazo en los usos del medio ambiente de la zona costera del área de estudio. No se han identificado compromisos irreversibles e irrecuperables de recursos resultantes de la acción propuesta en caso de que se aplique.

Resumen de Cumplimiento Legal Federal, Estatal y Local Aplicable

Referencia	Estatutos/Reglamentos Ambientales	Cumplimiento del Proyecto
Federal		
42 U.S.C. 7401, y siguientes.	Ley de Aire Limpio de 1970, según enmendada	C
33 U.S.C. 1251, y siguientes.	Ley de Aguas Limpias de 1977, según enmendada	C
16 U.S.C. 1451, y siguientes.	Ley del Manejo de la Zona Costanera de 1972, según enmendada	C
42 U.S.C. 9601, y siguientes.	Ley de Respuesta, Compensación y Responsabilidad Ambiental (CERCLA) de 1980	C
16 U.S.C. 1531, y siguientes.	Ley Federal de Especies Amenazadas de 1973, según enmendada	C
16 U.S.C. 661, y siguientes.	Ley de Coordinación de la Pesca y la Fauna Silvestre, según enmendada	C
EO 11990	Protección de los Humedales	C
EO 11988	Gestión de Llanura de Inundación	C
EO 12898	Acciones Federales para Abordar la Justicia Ambiental en las Poblaciones Minoritarias y de Bajos Ingresos	C
EO 13045	Protección de los Niños contra los Riesgos a la Salud y Seguridad	C
16 U.S.C. 1801, y siguientes.	Ley Magnuson-Stevens de Conservación y Manejo de Peces	C

16 U.S.C. 703, y siguientes.	Ley de Tratados Sobre Aves Migratorias de 1918, según enmendada	C
54 U.S.C. 300101, y siguientes.	Ley Nacional de Preservación Histórica, según enmendada	C
42 U.S.C. 6901, y siguientes.	Ley de Conservación y Recuperación de Recursos de 1976, según enmendada	C
Estado Libre Asociado		
12 L.P.R.A. 8001 y siguientes.	Ley d Política Publica Ambiental 2004, según enmendada	C

[a] NA = No Aplica, C = Cumple, P = Pendiente, and NC = No Cumple

PLAN RECOMENDADO

Alternativa #3 es el Plan Recomendado. El Plan Recomendado incluye la construcción de un canal de desvío de 100 pies de ancho al fondo y una pendiente lateral de 2:1. El canal de 9,000 pies de largo se extenderá desde una nueva estructura de desviación, construida a través del río existente aproximadamente 2,000 pies aguas abajo de la PR-127. La estructura de desviación dirigirá la mayoría de las aguas de inundación al canal de desvío trapezoidal mientras mantiene un flujo de banco lleno al Río Guayanilla. El canal de desvío y el canal existente se reconectarán aguas arriba del Fase I del Proyecto con una estructura de desviación adicional. Las estructuras de desvío mantendrán la conectividad fluvial para el transporte de sedimentos y el paso de peces. Se requerirá la reubicación de tres carreteras locales.

El canal de desvió también incluirá un dique a lo largo del lado este del canal. La ladera del fluvial del dique estará revestida de escollera ("rip-rap") para evitar la erosión. Aguas arriba del canal de desvío, se construirá una combinación de diques y muros de contención en el lado este del canal del río en lugares designados. Los diques se construirán con piedra caliza local procedente de una cantera abandonada dentro del área del proyecto. Se construirá un dique de tierra de 2,750 pies de largo para reducir el riesgo de inundación a la comunidad de El Faro de las inundaciones fluviales. Otras características del plan incluyen la elaboración de un plan de alerta/respuesta a las inundaciones y medidas de conservación de la conectividad, el caudal y el hábitat. Debido a los impactos asociados al dique en la comunidad de El Faro la mitigación de humedales de 6.0 acres también se en el Plan Recomendado. Las medidas de conservación para dos especies de estatus especial se aplicarán durante la extracción para minimizar los impactos potenciales a menos que significativos.

El Plan Recomendado tiene un costo inicial estimado de $154 millones y una relación beneficio-a-costo (BCR) de 3.3 a 1 en el actual año fiscal 2020 (FY20) a una tasa de descuento de 2.75%. El Plan Recomendado reduciría los daños anuales promedio en $19.8 millones.

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TECHNICAL TERMS

in (")	Inch(es)	°C	Degrees, Celsius
ft (')	Foot, feet	O_3	Ozone
yds	Yard(s)	CO	Carbon Monoxide
mi	Mile(s)	CO2	Carbon Dioxide
mm	Millimeters	CO2e	Carbon Dioxide equivalent
cm	Centimeters	NO_2	Nitrogen Dioxide
m	Meters	$\mu g/m^3$	Micro-gram-per-cubic-meter
km	Kilometers	Pb	Lead
ft/s	Foot-per-second	$PM_{2.5-}$	Particulate Matter 2.5
cfs (ft^3/s)	Cubic-foot-per-second	PM_{10}	Particulate Matter 10
cms (m^3/s)	Cubic-meter-per-second	SO_2	Sulfur Dioxide
dB	Decibels	ppb	Parts-per-billion
°F	Degrees, Fahrenheit	ppm	Parts-per-million

LIST OF ACRONYMS, ABBREVIATIONS, AND INITIALISMS

AAE	Average Annual Equivalent	NEI	National Emission Inventory
ACS	American Census Survey	NEPA	National Environmental Policy Act 42 U.S.C. § 4321 et seq.
ADM	Agency Decision Milestone	NFS	Non-Federal Sponsor
AL	Aquatic Life	NHPA	National Historic Preservation Act 54 U.S.C. § 300101 et seq.
Alt	Alternate	NMFS	National Marine Fisheries Services
AM	Alternative Milestone	NOAA	National Oceanic and Atmospheric Agency
APE	Area of Potential Effects	NPDES	National Pollutant Discharge Elimination System
ASA(CW)	Assistant Secretary of the Army (Civil Works)	NR	Natural Resource Effects
BCR	Benefit-to-Cost Ratio	NRCS	Natural Resources Conservation Service
BMP(s)	Best Management Practice(s)	NRHP	National Register of Historic Places
C	Completeness	O&M	Operations and Maintenance
C.F.R.	Code of Federal Regulations	OMRR&R	Operation and Maintenance, Repair, Replacement and Rehabilitation
CAA	Clean Air Act 42 U.S.C. § 7401 et seq.	OSE	Other Social Effects
CBRA	Coastal Barrier Resource Act 16 U.S.C. § 3501 et seq.	P&G	Principles and Guidelines
CBRS	Coastal Barrier Resource System	P.L.	Public Law
CEQ	Council on Environmental Quality	PAH	Polycyclic Aromatic Hydrocarbons
CWA	Clean Water Act 33 U.S.C. § 1251 et seq.	PB	Planning Bulletin
DW	Drinking Water	PDT	Project Delivery Team
E	Effectiveness	PR	Puerto Rico
EA	Environmental Assessment	PRASA	Puerto Rico Aqueduct and Sewer Authority
EAD	Expected Annual Damages	PRDNER, DNER	Puerto Rico Department of Natural and Environmental Resources
ECB	Engineering and Construction Bulletin	PREPA	Puerto Rico Electric Power Authority
Ef	Efficiency	PREQB	Puerto Rico Environmental Quality Board
EFH	Essential Fish Habitat	PVC	Polyvinyl Chloride
EIS	Environmental Impact Statement	RE	Real Estate
EO	Executive Order	REC	Recognized Environmental Concerns
EQ	Environmental Quality	RED	Regional Economic Development
ER	Engineer Regulations	RSLC	Relative Sea Level Change
ESA	Environmental Site Assessment	Sec.	Section
FCA	Flood Control Act 33 U.S.C. § 701 et seq.	SHPO	State Historic Preservation Officer
FCSA	Feasibility Cost Sharing Agreement	SIP	State Implementation Plans
FDR	Federal Discount Rate	SMART	Specific, Measureable, Attainable, Risk-Informed, and Timely
FE	Federally listed as “Endangered”	T&E	Threatened and Endangered (Species)
FEMA	Federal Emergency Management Agency	TMDL	Total Maximum Daily Load
FONSI	Finding of No Significant Impact	TSP	Tentatively Selected Plan
FR	Feasibility Report	U	Utility Relocation
FRM	Flood Risk Management	U.S.C.	United States Code
FWOP	Future Without-Project Conditions	USACE	U.S. Army Corps of Engineers
FY	Fiscal Year	USACE-HQ	Headquarters
GHG	Greenhouse Gas(ses)	USACE-IWR	Institute of Water Resources
H&H	Hydraulic and Hydrologic	USEPA, EPA	U.S. Environmental Protection Agency
HEC-RAS	Hydrologic Engineering Center’s River Analysis System	USFWS	U.S. Fish and Wildlife Service
HTRW	Hazardous, toxic, and radioactive waste	USGCRP	U.S. Global Change Research Program
IFR	Integrated Feasibility Report	USGS	U.S. Geological Survey
LERRD	Land, Easements, Rights-of-Way, Relocation, and Disposal	VT	Vertical Team
LPP	Locally Preferred Plan	w/	With
LS	Life-Safety	w/o	Without
NA (N/A)	Non-Applicable	WQS	Water Quality Standards
NAAQS	National Ambient Air Quality Standards	WRDA	Water Resources Development Act 33 U.S.C. § 2261 et seq.
NED	National Economic Development		

1.0 Introduction*

This document is the Final Integrated Feasibility Report (IFR) for the Rio Guayanilla Flood Risk Management (FRM) Study located in Guayanilla, Puerto Rico. This report integrates the Feasibility Report and Environmental Assessment (EA). This final report documents the elements of the feasibility study process including problems and opportunities, assessment of measures and alternatives to address problems, analysis of the environmental effects associated with implementing alternatives, evaluation of the alternatives and the identification of a Recommended Plan.

The U.S. Army Corps of Engineers (USACE) is the lead federal agency under the National Environmental Policy Act (NEPA) and is closely working with the U.S. Fish & Wildlife Service (USFWS), National Oceanic & Atmospheric Agency-National Marine Fisheries (NOAA-NMFS), the U.S. Geological Survey (USGS) and local stakeholders to develop the most cost-effective and environmentally-sound project which accomplishes the FRM study objectives. The non-federal sponsor (NFS) is the Department of Natural & Environmental Resources of Puerto Rico (DNER). The primary stakeholder is the Municipality of Guayanilla, Puerto Rico

1.1 Feasibility Study Regulations & Process

1.1.1 Study Authority

The study authority is the Water Resources Development Act of 1986 (P.L. 99-662), Sec 722.

SEC. 722. Rio Guayanilla Basin, Puerto Rico.

(a) The Secretary shall conduct a feasibility study on providing flood protection in the Rio Guayanilla Basin, Puerto Rico.

(b) Not later than two years after the date of the enactment of this Act, the Secretary shall submit to Congress a report on the results of such study together with such recommendations as the Secretary determines to be appropriate.

1.1.2 USACE Policy & Guidance

This study was initiated in response to appropriations to address hurricane and storm damage in 2017. (PL 115-123 SUPPLEMENTAL PROGRAM Rio Guayanilla, PR INVESTIGATIONS – NEW START) The study analyses focused on flood risk F problems and solutions within the Guayanilla floodplain specifically focusing on the Municipality of Guayanilla. This document was prepared to comply with NEPA (42 United States Code [U.S.C.] Section 4321, et seq.) in conformance with the Council on Environmental Quality (CEQ) Regulations for Implementing NEPA (40 Code of Federal Regulations [C.F.R.] Part 1500, et seq.), USACE regulations for implementing NEPA (33 C.F.R. Part 230), and USACE policies, including the Economic and Environmental Principles for Water and Related Resources (May 1983). All appropriate USACE guidance was considered during the planning process.

1.1.3 Feasibility Study Process

In February and March 2012, two planning memoranda were issued (Walsh 2012a and Walsh 2012b, respectively) that collectively revised USACE's approach to planning studies by emphasizing risk-based decision-making and early Vertical Team (VT)/ engagement during the Feasibility Study process. The memoranda were key guidance tied to an initiative known as Planning Modernization. Planning Modernization was a central component of the USACE Civil Works Transformation efforts. A key tenet of Planning Modernization is increased efficiency and efficacy in the processes USACE uses to make

decisions and produce planning decision documents. Collectively, these processes are referred to as SMART (Specific, Measurable, Attainable, Risk-Informed, and Timely) Planning, and is derived from the Principles and Guidelines (P&G) and the USACE Planning Guidance Notebook, ER 1105-2-100. Within the SMART Planning process, the Feasibility Study process includes progression through the six-step planning process, but also includes three key milestones (Figure 1) that mark points along the path to an effective and efficient study. Studies conducted within the new SMART Planning paradigm are expected to be completed within 3 years, at a cost not to exceed $3 million, and be fully coordinated among the three levels of USACE's VT.

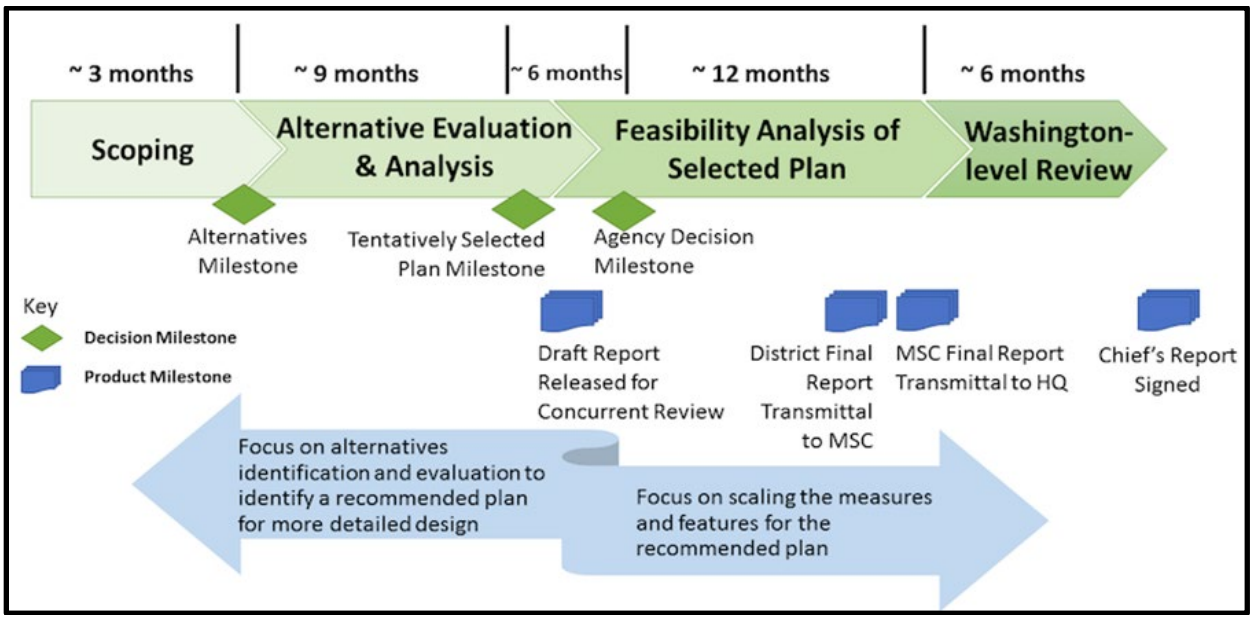

Figure 1: SMART Planning key decision and product milestones.

1.1.4 Planning Process to Date

In 1990, the USACE published the *Reconnaissance Report, Rio Guayanilla at Guayanilla.* This study was conducted under the authority of Section 722 of the Water Resources Development Act of 1986. The purpose was to investigate flooding problems associated with the overflow of Rio Guayanilla in the Municipality of Guayanilla and identify measures within the Federal interest. Although a federal interest was determined, the non-Federal sponsor indicated their intent to construct the Recommended Plan in the Reconnaissance Report rather than proceed to the Feasibility Study Phase.

In September 2003, the DNER began construction of a portion of the USACE's Recommended Plan as described in the 1990 Reconnaissance Report. This first phase of the construction project entailed the channelization of the lower Rio Guayanilla at the estuary mouth for better evacuation of floodwaters in the Guayanilla floodplain. The project also included levee construction along the western bank of the diversion channel. This Phase I of a greater project was completed in June 2006. The remaining elements of the proposed federal project were never constructed.

In August 2018, the Bipartisan Budget Act of 2018 (Public Law 115-123) provided supplemental appropriations to complete or initiate and complete studies that are federally authorized to reduce risk from future floods and hurricanes at full federal expense. The Rio Guayanilla had a previous study authorization under Section 722 of the Water Resources Development Act of 1986 and therefore was qualified to receive supplemental investigation funds. A Feasibility Cost Sharing Agreement (FCSA) was signed by the DNER on 6 September 2018 and by USACE on 24 September 2018.

1.1.5 Report Organization

The content for this Final IFR was established in accordance USACE guidelines, CEQ Guidelines, technical analyses, USACE standard NEPA practices and professional judgment. Chapters annotated with an asterisk (*) are required for complying with NEPA. Detailed technical and background information are provided in the accompanying appendices.

Executive Summary:* Summary of the Final IFR, which includes a brief overview of major conclusions, and a description of the Recommended Plan.

List of Acronyms:* A list of acronyms is included at the end of the Table of Contents

1 - Introduction:* Contains a discussion regarding the lead agencies, guiding regulations, study authority, statement of purpose and need, proposed project area and scope, study participants, prior reports and coordination. Also includes description of these key elements of the six-step planning process: problems and opportunities, project objectives and planning constraints.

2 - Affected Environment:* Contains a description of the existing, potentially affected environment in the Río Guayanilla study area.

3 - Plan Formulation:* Contains detailed discussion of the plan formulation process for this study that includes: a range of potential management measures that address specific problems identified in Chapter 1; provides basis (strategies) and considerations for development of alternative plans; screening processes for measures and alternatives; and the development of a focused alternative plans that adequately address project objectives.

4- Comparison of the Final Array of Alternatives:* Includes a description of the quantitative evaluation process used to identify the final array of alternatives and the identification of a Recommended Plan that best meets the study objectives.

5 - Environmental Consequences:* Contains an evaluation of the potential environmental impacts associated with implementing each of the alternatives in the final array. This chapter also identifies conservation measures to avoid or minimize impacts to sensitive or special status resources. Mitigation requirements are also discussed.

6 - Public Involvement, Review and Coordination:* Summarizes the coordination with agencies and the public that has taken place during the study.

7 - Compliance with Applicable Laws, Policies, and Plans:* Provides a description of applicable laws, policies, and plans, and a summary of project compliance.

8 - Recommended Plan:* Describes the plan that best meets study objectives and maximizes net benefits. The discussion of the Recommended Plan includes costs, project-specific considerations including design and construction considerations, and a project implementation strategy.

9 - Recommendation*

10 - Bibliography:* Lists the references cited throughout the report.

Appendices: Separate documents that provide additional technical detail for analyses referenced throughout the main report.

1.2 Study Purpose & Need

1.2.1 Purpose

The purpose of flood risk evaluation is to identify measures necessary to reduce the consequences of flooding, such as those measures that reduce risks to life safety, damages to residential and commercial structures and public infrastructure, damage to agricultural lands, and lost economic output due to recovery efforts.

1.2.2 Need

The Municipality of Guayanilla, Puerto Rico is located in the active floodplain of the Río Guayanilla, with the natural river channel bisecting the community. Heavy rainfall combined with very steep slopes in the upper catchment can produce high peak discharges in a relatively short period of time. The 100-year flood event (with a discharge of 41,863 cfs) can inundate over 3 square miles (8 square kilometers) of land within the study area.

Significant flood events occurred in the Rio Guayanilla floodplain in: 1975, 1979, 1982, 1985, 1996, 1998, 2004, 2008, 2012 and 2017. This history of significant flood events established the need for action. The 1975 flood caused by Hurricane Eloise resulted in damages. Several hundred residents were forced from their homes as 99 houses were destroyed and 276 additional houses were damaged. Fatalities were reported in the 1975, 1979, 1985, and 1998 and 2012 floods. In addition to the damaged structures and lives lost, floodwaters and sediment (rock and silt) deposition resulted in closures of major area roadways and impeded access to critical facilities. These facilities include a regional hospital and the local fire, emergency services and police stations. In 2017 Hurricane Maria caused significant flooding in the community. During the storm overbank flooding from the Rio Guayanilla washed out a major bridge and caused significant damage to 106 homes and numerous commercial establishments including the community supermarket, the local pharmacy, and the local bakery. Several other critical public structures were inundated, banana and coffee harvests were destroyed and the area was left without electricity and telecommunications for months.

As established by the Flood Control Act of 1936, flood risk management projects are in the Federal Interest if the benefits over the period of analysis exceed estimated costs and if the lives, safety and property within the project area would be adversely affected. The 1990 Reconnaissance Study concluded that there was a Federal Interest in a project based on the potential benefits derived from five different structural alternatives. The 1990 Recommended Plan included 4 miles (6.5 kilometers) of earthen levee, 2.25 miles of (3.6 kilometers) of trapezoidal channel improvements (stream channelization), 0.8 miles (1.3 kilometers) of trapezoidal channel diversion, 984 feet (300 meters) of rectangular concrete channels and the replacement of three vehicular bridges.

1.3 Study Area & Location

The Río Guayanilla watershed is located within the Municipality of Guayanilla on the southwestern coast of Puerto Rico. The watershed is bordered on the west by the Río Yauco, on the east by the Río Tallaboa, on the northwest by the Río Grande de Añasco, on the northeast by the upper Río Grande de Arecibo, and on the south by the Caribbean Sea.

The Rio Guayanilla originates at a point near the central mountain range at an elevation of approximately 3,280 feet, (1,000 meters) above mean sea level. The Rio Guayanilla flows in a southerly direction through steep slopes in the upper part of the watershed producing rapid runoff velocities and allowing

minimal infiltration. The total length of the river channel is approximately 13.9 miles (23 kilometers). The total drainage area of the Rio Guayanilla watershed is approximately 37 square miles (96 square kilometers) (Figure 2). There is potential for the river system to the east, the Rio Macaná, to overflow into the Rio Guayanilla's lower basin during floods in that watershed. The focused study area includes the whole floodplain of the lower Rio Guayanilla, where the Municipality of Guayanilla is located, portions of the mountains to the west, and to a lesser degree, the marine/estuarine coastline (Figure 3).

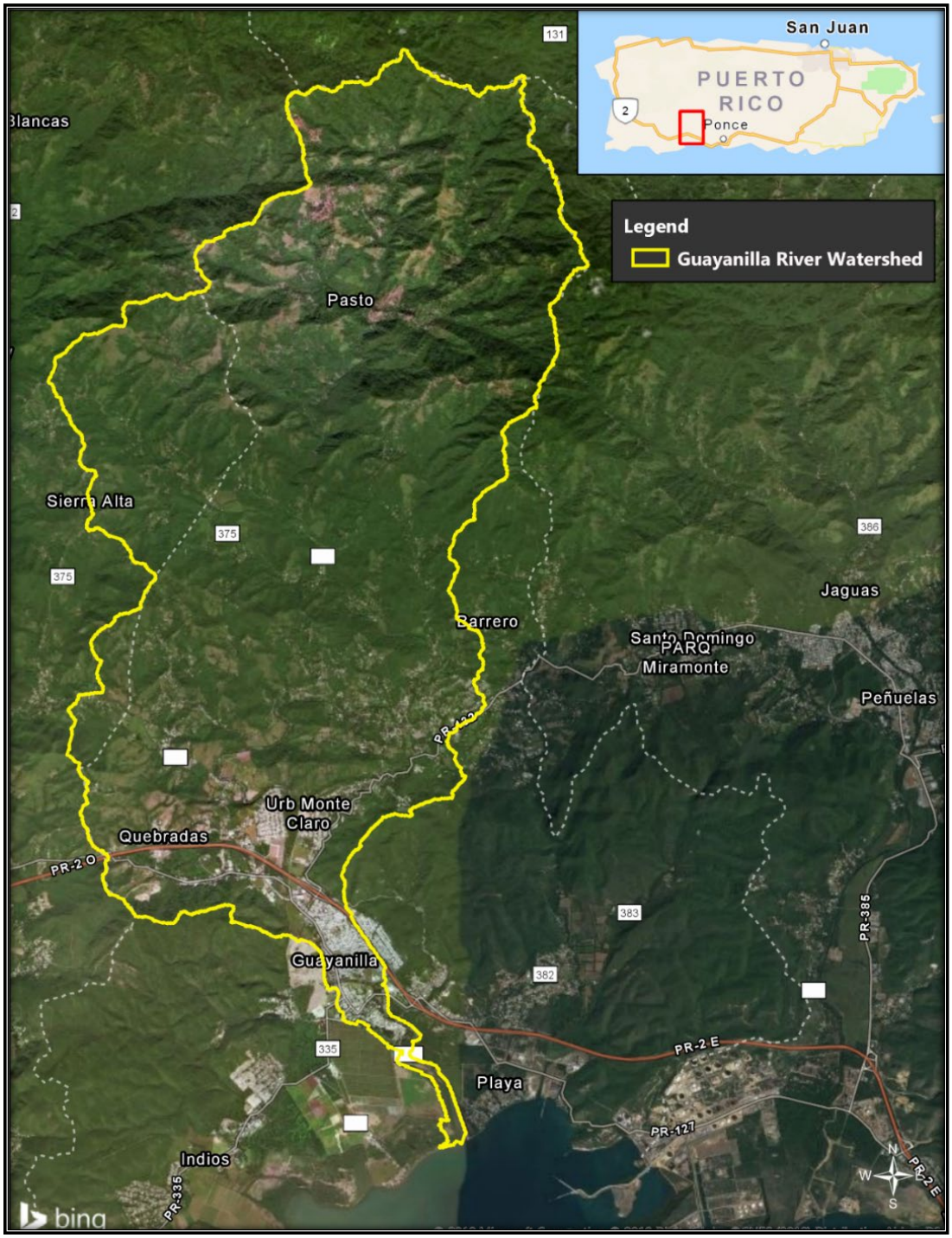

Figure 2: Rio Guayanilla Watershed

Figure 3: Focused Study Area with Rio Guayanilla Watershed and USGS Gaging Station

1.4 Prior Reports & Existing Projects

1.4.1 Report & Studies

1967. USACE. *Flood Plain Information Rio Guayanilla, Guayanilla, Puerto Rico*

1968. USGS. *Water Resources of the Guayanilla-Yauco Area, Puerto Rico*

1969. USGS. *Floods in the Guayanilla-Yauco Area, Puerto Rico*

1971. USGS. *Floods in the Guatanilla-Yauco Area, Puerto Rico; Hydrologic Investigations Atlas HA-414*

1980. USACE/FEMA. *Flood Insurance Study, Rio Guayanilla Basin, Puerto Rico*

1982. USGS. *Floods of September 16, 1975, in the Guayanilla Valley, Puerto Rico*

1987. DNER. *Conceptual Study for Flood Protection Works for the Flood Plain of the Rio Guayanilla, Guayanilla, Puerto Rico*

1988. Municipality of Guayanilla. *Hydrologic and Hydraulic Study for the Construction of a Public Transportation Terminal and Recreation Facilities at the Municipality of Guayanilla*

1989. DNER. *Channelization of Rio Guayanilla, Preliminary Environmental Impact Statement*

1990. USACE. *Reconnaissance Report, Rio Guayanilla at Guayanilla*

1992. USACE. *Regulatory & Wetlands; Environmental Impact Statement SAJ-1992-50001*

1.4.2 Existing Projects

2003 – 2006. *DNER Phase I Construction*– The project consisted of the channelization of the Rio Guayanilla for the control of flooding in the Guayanilla floodplain. Major project features included the construction of the downstream reach of the diversion channel, and levee embankment on one side of the diversion channel. The project also included various types of stone revetment, filter materials and core stones which had to be mechanically processed at a quarry location 20 miles away.

DNER Mitigation – The Army Corps of Engineers (USACE) required that the Puerto Rico Department of Natural and Environmental Resources (DNER) mitigate for the loss of 7.57 acres of forested wetland and salt flat, resulting from the construction of the Phase I of the Channelization of Rio Guayanilla Flood Control Project. The compensatory mitigation for the impacted wetland was completed on 8.5 acres. This included mitigation for 1.5 acres of wetland that were impacted outside the scope of the December 2000 USACE's permit.

Photo 1: Phase I Construction Activities

1.5 Problems & Opportunities

Problem and opportunity statements were framed in terms of the Federal objective and the specific study planning objectives. Problems and opportunities were defined in a manner that does not preclude the consideration of all potential alternatives and does not include discussion of potential solutions. The problem and opportunity statements provided below were evaluated and modified at multiple times during plan formulation, therefore accounting for the dynamics of the iterative planning process.

1.5.1 Problems

Problem Statement – Problems considered for this study are defined in terms of life safety and economic losses associated with flash flooding. Heavy rainfall combined with very steep slopes in the upper mountain catchment can produce high peak discharges in a relatively short period of time (hours). High rates of runoff are driven by topography and naturally impervious ground surfaces. This natural flooding regime once helped created a diverse ecosystem within the coastal floodplain and estuary. Since the area was developed, flooding has become a significant problem for citizens in the community, other local homesteads and the agriculture lands situated within the floodplain. Flash flooding occurs with little to no warning and can result in large areas of inundation within the community. The risks associated with flooding are high based on the resources at risk in the community and the frequency of overbank flooding. The 100-year flood event can inundate over 3 square miles (8-square kilometers) within the municipality and rural areas of Guayanilla (Figure 4).

Life Safety & Health

Life Safety Problems – The municipality and surrounding rural residences do not have a reliable flood warning system in place. Evacuation of residents is challenging due to limited warning time, and flash flood waters that can physically entrap residents. The 100-year floodplain is extensive, including a large number of structures as well as many major roadways in the community which exacerbates risk to residents associated with evacuation. (Figure 4). Fatalities were reported in the 1975, 1979, 1985, 1998 and 2012 floods. There was no loss of life due to Hurricane Marie in 2017.

Photo 2: Road PR-127 Becomes Flood Diversion Channel for most Floods

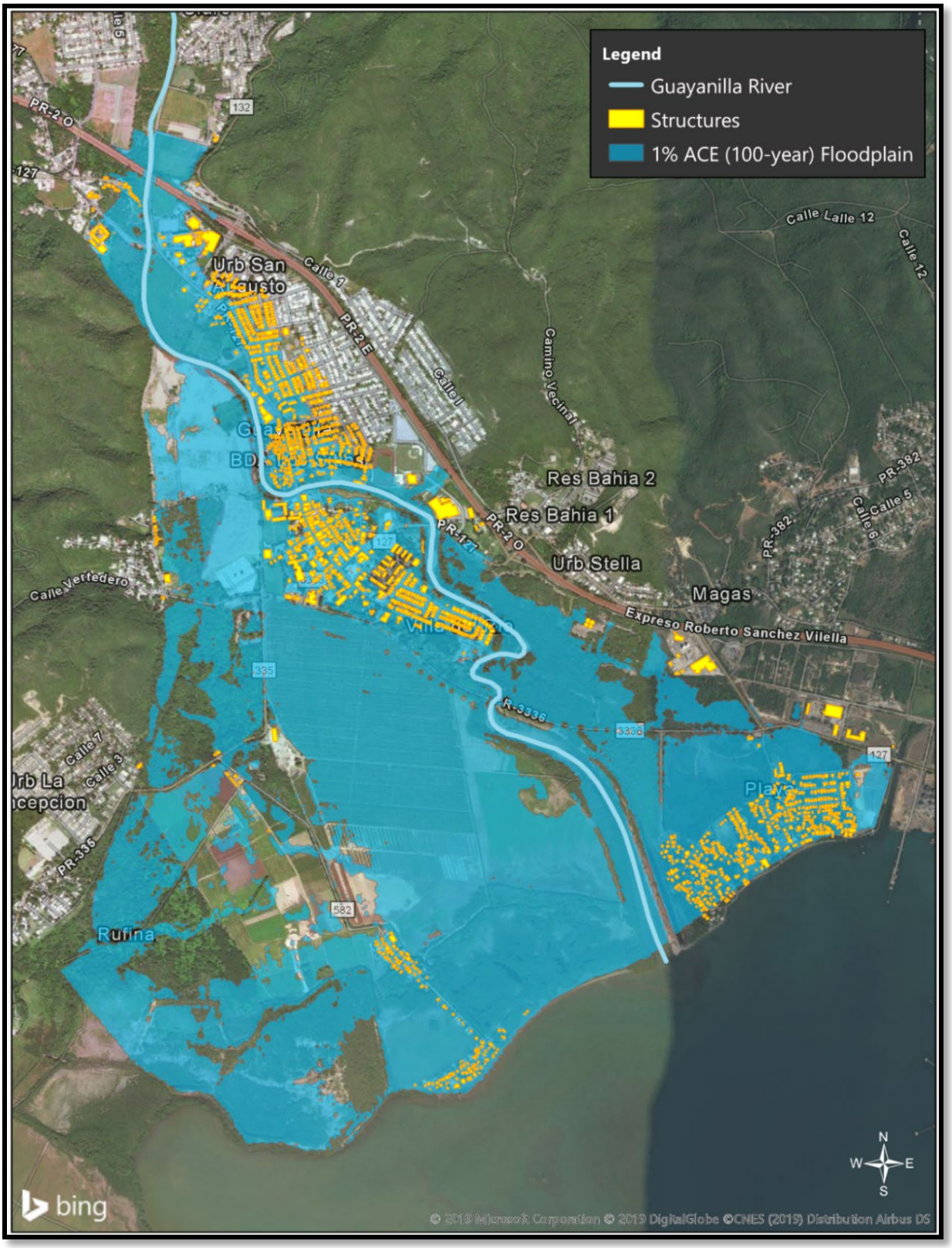

Figure 4: Floodplain Map to Show Affected Area & Structures in the 1% AEP (100-yr) Floodplain

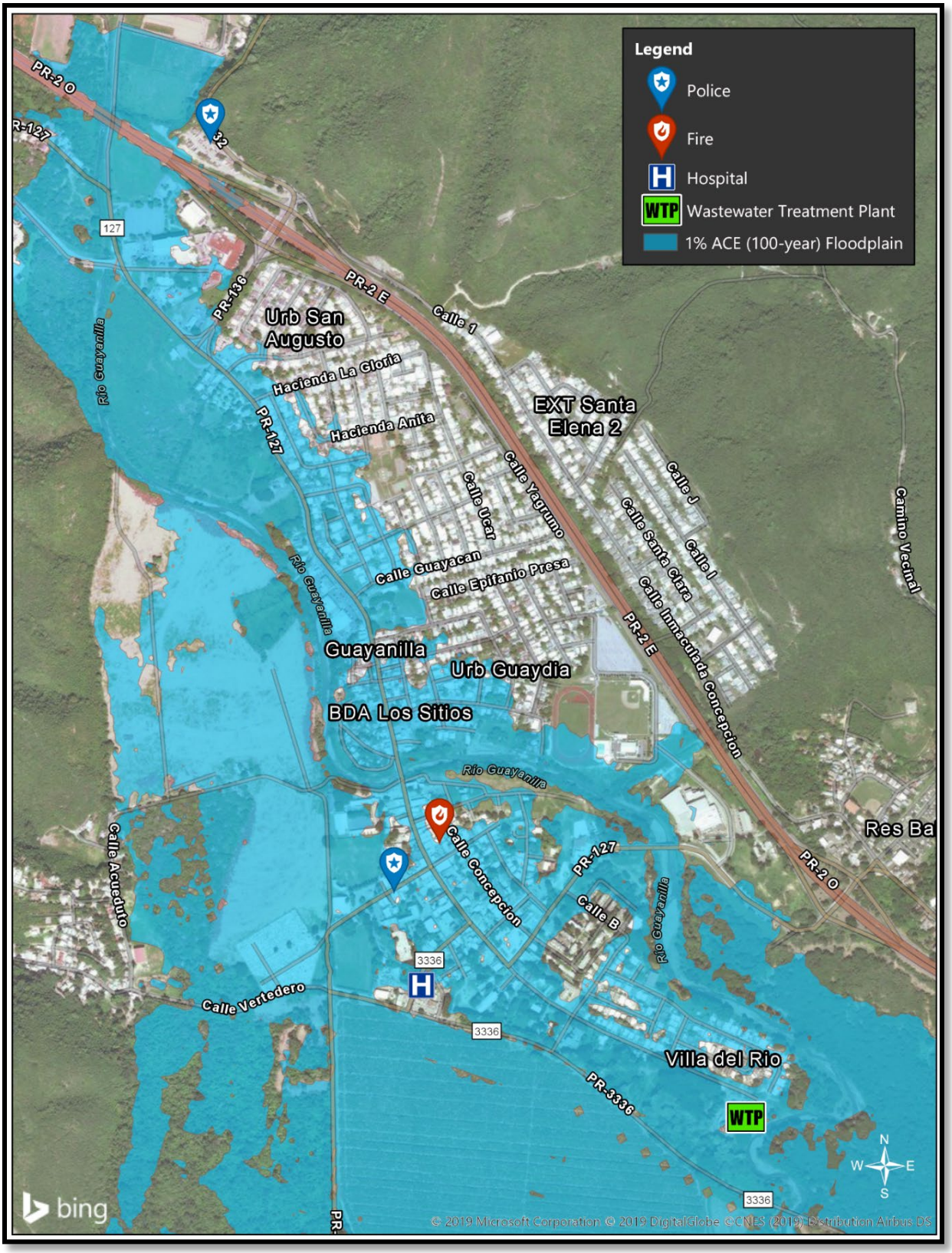

Figure 5: Emergency Facilities Affected by Flooding

Evacuation Problems – Floodwaters, currents, velocities, erosion and sediment deposition result in the closures of major area roadways and bridges. These road closures have historically impeded access to critical emergency facilities including the regional hospital, local fire and police stations, emergency services and evacuation shelters. Critical facilities are also affected by flooding, see Figure 5.

Emergency Facilities Problems – Floodwaters, currents, velocities, erosion and sediment deposition impact critical emergency services and facilities. In addition to the riverine flood impacts, gully and ravine washout along the valley walls also affects municipal facilities. The emergency shelter where the community gathers has been unavailable during past floods due to inundation. The loss of this critical structure increases life-safety risk to community residents who chose to evacuate. Impacts to first responder facilities (fire and police) delay emergency responses to at-risk populations. Commercial facilities in Guayanilla including pharmacies and groceries are also significantly affected during flood events. Floods have resulted in significant damage to these sources for critical life requisites, including food, water and pharmaceuticals. Damages to the Guayanilla pharmacy are shown in Photo 3, below.

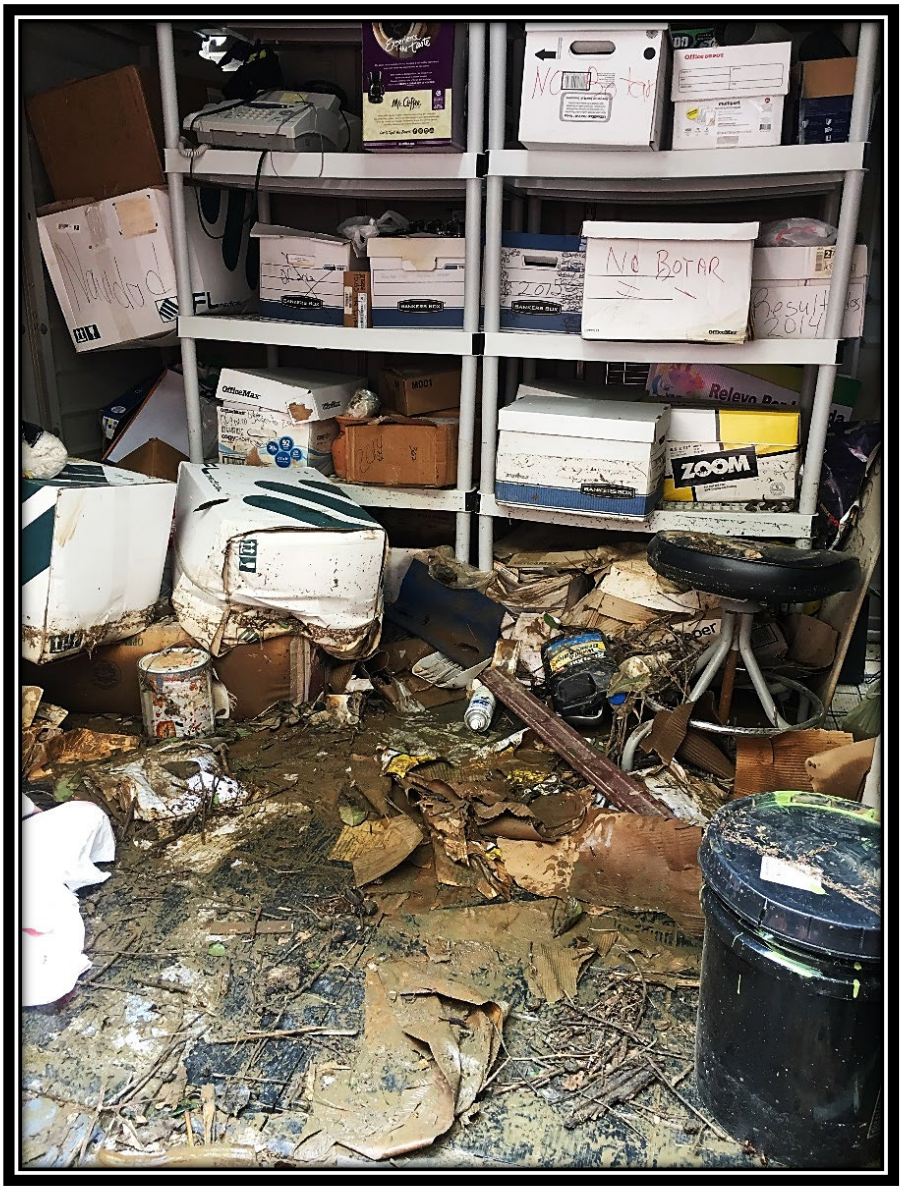

Photo 3: Rio Guayanilla Flood Damages to Critical Businesses (Pharmacy)

Health Problems – Floodwaters, currents, velocities, erosion and sediment deposition can affect the municipal wastewater treatment plant. Large events could inundate the wastewater treatment plant with the potential for the overflow of wastewater into the Río Guayanilla that would eventually reach Guayanilla Bay. In addition, flood waters flowing through industrial, commercial and agricultural areas can become contaminated. Discharge of these contaminated waters to Rio Guayanilla could have significant impacts on the natural resources and water quality in the river.

Flood Damages

Damages to Structures – Riverine flooding causes significant damages to residential and commercial structures as well as contents within the floodplain of Rio Guayanilla. Frequent flash floods with wide-spread inundation result in significant and repetitive damages to residential, agricultural, commercial and critical public facilities and utilities (water, electric, gas). Table 1 displays the estimated number of structures damaged by various flood events and by structure type. Nearly 1,600 structures are damaged by the 500-year flood event.

Table 1: Number of Structures Damaged, by Flood Event and Type

AEP Event*	0.2	0.02	0.01	0.002
Residential	220	868	1065	1187
Public	16	72	88	96
Commercial	59	227	286	316
Total	295	1167	1439	1599

*The 0.2, 0.02, 0.01, and 0.002 AEP events correspond with the 5-yr, 50-yr, 100-yr and 500-yr flood events, respectively

Delays in Transportation – Floodwaters, currents, velocities, erosion and sediment deposition result in closures of major area roadways and bridges. These closures impede access to critical businesses and the conveyance of commercial and agricultural goods and services. No transportation delay analysis was undertaken for this study.

Damages to Agriculture – Flood impacts to agricultural lands include inundation, sediment depositions and erosive velocities, which negatively affect all agricultural production. Past floods have destroyed banana and coffee harvests while farmsteads were left without access to electricity and telecommunications. Over 400 acres of productive agricultural land is subject to flooding. The 500-year flood event results in an estimated $1.7 million (FY 2020 price levels) in agricultural damages (Photo 4). See the *Appendix C*, *Economic Analyses* for estimation methodology.

1.5.2 Opportunities

Opportunities are positive outcomes that can be achieved in addition to the study objectives. Below are the primary opportunities for the Guayanilla study:

- Improve water quality and support local initiatives
- Increase recreation areas
- Improve economic sustainability, cohesion and development within the Municipality of Guayanilla
- Improve ecosystems and habitat in the Río Guayanilla agricultural and estuary areas

Photo 4: Example Río Guayanilla flooding damages; Destroyed Banana Field

1.6 Planning Goal, Objectives and Constraints

1.6.1 Study Goal

The goal of the study is to identify a cost effective and sustainable flood risk management solution, the National Economic Development (NED) Plan, at the Municipality of Guayanilla, Puerto Rico.

1.6.2 National Objective

The national or federal objective of water and related land resources planning is to contribute to National Economic Development (NED) consistent with protecting the Nation's Environmental Quality (EQ) pursuant to national environmental statutes, applicable Executive Orders and other federal planning requirements. Contributions to NED include increases in the net value of the national output of goods and services expressed in monetary units. These contributions are the direct net benefits that accrue in the study area and the rest of the Nation. Per USACE guidance, the plan that results from this study is whichever plan appears to maximize NED net benefits at the least cost to the environment (EQ).

1.6.3 Planning Objectives

Planning objectives are statements that describe the desired result(s) of the planning process by refining the problems identified into achievable actions. Objectives must be clearly defined and flexible (non-prescriptive). They should be supported by information on the effect desired (quantified and or qualified), the subject of the objective (what will be changed), the location where the expected result will occur, the timing of the effect and the duration of the effect. The planning objectives presented below are directly related to the problems identified in the previous sections.

- *Reduce Risk of Flood Damages to Structures and Infrastructure* – To lower the risk of damages induced by flooding and associated effects, this objective seeks to reduce the depth, duration and likelihood of flooding. Evaluation of how successfully an alternative meets this objective will be

measured by the reduction in estimated average annual damages for the with-project condition versus the without project condition. Within the study area, flood risk reduction was specifically focused on residential, public and commercial structures, utilities, transportation infrastructure and agricultural fields in production. Benefits associated with the project begin at completion of project implementation and continue for project design life.

- *Reduce Risks to Life Safety* – To lower the risks to life safety from flash flooding and associated effects this objective seeks to properly inform the public of pending floods, and reduce the depth, duration and likelihood of flooding. Success would be measured by the reduction in flooding within the community which significantly affect life safety. Measures formulated to satisfy this objective include appropriate warning and flood response. Within the study area, flood risk reduction was specifically focused on the population at risk and the risk to commercial structures, utilities, transportation infrastructure and agricultural fields in production. Benefits associated with the project begin at completion of the project implementation and continue for project design life.

1.6.4 Planning Constraints

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that should not be violated. The planning constraints considered to this point in the study are as follows:

- Avoid or minimize impacts to karst habitat from rock borrow over the project life cycle; this karst area potentially provides habitat for 5 federally endangered species and over 20 endemic plant species; and,
- Avoid the fragmentation of riverine habitat for ephemeral migratory amphidromous fishes

1.6.5 Planning Considerations

Additional considerations for the study were identified during the Study Charrette and through public input during the scoping period. These considerations were incorporated into the project through the planning process.

- Minimize project lifecycle costs by considering features with lower maintenance requirements as well as considering the potential effects of the rapid vegetation growth, woody debris, rocky debris and sedimentation on project features;
- Consider the use of nature-based features that mimic, enhance or restore natural and beneficial riverine, floodplain, estuary or other ecosystem values; and,
- Preserve natural and beneficial sediment transport and floodplain processes where possible.

2.0 Affected Environment*

This Chapter includes a description of the Affected Environment as required for NEPA compliance purposes as well as the Inventory and Forecasting of existing conditions required as part of the feasibility study process. The affected or potentially affected natural resources for the Rio Guayanilla FRM study are presented in the following sections. The evaluation of resources necessary for plan formulation include the historic, existing and future without-project conditions (FWOP). The fifty year period analysis for the project begins in 2026 (base year) and extends to 2076.

2.1 General Setting

The Island of Puerto Rico is located in the Caribbean Sea and has a relatively stable annual climate (75-85°F year round/subtropical). This type of climate allows for high biological productivity that drives biodiversity and valued human resources. Its collocation along the Puerto Rico Trench and within the Atlantic Hurricane zone makes it susceptible to drastic environmental disturbance regimes that include earthquakes, tsunamis, hurricanes and distinct wet/dry periods. The Rio Guayanilla watershed itself is located in the southwest of the island, which typically receives a much less consistent rainfall than the north side; with storms being more intense but notably less frequent. The Rio Guayanilla is naturally an ephemeral river with two distinct segments (for the purposes of this study) – the upper montane and the lower coastal floodplain. The upper segment flows through mountain parent material, which is typically impervious bed rock. The riparian zone is dense with Subtropical Dry Forest community and although some deforestation has occurred, it adds beneficial large woody debris and organic materials to an otherwise nutrient deficient mountain stream. Sparsely arranged homesteads occur here where the topography allows for roads and pathways; utilities span up the mountain side to reach some of these structures. Water quality may be affected by mountain homestead inputs.

As the river flows into the coastal plain near PR-379, the land use and topography reflect modifications for agriculture, residential, commercial and to a much lesser degree light industry. The natural riparian zone hydrology, soils, native plant communities and in some cases the geology have been modified from their natural state for these purposes. The confining valley wall to the west is a mountain range primarily of karstic limestone, which is generally undisturbed and considered an area of high biodiversity. This area provides habitat for several federally endangered species and is contiguous with the Guánica National Forest Preserve. The confining valley wall to the east is similar, but smaller, more developed and less biologically diverse. The valley walls serves as a watershed divide between Rio Guayanilla and Rio Macaná.

High hazard montane discharges into the coastal plain created a thick alluvial deposition of gravel and sand between the two confining valley walls. The river channel itself has for the most part maintained connectivity, substrate sorting, sediment transport and active meandering; although evidence of modification in certain reaches is apparent. Observed modifications to the channel include induced channel incision (minor) from confinement and channelization and bank armoring/stabilization projects. Aside from these modifications, sufficient ephemeral riverine habitat is created and sustained for a small suite of migratory, amphidromous (fresh or saltwater tolerant) fishes recorded by Kwak (2007) at PR-127.

The Municipality of Guayanilla itself is nestled in the upper portion of the coastal floodplain valley where the valley is narrower. This location makes the Municipality susceptible to both riverine flooding and gully/ravine washes from the eastern hilly and mountainous valley wall. The river generally flows to the west of and through the middle of Municipality maintaining a meandering pattern. The floodplain is semi-connected at small rain events and fully connected at larger events as widespread flood damages are apparent. There are several major bridge over-road crossings and a variety of structures set alongside the

banks. Within the 100-year event floodplain there are 1,500 structures and utilities. Water quality is affected by agricultural drainage and waste water discharged to the river during flood events.

The land use to the south of PR-3337 is primarily agricultural, with the exception of the small coastal municipalities of El Faro and Playa de Guayanilla. Portions of the agricultural lands are no longer in use and have become heavily vegetated wetlands. The river in this reach was channelized and leveed as part of the Phase I DNER project in 2006. Based on the calculated flows entering the coastal alluvial plain at PR-379, large floods inundated the entire valley in the past, inducing many braided and overland flowages that would temporally flush and maintain estuarine habitats along the coastline at the Bay of Guayanilla. These natural processes created the conditions for an interior basin mangrove swamp to become established between the agricultural fields and the coastline and between Rio Guayanilla and the El Faro community.

Based on the natural deep depth of the bay and the flat coastal floodplain, shallow estuary wetland habitat is limited along the coastline. Outside of the deep natural bay, there are several coral reefs of the true marine environment, which are considered adjacent to the study area. These may or may not be influenced by the collocated gas liquefaction plants.

2.2 Earth Resources

2.2.1 Geology & Topography

The Municipality of Guayanilla is located in a coastal plain approximately 11.5 miles west of Ponce (Figure 6). The topography of Puerto Rico is extremely varied, but most of the island is hilly to mountainous, with very steep slopes and narrow valleys in the interior (Kaye, 1959). The south coast of the island is a low alluvial plain where nearly flat areas slope slightly upward to the foothills and grade into the alluvial plains of the larger rivers (Monroe 1980). The plains consist of combined alluvial fans with deposits from the Quaternary age consisting of sand, clay, and gravel (Monroe 1980).

The soils in the Rio Guayanilla basin consist of alluvial deposits of sand, clay, and talus in the floodplain, and limestone overlain by strata of clay, slates and sands in the mountain slopes. The soils map from the Natural Resources Conservation Services (NRCS) shows that the proposed project will encounter Constancia silty clay (Ct) and San Anton clay loam (Sa). The Constancia series consists of silty clay. It is somewhat poorly drained with very low to moderately low permeability and found in riverine floodplains. They formed in calcareous fine-textured sediments derived from volcanic and limestone rocks. The San Anton series consists of clay loam, loam, silty clay loam, and silt loam. It is well drained with moderately low to moderately high permeability and found on alluvial fans and flood plains. They formed in stratified alluvial deposits that weathered from volcanic rock and limestone.

Monroe (1980) described the mountainous area as steep eroded slopes of 30° to 45° in the valley. The rocks in the mountainous core consist predominantly of Lower Cretaceous to middle Eocene volcanic formations and are bordered by sedimentary rocks of Oligocene and Miocene age along the south coast (Monroe 1980). Most of the Lower Cretaceous rocks are submarine, deep-water volcanic-ash deposits interspersed with pillow lava and intruded by masses of granitic rock from the very Late Cretaceous to Eocene time (Monroe, 1980). Paleocene and lower Eocene rocks are volcanic and sedimentary (Monroe, 1980). The Cretaceous and early Tertiary rocks have been folded and intensely faulted into hundreds of fault blocks (Briggs and Akers, 1965). The younger rocks consist of conglomerate, sand, clay, chalk, and limestone of late Oligocene to early Miocene age (Kaye, 1959).

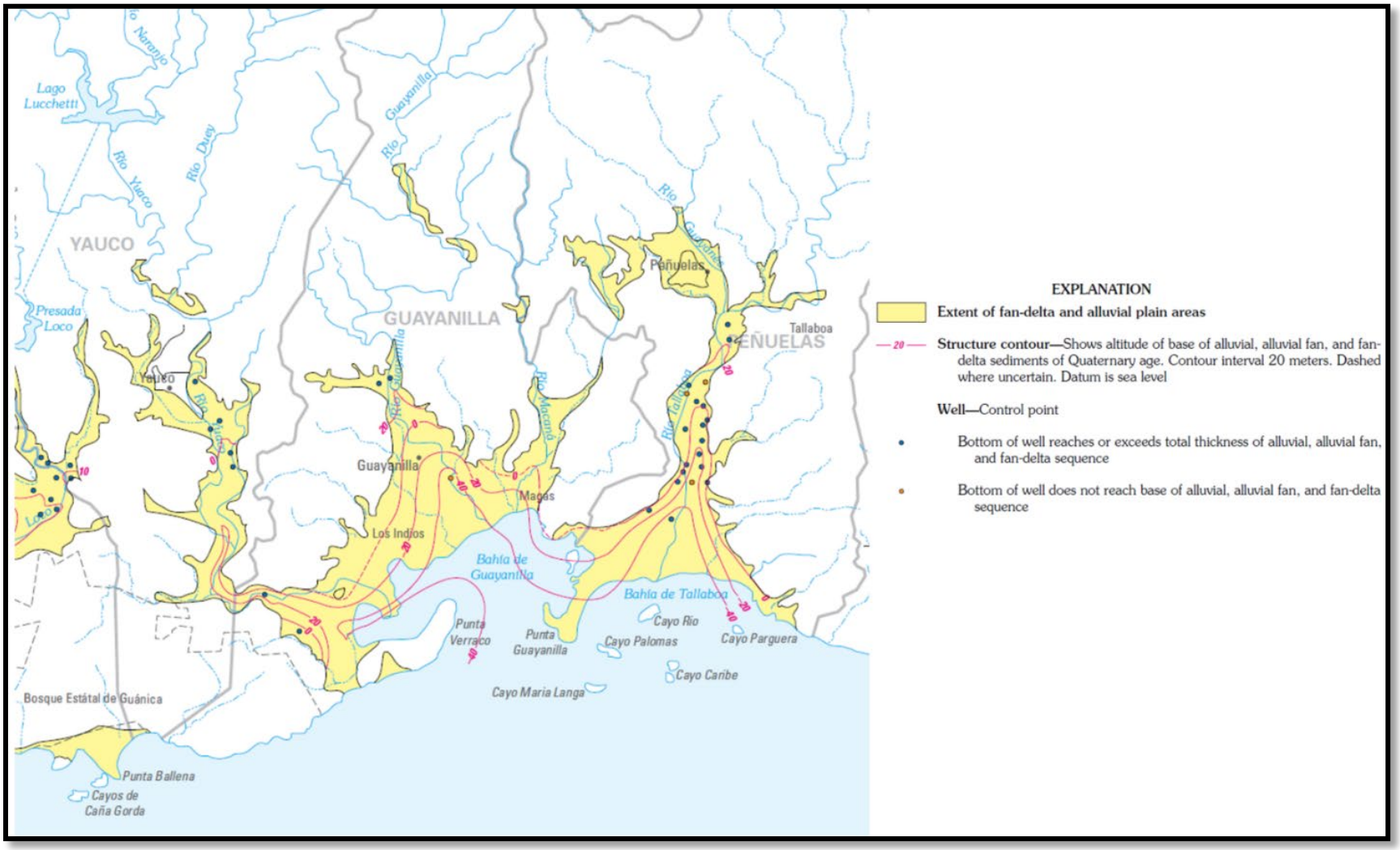

Figure 6: Bedrock Surface Underlying Alluvial-Fan & Fan-Delta Sediments (Renken et al, 2002)

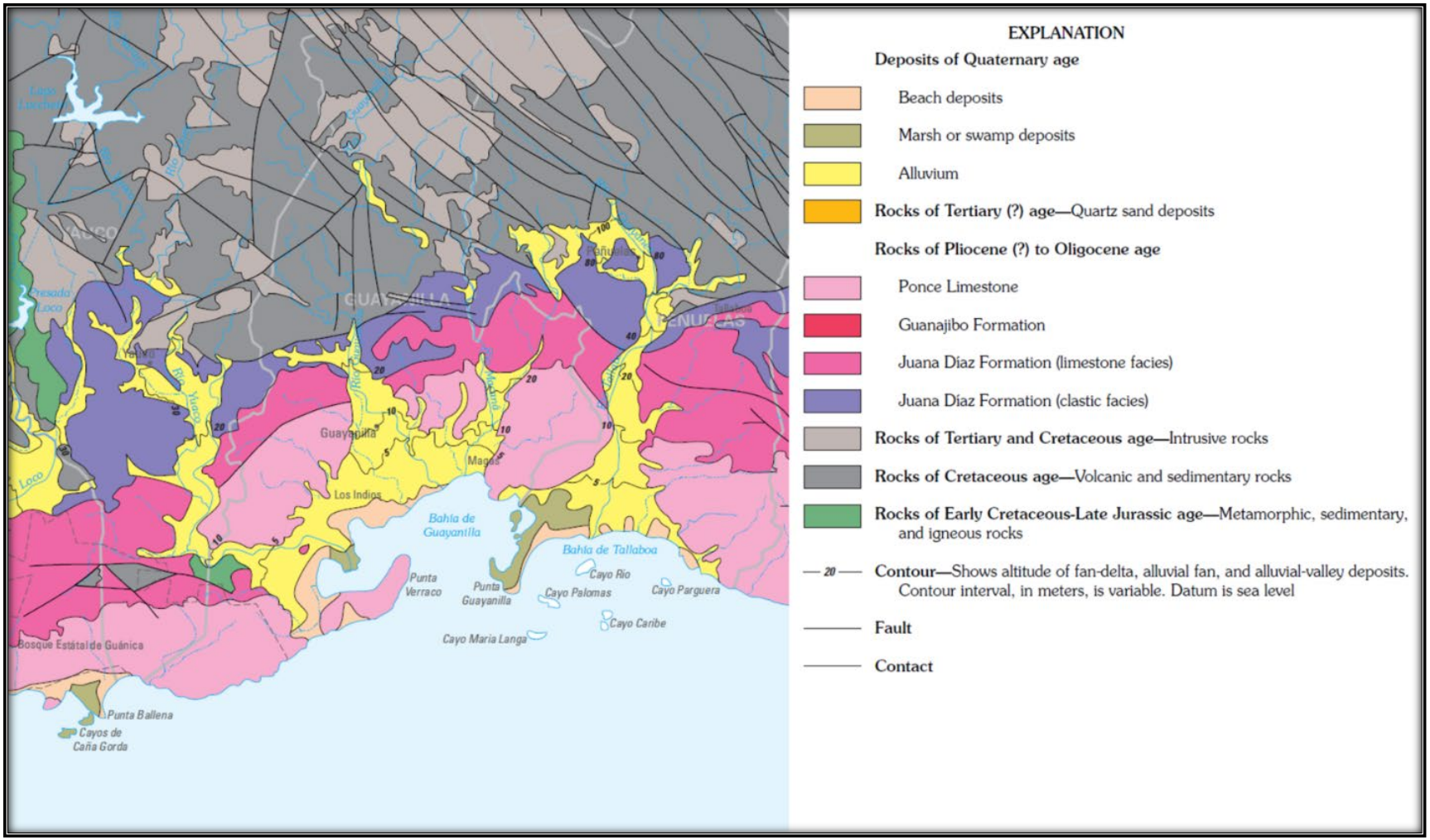

Figure 7: Geologic Map of Tertiary Rocks (Renken et al, 2002)

Large faults are common in southern Puerto Rico and older rocks have been folded, faulted, uplifted, and eroded into a rugged landscape before the Juana Diaz Formation of southern Puerto Rico were deposited upon them (Monroe, 1980). The Juana Diaz Formation is middle Tertiary in age and consists of a very thick mass of intertonguing mudstone, conglomerate, limestone, and a small amount of unconsolidated sand and lignite (Monroe, 1980). The Juana Diaz is overlain unconformably by the Ponce Limestone. The Ponce Limestone is an organic reef deposit that probably formed as a fringing reef on the southern coast of Puerto Rico in Miocene time and became thicker as the coastal shelf slowly subsided (Monroe, 1980). The Guanajibo Formation consists of light-yellow to gray limestones and sands, silts, and clays, probably from late Miocene or Pliocene age (Monroe, 1980). Though Guayanilla is officially outside of the known area of southern coastal karst, there are karstic formations near Guayanilla (Monroe, Karst 14).

Future Without-Project Condition: In the absence of a federal project, the geology of the study area would remain in its current condition, subject to earthquakes and natural erosion from wind, water and plant growth. Riverine processes would continue to deposit and move quaternary deposits of sand, gravel and clay within the alluvial fan system; however, this would be quite limited from the natural historic condition by the continued constraints put on natural riverine erosion.

2.2.2 Soils

The soils in the Río Guayanilla basin (Figure 8) consist of alluvial deposits of sand, clay, and talus in the floodplain; and limestone overlain by strata of clay, slates and sands in the mountain slopes. Closer to the coast, there is a thick highly compressible, organic clayey silt/silty clay layer overlying a stiff to very stiff clayey silt/silty clay. Specific existing soil types are presented in Table 2.

Table 2: Study Area Soils & Characteristics

Soil Type	Soil Characteristics	Hydric Soil Rating	Depth to Water Table	Drainage	Runoff Potential	Farmland Use
Aguilita	Gravelly clay loam	No	NA	Well	High	Not
Aguilita	Stoney clay loam	No	NA	Well	High	Not
Constancia	Silty clay		NA	Poorly	Moderate	Statewide Importance
Machuelo	Clay	No	18-36”	Poorly	Moderate	Statewide Importance
San Anton	Clay Loam	No	NA	Well	Moderate	Prime if Irrigated
Teresa	Clay; saline	No	NA	Poorly	High	Not
Meros	Sand	No	beach	Excessively	Low	Not

The Aguilita series consists of very deep, well drained, moderately permeable soils on ridge tops, summits and side slopes in uplands and limestone hills. They formed of colluvium and residual grains that weathered from soft limestone bedrock. Most areas of Aguilita soils are used for hay and pasture lands. Native vegetation is typically xerophytes, predominated by Hurricán (*Andropogon pertusus*) and African Kleberg Bluestem grasses (*Andropogon* spp). This soil type is also utilized for mesquite production.

The Constancia series consists of very deep, somewhat poorly drained, slowly permeable soils in riverine floodplains. They formed in calcareous fine-textured sediments derived from volcanic and limestone rocks. Vegetation is dominated by invasive and nonnative species such as African Guinea Grass (*Panicum maximum*). Most areas of Constancia soils are used for cropland and pasture land.

The Machuelo soils are on nearly level flood plains with slope gradients of 0 to 2 percent. The soil formed in clayey sediments washed out from the volcanic and limestone hills. Nearly all of this soil type has been converted to Sugar Cane (*Saccharum officinarum*) production.

The San Anton series consists of very deep, well drained, moderately permeable soils on alluvial fans and floodplains. They formed in stratified alluvial deposits that weathered from volcanic rock and limestone. Vegetation is dominated by African Guinea Grass, Buffel Grass (*Cenchrus ciliaris*), Puerto Rican Stargrass (*Cynodon nlemfuensis*), Pangola Grass (*Digitaria eriantha*) and other native and introduced species. San Anton soils are used for pasture and for growing Sugar Cane, Plantains (*Musa* spp. cultivars) and other crops.

The Teresa series consists of very deep, somewhat poorly drained, very slowly permeable soils on alluvial flats in valley floors. They formed in clayey marine sediments. Vegetation is xerophytic and salt tolerant with predominant species of Puerto Rican Oregano (*Lippia dulcis*) and/or Toad Grass (*Lippia nodiflora*), Bayahonda (*Prosopis juliflora* and/or *Prosopis pallidus*) and Bundleflower Trees (*Desmanthus* spp.). Most areas of Teresa soils are used for pastureland.

The Meros and Hydraquents soils occur on nearly level benches along the coast at elevations slightly above sea level. They formed in sandy sediments derived from volcanic fragments, sea shells, and corals. Coastal beach is a land type that consists of miscellaneous sandy materials reworked by wave action; hydraquents are the clayey soils of the tidal marches that are permanently saturated with water.

Future Without-Project Condition: In the absence of a federal project, soils within the study area would continue to be disturbed predominantly by agricultural practices and infrastructure. The natural processes that form and maintain soils are also impaired or gone, which over time soils will begin to lose their characteristics (if they have not already) and eventually become just growing mediums for crops. Soils in some areas have already been significantly impacted. Soils in natural areas would remain relatively undisturbed and preserved, should the lands not be clear cut or developed in the future. In short, intensive agriculture, altered hydrology and other human activities have greatly impaired natural soil characteristics.

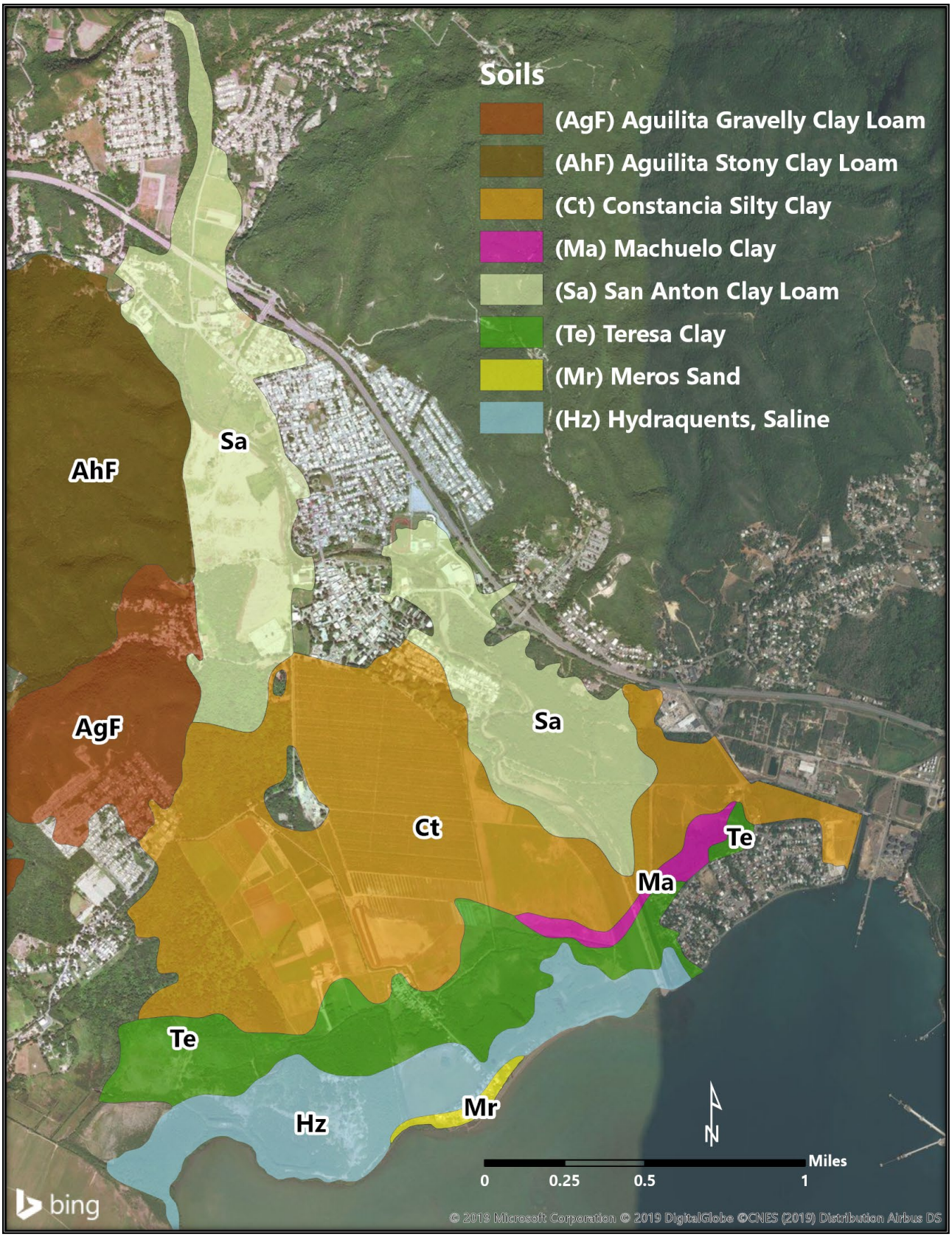

Figure 8: Río Guayanilla Study Area Soils

2.2.3 Faults, Seismic Activity & Tsunami

A fault is a fracture or zone of fractures between two blocks of rock. Faults allow the blocks to move relative to each other. This movement may occur rapidly, in the form of an earthquake - or may occur slowly, in the form of creep. Faults may range in length from a few millimeters to thousands of kilometers. Most faults produce repeated displacements over geologic time. During an earthquake, the rock on one side of the fault suddenly slips with respect to the other. The fault surface can be horizontal or vertical or some arbitrary angle in between.

Two through-going fault zones, the Great Northern Fault Zone and the Great Southern Fault Zone, divide Puerto Rico into the northeastern, central and southwestern blocks (Larue, 1988). Puerto Rico is presently bound on the north by the Puerto Rico trench, which is characterized by oblique subduction, and on the south by the Muertos trough, which is characterized by extremely slow subduction (Larue, 1988). Puerto Rico is a broad arch, as younger rocks on the south coast dip south away from the outcrop of the older rocks that extends as a continuous belt from the west to the east coast in the middle of the island (Kaye, 1959). In southern Puerto Rico, the attitudes are much more irregular and much steeper, ranging from a few degrees to as much as 30° and the direction of dip is generally south but is influenced by the faulting commonly present in that area (Monroe, 1980). Large faults are common in southern Puerto Rico. The older rocks had been folded, faulted, uplifted, and eroded into a rugged landscape before the Juana Diaz Formation of southern Puerto Rico were deposited upon them (Monroe, 1980).

The closest major tectonic fault to Puerto Rico is a transform fault running east-west approximately 125 miles north of Guayanilla. According to the USGS, there have been several very large earthquakes north of Puerto Rico (magnitude 7.3 in 1918; magnitude 7.8 in 1943; magnitude 8.0 in 1946 and four major aftershocks of magnitude 7.6, 7.0, 7.3 and 7.1 between 1946 and 1953). The October 1918 earthquake originated west of the island in an underwater canyon between Puerto Rico and the Dominican Republic and caused significant property damage along the west coast. Southern Puerto Rico experienced an earthquake sequence starting with a 4.7 magnitude earthquake on December 2019. The USGS has reported more than 300 earthquakes greater than a magnitude of 3, which people can feel, as of 16 January 2020. These earthquakes occurred offshore of southwest Puerto Rico in a deformation zone bounded by the Punta Montalva Fault on land and the Guayanilla Canyon offshore.

Tsunamis are extremely large waves caused by earthquakes or volcanic eruptions under the sea. Out in the depths of the ocean, tsunami waves do not dramatically increase in height. But as the waves travel inland, they build up to higher and higher heights as the depth of the ocean decreases. The speed of tsunami waves depends on ocean depth rather than the distance from the source of the wave. Tsunami waves may travel as fast as jet planes over deep waters, only slowing down when reaching shallow waters. While tsunamis are often referred to as tidal waves, this name is discouraged by oceanographers because tides have little to do with these giant waves (NOAA). The 1918 earthquake caused a tsunami which then caused major damage to two coastal cities, Aguada and Añasco. Similar tsunamis have accompanied every major earthquake on record, flooding the coast nearest to the epicenter. Guayanilla has evacuation zones identified along the coast (Figure 10). No tsunamis were observed in conjunction with the 2019 and 2020 earthquakes.

Future Without-Project Condition: These natural earth processes would continue indefinitely throughout the future. Any future projects should consider these conditions when establishing design parameters.

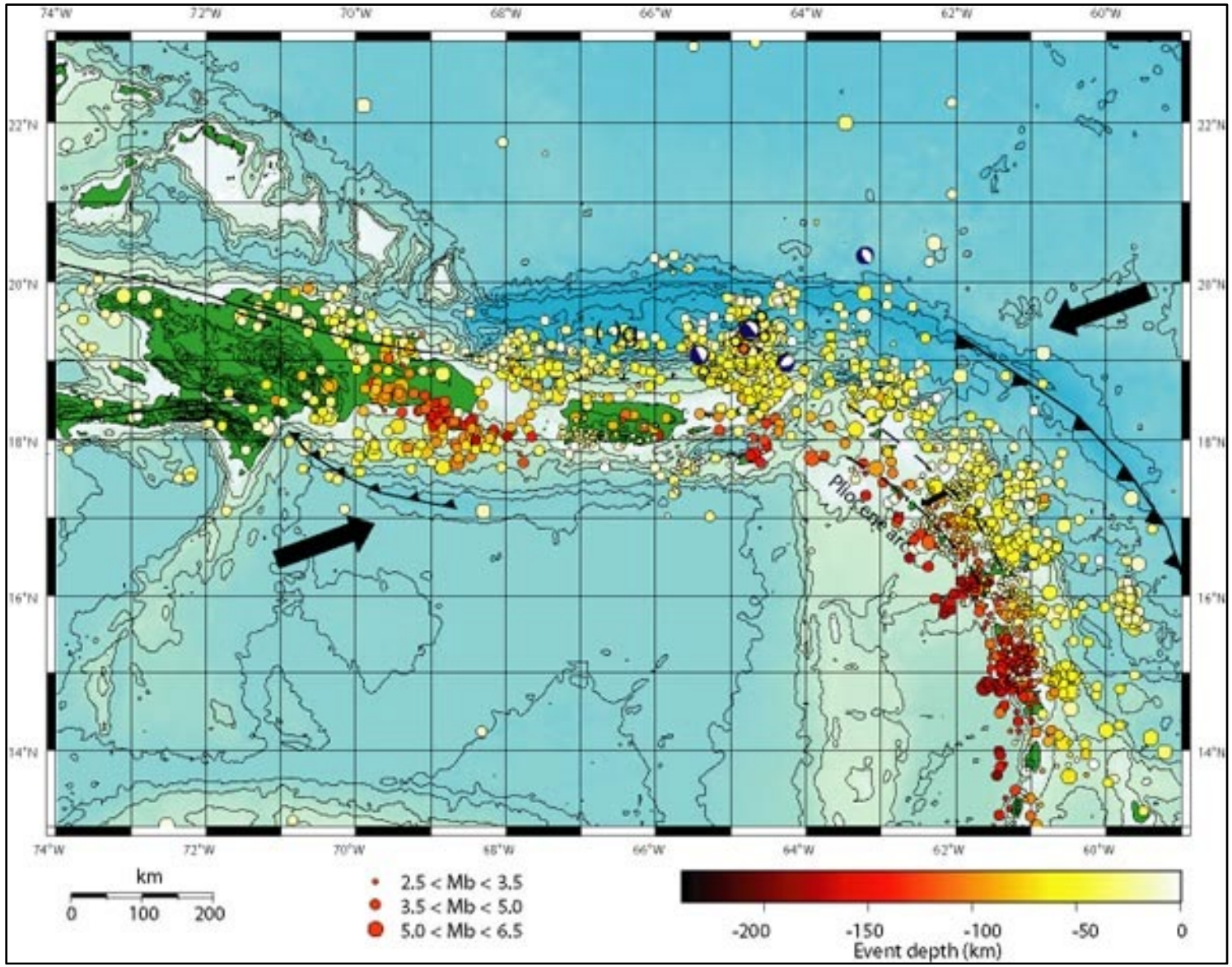

Figure 9: USGS Map of Puerto Rico Trench, Tectonic Plate Direction and Occurrence & Magnitudes of Resulting Earthquakes

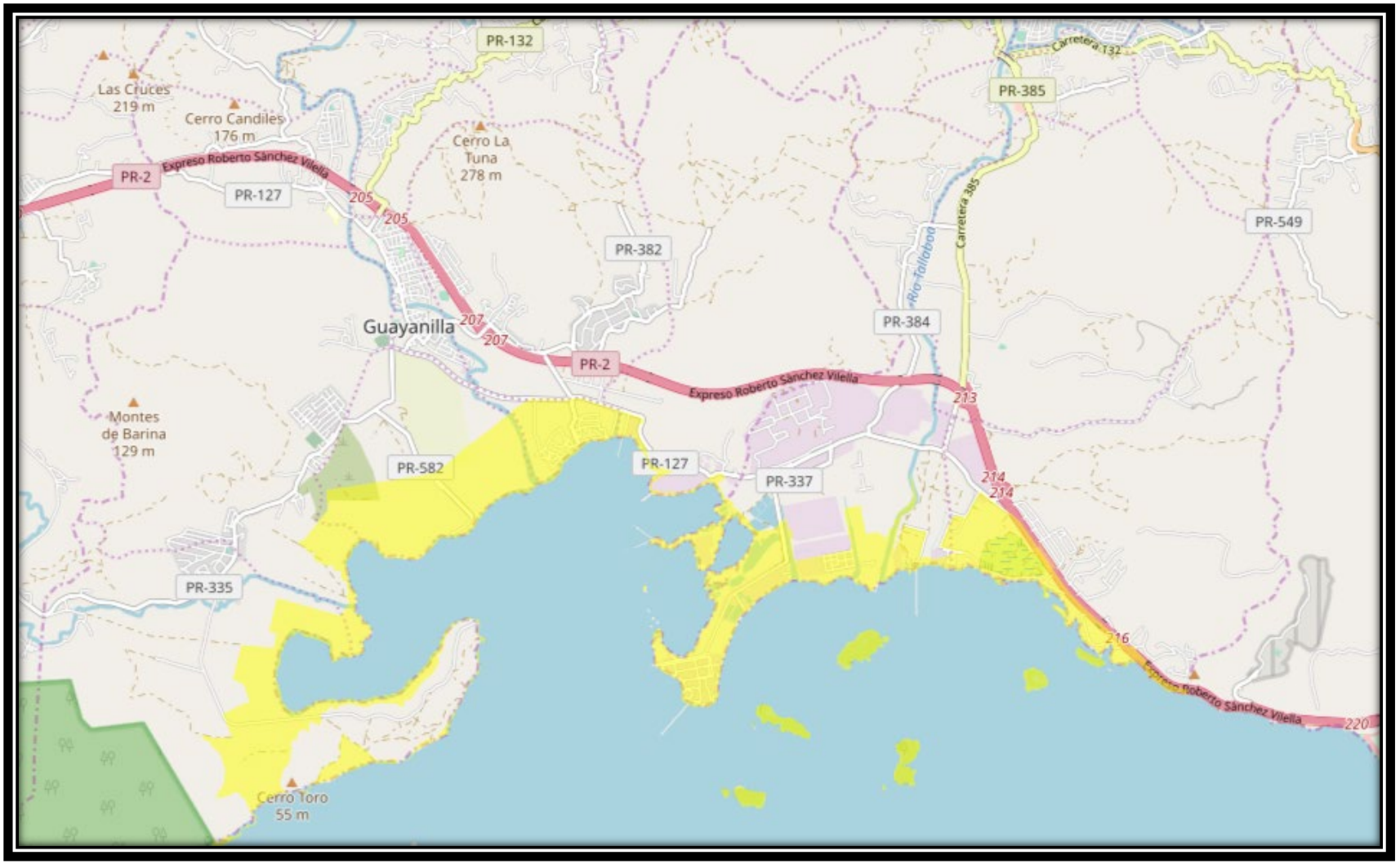

Figure 10: Tsunami Evacuation Zone

2.2.4 *Liquefaction & Landslides*

A landslide is defined as the movement of a mass of rock, debris, or earth down a slope under the direct influence of gravity. The term "landslide" encompasses five modes of slope movement: falls, topples, slides, spreads, and flows (USGS). Slope movement occurs when forces acting down-slope (mainly due to gravity) exceed the strength of the earth materials that compose the slope. Causes include factors that increase the effects of down-slope forces and factors that contribute to low or reduced strength. Landslides can be initiated in slopes already on the verge of movement by rainfall, snowmelt, changes in water level, stream erosion, changes in ground water, earthquakes, volcanic activity, disturbance by human activities, or any combination of these factors. Earthquake shaking and other factors can also induce landslides underwater, which are called submarine landslides. Submarine landslides sometimes cause tsunamis that damage coastal areas.

On September 20, 2017, Hurricane Maria hit the U.S. territory of Puerto Rico as a Category 4 Storm. Heavy rainfall caused landslides in mountainous regions throughout the territory. It is assumed that the majority of landslides were triggered by rainfall from Hurricane Maria, but rainfall from Hurricane Irma during the first week of September and rainfall from thunderstorms after Hurricane Maria may have also initiated landslides. Figure 11 below shows the locations of landslides caused by Hurricane Maria.

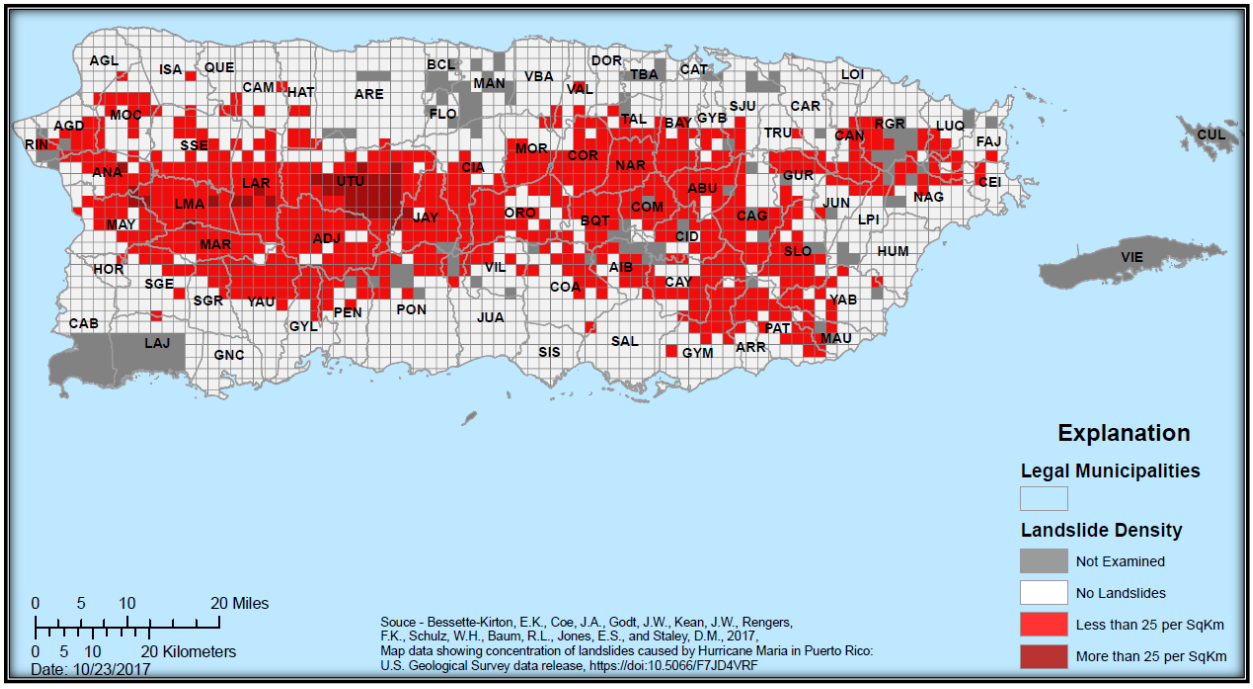

Figure 11: USGS Map of Landslides Caused by Hurricane Maria (2017)

Liquefaction is caused when the ground shakes wet granular soil and changes it to an unstable liquid state. This subsurface process can lead to near-surface or surface ground failure that can result in property damage and structural failure. Areas prone to liquefaction have thick alluvial soils that are poorly consolidated. During the 2020 earthquakes, the USGS reported that the ground dropped about 6 inches at Playa de Guayanilla. Areas where ground shaking caused liquefaction, lateral spreading, and landslides were also reported. There were also reports that El Faro experienced more than 6 inches of settlement.

Future Without-Project Condition: These natural earth processes would continue indefinitely throughout the future. Any future projects should consider these conditions when establishing design parameters.

2.2.5 *Hurricane*

The island is in the hurricane belt of the western Atlantic and Caribbean. Most hurricanes form as tropical lows off the coast of Africa from June through October and intensify as they proceed west over the warm waters of the Atlantic. Hurricanes are Puerto Rico's number one weather problem because of the catastrophic high winds and waves, large volumes of rain, and associated impacts on humans and human infrastructure. Most hurricanes are peripheral and produce minor effects, but those termed killer hurricanes owing to their intensity and direct hits, have the potential to produce enormous damage and hardship. Typically, 6 to 10 hurricanes develop yearly in the western North Atlantic region. Hurricanes have impacted Puerto Rico recently, with Hortense, Hugo, George, Irma and Maria classed as major hurricanes.

Historically, the study area has never been flooded by hurricane or storm tides, although heavy wave action has occurred during the passage of some storms. Very high storm tides may cause disastrous flooding in the low-lying coastal areas, specifically in the Playa de Guayanilla and El Faro sectors.

This is demonstrated by the National Storm Surge Maps (https://www.nhc.noaa.gov/nationalsurge/) depicted below in Figure 12 and Figure 13. Based on local expert's (USACE SAJ, USGS, Guayanilla staff) knowledge of the area, the peak discharge due to riverine flooding and the high tides due to a storm surge do not occur at the same time. The high storm tides have always occurred prior to the peak of the riverine flooding, which is not reflected in the figures below.

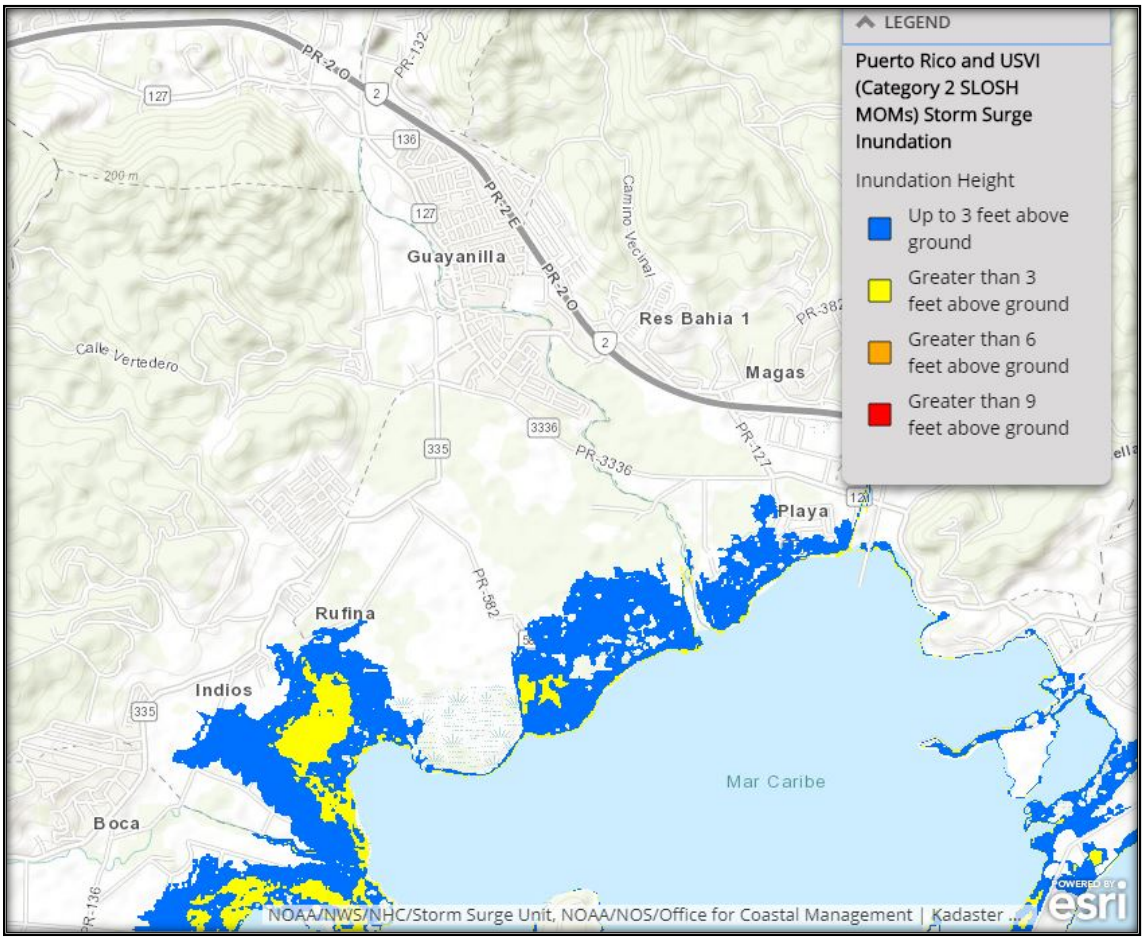

Figure 12: Potential Storm Surge Vulnerability for USVI Category 2 storm

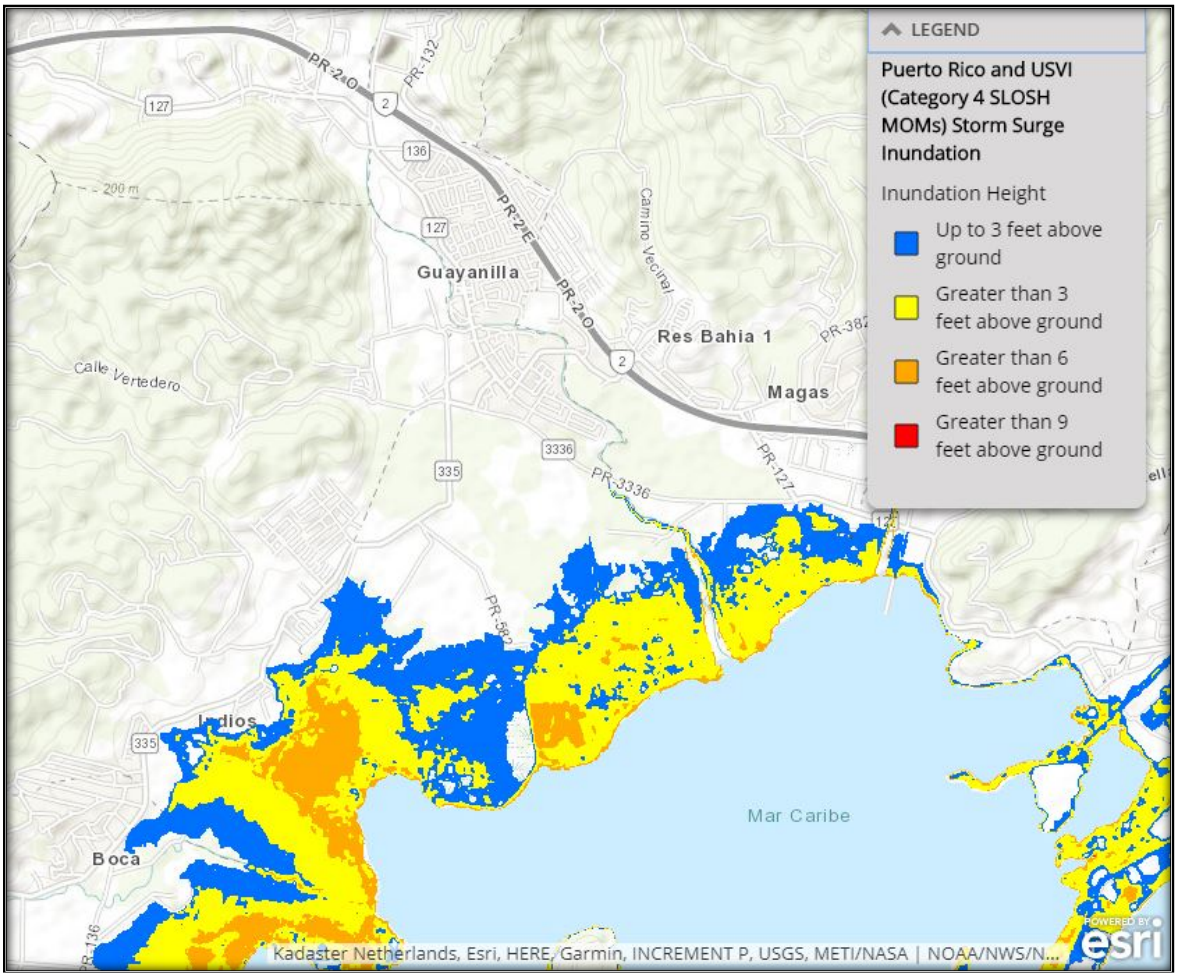

Figure 13: Potential Storm Surge Vulnerability for USVI Category 4 storm

Future Without-Project Condition: These natural earth processes would continue indefinitely throughout the future. Any future projects should consider these conditions when establishing design parameters.

2.3 Water Resources & Quality

2.3.1 Hydrology & Hydraulics

The Río Guayanilla watershed is approximately 96 square kilometers (37 square miles). The total length of the river channel is approximately 23 kilometers (13.9 miles). The river flows generally southerly via a winding, well-defined channel, which passes through the municipality of Guayanilla. There is one stream gaging station, 50124200, within the watershed that has been operated continually by the USGS on the Río Guayanilla since 1981 (Figure 3).

The study area, as defined for the hydraulic analyses, consists of the reach starting at the mouth of the river and extending just past the bridge on PR Highway 2. The area is characterized by low ground elevations and flat terrain. The hydraulic capacity of the Rio Guayanilla channel in the lower flood plain is estimated to be about 3,800 cfs for the 0.5 AEP event (2-year flood) Table 3, provided below, summarizes the discharges and corresponding recurrence interval from the hydrologic and hydraulic models.

Table 3:Annual Exceedance Probability Discharges

Annual Exceedance Probability (AEP)	Discharge (cfs)
0.5	3,575
0.2	7,565
0.1	11,257
0.04	20,842
0.02	29,052
0.01	41,863
0.005	54,524
0.002	74,561

The following discussion summarizes the assessment carried out to evaluate what the potential impacts of climate change could be on the study area. The assessment includes an evaluation of changes in temperature, precipitation, streamflow and sea level. For more detailed discussion related to how changes in hydrometeorology and sea level are evaluated in support of this study refer to *Appendix B*, *Hydrology & Hydraulic*s. Sea Level Change and the effects of climate change on inland hydrology are evaluated in accordance with the following USACE guidance: ECB 2018-14, ETL 1100-2-3, ER 1100-2-8162 and ETL 1100-2-1.

Inland Hydrology Climate Change

USACE ECB 2018-14, *Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects*, "provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaptation policy. This policy requires consideration of climate change in all current and future studies to reduce vulnerabilities and enhance the resilience of our water resources infrastructure." The document "helps support a qualitative assessment of potential climate change threats and impacts" related to USACE analyses. For the Rio Guyanilla study the qualitative climate change assessment consists of carrying out a literature review that focuses on both regional and local scale trends in observed and projected temperature, precipitation and streamflow, as well as a first order statistical analysis of trends and nonstationarities in an observed, annual peak streamflow record.

Literature reviewed specific to both Puerto Rico and the Caribbean Region as a whole indicate that increasing temperature trends are evident in the observed, historic record as well as within projections of future conditions. There is a lot more uncertainty with regards to trends in observed and projected streamflow and precipitation. Resources reviewed do not point to a definitive trend in either precipitation or streamflow. As part of the inland hydrology assessment a nonstationarity analysis and a monotonic trend analysis of annual peak streamflows collected at USGS gaging station 050124200 is carried out in accordance to *ETL 1110-2-3: Guidance for Detection of Nonstationarities in Annual Maximum Discharges.* No statistically significant nonstationarities or trends are identified within the observed peak streamflow record. Based on the results of this analysis, the study area is not likely to experience increased flood risk due to climate change in the near term.

Sea Level Rise

Relative Sea Level Change (RSLC) is an important variable in flood risk management projects because sea level change can potentially affect the project and system performance. Therefore, projects need to consider how sensitive and adaptable engineered systems are sea level change. USACE guidance (ER 1100-2-8162 and ETL 1100-2-1) recommends an expansive approach to considering and incorporating RSLC into civil works projects.

As specified within ER 1110-2-8159, the effects of sea level rise must be evaluated both over the period of analysis (POA) adopted for economics and the project planning horizon. USACE projects are justified over a typical POA of 50 years. However, USACE projects can remain in service much longer than the POA consequently, the project planning horizon should be longer and is typically adopted as 100 years.

Using the USACE Sea Level Change Calculator, Figure 14 shows that for a 50 year period of analysis future sea level rise estimates range from 0.345 to 2.601 feet above relative mean sea level by the year 2070. For the year 2120, the estimates range from 0.567 to 6.641 feet above relative mean sea level. Consistent with Engineering Regulation (ER) 1100-2-8162, sea level rise was incorporated into the downstream boundary condition. For the more frequent events (50% - 10% AEP) a stage of 4.66 feet was used. For the less frequent events (4% - 0.2% AEP) a stage of 5.25 feet was used. This represents a high rate estimate somewhere between the 50-yr period of analysis and 100-year planning horizon and is a fairly conservative estimate. This was used as the downstream boundary condition in all future without- and with-project conditions model runs. Even with this conservative assumption, the increased water surface elevation has no impact on the recommended plan since it is outside of tidal influence.

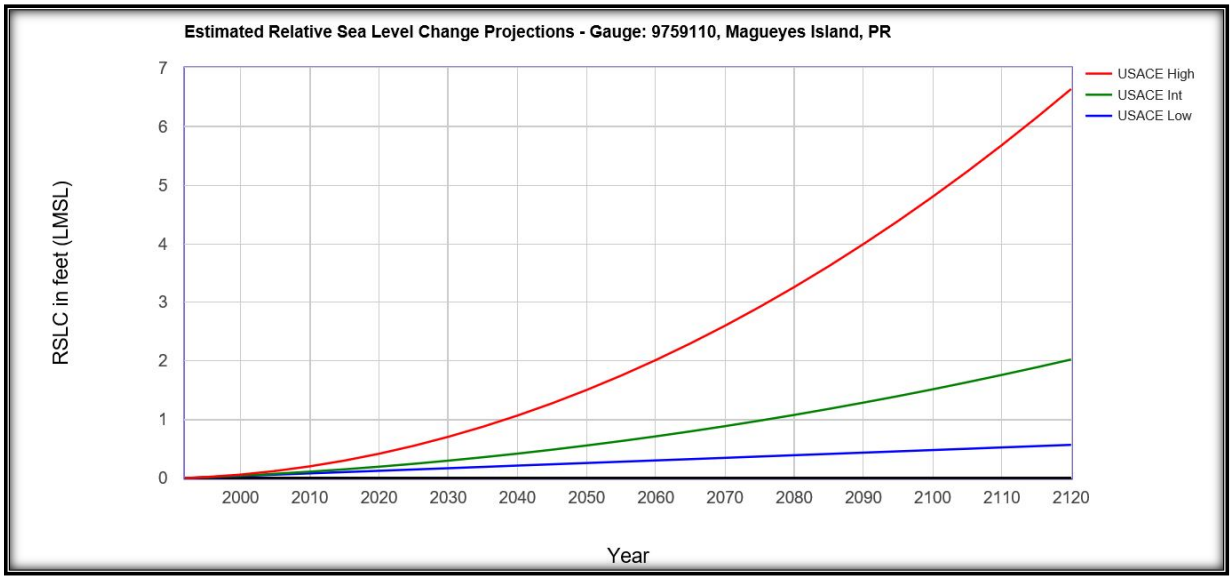

Figure 14: USACE Sea Level Change Curve Calculator for gage closest to Guayanilla

Climate Change Assessment Summary & Evaluation of Residual Risk

Table 4 summarizes residual risk due to climate associated with the recommended plan. The quantitative assessment of the impact of climate change on the study area's inland hydrology implies a very low likelihood of either precipitation or streamflow impacting project performance over the 100-year planning horizon. Similarly, because project features are outside the area impacted by tidal influence, even when sea level rise is accounted for it is unlikely that rising sea levels will impact project performance over the next 100-years. Based on this assessment, the recommendation is to treat the potential effects of climate change as occurring within the uncertainty range calculated for the current hydrologic and hydraulic analyses.

Table 4. Climate Risk Register

Feature or Measure	Trigger	Hazard	Consequence	Qualitative Likelihood
Levee Heights	Increased water levels in the floodplain from storm events due to sea level rise	Reduced assurance on levee/floodwalls; increased probability of overtopping	Flooding of protected area, economic damages and transportation delays	Unlikely – Peak elevations remain the same regardless of SLC
Levee Heights	Increased water surface elevations in levee/floodwall areas due to higher intensity rainfall	Reduced assurance on levee/floodwalls; increased probability of overtopping	Flooding of protected area, economic damages and transportation delays	Unlikely – observed trends in precipitation are unclear

Land Use

Present land (Figure 15) use in the Rio Guayanilla basin is varied. About 69 percent is uncultivated or undeveloped land, with a large extension of forest cover in the northern upper reaches and wild grass and brush in the lowland and limestone hills around the flood plain.

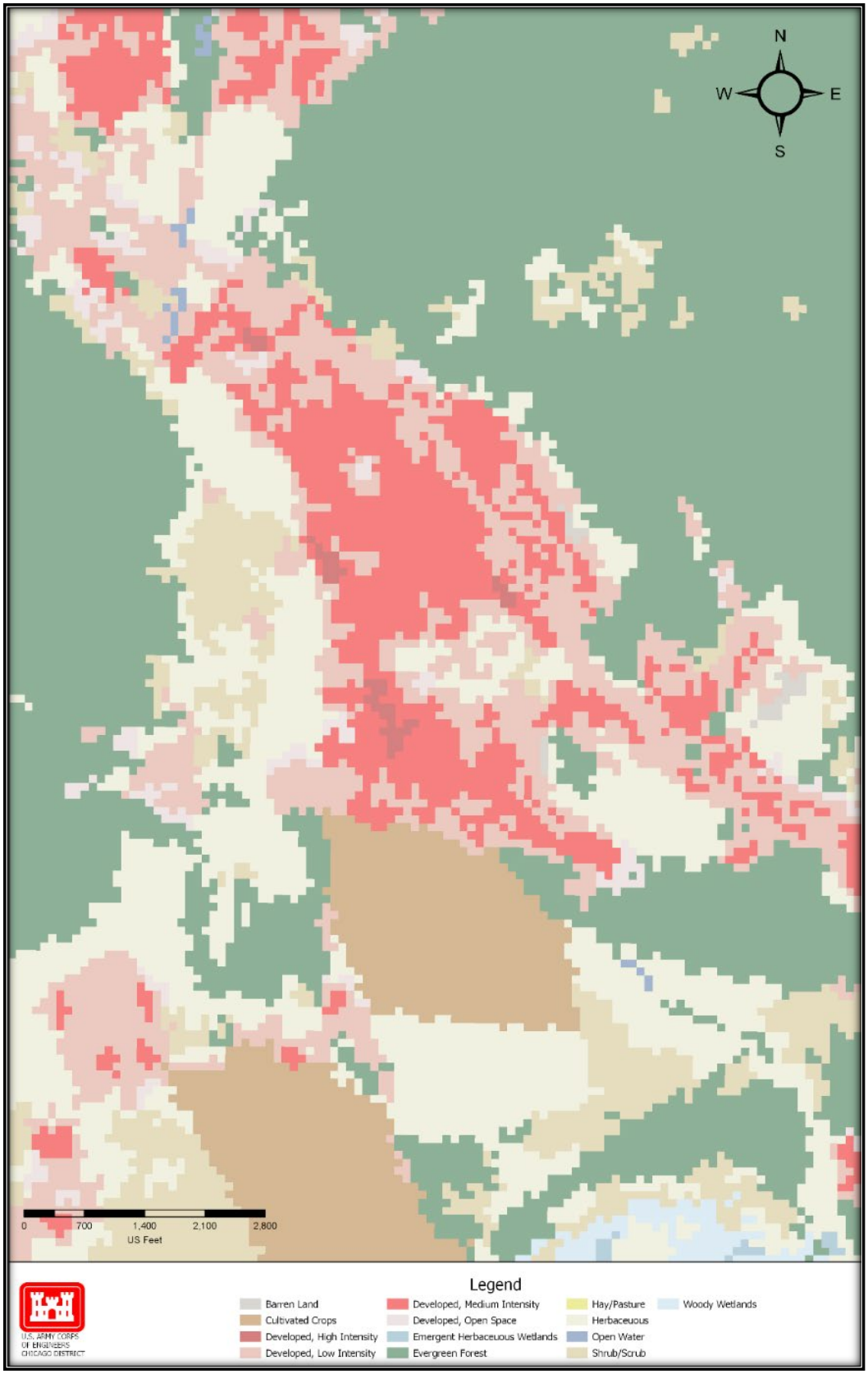

Figure 15: Study Area Land Use as Utilized by HEC-RAS Modeling

About 22 percent is or has been cultivated. Typical crops are bananas in the floodplain and foothills, coffee, grazing pasture, and some minor crops in the hills and mountain slopes. About 7 percent is urban developed land, more than 3 percent is occupied by roads and highways and another 1 percent is swampy mangrove land near the bay. According to the Puerto Rico Planning Board Land Use Plan for year 2016, the land proposed for future urban expansion is mostly located in the north of the Municipality of Guayanilla and to some extent east of the municipality near existing industry.

2.3.2 Flooding

During flood seasons, which is generally May through December, the Rio Guayanilla is a source of frequent flood damages within the study area. Due to the steep slopes in the basin, this flooding is often caused by flash floods that result with little warning time for area residents. Flood waters inundate major roads and impact critical facilities, such as the police and fire station, within the broad and flat coastal flood plain. Historically, there have been at least 13 damaging floods along the Rio Guayanilla. Peak discharges are summarized for those historic flood events in Table 4. The USGS has not yet published the peak flow data for Hurricane Maria in September 2017.

Table 5: Damaging Historic Floods Recorded on the Río Guayanilla

Date of Flood	Discharge (cfs)
September 13, 1928	23,000
May 7, 1932	28,000
October 13, 1954	18,000
May 6, 1958	11,600
September 16, 1975	22,400
August 31, 1979	16,000
September 12, 1982	14,700
October 7, 1985	11,900
September 22, 1998	18,700
May 6, 2001	18,700
September 22, 2008	14,500
October 26, 2012	23,800
September 19, 2017	***

*** The USGS has not yet published the peak flow data for Hurricane Maria*

2.3.3 Water Quality

As required by the Clean Water Act (CWA), Puerto Rico has established water quality standards (WQS) for its rivers, lakes, coastal waters, and estuaries based on their designed uses. The Puerto Rico Environmental Quality Board (PREQB) collects data for the Rio Guayanilla and Guayanilla Bay through a number of water quality monitoring networks in the project area. Under section 303(d) of the CWA, water quality data are evaluated, and a list of waters too degraded by one or more pollutants to meet WQSs is developed. Existing impairments for the Guayanilla watershed are summarized in Table 6 (PREQB, 2018a).

Table 6: 2018 Rio Guayanilla and Guayanilla Bay 303(d) listed pollutants.

Water body (river/coast length)	Designated Uses	Impairments	TMDL Development Priority (projected submittal date)	Sources
Rio Guayanilla / Río Guayanilla (60 miles)	Contact and non-contact water recreation (REC-1, REC-2), preservation and propagation of aquatic life including T&E species (AL), drinking water supply (DW)	Ammonia	High	Agriculture, Collection System Failure, Landfills, Minor Industrial Point Source, Minor Municipal Point Source, Onsite Wastewater Treatment Systems, Urban Runoff/Storm Sewers
		Enterococci	High	
		Fecal Coliform	Already Established (Approved September 2012)	
		Low Dissolved Oxygen	High	
		Total Nitrogen	High (2019)	
		Total Phosphorus	High (2019)	
Guayanilla Bay / Punta Guayanilla to Punta Verraco (13.20 miles)	Contact and non-contact water recreation (REC-1, REC-2), preservation and propagation of aquatic life including T&E species (AL)	Copper	*	Major Municipal Point Sources, Marinas and Recreational Boating, Onsite Wastewater Systems, Upstream Impoundment, Urban Runoff/Storm Sewers
		Enterococci	*	
		Oil and Grease	*	
		pH	*	
		Thermal Modification	*	
		Turbidity	*	

*Not in rankings. Source: PREQB, 2018a.

The Rio Guayanilla is on the 303(d) list for ammonia, enterococci, low dissolved oxygen, total nitrogen, and total phosphorus from multiple sources. National Pollutant Discharge Elimination System (NPDES) permitted point sources to the Rio Guayanilla include the Puerto Rico Aqueduct and Sewer Authority (PRASA) Guayanilla Wastewater Treatment Plant and Juana Díaz water filtration plant, and Municipality of Guayanilla storm sewer discharge. In response to violations of its NPDES permit and the CWA, PRASA has agreed to implement measures to reduce pollutant loading to receiving waters from WWTPs island-wide (https://www.epa.gov/sites/production/files/2015-09/documents/prasacwa-cd.pdf). Nonpoint sources include non-permitted stormwater runoff, leaking septics and latrines, and agricultural runoff. The river also experiences high erosion and sedimentation rates due to a combination of soil types, steep terrain, heavy rain events, and land use.

Guayanilla Bay is listed as impaired for enterococci as well as copper, oil and grease, pH, thermal modification, and turbidity from multiple sources. The bay is impacted through riverine discharge, boating/shipping inputs and sediment re-suspension, and electrical or petrochemical industrial releases on the east side of the bay.

Listed pollutant/waterbody combinations are required to develop total maximum daily loads (TMDLs) which are the maximum amount of a pollutant the waterbody can receive and still safely meet WQSs. A fecal coliform bacteria TMDL was developed for the Río Guayanilla (PREQB, 2012) and allocated among various point and nonpoint sources. TMDLs are still needed for other river impairments, and are expected to be developed as soon as 2019 (PREQB, 2018b).

The alluvial aquifer in the Rio Guayanilla watershed varies in quality based on aquifer recharge (rainfall, irrigation), magnitude and pattern of water withdrawals, and infiltration from agricultural, urban, and industrial sources. The Department of Natural and Environmental Resources (DNER) has identified saline intrusion as critical threat to south coast aquifers (Figure 16) including in the Guayanilla alluvial valley, and established restrictions on additional well development (DNER, 2008).

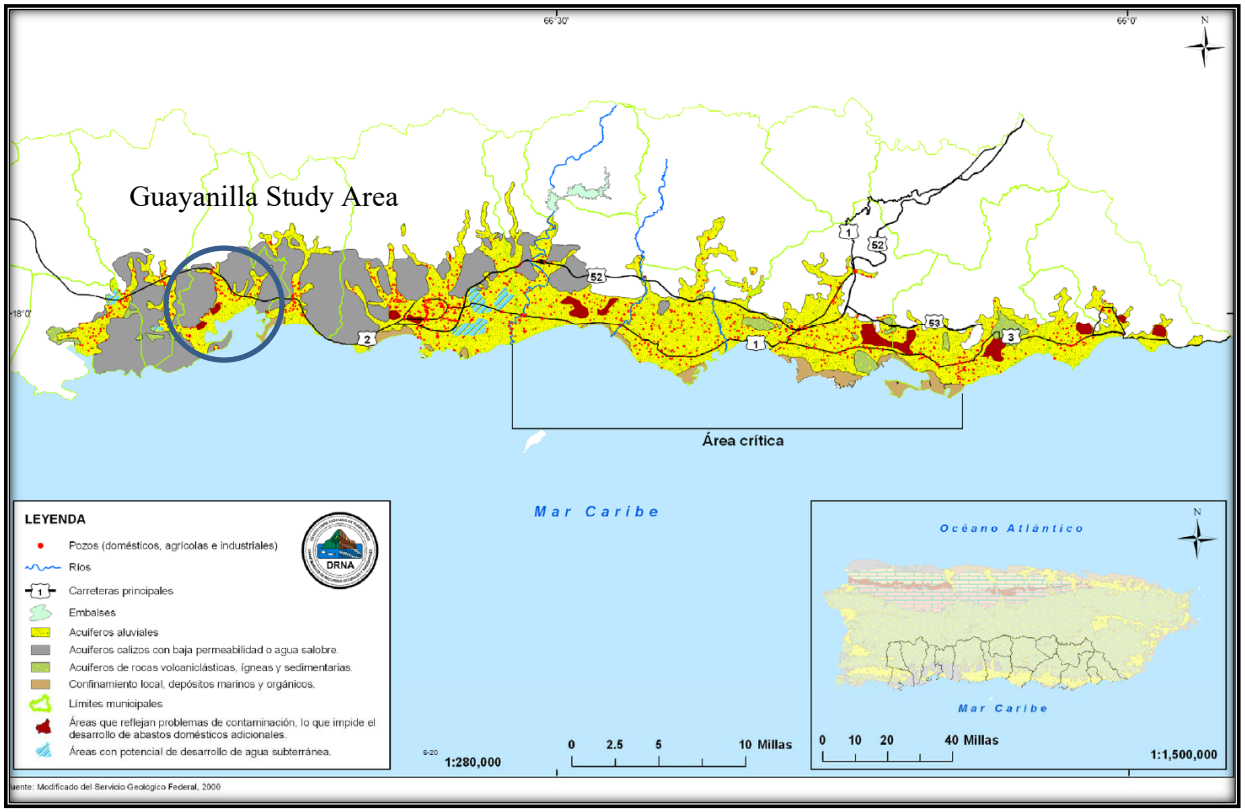

Figure 16: PR South Coast Aquifers, with Critical Areas of Saline Intrusion Highlighted in Red

Future Without-Project Condition: In the absence of a federal project, future water quality conditions in the Guayanilla watershed would not change significantly. Collection system failures, heavy sediment loads, industrial releases, and salt water intrusion will continue to impact Guayanilla waters until TMDLs, infrastructure improvements, efficient water use strategies, and other restoration efforts can be implemented. Future projects should consider these conditions when establishing design parameters.

2.3.4 Groundwater

Guayanilla is located in the Guayanilla alluvial valley that is part of the South Coast Groundwater Province (Figure 17). The principal water bearing units within the alluvial and fan-delta deposits in Guayanilla contains boulder to sand size sediments (USGS). Recharge is mostly from stream and irrigation ditch seepage with minor recharge from infiltration of precipitation. Specific capacity ranges from 1 to 10 (L/sec)/m (Giusti, 1978). There is a USGS well (USGS 180052066471000 MER 3 WELL) located in the banana plantation south of 3336 and west of the Río Guayanilla. Groundwater flows to the southeast towards the coast. The South Coast Aquifer extends from Patillas to Ponce, east of Guayanilla. It is an alluvial aquifer deposited from fan-deltas that merged from major streams (USGS, 2010). There are also reports of a conductivity of 8 to 63 L/s from wells penetrating a cavernous limestone strata. Borings in the area show the groundwater levels around 25-ft below ground surface.

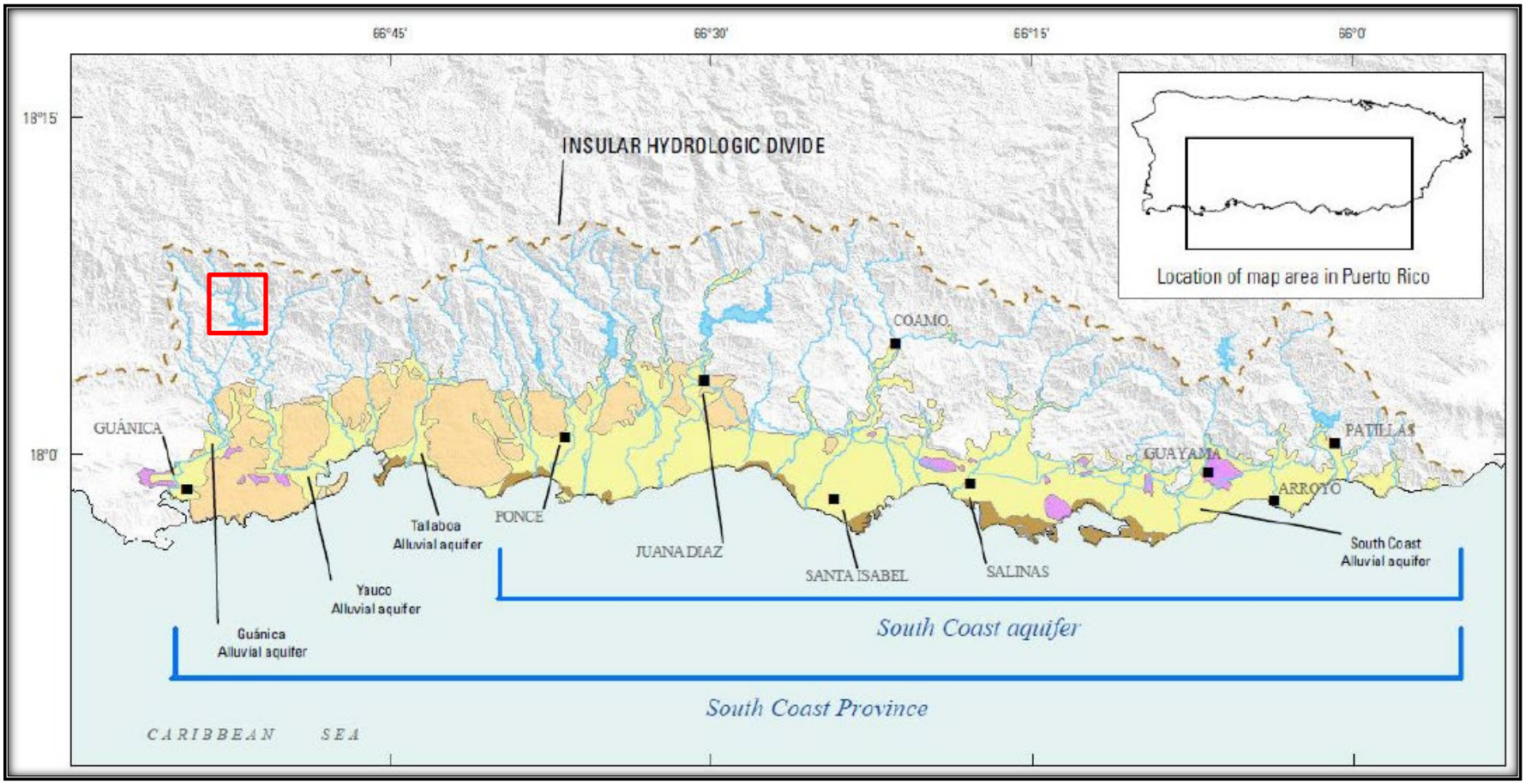

Figure 17: USGS Location Map of Aquifers within and surrounding the Study Area

2.4 Air Quality

2.4.1 Regional Climate

The climate of Puerto Rico is influenced by its tropical location, surrounding ocean, east trade winds, and mountainous topography. Puerto Rico experiences warm, humid climatic conditions with minimal temperature change throughout the year. Temperatures in higher altitudes of the interior are on average up to 15°F cooler than temperatures along the coast. Precipitation varies across the island (Figure 18) and also between seasons, with significantly wetter summers and relatively drier winters (https://w2.weather.gov/climate/local_data.php?wfo=sju). Located in the hurricane belt, the island experiences hurricanes, tropical storms, or tropical depressions within 200 nautical miles about once every two years (Runkle et. al., 2018).

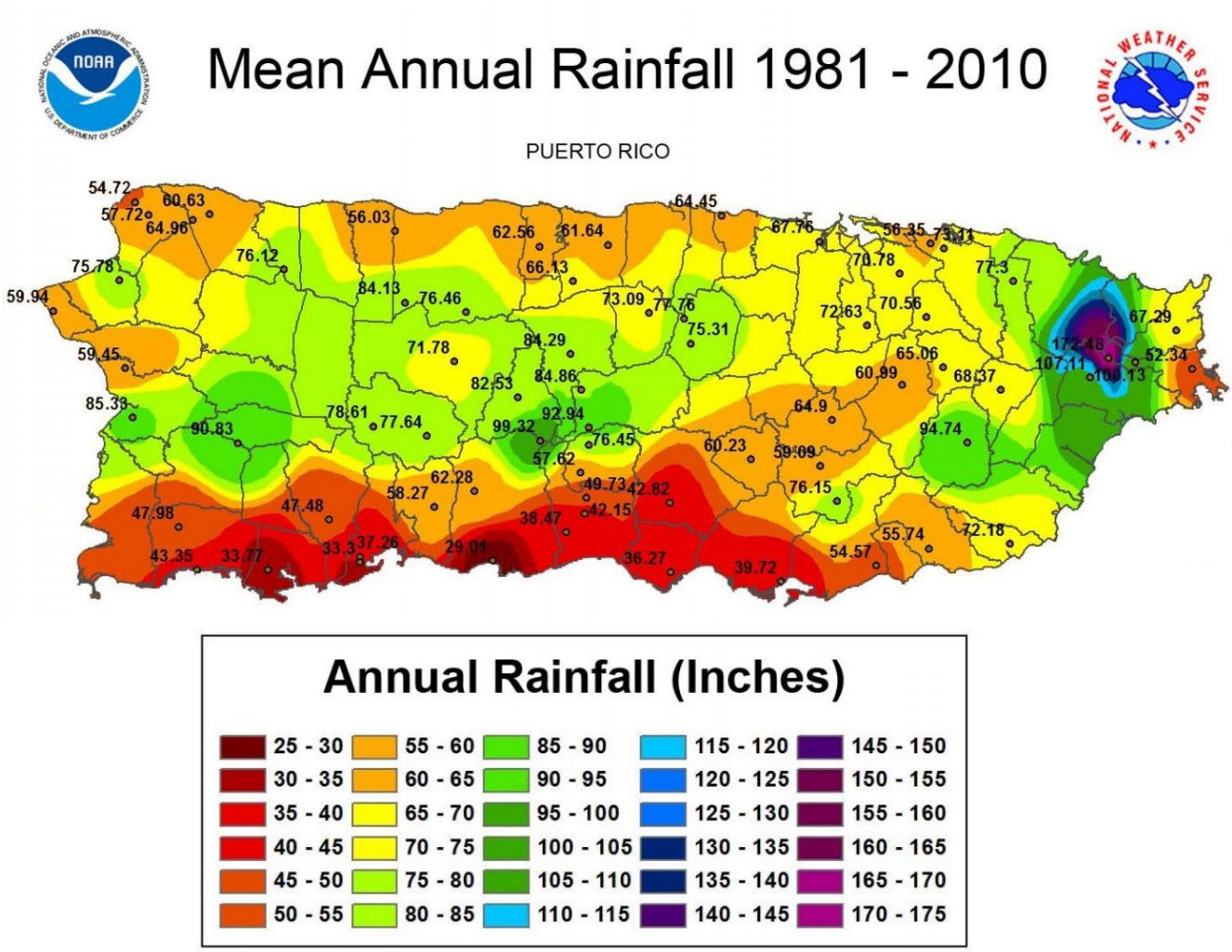

Figure 18: Mean Annual Rainfall for Puerto Rico 1981 – 2010. Source: National Weather Service

The North Atlantic subtropical high, a large atmospheric pressure center in subtropical Atlantic, causes prevailing trade winds predominantly from the east and northeast. This combines with the east-to-west positioning of the Central Mountain Range to separate Puerto Rico into two climatologically distinct regions: the humid, northern two-thirds of the island and the drier, semi-arid southern region. The

Municipality of Guayanilla is located on the southern coast of Puerto Rico, where rainfall averages 33 inches per year. The average annual temperature in Guayanilla is 79.3°F, ranging from 76.3°F in January to 81.5°F in June.

Future Without-Project Condition: In the absence of a federal project, future climate condition predictions would not change. Any future projects should consider these conditions when establishing design parameters.

2.4.2 Regional Air Quality

The air quality of Puerto Rico has long been impacted by anthropogenic activities. Emissions from industry including power generation, manufacturing, petrochemical and oil refining sharply increased in the mid-20th century. With passage of the Clean Air Act (CAA) in 1970, the EPA established National Ambient Air Quality Standards (NAAQS) (Table 7) requiring states and commonwealths to develop State Implementation Plans (SIP) demonstrating achievement of these standards. The Puerto Rico Environmental Quality Board (PREQB) maintains an air monitoring network to ensure compliance with these standards and protect the population. Some parts of the island were shown to exceed NAAQS in recent years and have been designated as non-attainment areas: Arecibo (lead, 2011), San Juan (sulfur dioxide, 2018), and Guayama-Salinas (sulfur dioxide, 2018). Guayanilla was designated as unclassifiable/attainment for sulfur dioxide in 2018, following air dispersion modeling where the highest predicted 99th percentile daily maximum 1-hour concentration of 193 ug/m3 did not exceed the 196.4 ug/m3 (75 ppb) standard (EPA, 2017). Guayanilla has been in attainment of all NAAQS since at least 1992 (EPA, 2019).

Table 7: National Ambient Air Quality Standards for Six Criteria Pollutants.

Pollutant		Primary/Secondary Pollutant Status	Averaging Time	Level	Form
Carbon Monoxide (CO)		Primary	8 hours	9 ppm	Not to be exceeded more than once per year
			1 hours	35 ppm	
Lead (Pb)		Primary & secondary	Rolling 3 month average	0.15 ug/m^3	Not to be exceeded
Nitrogen Dioxide (NO_2)		Primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Primary & secondary	1 year	53 ppb	Annual Mean
Ozone (O_3)		Primary & secondary	8 hours	0.070 ppm	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particulate Matter (PM)	$PM_{2.5}$	Primary	1 year	12.0 ug/m^3	annual mean, averaged over 3 years
		Secondary	1 year	15.0 ug/m^3	annual mean, averaged over 3 years
		Primary & secondary	24 hours	35 ug/m^3	98th percentile, averaged over 3 years

	PM_{10}	Primary & secondary	24 hours	150 ug/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		Primary	1 hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

Source: NAAQS Table, EPA: https://www.epa.gov/criteria-air-pollutants/naaqs-table

There is one PREQB monitoring station in Guayanilla which measures $PM_{2.5}$ (particulate matter with diameter less than 2.5 um) concentrations. As described in the 2015 PREQB Environmental Report, annual mean and maximum 24-hr concentrations averaged over 2013-2015 were 5.0 µg/m³ and 12 µg/m³ respectively (Table 8 & Table 9). These levels are less than the two national primary $PM_{2.5}$ standards (12 µg/m³; 35 µg/m³), demonstrating the air quality of Guayanilla is within the parameters established by the primary national standard for $PM_{2.5}$.

Table 8: Annual Average PM2.5 concentrations (µg/m³) per Monitoring Station

Station	2013	2014	2015	Average (ug/m3)
Adjuntas	4.7	5.2	5.6	5.2
Bayamon	-	-	8.8	8.8
Fajardo	-	-	5.0	5.0
Guayama	4.8	5.2	6.0	5.3
Guayanilla	4.9	4.5	5.7	5.0
Guaynabo	6.7	6.4	6.8	6.6
Ponce	5.8	5.7	6.0	5.9
San Juan	-	-	10.0	10.0

Source: PREQB, 2016

Table 9: Maximum (98th Percentile) 24-hr PM2.5 concentrations (µg/m³) per Monitoring Station

Station	2013	2014	2015	Average (ug/m3)
Adjuntas	12.9	14.2	15.7	14
Bayamon	-	-	23.8	24
Fajardo	-	-	13.4	13
Guayama	11.5	12.6	15.3	13
Guayanilla	10.3	11.0	14.6	12
Guaynabo	12.5	13.9	16.0	14
Ponce	11.6	14.3	15.5	14
San Juan	-	-	17.1	17

Source: PREQB, 2016

In addition to maintaining the air monitoring network, PREQB also maintains an inventory of air emissions, writes permits for emission sources, and models ambient concentrations from emission sources. The 2014 National Emission Inventory (NEI) reports 20,960 tons of criteria and hazardous air pollutants generated in Guayanilla County (EPA, 2018). Figure 19 shows the vast majority, over 18,000 tons, were from stationary sources and composed primarily of nitrogen oxides (46 percent) and sulfur dioxide (43 percent). Mobile sources, about 2,000 tons, were composed of carbon monoxide (74 percent), nitrogen oxides (14 percent) and volatile organic compounds (8 percent). Fuel combustion for electricity

generation made up virtually all of the stationary emissions, dominated by the Puerto Rico Electric Power Authority (PREPA) South Coast Plant operating in the southeast of the county. As a result of these emissions, atmospheric sulfur dioxide concentrations in parts of Guayanilla were shown to approach (but not exceed) the primary sulfur dioxide NAAQS (EPA, 2017).

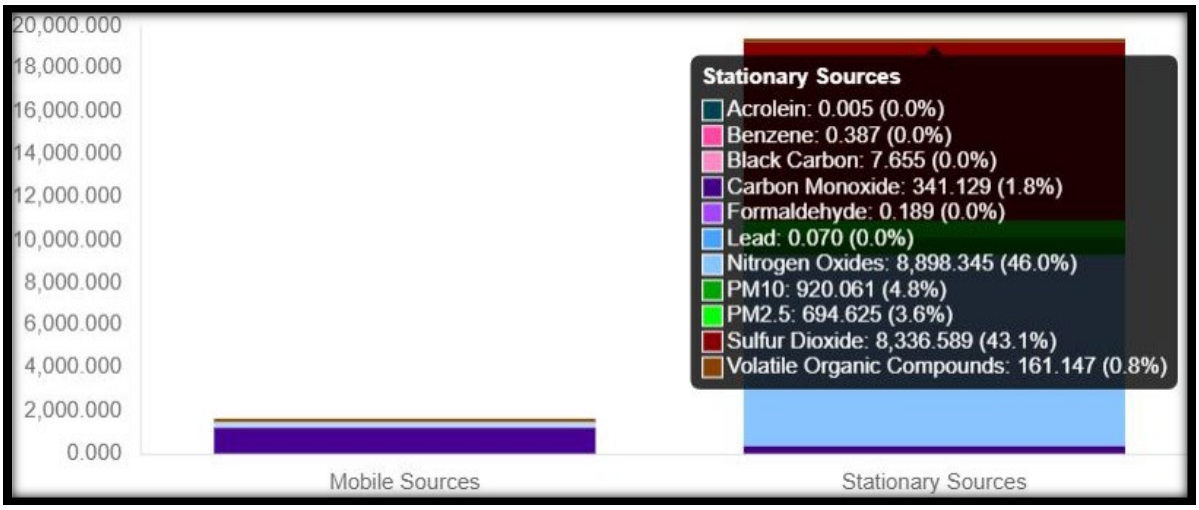

Figure 19: Guayanilla County 2014 Total Emissions (tons) of Multiple Pollutants
Source: USEPA National Emissions Inventory 2014 ver. 2

Greenhouse gas (GHG) emissions, which can trap heat in the atmosphere and contribute to climate change, are reported to the EPA by large emitters through the Greenhouse Gas Reporting Program. The PREPA South Coast Power Plant located in southeast Guayanilla reported 1,210,937 metric tons CO_2e for year 2016. The same year, large emitters across the island reported a total of 14,568,742 metric tons CO_2e.

Future Without-Project Condition: In the absence of a federal project, existing ambient air quality conditions would likely remain the same; however, Guayanilla remains at risk for air quality impacts from the South Coast Plant, particularly if financial hardship and hurricane recovery efforts delay improvements that might reduce emissions. Increased severity of storms in the future may also contribute to poor air quality due to widespread use of fossil fuel burning backup-generators and other emergency response equipment. These can increase air pollution above NAAQS (R. Subramanian et. al., 2018) when electric supply or distribution are down.

2.5 Noise

The study area includes a combination of residential, commercial and agricultural uses. Ambient noise levels are affected by traffic noise and noise associated with residential and agricultural daily activities. Roadway traffic consisting of cars, buses, and commercial trucks generate the highest ground vibrations, especially over rough pavement conditions; pot holes, joints, and settlement all increase vibration levels from traffic. Generally, based on several days of observation, ambient background noise levels would be attributed to Power Tools in the denser neighborhoods during work hours, and Freeway Traffic in the sparsely populated agricultural areas. Of course there is always the occasional Ambulance Siren or Jackhammer for road repairs.

Table 10: Noise levels for common sounds

Noise	Average Decibels (dB)
Library	40
Large Office	50
Normal Conversation	60
Freeway Traffic	70
Handsaw	85*
Factory Machinery	100
Power Saw	110
Ambulance Siren	120
Jackhammer	130
Airplane Taking Off	140
Rocket Launch	180

*Sounds above 85 dB are considered harmful depending on how long and how often someone is exposed to them and whether hearing protection is being used.

Future Without-Project Condition: In the absence of a Federal project, noise levels would remain the same if industrial and highway development remain the same. Should these increase, so would the associated noises and noise levels.

2.6 Biological Resources

2.6.1 Riverine Ephemeral Communities

The Río Guayanilla is a natural ephemeral river (drying out completely for months at a time) in the lower segment. It is likely that there are standing pools and low flows provided by groundwater discharge in the upper montane segment year round. The upper segment is naturally fragmented from the lower due to steep riffle and waterfall like channel development coupled with the ephemeral nature of the system. This naturally limited the species richness and abundance of riverine aquatic organisms, but has also isolated organisms in the upper catchment to be subjected to adaptation and speciation pressures i.e. the Sirajo Goby's *Sidydium plumeri* (Photo 5) ability to climb waterfalls in which there may be several distinct isolated species throughout the island and Caribbean. This situation coupled with the geology and proximity to marine environments has created a unique ecosystem. As example, a highly diverse (genetics, habitat adaptations, behaviors, etc.), but low species richness (low number of species) fish community evolved to these conditions. Although there have been no studies describing historic or natural setting fish communities in the Rio Guayanilla, this fish community seems to be what is typically found in other similar streams throughout the Caribbean.

The existing condition of the Río Guayanilla is considered moderately impacted based on land use, hydrologic inputs and observable fluviogeomorphic characteristics (eroding banks, large active point bars, sediment transport and sorting). The channelized reach at the mouth of the river, bridge crossings, channelized reaches through agricultural fields and several areas of bank armoring/channel modification are those reaches considered to be highly impacted. There have been some changes in the upper segment from road and residential development, but the river is protected from change by steep karst valley walls. In the lower segment land use change for agriculture and residential along the coastal plain of the river has adversely impacted habitat in terms of riparian inputs (vegetation, large woody debris) and less so to channel morphology (natural and recovering) and development (in-channel habitat, riffles). The main

change to the river occurred during 2003 – 2006 as the downstream portions of the river was channelized (Phase I construction). The modification to the channel significantly affected the natural fluviogeomorphic processes of the river to its mouth at Guayanilla Bay.

Although considered moderately impacted, the existing condition provides sufficient flow, clean rocky substrates and diverse velocities during the rainy season to provide ephemeral riverine habitat for amphidromous (fresh and salt water tolerant) fishes, shrimp and other macroinvertebrates. In November 2006, during the rainy season, six (6) native and one (1) invasive species were collected (Table 11) from the Río Guayanilla at PR-127 Bridge crossing in Guayanilla (Kwak 2007). In November 2019, the USFWS observed four (4) of these species within the study area. All of these fish exhibit adaptation to an ephemeral freshwater system discharging into a marine environment. All of the species are amphidromous, coming and going as the river hydrology allows. The American Eel, and potentially the Mountain Mullet, are also known to have some catadromous spawning behavior, but are not obligates in this sense and the Rio Guayanilla doesn't provide yearlong residence habitat for American Eel or Mullet to become established as resident species. Several of these species have also overcome natural riverine fragmentation by either being able to squirm across land (American Eel, Smallscaled Spinycheeked Sleeper) or climb sheer rock faces (Sirajo Goby) (Photo 5). The American Eel, River Goby, Burro Grunt and Mountain Mullet are all seemingly important fisheries species for local purposes of recreation and food source.

Table 11: Fishes Collected in 2006 at PR-127 Crossing, Río Guayanilla, Guayanilla, PR

Species	Common Name	Nativity	Habit	Diet	Status
Anguilla rostrata	American Eel	Native	Amphidromous	Piscivore	Concern
Oreochromis mossambicus	Mosambique Tilapia	Introduced	Amphidromous	Detrivore	Nuisance
Eleotris perniger	Smallscaled Spinycheeked Sleeper	Native	Amphidromous	Ominvore	Least Concern
Gobiomorus dormitor	Bigmouth Sleeper	Native	Amphidromous	Carnivore	Least Concern
Awaous banana	River Goby	Native	Amphidromous	Algaevore	Common
Sicydium plumeri	Sirajo Goby	Native	Amphidromous	Algaevore	Common
Pomadasys crocro	Burro Grunt	Native	Amphidromous	Piscivore	Common
Agonostromus monticola	Mountain Mullet	Native	Amphidromous	Ominvore	Least Concern

Previous fieldwork by the USFWS Caribbean indicates it is likely that freshwater shrimp hatch and reproduce during the rainy season. The *Xiphocaris* spp. was observed in the November 2019 field visits and based on other similar rivers, the following river shrimp could be found in Rio Guayanilla: *Macrobrachium acanthurus, Macrobrachium carcinum, Macrobrachium faustinum, Micratya poeyi* and *Potimirim glabra*.

Future Without-Project Condition: In the absence of a federal project there are no apparent reasons to indicate improvement in terms of riverine habitat and resulting aquatic communities. The river would be maintained to support agricultural and drainage needs throughout the study area.

Photo 5: Sirajo Goby (*Scicydium plumeri*) Can Cling to and Climb Rock Faces (Kwak 2007)

2.6.2 Essential Fish Habitat (EFH)

EFH are those areas that have been identified and described as essential for the life requisites for aquatic and marine species. EFH can include various habitat types, such as wetlands, coral reefs, sea grasses, rivers, etc. that are required by fish for spawning, breeding, foraging, and nursery. These habitats are necessary for fish to successfully reproduce, grow to maturity, and survive.

The USACE provided NOAA with an evaluation and request for a determination of the proposed project impacts dated 09 May 2019. Based on the information provided, the National Marine Fisheries Service (NMFS) provided in a letter dated 13 May 2019, (*Appendix A.5 Agency & Public Coordination*) that adverse effects occurring from this project to NOAA trust resources would be minimal due to best management practices for maintaining river flows, controlling erosion, and managing stormwater. The project area does not include essential fish habitat (EFH) designated by the Caribbean Fishery Management Council or the NMFS. As a result, the NMFS had no EFH conservation recommendations pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, and no recommendations under the Fish and Wildlife Coordination Act.

2.6.3 Subtropical Dry Forest Zone- Natural Estuarine Communities

The entire study area is considered to be within the Subtropical Dry Forest plant zonation, which includes all habitats and local hydrology, as it is a greater classification based on regional climatic conditions. The natural climax vegetation community within the study area should be dry deciduous forest in the coastal plain dominated by the Ucar (*Bucida buceras*) and a riparian zone gallery forest along the water courses, also dominated by the Ucar but with the addition of other deep-rooted arboreal species such as Guacima (*Guazuma ulmifolia*) and Red Manjack (*Cordia collococca*). Moving towards the coast where soils become moist to wet and saline, dry forest changes to mangrove forest/swamp.

The following descriptions of plant communities and associated fauna were derived from the DNER survey conducted in 1988 unless specifically noted. More recent surveys were performed by the USFWS as needed to support Section 7 and FWCAR analyses and is specifically cited. In 1988, the DNER's Scientific Division performed a floral and faunal observational inventory to support the EIS for the Phase I flood control project and was published as part of the 1989 EIS. The floral and faunal assessment is included in *Appendix A2 Attachment 1,* with map and species lists.

At the time of the 1988 survey most of the land reflected a recent agricultural use and the predominant vegetation type was considered Sugar Cane, or Cañaveral, (now abandoned) and old fields. Since then, agriculture still dominates the landscape (banana and coffee). Based on aerial photography, not much if anything has changed since except for the implementation of the Phase I flood control project by the DNER. There is an interior mangrove forest surrounding the "Playa de Guayanilla " community adjacent to the coast located between the mouths of the Río Guayanilla and Río Macána. On the east bank of the river mouth there was a brackish swamp dominated by Giant Grass (*Fimbristylis spadicea*), which was impacted by the Phase I project. As previously noted, mitigation was completed to address those impacts.

During April and May 1988, field investigations to identify the predominant floristic components and associated fauna of the study area occurred. The following plant associations were described from the coastal plain south of PR-2 south to the Río Guayanilla mouth. Plant associations and sampling stations are located on the map in *Appendix A2 Attachment 1*. Most of the species encountered were shrubs and annual herbs of widespread or weedy distribution, noted as being ruderal (introduced) species.

Future Without-Project Condition: In the absence of a federal project there are no apparent reasons to anticipate changes to natural estuarine communities.

2.6.4 Subtropical Dry Forest – Abandoned Limestone Quarry Site

The Subtropical Dry Forest community in the karstic mountains at Guayanilla is contiguous with and comparable to the Guánica State Forest (Holdridge et al. 1971, Ewel and Whitmore 1973). Guánica's driest period is December to April when nearly 50 percent of the trees drop their leaves, generally classifying this community type as deciduous forest. New leaves and flowers generally reappear from August to November. Temperatures fluctuate little in this sub-region, with daily temperatures averaging 25 ºC (79 ºF). Guánica is in a windward area; winds frequently come off the Caribbean Sea in this low topographic system and may create a drying effect. Dry forests in Puerto Rico extend inland up to 20 kilometers (12 miles). This area is characterized by a strong precipitation deficit compared to evapotranspiration annual, where an average annual precipitation of less than 1,000 mm (~40"), while the rate of evaporation in the wetter zones adjacent fluctuates between 1,400-2,000 mm (70-80") annually. Guánica has a variety of succulent plants that exhibit special adaptations for coping in a heat and water stressed environment. Water deficits may occur up to 10 months of the year.

The abandoned limestone quarry site that will be utilized for levee materials is located within the subtropical dry forest community overlying a limestone substrate (Ewel and Whitmore 1973). The abandoned quarry is within the geographical range known as Montes de Barinas (group of hills along the boundary of the municipalities of Yauco and Guayanilla). This site is located adjacent to the designated critical habitat of *Varronia rupicola* (threatened) (Montes de Barina Unit). The site is also adjacent to the Beldum Neighborhood. An assessment of historic aerial images shows the quarry project site was bulldozed by 2003 (*Appendix A4 ESA*).

On August 5, 2019 the USFWS carried out a field visit and rapid assessment of the ~10 acre site just north of the Beldum Neighborhood. The goal of the assessment was to determine if the quarry site could be utilized for levee materials without significant adverse effect to listed species. The site is composed of four hills separated by three drainages. Although the area was previously cleared, some forested areas were left intact and have remained relatively undisturbed to the present day.

On November 4, 2019 staff from the USFWS and the DNER surveyed the proposed quarry area and its surroundings for listed plant species and sensitive habitats. The majority of the site was found to be

altered with the exception of a small remnant forest associated with a hilltop immediately west of the proposed quarry. The best quality habitat is associated with the hilltop remnant of native forest, with little to no invasive species present. Native species recorded were *Ipomoea steudelii*, *Thouinia striata* var. *portoricensis* and *Machaonia portoricensis*, all of which are considered common in dry forest habitat. The quarry itself curves around this hilltop. The vegetation structure of the quarry area is an early successional forest dominated by species such as *Bourreria succulenta*, *Leucaena leucocephala*, *Croton* spp. and *Lantana involucrata*. In fact, the majority of the site is dominated by nonnative and invasive stands of *Leucaena leucocephala* and *Megathyrsus maximus*.

Future Without-Project Condition: In the absence of a federal project it is likely at some point this abandoned quarry would be reopened, cleared and quarried. Stone is not imported into the island, therefore it is anticipated that there will be future needs for quarried stone such as road repair, construction, natural disaster repairs and improved maintenance of infrastructure and utilities. To avoid natural resource impacts, stone sourcing would be directed to those already existing before new quarries would open.

2.6.5 Dry Grassland & Riparian Vegetation

The vegetation within the channel is primarily composed of sedges, grasses and many other weedy species. Along the wetted edges of the river, Common Reed (*Phragmites australis*), Wild Cane (*Gynerium sagittatum)*, and Umbrella Palm (*Cyperus alternifolius*) were dominant. Among the herbaceous and shrubby species, Beggar's Ticks (*Bidens alba*), Devil's Horsewhip (*Achyranthes aspera*), Spiny Amaranth (*Amaranthus spinosus*), Spiny Spiderflower (*Cleome spinosa*), Bastard Vervain *(Stachytarpheta jamaicensis*), Spurges (*Chamaesyce* spp.) and many others were found. The river channel through town was noted as being channelized, but recovered, and dominated by Spiny Spiderflower.

Remnants of riparian forest are found along the river, with most common species including Mocha (*Andira inermis*), Guacima, American Guama (*Pithecellobium dulce*), Anacaguita (*Sterculia apetala*) and Red Manjack.

Other modified riparian zone areas had vegetation typical of dry pasture, dominated by the invasive grass African Guinea Grass (*Panicum maximum*). Horse Grass (*Eleusine indica*), Hurricán (*Andropogon pertusus*), American Rat's Tail Grass (*Sporobolus jacguemontiana*), Yerba Rosada (*Tricholenia rosea*) and Silk Pump (*Calotropis procera*) were also found sporadically in these pastures.

Future Without-Project Condition: In the absence of a federal project the dry grassland and riparian vegetation would remain relatively constant due to agricultural practice that are anticipated to continue as an integral part of the area's economy as well as maintenance of river bank areas. Nonnative and invasive plant species would continue to be an issue in the future, due to the requirements associated with vegetation management.

2.6.6 Grassland & Abandoned Sugar Cane Plantation (Cañaveral)

Most of the open agricultural and successional old fields west and south of Guayanilla and north of El Faro are dominated by African Guinea Grass and Sugar Cane. Tree species such as the African Tulip (*Spathodea campanulata*), Guacima, Manjack and Moca (*Andira inermis*) are also abundant.

Future Without-Project Condition: In the absence of a federal project the grassland and old field vegetation would remain relatively constant due to agricultural practices. Agriculture is expected to continue in the future as an integral part of the area's economy. Nonnative and invasive plant species

would continue to be an issue in the future, due to the requirements associated with vegetation management.

2.6.7 Brackish Swamp

The brackish swamp located between PR-336 and Rio Guayanilla is dominated by Giant Grass with partial ground covering of Toad Grass (*Lippia nodiflora*). The land north of the houses extending to the east bank of the Rio Guayanilla is used as grazing pasture. Trees occur widely scattered among the dominant grasses and sedges that creates a dry savanna-like setting. Trees include Cat's Claw (*Pithecellobium unguis-catis*), Lightning Stick (*Parkinsonia aculeata*), Bayahonda (*Prosopis iuliflora*), Almond (*Terminalia catappa*) and Aroma (*Acacia farnesiana*).

Future Without-Project Condition: In the absence of a federal project the brackish swamp and associated drained areas would remain relatively constant due to agricultural practices. Agriculture is expected to continue in the future as an integral part of the area's economy. Nonnative and invasive plant species would continue to be an issue in the future, due to the requirements associated with vegetation management.

2.6.8 Interior Mangrove Basin & Edge at Guayanilla Beach

This basin type mangrove system utilizes hydrology from extreme high tides, coastal flooding and river flooding. Freshwater input provided by the agricultural drainage canals and overbank flooding from the Rio Guayanilla help maintain salinity levels. The mangrove stand to the north of Playa is mostly dominated by Black Mangrove (*Avicennia nitida*), although White Mangrove (*Laguncularia racemosa*) and Red Mangrove (*Rhizophora mangle*) are present. All trees are of small size and show evidence of frequent cutting (probably used for posts). Other species found in contact with the mangrove include Majaguilla (*Thespesia populnea*), Escambron (*Clerodenrum aculeatum*), and a few Almond and Bayahonda trees. The exotic vine Canario Morado Falso (*Cryptostegia grandiflora*) has invaded this mangrove stand. The mangrove floor is covered by Snake Grass (*Bacopa monnieri*) and Marsh Fern (*Acrostichum daneifolium*). A small salt flat is also part of the system.

Future Without-Project Condition: In the absence of a federal project the mangrove communities would remain relatively healthy in terms of hydrology; however, there is evidence of continual mangrove tree cutting and filling for land use. Nonnative and invasive plant species would continue to be an issue as well in the future, due to the requirements associated with vegetation management.

2.6.9 Associated Fauna

The area reflects a low diversity of avifauna compared with the Guánica Forest located a few kilometers away. During the 1988 survey, only 12 bird species were observed, mostly from the mangrove area. Species observed in areas of dry pasture, abandoned sugarcane fields, brackish swamp and grasslands included the Nightingale (*Mimus polyglottos*), Pitirre (*Tyrannus dominicensis*), Smooth-billed Ani (*Crotophaga ani*) and the Rolita (*Columbina passerina*). Most likely due to its greater structural complexity of vegetation than the other ruderal plant communities, the mangrove area seemingly provided refuge and food for the greatest number of bird species and abundances observed, including Common Yaboa (*Nyctanassa violacea*), Pile Driver (*Buturoides striatus*), Thrush (*Molothrus bonairiensis*), Mangrove Canary (*Dendroica petechia*), and Common Warbler (*Coereba flaveola*).

The observed herpetofauna was typical with several species of lizards (*Anolis* spp.), the Toad (*Bufo marinus*), and White-footed Toad (*Leptodactylus albilabris*). Based on habitat, it was anticipated that

several species of Coquí (*Eleutherodactylus* spp.) would be common throughout all plant communities, however, none were observed since surveys were not performed at night.

Mammals observed included nonnative Indian Mongoose (*Herpestes auropunctatus*), nonnative Rats (*Rattus* spp.) and several unidentified species of bat.

Future Without-Project Condition: In the absence of a federal project the fauna associated with the natural dry forest, brackish swamp and mangrove swamp communities, and secondary growth/weedy dry grassland, riparian and old field communities would remain relatively constant due to continuing agricultural practices. Agriculture is expected to continue in the future as an integral part of the area's economy. Nonnative animal species would continue to be an issue.

2.6.10 Federal Listed Species

The most cost effective source of stone for a potential project is located in the study area in the karstic mountain range on the west side of the basin. The USFWS initially advised that the karst hills and forests immediately west of the project site are within the range of four (4) federally listed species. This information was considered during alternative plan development. The four listed species are the Puerto Rican Nightjar (bird) (FE), the Puerto Rican Boa (snake) (FE), *Eugenia woodburyana* (evergreen tree) (FE) and *Trichilia tricantha* (evergreen tree) (FE). Avoidance and minimization planning was undertaken by USACE and USFWS to both reduce the footprint of the affected acres of T&E species habitat considered for mining, and avoid those areas of known high quality habitat. In doing so an abandoned quarry was located and about 7 acres of it was found to be sufficient to provide a cost effective rock source for potential FRM alternatives.

The abandoned limestone quarry site was previously described in Section 2.6.4. This site is adjacent to the designated critical habitat of *Varronia rupicola* (threatened) (Montes de Barina Unit). However, the project site is also adjacent to an urban area (Beldum Neighborhood) was quarried in the early 2000s. An assessment of aerial images shows the project site was bulldozed by 2003 (*Appendix A4 ESA*).

On August 5, 2019 the USFWS carried out a field visit and rapid assessment of the ~7 acre site just north of the Beldum Neighborhood. The site is composed of four hills separated by three drainages. Although the area was previously cleared, some forested areas were left intact and have remained relatively undisturbed to the present day. The condition of the area was sufficient enough that surveys for listed plant and animal species typical of sub-tropical dry forest were determined to be necessary.

T&E Plant Species: On November 4, 2019 the USFWS and the DNER surveyed the proposed quarry area and its surroundings for listed plant species and sensitive habitats. The site was found to be altered with the exception of a small remnant forest associated with a hilltop immediately west of the proposed quarry. The USFWS concluded that the only federally listed plants that may occur at a disturbed site included *Varronia rupicola* and *Catesbaea melanocarpa*. However, no federally listed plants were identified within the proposed project area. The likelihood for the presence of *V. rupicola* and *C. melanocarpa* is minimal considering the area was previously bulldozed and quarried.

T&E Animal Species: Two AudioMoth recorders were activated and deployed during the November 4, 2019 vegetation survey. Both recorders were configured to record for 1 minute every 10 minutes for a total of 144 recordings per each 24 hour period (6 per hour). Recorders were collected and deactivated the night of November 13, 2019. Nightjars were recorded calling on both recorders, indicating presence within the hilltop forest habitat and communication with nightjars in the surrounding high quality forest. No Puerto Rican Boas were observed. See *Appendix A4 ESA* for details.

Based on specific site surveys for T&E plant and animal species, the USFWS has provided the following species for consideration under Section 7 of the ESA:

The Puerto Rican Nightjar (*Caprimulgus noctitherus* aka *Antrostomus noctitherus*) – The common name in English is the Puerto Rican Nightjar or Puerto Rican Whip-poor-Will, and in Spanish, the Guabairo. This species is a small member of the family Caprimuglidae (Nightjars & Nighthawks) that specifically occupy sparse understory habitats of the dry coastal and montane forests within the study area. This species was downgraded from Critically Endangered to Endangered (FE) based on discovery of a wider range breadth within the southwestern corner of the island. It nests on the ground under closed canopies and needs an abundant leaf layer to hold the eggs. The peak months for nesting activity are April–June. Like many ground-nesting birds, the nightjar will try to divert the attention of potential predators away from the nest by conspicuously flying away and vibrating its wings.

The Puerto Rican Boa (*Epicrates inornatus* aka *Chilabothrus inornatus*) – The common name in English is the Puerto Rican Boa, and in Spanish, the Boa Puertorriqueña. This largest nonvenomous species of Puerto Rican snake is a member of the family Boidae (Boas & Pythons), which primarily occupy tree and cave habitats of the subtropical forest units within the study area; however, this species is well adapted and can be found in almost any habitat, including those induced by man. This species is Endangered (FE) primarily due to depredation by introduced mongoose species and man, but not necessarily habitat destruction given its adaptability.

Future Without-Project Condition: In the absence of a federal project it is likely at some point this abandoned quarry would be reopened, cleared and quarried. Stone is no imported to the island, therefore it is anticipated that there will be future needs for quarried stone such as road repair, construction, natural disaster repairs and improved maintenance of infrastructure and utilities. To avoid natural resource impacts, stone sourcing would be directed to those already existing before new quarries would open. Impacts to listed species could occur through the process associated with the development of existing open space if appropriate steps were not taken to limit adverse impacts.

2.6.11 State Listed Species & Species of Special Concern

The USFWS indicated that the DNER does not have a state level threatened/endangered species list for the Guayanilla study area. The DNER was contacted on July 7, 2019 requesting information on critical habitats or species in which the state is aware of or has management plan for within the study area. In 2009, the USFWS (Monsegur 2009) confirmed (47) plant taxa that correspond to species designated by the DNER as Critical Elements; seven of them are protected by the USFWS. On November 4, 2019 the DNER accompanied the USFWS on T&E habitat, vegetation and animal surveys; it is assumed information provided by the USFWS includes input from the DNER.

Future Without-Project Condition: No change in current conditions expected based on available information on state listed species.

2.6.12 Nature Preserves & Conservation Areas

Bosque Estatal de Guánica

The Guánica State Forest is a subtropical dry forest located in southwest Puerto Rico. The area was designated as a forest reserve in 1919 and a United Nations Biosphere Reserve in 1981. It is considered the best preserved, subtropical forest and the best example of dry forest in the Caribbean. This natural area's official boundaries are adjacent to the study area; however does share connectivity with the dry forest karst habitat within the study area.

In 2009, Monsegur completed a systematic review of the Guánica Forest Reserve flora, which indicates that it consists of 460 accepted species and an additional 258 species that require confirmation. The number of unconfirmed records is greater than that of other dry forest areas in Puerto Rico, suggesting that further inventory is needed. Also, a total of 102 new records were identified by Monsegur (2009), including *Sansevieria concinna* as a new record for the island of Puerto Rico and the Caribbean. The Guánica Forest is a major depository of the Puerto Rican and Caribbean dry forest plant diversity. Three of the endemics are restricted to the Forest and do not occur elsewhere in the world. *Reynosia vivesiana* and *Zephyranthes proctorii* are identified as species that should be considered for listing as endangered species. In general the number of exotics and naturalized species is relatively low. Nevertheless, *Haematoxylon campechianum* and *Sansevieria concinna* are examples of the species that deserve further concern.

Future Without-Project Conditions: No change in current conditions at these Puerto Rico nature preserves and conservations areas is anticipated in the future.

2.6.13 Coastal Barrier Resources

After reviewing the Coastal Barrier Resources System (CBRS) mapper no portion of the project falls within a CBRS system unit. This investigation was conducted based on the Coastal Barrier Resources Act of 1982, 16 U.S.C. 3501. USFWS concurs there are no designated CBRA units within the project area. The closest CBRA units are PR-58-P, Bahia Tallaboa to the east and PR-59, Punta Ballena to the west.

2.7 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 Part 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), which 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.

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 Guayanilla provides an environment that is rich in prehistoric and historic human activity and has a high potential for containing intact cultural resources.

2.7.1 Prehistoric Resources

The earliest human occupation on the island of Puerto Rico dates from circa (ca.) 5000 BC. In Puerto Rico, the pre-ceramic, lithic period termed the Archaic consists of small, ephemeral occupations dating from ca. 5000 BC to AD 100. The Archaic period on Puerto Rico is characterized by the use of flaked and groundstone technologies, shell tools, with some degree of food cultivation (Espenshade 2014).

The pre-contact ceramic period on Puerto Rico dates from ca. 500 BC to AD 1500, and is generally divided into the Saladoid (ca. 500 BC – AD 600) and Ostionoid (AD 600 – 1500) cultural traditions based on ceramics, social configurations, and settlement patterns. These cultural series can be further divided by ceramic styles and island distribution. The first major population of Puerto Rico began ca. 500 BC with the migration of Arawak-speaking people from the northern Venezuela coastal region (Carlson and Altes 2018). The Saladoid peoples generally settled close to the coast adjacent to freshwater streams and rivers in order to subsist on a combination of horticulture, marine resources, and terrestrial faunal. They produced elaborately decorated ceramic vessels and figures, groundstone lithic artifacts, carved and ground shell and bone artifacts, in addition to wood, clay, and cloth artifacts (Siegel 1999). Saladoid settlements were typically oriented with domestic structures surrounding a central plaza. Lack of elaborate grave goods, settlement structure, and bone chemistry that do not show differential access to high-quality foods by individuals, suggest a somewhat equitable or tribal society (Siegel 1999). The early Saladoid site of Tecla (GL0100001) is located 1.3 km south of the APE within the floodplain of the Rio Guayanilla. Tecla is a large, significant village site that measures more than 300 meters in diameter and has produced some extraordinary artifacts from the Saladoid tradition. During the late Saladoid period (ca. AD 400), settlements appeared to move upstream within the major river valleys which may be a result of environmental change and may led to a cultural shift around ca. AD 600.

The transition from the Saladoid to the Ostionoid (ca. AD 600 – 1500) periods is marked changes in ceramic styles, the development of ceremonial architectural, ball courts, and an increase in settlements within the foothills and mountains of Puerto Rico. Domestic structures during the Ostionoid period show an increase in diversity in the size and function of villages, farmsteads, and specialized use areas suggesting a shift in sociopolitical conditions (Curet 1992). Pottery during this period is characterized by a split in typologies between the western and eastern portions of the island. Generally speaking, the late Ostionoid period (AD 1200 – 1500) is characterized by the highly stratified chiefdom of the Taínos. During this period, regional territorial units began to emerge, and ceremonial sites and religious artifacts are at a high frequency. Ceremonial objects in the form of *cemís*, stone collars, and *duhos* (wooden seats) point to an increase in symbolism associated with ritual practices of an elite power or authority (Oliver 2009). At the time of European contact, the island was highly stratified under 18 regional political territories.

2.7.2 Historic Resources

Christopher Columbus explored the coast of Puerto Rico during his second voyage to the New World in 1493. The location of his landing has been debated, and it has been theorized that he disembarked at the Port of Guayanilla (Nazario y Caucel 1893). In 1511 or 1512, a group of Spaniards created the settlement of Santa María de Guadianilla, located northwest of the present village of Guayanilla at the community of Parcelas de Quebradas. The settlement was attached by the French in 1565 and the Carib Indians in 1567. During the European War of the Spanish Succession (1701–1713) the area was further attached by English and Dutch pirates.

The Battery of San Fernando was built in 1811 for the defense of ships at the port and entrance to the village. However, the Municipality of Guayanilla was formally founded under the direction of the Spanish Provincial Council by Governor Don Miguel de la Torre in 1833. Guayanilla was politically organized as a *Cabildo*, composed of the village Mayor, Priest, and several prominent members of the community. By 1846, the urban area of Guayanilla consisted of a single street with forty houses. Due to the proximately of the Guayanilla and Yauco rivers, sugarcane, coffee, and fruits were produced within the municipality. The majority of the haciendas surrounding Guayanilla produced sugar cane or coffee (Daubón Vidal 1988a). In 1878, Guayanilla was divided into the *barrios* or neighborhoods of Pueblo, Llano, and Macaná, Jaguas del Pasto, Barrero, Playa, Indios, Bocas, and Quebradas. Table 12 provides a list of the major plantations in the nineteenth century by *barrio* within Guayanilla (Sievens Irizzarry 1983).

Table 12: Nineteenth-century sugar and coffee plantations in the Guayanilla region.

Estate Type	Name	Barrio
Sugar Plantations	Buena Vista (El Peñon)	Playa
	San Colombano	Playa
	El Faro (Luisa) Miguel	Indios
	Mercedes	Boca
	Rufina	Indios
Coffee Plantations	Hacienda Anita	Jagua Pasto
	Hacienda Beldogere	Jagua Pasto
	Hacienda Casanova	Quebradas
	Hacienda Catalina	Jagua Pasto
	Hacienda Concepción	Jagua Pasto
	Hacienda Tomino	Jagua Pasto
	Hacienda Formalidad	Jagua Pasto

Sugarcane remained the prominent crop in Guayanilla in the twentieth century. Like other parts of Puerto Rico, Guayanilla saw its local sugar haciendas merge to form large companies. Central Rufina, a sugar hacienda and processing facility, was founded by Trujillo-Mercado and Company in 1901 by consolidating the San Colombano, Faro, and Rufina (Daubón Vidal 1988a). Central Rufina was the first centralized sugar operation of its kind in Guayanilla and was the Municipality's principal employer for 50 years. Operation of Central Rufina ended in 1967, consistent with the island-wide decline in the sugar industry of the 1960s and 1970s.

2.7.3 Previously Identified Cultural Resources

A total of six cultural resources surveys have been conducted within the vicinity of the APE (Table 13). Specifically related to the 1990 USACE Río Guayanilla Flood Risk Management Study, the Corps contracted an historic and archaeological reconnaissance of the study area in 1988. Daubón Vidal (1988a) documented a number of cultural resources within or adjacent to the project area. These sites consist of historic resources related to the haciendas noted above, general farming implements, prehistoric petroglyphs, and archaeological deposits dating from the Ostionoid period. Based on the results of this reconnaissance survey, Daubón Vidal (1988a) recommended an intensive, subsurface cultural resources survey be undertaken within the APE. An intensive cultural resources survey within portions of the current study area was conducted by Daubón Vidal (1988b) in March 1988; however, few portions of this study overlap with the current APE.

Table 13: Previously conducted cultural resources within the vicinity of the study area.

Survey Title	Date	Author(s)
Reconocimiento Arqueologico del Bajo Couce del Río Guayanilla	1984	M. Rodríguez López
Municipio de Guayanilla Puerto Rico Evaluación Arquelógica: Fase 1a y 1b	1986	L. Chanlatte Baik
Investigación Arqueológica Fase Ia Proyecto Canalización Rio Guayanilla, Guayanilla, Puerto Rico	1988a	Daubón Vidal
Investigación Arqueológica Fase Ib Proyecto Canalización Rio Guayanilla, Guayanilla, Puerto Rico	1988b	Daubón Vidal
Stage II Evaluation of Cultural Resource Sites, Rio Guayanilla Channel Project, Guayanilla, Puerto Rico	1994	G.A. Pantel
Rio Guayanilla Channel Improvements, Archaeological Mitigation Program, Data Recovery Final Report	2002	G.A. Pantel

A total of nine cultural resources have been identified adjacent to or within the APE as result of these surveys (Table 14). Of these nine sites, only one resource (GL0100046) has been evaluated for eligibility for inclusion in the NRHP. Site GL0100046 was discovered during the 1988 survey by Daubón Vital (1988a, 1988b) and consisted of a scatter of nineteenth-century ceramic sherds associated with the former Hacienda San Colombano. In 1994 the site was recommended as eligible for listing in the NRHP; however, a Phase III mitigation of the site occurred 2002, rendering it no longer eligible for listing in the NRHP. Based on the existing cultural resources adjacent to the APE that require evaluation for NRHP eligibility and the high probability of identifying historic properties within the APE, a cultural resources survey of the project APE is required to identify and determine effects of the undertaking pursuant to Section 106 of the NHPA.

Table 14: Previously identified cultural resources within or adjacent to the APE.

Site Number	Resource Type	Period	Date/	NRHP evaluation
GL0100006	Petroglyphs within a rock shelter	Prehistoric	Unknown Prehistoric	Not evaluated
GL0100045	Low density surface artifact scatter	Historic	Nineteenth Century	Not eligible
GL0100034	Artifact scatter	Historic	Nineteenth Century	Not evaluated
GL0100035	Artifact scatter	Prehistoric	Ostionoid	Not evaluated
GL0100046 (Hacienda San Colombano)	Artifact scatter with architectural remnants	Historic	Eighteenth through early twentieth centuries	Eligible (mitigated in 2002)
GL0100049	Artifact scatter	Prehistoric	Unknown Prehistoric	Not evaluated
GL0100030	Canal	Historic	Twentieth Century	Not evaluated
GL0100043	Steam pump of Central Rufina	Historic	Nineteenth and Twentieth Century	Not evaluated
GL0100023 (Puente Colorado)	Bridge (ruins) associated with Central Rufina	Historic	Nineteenth Century	Not evaluated

Future Without Project Conditions: In the absence of a Federal project, cultural resources conditions would remain the same. The study area would remain a rural setting, with a low rate of disturbances from residential, commercial, and agricultural uses. Historic properties would continue to be protected under several Federal laws and regulations.

2.8 Socioeconomic/Environmental Justice

2.8.1 Demographic Survey

Demographics of the study area describe the characteristics of the population at risk, and inform of potential social and economic vulnerabilities among residents of the study area. Population, income, poverty, age, and education statistics are shown below. Estimates shown are calculated by census tract, and therefore include a small number of residents who reside outside of the 500 year floodplain, but within the Rio Guayanilla Basin. There are approximately 8,800 residents in the study area (Table 15). The age distribution of the study area is shown below.

Table 15: Population Count by Age

	Count	%
Total Population	8,800	100
Age 65-69	546	6
Age 70-74	491	6
Age 75-79	370	4
Age 80-84	223	3
Age 85+	239	3
Total 65+	1,869	21

Source: ACS 2013-2017 estimates taken from census.gov

Approximately 21 percent of the total population in the study area is 65 or older, and approximately 3 percent is above the age of 85. Individuals above the age of 65 are particularly vulnerable to flood risk, due to difficulty mobilizing and evacuating.

Table 16 shows annual mean income for the study area and compares it to the rest of the island. Mean annual income in the study area is about $10,700 less than mean income in the entire territory. Per capita income in the study area is about $3,900 less than per capita income in Puerto Rico as a whole.

Table 16: Income, 2017 Inflation-adjusted Dollars

	Mean Income	Per Capita Income (Hispanic or Latino Origin)
Study Area	$20,994	$8,214
Puerto Rico	$31,672	$12,081

Source: ACS 2013-2017 estimates taken from census.gov

In the study area, nearly 60 percent of the population is below the poverty line, as shown in Table 17.[1] In Puerto Rico as a whole, 45 percent of the population is below the poverty threshold. In the study area, children under 18 years of age are particularly susceptible to being in an impoverished household, with 73 percent of this age group under the poverty line. In Puerto Rico as a whole, 57 percent of this age group is below the poverty line. Poverty for individuals aged 65 and above is also more persistent in the study area than in Puerto Rico as a whole, with 49 percent of this group in the study area being below the poverty threshold.

[1] For poverty thresholds, see https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html

Table 17: Poverty Count

	Total Population	Below Poverty Count	% Below Poverty Line	% Below Poverty, under 18 years	% Below Poverty Line, 65+
Study Area	8,749	4,962	57	73	49
Puerto Rico	3,437,079	1,543,220	45	57	40

Source: ACS 2013-2017 estimates taken from census.gov

Table 18 shows education attainment for the two primary census tracts in the study area, and Puerto Rico as a whole. Census Tract 7403 corresponds with the more urban part of the municipality of Guayanilla, beginning near the first urban development south of the Mayor's office and continuing to Highway PR-2. Census tract 7404 encompasses the rest of the study area, including the Playa neighborhood on both the east and west sides of the river. Education attainment for individuals in Playa is lower than that of the census tract near Municipality. In the public meeting held in November 2018, residents of Playa mentioned the economic and social difficulty of attaining an education when their residences consistently flooded from Río Guayanilla overtopping, and they lost all belongings, including clothes to wear to school. Distance from schools may also play a factor in the lower educational attainment in Playa, as the schools are located closer to Municipality. In Playa, 25 percent of individuals aged 18-24 years have less than a high school degree, while that number is 11 percent for all of Puerto Rico. High school graduation rates in the study area are higher than Puerto Rico as a whole, as is Bachelor's degree attainment, among individuals aged 18-24.

Table 18: Education Attainment

	Population, 18-24 years	% Less than High School Degree, 18-24 years	% High School Graduate, 18-24 years	% Bachelor's Degree, 18-24 years
Census Tract 7403	290	0	29	8
Census Tract 7404	471	25	26	5
Study Area Average	761	12	27	6
Puerto Rico	346,845	11	10	3

Source: ACS 2013-2017 estimates taken from census.gov

Future Without-Project Condition:

Population in the study area has seen a decline since the year 2000. Residents explain that due to the frequency of flooding, many individuals and businesses have left the area. Based on these trends, it is not expected that the future population will increase significantly; however, marginal changes in population may be present if flood risk is reduced in the future.

2.9 Other Human Resources

2.9.1 Hazardous, Toxic, and Radioactive Waste

The project is located in a predominantly rural area adjacent to the Municipality of Guayanilla and the Rio Guayanilla. A Phase I Environmental Site Assessment (ESA) was used to identify HTRW or non-HTRW recognized environmental conditions (RECs) within the study area (Appendix H: Hazardous, Toxic, and Radioactive Waste (HTRW) Report.) Review of historical topographic maps and aerial photographs suggest the project area was largely undeveloped and used for agricultural purposes. An environmental records search identified potential RECs on or near the project study area. One REC was found to impact the study area:

- Banana fields farmed by Tropical Fruit Company are located south and west of the Rio Guayanilla on the site of the proposed diversion channel. In 1996-1997 pesticides from farming activities were released to air and impacted a neighboring community. In response, Tropical Fruit Company was ordered under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to cease high-pressure application of pesticides containing hazardous substances, and cited for violation of worker protection standards and use of unregistered pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Actions against Tropical Fruit resolved with a consent decree which included modifying application practices to minimize hazards.

Based on historic land use and environmental records, fertilizer and pesticide residues are likely in the soil of the project study area at the location of the fruit farm. Soils may also contain *de minimis* concentrations of PAHs and metals due to proximity to the Municipality of Guayanilla. Petrochemical facilities in an industrial area (Barrio Magas) east/northeast of the project site are known to have impacted local soils and the Macaná River, groundwater as far southwest as the Playa neighborhood, and the Bay of Guayanilla; however, there is no indication that contaminants have migrated to or impacted the study area west of the Rio Guayanilla.

Future Without-Project Condition: In the absence of a Federal project, HTRW conditions would remain the same. Future projects should consider these conditions when establishing design parameters.

2.9.2 Agricultural Lands

Based on NRCS soils survey data, there are three (3) soil types that provide agricultural opportunity, Constancia, Machuelo and San Anton (Figure 8). The Constancia and Machuelo are considered of Statewide Importance, while the San Anton is considered Prime if Irrigated. The Constancia series makes up the majority of the current farmland within the Guayanilla study area, with a small sliver of Machuelo being available for agricultural production. The San Anton series within the study is not currently being farmed or irrigated, but lies under primary and secondary growth forest. Farming further south, closer to the coastline, has seemingly stopped in the 1980s; it is speculated the Cañaveral were abandoned due to high salinity levels from saltwater intrusion.

Future Without-Project Condition: In the absence of a Federal project, agricultural spatial occupancy would generally remain the same. Most agricultural lands would remain in the 1% AEP (100-yr) Floodplain and be subject to river flooding.

2.9.3 Aesthetic Quality

The study area is considered a rural setting, with low disturbance residential, commercial and agricultural uses. Caribbean coastline, mountain, valley and forest types make up many different aesthetically pleasing vistas.

Future Without-Project Condition: In the absence of a Federal project, the study area would remain a small rural community, with low disturbance residential, commercial and agricultural uses.

2.9.4 Public Health & Safety

Flooding is common along PR-127, the principal road that goes through the main residential and commercial area of Guayanilla. Large storm events have resulted in mud and water flows along PR-127 that resulted in lengthy road closures, damage to existing roadbeds, flood damages to vehicles and other portable property. Closures at flooded roadways impede access to critical emergency facilities (Figure 5).

The emergency shelter where the community gathers during evacuations was inundated during past floods, causing issues for evacuating residents and accountability for individual citizens. Key municipal facilities including the regional hospital, local fire and police stations, and emergency services are affected during frequent storm events. Flooding of these facilities also effects evacuation, emergency response, medical care and law enforcement. Second tier emergency support such as pharmacies (Photo 3), food, clothing and other supply shops are impacted. Most of these vital commercial facilities have been heavily damaged by past floods. Also of concern is the potential for flooding of theWastewater Treatment Plant. Inundation of the plant could result in a spill of wastewater to the Río Guayanilla and Guayanilla Bay. Also, flood waters flowing through urban and other land use types can entrain debris and chemicals. Widespread inundation can result in contaminated flow overland within the community and into the Rio Guayanilla and Guayanilla Bay. Contaminated overflows could potentially have significant affects to water quality, human health and safety and fisheries health. There is also potential for gully/ravine wash along the valley walls to discharge waters into these facilities that is not associated with riverine flooding.

Future Without-Project Condition: In the absence of a Federal project, the existing condition would remain, with the possibility of increased public health and life safety risks attributed to flooding due to potential increase in storm intensities in the future.

2.9.5 Traffic and Transportation

Flooding causes road closures along PR-127 in the center of municipality. PR-127 becomes a make-shift channel for water, mud, and debris during flood events. The Playa neighborhood has also experienced significant road closures due to Río Guayanilla overtopping, specifically in 2008 when a flood washed out the PR-3336 bridge. The PR-3336 bridge was not rebuilt until 2016 due to lack of government funds. Hurricane Maria caused significant damage to the PR-127 bridge located on the southeast side of the municipality in 2017. The bridge was impassible for months, resulting in significant delays to local traffic. Road closures also impact evacuation routes, which can create public safety challenges if individuals are unable to evacuate safely, or reach medical facilities.

Future Without-Project Condition: In the absence of a Federal project, the existing condition would remain, with possibility for increased transportation delays and life-safety risks attributed to flooding due to the potential increase of storms intensities in the future.

2.9.6 Utilities

The proposed study area contains numerous existing utilities. These utility lines provide sewer, water, electrical and communications services. The potentially impacted utility lines are located both above and below ground. The major utility lines that cross the proposed channel system are listed in Table 18..

Table 19: Existing Major Utilities

Utility	Location
Northern Zone - North of PR-127 Along Calle Luis Munoz Rivera	
10" PVC Sanitary Sewer Changes to 12" PVC farther South	Along Calle Luis Muñoz Rivera Road From Highway 2 to south of PR-127
2" Metal Water line Underground	Along Calle Luis Muñoz Rivera Road just north of PR-127
Overhead Communication	Along Calle Luis Muñoz Rivera Road just north of PR-127
6" Metal Water line Underground	Down the middle of Calle Luis Muñoz Rivera Road just north of PR 127 through the intersection of PR-127
Primary Overhead Electrical/Telephone	Along Calle Luis Muñoz Rivera Road From Highway 2 to south of PR-127
8" Sanitary Sewer	Calle Luis Muñoz Rivera Road just north of PR-127 coming from the east
54" Storm Sewer	Calle Luis Muñoz Rivera Road just north of PR-127 coming from the east
Underground Electrical to Light Pole	Calle Luis Muñoz Rivera Road just north of PR-127 coming from the east
Overhead Primary Electrical	Calle Luis Muñoz Rivera Road just north of PR-127 coming from the east
6" Metal Water line Underground	Running Across the channel just north of PR-127
Overhead Communication	Running Across the channel just north of PR-127 & crosses PR-127 on east side of channel and runs south
Overhead Electrical	Running Across the channel just north of PR-127
Overhead Telephone	Running Across the channel just north of PR-127
Overhead Primary Electrical	Running Across the channel just north of PR-127 & crosses PR-127 on east side of channel and runs south
4" Underground Communication	Running Across the channel just south of PR-127 and runs south
Central Zone - Vertedero Road south of cemetery to be re-aligned	
Unkown Underground Utility	Running Along Vertedero street
Overhead Communication Line	Running Along Vertedero street
Overhead Electrical and Telephone	Running Along Vertedero street on south side of street and crossing to the north side
(3) Overhead Primary Electrical	South of Vertedero street
Southern Zone - Running parallel along PR-335 (Cam Boca) and adjacent to proposed bridge	
6" Metal Sanitary Sewer	Running parallel to State Road PR-335 on west side
6" PVC Water line	Running parallel to State Road PR-335 on east side
4" Underground Communication	Running parallel to State Road PR-335 on east side
Overhead Telephone	Running parallel to State Road PR-335 on east side

2.10 Future Without-Project Condition Summary

The future without-project condition (FWOP) represents the most likely (forecasted) future conditions in absence of a federal project, based on a period of analysis of 50 years with a base year of 2026. The FWOP is synonymous with the No Action Alternative. Each alternative plan that is formulated is compared to the FWOP.

Flood risk and flood related damages have been reported for the Municipality of Guayanilla for more than three decades. The 1980 Reconnaissance Report notes that development and future population trends would be contingent on addressing the ongoing flood impacts to residential and commercial structures. While the Commonwealth of Puerto Rico initiated construction of a flood risk management project for Guayanilla in the early 2000s, non-federal funding has not been available to complete project construction. Considering the scale of damage related to recent natural disasters (Hurricane Maria, 2019-2020 swarm earthquakes) and changes in local and regional economy, it is very unlikely that the Commonwealth of Puerto Rico will have the resources to construct this project. Based on the slightly negative population growth rate over the last two decades, it is estimated that future without project conditions will maintain current or slightly lower than current population levels. Additionally, no new development is expected to occur that would significantly alter the future without project condition, nor are any laws expected to be passed that would change the future without project condition. The following is a summary of FWOP for elements that could have the most direct effect on plan formulation.

- Flash floods and overtopping of the Río Guayanilla natural channel would continue with existing climate patterns (Section 2.3.1) within the Rio Guayanilla riverine and coastal floodplain. Prevalent trends of increasing rainfall intensity may continue during the FWOP condition which could result in an increase in the magnitude and risk of inundation. Risk to public safety and health would continue to remain high and evacuation routes and emergency services would remain impacted. Risks associated with flood damages to structures would continue to remain high. Vulnerable populations would continue to at high risk from flooding.
- The Río Guayanilla would be expected to continue to exhibit natural fluviogeomorphic processes, which includes erosion of banks, deposition of point bars and transport or large amounts of rocky sediment. The high volumes and velocities induced by the upper montane catchment would over time scour and undermine critical infrastructure and facilities along the river. Critical facilities, including emergency responders would continue to be at risk.
- Biological resources would be expected to remain in the existing condition within the Río Guayanilla and affected study area. The Río Guayanilla is a naturally functioning river system with limitations placed upon its natural processes and habitat quality by agriculture and urbanization.
- Cultural resources would not be affected in the existing condition. Ground disturbance by urban development is the greatest threat to cultural resources. In the absence of the project, it is unlikely that additional development would occur in the floodplain thereby posing no affect to historic properties.
- Population in the study area has seen a slight decline since the year 2000. Residents explain that due to the frequency of flooding, many individuals and businesses have left the area. Based on these trends, it is not expected that the future population will increase significantly; however, marginal changes in population may be present if flood risk is reduced in the future.
- Land use in the study are is not expected to change significantly. In the absence of the project, it is unlikely that additional development would occur in the floodplain.
- Existing recreation areas are not expected to change significantly. Possible changes may occur near the public park located east of the Playa as recreation needs change over time. There are currently no known plans to develop additional parks within the study area.

3.0 Plan Formulation*

Overview

Plan formulation is an iterative process resulting in the development, evaluation and comparison of alternative plans to address identified study problems by achieving the outlined objectives. The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) (1983) established four accounts to facilitate the evaluation and display of the effects of alternative plans. These accounts are: national economic development (NED), environmental quality (EQ), regional economic development (RED), and other social effects (OSE). These four accounts encompass all significant effects of a plan on the human environment as required by NEPA) (42 U.S.C. 4321 et seq.). They also encompass social well-being as required by Section 122 of the Flood Control Act of 1970 (Pub. L. 91-611, 84 Stat. 1823). The EQ account considers effects on ecological, cultural, and aesthetic attributes of significant natural and cultural resources that cannot be measured in monetary terms. The OSE account considers urban and community impacts and effects on life, health and safety. The NED account considers effects on the national economy. The RED account considers the regional incidence of NED effects, income transfers and employment effects.

While the NED account is the only required account, the P&G specifies that information that is required by law or that will have a material bearing on the decision making process should be included in the other accounts (EQ, RED, and OSE) or in some other appropriate format used to organize information on effects. As described in Chapter 2, flooding in the study area poses risk to a low income population with nearly 60 percent of the population in the study area below the poverty line. Flash floods pose risks to the life and safety of those in the community. For this study, the NED and OSE accounts were used to support plan selection.

Current and Future without Project Conditions

The 1990 Reconnaissance Report noted that flooding in the 100 year floodplain affects over 880 housing units, 147 commercial structures, 56 public buildings, 21 non-profit establishments, 3 industrial plants and 2 public utilities. Hurricane Eloise, which occurred in 1975, destroyed 99 homes and damaged an additional 276. Flood related fatalities were been reported in 1975, 1979, 1985, 198 and 2012 floods. Hurricane Maria caused significant overtopping of the Rio Guayanilla into the community where floodwaters washed out a portion of a major bridge, and caused significant damage to the supermarket, a pharmacy, a bakery, and more than 106 homes. Several other critical public structures were inundated, banana crops were destroyed, and the area was left without electricity and telecommunications for months. Other flood related impacts associated include emergency and clean-up costs as well as damages to vehicles.

Analysis of without project conditions indicates that there is an annual risk of flooding within the municipality. Analysis of structure, content and other damage categories identified an estimated $19.8 million in expected average annual damages for without project conditions. Average annual damages to residential, commercial and public structures are estimated at approximately $17 million. Expected annual damages in other categories (auto/emergency/cleanup and agriculture) are estimated at ~$3 million. Additional information regarding flood vulnerability and damages are including in Tables 11 and 12 in Appendix C, Economic Analysis.

In addition to the quantifiable impacts associated with flood damages, flooding poses a significant life safety risk to the residents of Guayanilla. The population at risk is nearly 5,000 individuals during the daytime for events up to the 0.02% AEP (500 year event), with potential for significant life loss during

a flood event. Further, an assessment of the community socio-economics demonstrated that the population in the study area is particularly economically and socially vulnerable when flood events occur. Unemployment in the study area is 3.7 times that of the U.S. average. The poverty rate in the study area is nearly four times the U.S. average, and is 12 percent higher than the average rate in Puerto Rico. Average income in the study area is 75 percent lower than the U.S. average and 35 percent lower than the average income in Puerto Rico as a whole. These factors can increase the community's propensity to suffer mentally and financially in the event of a flood. An assessment of social vulnerability for Guayanilla indicated that the municipality is 47 more vulnerable than other communities in Puerto Rico considering: socioeconomic status; household composition and disability; minority status and language; and housing and transportation. Additional discussion on damages, life safety and social vulnerability analyses are contained in Appendix C, Economic Analyses.

Despite construction of the Phase I levee in the early 2000s, there has been no substantial reduction in life safety or flood risk in the past several decades. Non-federal funding has not been available to complete project construction. Considering the scale of damages related to recent natural disasters and changes in local and regional economy, it is very unlikely that the Commonwealth of Puerto Rico will have the resources to complete construction of a project in the Municipality of Guayanilla. As a result, flood related life safety risks would remain unchanged from current conditions. Without a reduction in life safety and flood risks, social and economic vulnerability is likely to remain high. Economic damages to residential, commercial and public structures would continue throughout the period of analysis. As discussed in further detail in *Appendix C, Economic Analyses,* average annual damages of $19.8 million dollars for the without project condition and 29 fatalities are expected for the 0.02% AEP event.

Risk–Informed Planning

This feasibility study followed the six-step planning process defined in the 1983 P&G adopted by the Water Resource Council and the Planning Guidance Notebook, ER 1105-2-100. Planning has continued to evolve since the 1983 P&G, an evolution that now includes risk analysis. Risk-informed planning (IWR Publication 2017-R-03) pays careful attention to uncertainty, and it uses a set of risk performance measures, together with other considerations, to *inform* planning. Risk-informed planning is an analytic process that aims to reduce uncertainty, but acknowledges that it can never be eliminated entirely. The goal here is to efficiently reduce uncertainty by gathering only the evidence needed to make the next planning decision and to manage the risks that result from doing so without more complete information. Flood risks for the municipality include damages to structures and life safety risks. Under risk-informed planning, the six-step planning process is demonstrated as shown in Figure 20. The cyclical progress of the figure depicts the iterative nature of the planning process; as more data is gathered and analyses completed, the process is refined and updated in cycles until an acceptable solution has been identified.

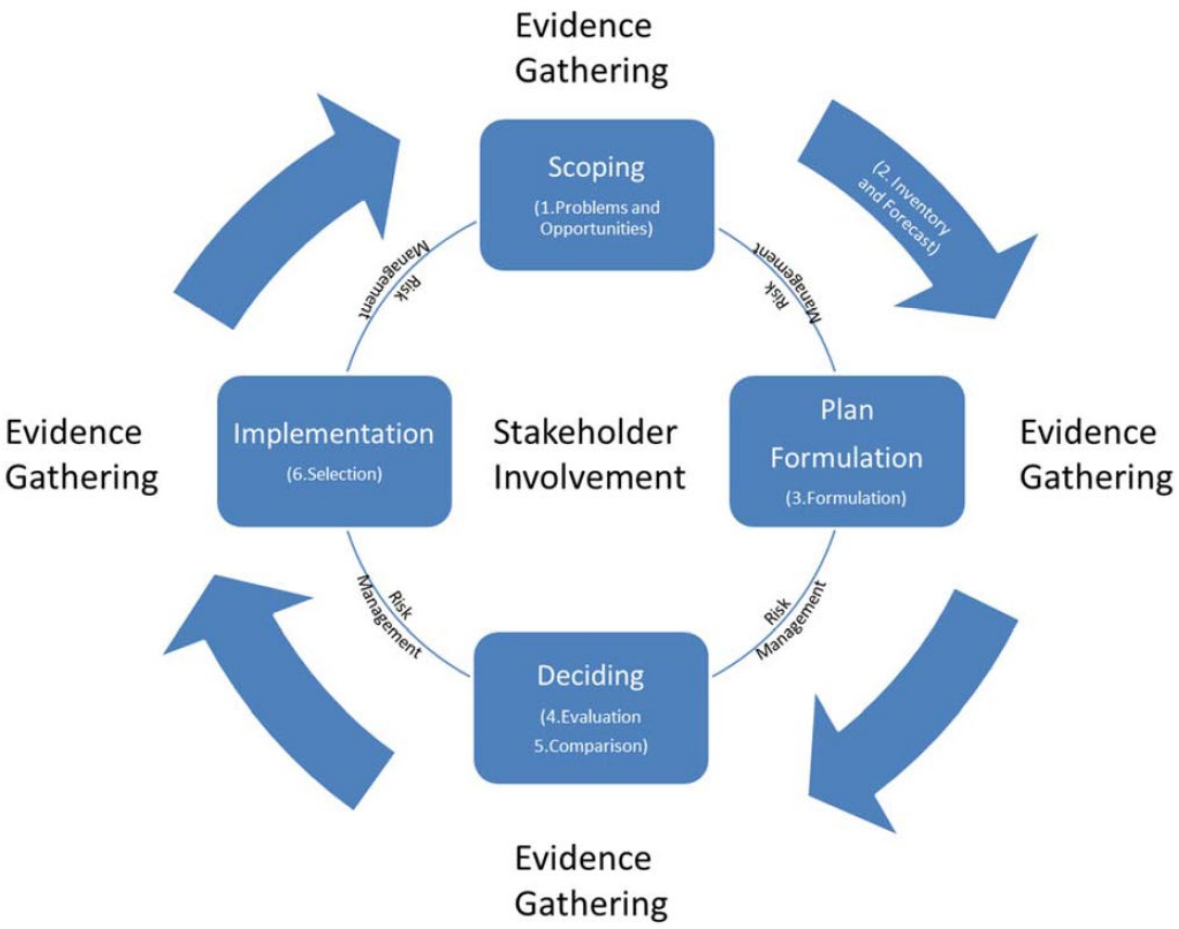

Figure 20: USACE Risk-informed planning process.

3.1.1 Risk Assessment for Flood Risk Planning

Risk is a measure of the probability and consequence of future events occurring. USACE follows a conceptual flood risk model (Figure 21) which is a function of hazard, performance, and consequences, as the problems identified in Section 1.5 were presented. These three (3) concepts are utilized to evaluate the effectiveness of potential flood risk reduction measures under consideration for federal investment. Each term is discussed more completely in ER 1105-2-101 "Risk Assessment for Flood Risk Management Studies" dated 17 July 2017.

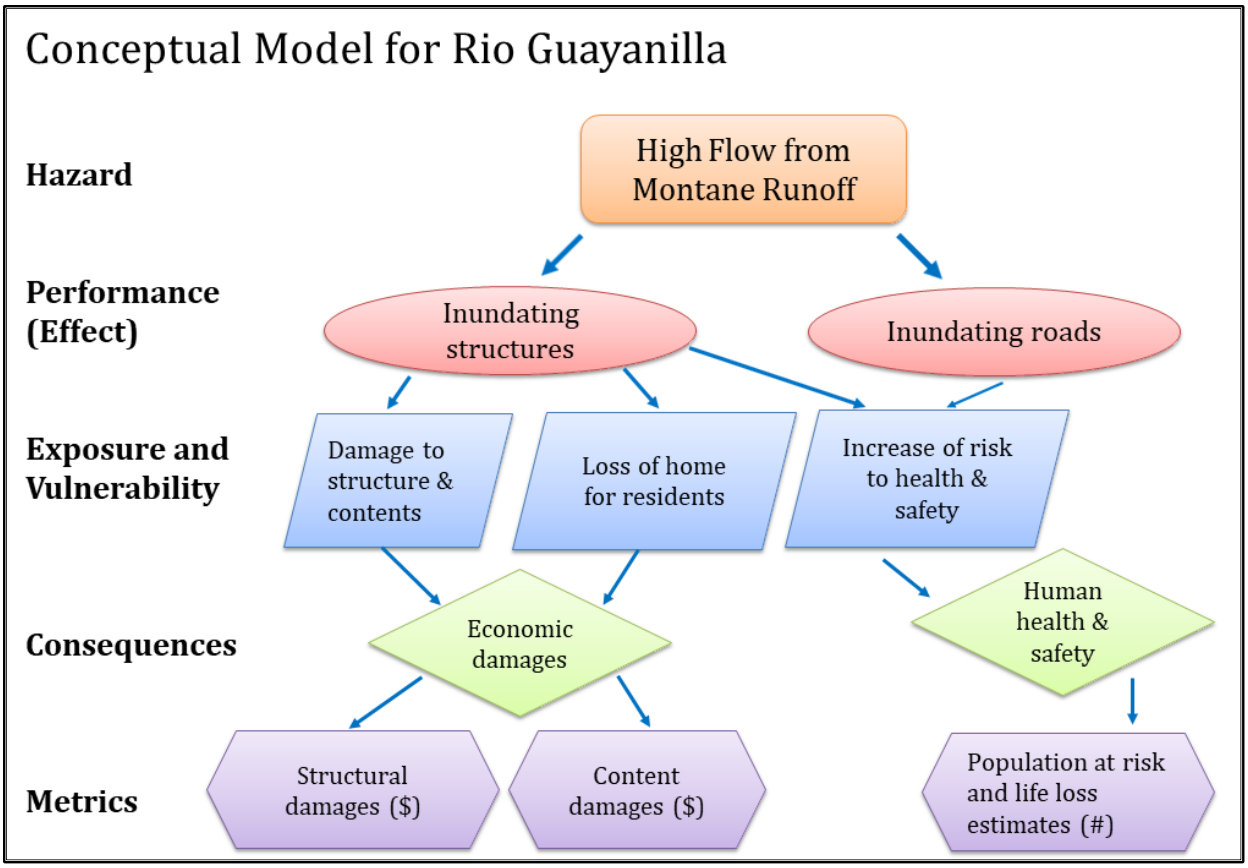

Figure 21: Flood Risk Management Model for the Río Guayanilla Study

Hazard

The hazard, or potential cause for harm, refers to flooding and erosion caused by flows from the upper montane catchment, which is described in Sections 2.3.1 and 2.3.2, as well as in *Appendix B – Hydrology & Hydraulics*. Expected inundation (flooded area) in the study area for the without project condition for the .02% AEP (500-year) and 1% AEP (100-year) events (Figure 22 & Figure 23).

Performance

Performance refers to the system's reaction to the hazard, or how the Río Guayanilla is anticipated to handle various flood loadings. Performance in this study is primarily tied to the conveyance capacity in the natural river channel. A description of the existing system's performance during storm events is also included in Sections 2.3.1 and 2.3.2, as well as in *Appendix B – Hydrology & Hydraulics*. Additional information on the fragility of leveed channel reach (Phase I DNER) in the study area is included in *Appendix G – Geotechnical Engineering*.

Consequences

Consequences are measured in terms of metrics such as economic damage, acreage of habitat lost, value of crops damaged, and lives lost.

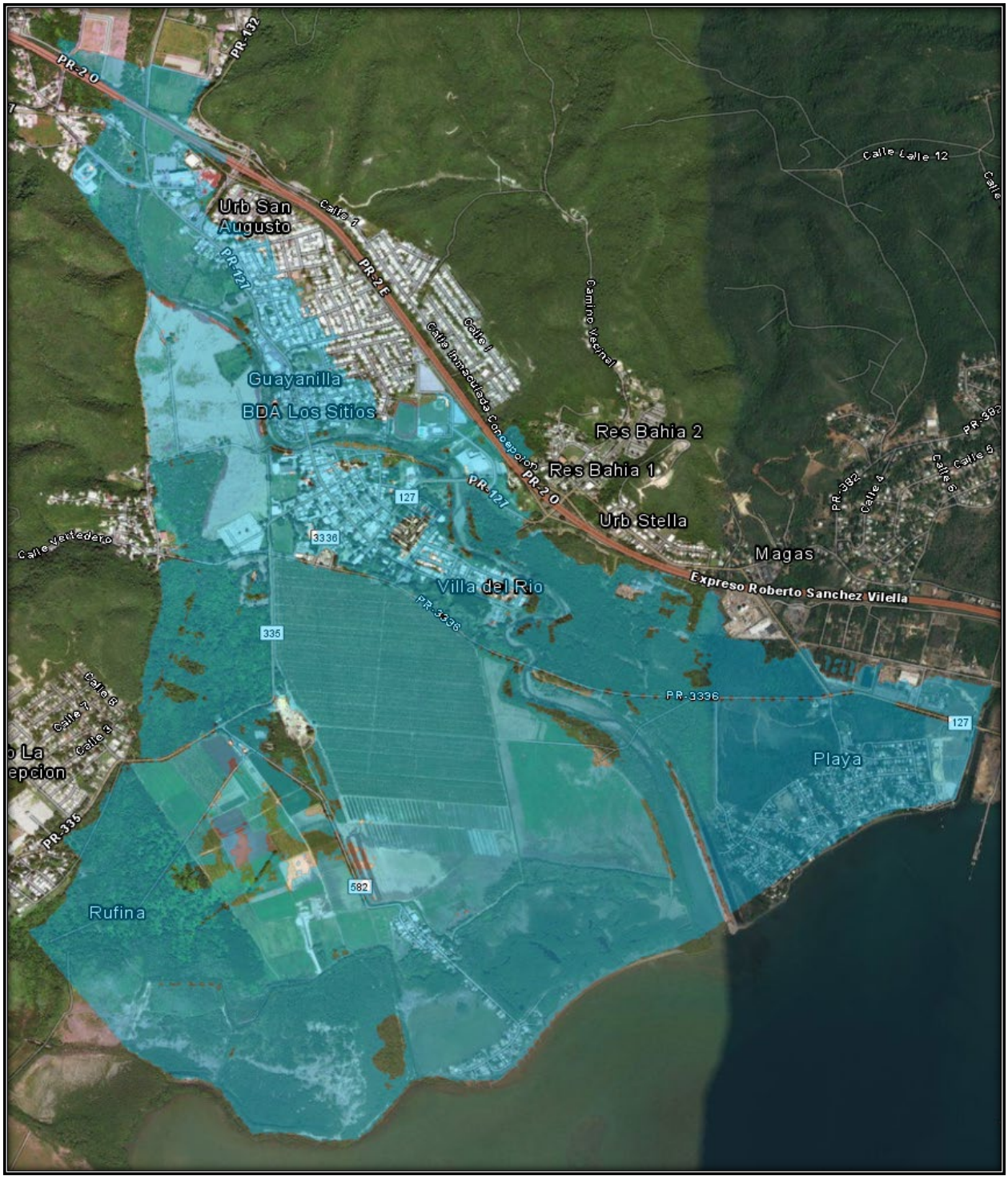

Figure 22: 0.2% AEP (500 year) Anticipated Study Area Flooding under Current FWOP

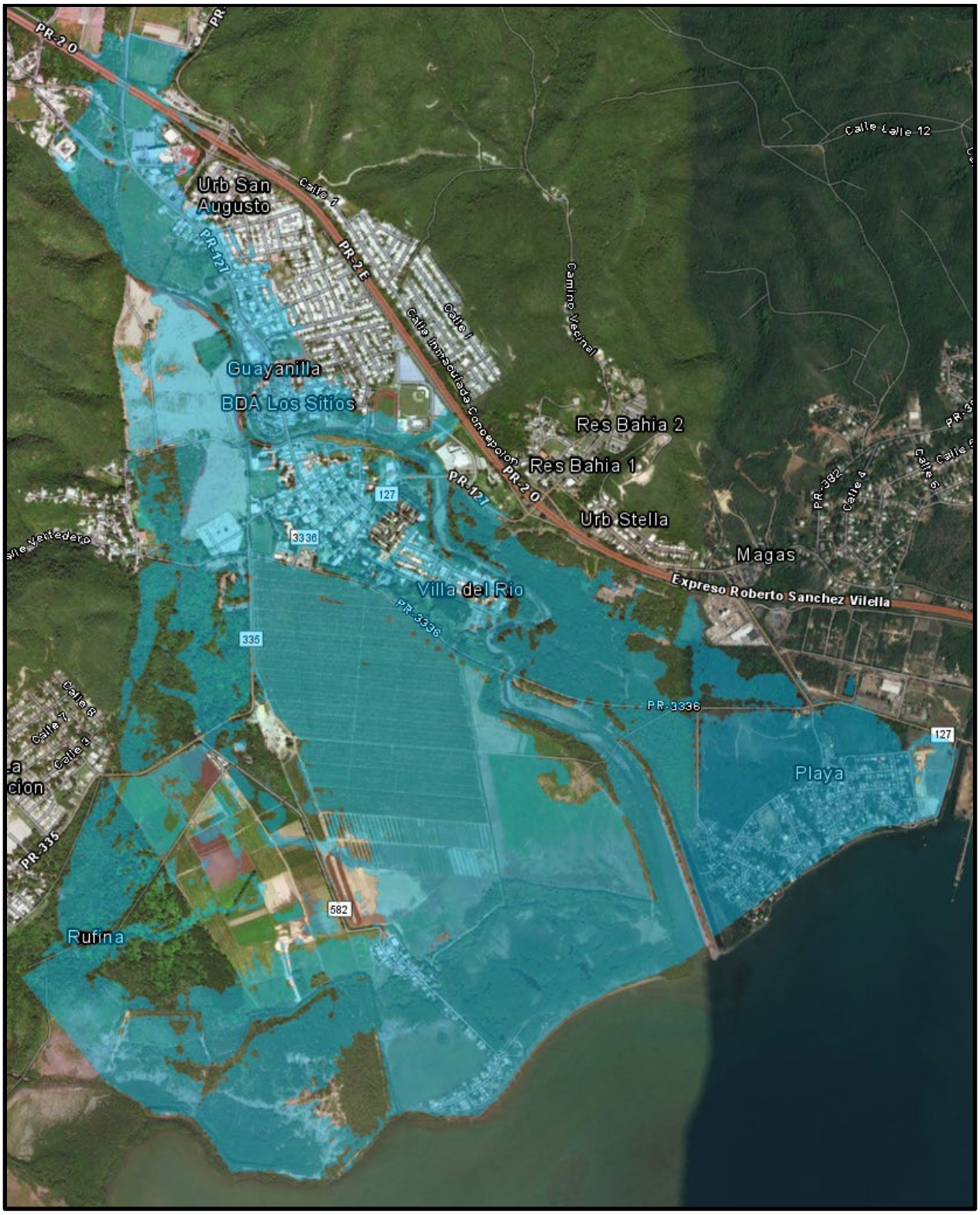

Figure 23: 1% AEP (100 year) Anticipated Study Area Flooding under Current FWOP

Floodplain Management Formulation Considerations

Because the entire project area and the majority of the Municipality of Guayanilla are located in the regulatory floodplain, the planning process also considered requirements contained in E.O.11988, Floodplain Management and ER 1165-2-26, Implementation Guidance for Executive Order 11988, Floodplain Management. It was confirmed early in the study process that the entire project, including the majority of the Municipality of Guayanilla, is located in the regulatory floodplain. Requirements needed to address the requirements in the Executive Order were added to the plan formulation process for the study. The steps outlined in ER1165-2-26 to comply with the Executive Order are illustrated in Figure 33. These requirements were discussed with stakeholders during meetings in November 2018. Discussion in this chapter includes detail on the development of measures and alternatives considering the impacts to the beneficial uses of the floodplain. Historic settlement patterns and the configuration of the river channel made it challenging to identify effective measures and alternatives outside of the floodplain Consideration was given as to what steps could be taken to reduce the impacts to beneficial uses of the floodplain. An iterative process was utilized to identify the least environmentally damaging alternative, including conservation measures to address floodplain impacts. Opportunities for public input were provided during public meetings during the scoping process and the public comment period. Presentations at both meetings focused on steps that could be taken to address flood risk within the study area. Extensive coordination was undertaken with resource agencies as well to identify conservation measures that could be incorporated into structural measures that would reduce adverse impacts to the beneficial uses of the floodplain. At the community level, future land use changes are expected to occur to the north and east of the community. As much of the existing floodplain is developed, it is not expected that the project will induce additional development in the floodplain.

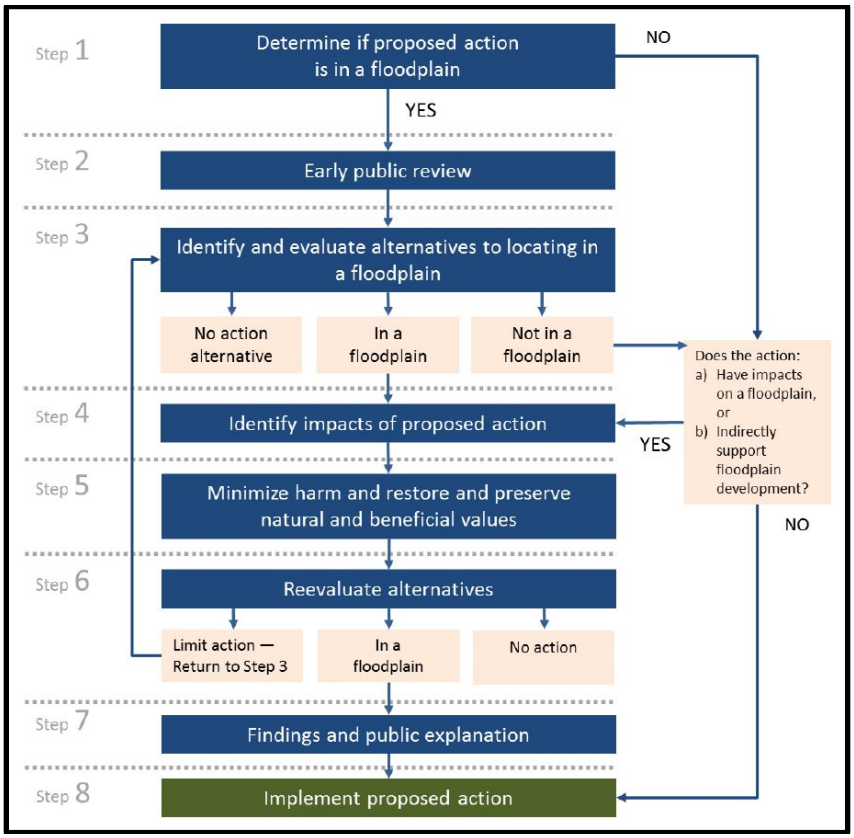

Figure 24: Eight Step Decision-making process for E.O. 11988

Plan formulation, informed by existing risks, proceeded with the identification of measures and the formulation of alternatives. Identified risks included the hazards associated with flood risk and consequences for residents in the municipality of Guyanailla, for both current and future without project conditions. Damages of $19.8 million for the without project condition that are primarily associated with structure flooding and significant life safety risk (up to 29 fatalities for the 0.02% AEP) indicate the need for measures that can reduce damages and life safety risk. Both structural and non-structural measures were developed to address the study objectives.

3.2 Management Measures

Management measures are features or activities that can be implemented at a specific geographic location to address all or a portion of the identified study problems. Measures can directly address the hazards, the way the hazards behave (performance), or indirectly address them through eliminating or reducing the consequences. Measures considered for this study are either nonstructural or structural.

3.2.1 Nonstructural Measures

As outlined in PB 2016-01, "Clarification of Existing Policy for Participation in Nonstructural Flood Risk Management and Coastal Storm Damage Reduction Measures," nonstructural measures reduce human exposure or vulnerability without altering the nature or extent of that hazard. In this case, hazard refers to water associated with montane flash flooding that can cause damages and impact life safety. Exposure is defined as who or what would be impacted by a hazard and vulnerability is how susceptible the exposed population are to life safety risk and properties are to damage from the flood hazard. This group of measures typically includes modifications to existing residential and non-residential buildings, planning activities, maintenance and behavioral solutions.

Floodplain Regulation – seeks to regulate floodplain uses to minimize current and future damages by controlling construction activities and land use. This measure utilizes political and or social controls to minimize land use activities – that are incompatible with floodplain conditions – while maximizing more compatible uses such as recreation, open space, habitat, and parking. Examples of floodplain regulation tools include: master plans, zoning controls, and building codes. Non-federal governing bodies are typically responsible for floodplain regulation.

Emergency Response – involves the development of an emergency plan that provides for the dispatch of emergency services and a framework within which local agencies would operate during a flood event. It does not specifically reduce flooding, rather it seeks to provide for public safety and quickly address problem areas with pre-planned measures. Emergency response does not reduce damages or prevent emergency costs in the affected floodplain. Law enforcement and emergency service departments are typically the primary responsible parties for emergency response operations.

Evacuation Planning – involves the development of an emergency plan that provides for the physical removal of residents from the floodplain on a temporary basis in the event of flooding. It does not solve the issue of flooding but rather seeks to provide for public safety during hazardous flooding conditions. Evacuation planning reduces the risk of injury or loss of life as a result of flooding, but does not reduce damages in the affected floodplain. Local and county governing bodies are typically responsible for leading evacuation planning efforts.

Flood Warning System – facilitates the evacuation of flood prone areas during larger storm events by providing residents and emergency services with real-time gage information/advance warning. Similar to emergency response and evacuation planning measures, this measure would not reduce damages to

structures but it would reduce the risk to life safety. Flood Warning Systems can include gaging and is typically incorporated into response and evacuation planning.

Flood Proofing – involves modifying existing structures to prevent damage during flood events. Flood proofing methods include raising buildings, waterproofing or sealing the lowest entry points of a structure, and or construction of berms or floodwalls.

Razing & Removal of Structures – involves demolishing flood prone structures or relocating such structures outside of the floodplain. For structures that are shown to be regularly impacted by flooding, this course of action may be preferable to flood proofing or filing repeated flood insurance claims.

Removal of Impediments to Flow – involves the removal of vegetation, sediment, and debris that can accumulate in drainage channels and interfere with the conveyance of flood flows. Removing impediments to flow could be implemented on a priority-basis, increasing maintenance investments in locations that are known to require greater capacity during flood events.

3.2.2 Structural Measures

Bridge & Conveyance Modifications – involve replacing, repairing, modifying bridge structures and the cross sectional floodway to improve in channel conveyance of flood flows.

Reservoirs – involves constructing large reservoirs in montane river units to retain and detain rainwaters.

Channelization – involves deepening, widening and straightening of the natural channel in order to increase the capacity and/or conveyance efficiency of the river or stream. Generally, the configuration for this measure would be the existing natural channel and adjacent floodplain terraces.

Levees & Floodwalls – involve construction of earthen or stone berms (levees) or concrete/steel walls (floodwalls) at the edge of an existing channel to provide extra capacity by raising the bank height. Levees and floodwalls would be constructed to USACE standards. Levees can be constructed of earthen materials, whereas floodwalls are made of steel sheet pile and formed concrete. While floodwalls present a higher risk of failure than levees, they can be an effective means of adding capacity where there are constraints on real estate or right-of-way restrictions. Levees and/or floodwalls could be combined with other measures, such as the diversion channel, as necessary to realize the needed level of risk reduction.

Engineered Diversion Channels – involves construction of engineered channels to serve as the primary conveyance for flood flows. These channels are designed to contain floodwaters and transport them around or past areas that are prone to flood risks. Engineered channels are typically constructed out of concrete, steel sheet pile, angular riprap or a combination of these. Typically channel cross sections are rectangular or trapezoidal. Due to the constraint cross section for the engineered channel, velocities can be high under flood conditions.

Staged Greenway Terraces – involves the construction of a natural greenway that would serve as a diversion for flood flows. The staged greenway would be composed of wide open channel reaches to contain flood flows. Overbank areas would be contoured to mimic natural floodplains. The terraced greenway could provide habitat and open space during the periods between flood events and recovery. Due to landform and open space constraints, this measure would need to be supported by engineered features in certain segments of the diversion for Guayanilla. This measure evolved from the agency planning Charrette (28 November 2018) and discussions between USACE, USFWS, and NOAA. This greenway diversion would require more real estate and easements than an engineered diversion channel measure, both for footprint and excavated material (sand, gravel, et cetera) disposal and beneficial reuse.

Rehabilitate Phase I (DNER Constructed) – involves rehabilitating the existing levees, clearing trees and other vegetation from the levee cross section and potentially changing the size of the channel in order to achieve compatibility with other alternative components. Junction points between the constructed Phase I and alternative components would also need to be reconstructed.

Vegetation Control – involves removing vegetation per USACE standards for levee construction and maintenance; this generally would include keeping levees and engineered channels and structures free of tree and shrub species of plant. Herbaceous grasses, flowers, and ground cover are generally considered acceptable. Vegetation utilized for erosion control can include native species resulting in incidental habitat.

Utility Relocation – involves removing, replacing, relocating, or otherwise altering a utility such as electricity, water, natural gas, telecommunication lines, et cetera, in order to maintain connectivity and functionality of the municipality and regional system. This also includes the same measures for agricultural irrigation systems and small vehicular bridges for those lands or roadways bisected by the alternative components.

Engineered Features & Bank Protection – involves engineered features such as where tolerances of nature based erosion repair and or protection are not conservative enough to support alternative features or manmade resources. If necessary, these could include riprap, concrete walls, steel sheet-pile, geotextile fabrics, gabions, et cetera.

Minor Nature Based Features (Channel Stabilization) – involves in-stream structures such as J-hooks, cross-veins, boulder clusters, glide, riffles, et cetera, that mimic natural riverine geomorphology and utilize riverine flows to accomplish their function. Large woody debris could also be utilized as part of stone revetments to add armored habitat to dynamic reaches while vegetation establishes. Select native grasses and shrubs would also be utilized to stabilize disturbed or repaired areas.

3.3 Initial Screening of Measures

Once the initial list of possible flood risk reduction measures was assembled, each measure was then considered in the context of the study area and either screened out and removed from further consideration or were retained for alternative development.

3.3.1 Screened Nonstructural Measures

The National Nonstructural Committee's Flood Damage Reduction Matrix was used to evaluate the feasibility of multiple nonstructural measures. Nonstructural measures which were not screened out (Section 3.3.2) using the matrix were economically evaluated to compare the net benefits with structural alternatives. The following nonstructural measures were screened out and removed from consideration:

Floodplain Regulation – The Water Resources Development Act (WRDA) of 1996 provides that a non-federal interest in a federal flood damage reduction project must participate in and comply with federal flood plain management and flood insurance programs. Local, county, and state governing bodies are typically responsible for floodplain regulation.

Elevation – Elevating structures on foundation walls, on piers, on posts or columns, and on fill were screened out given that the flood velocities in most reaches were greater than 5 feet-per-second (fps). In those reaches, elevation would only partially address life-safety risks associated with rapid inundation events. Further, because of the density of development in the floodplain, structure elevation in the

developed reaches was unlikely to be cost effective. There are approximately 1,500 structures within the 0.002 AEP floodplain in the study area (Figure 22).

Emergency Response & Evacuation Planning– Emergency response operations primarily fall under the police and fire department's jurisdiction. Emergency response and evacuation planning measures could be improved in the study area. As stand alone measures, Response and Evacuation planning were screened out, but are incorporated into the development of the Flood Warning System Measure which was retained. In order for these measures to be effective, the inclusion of real-time data for use in decision making in critical.

Flood Proofing and the Razing and or Removal of Structures – Significant, basin-wide nonstructural alternatives were screened out because dense development makes these measures too expensive to implement on such a large scale when more efficient solutions are viable. Further, the high flood velocities (5 fps) make dry and wet flood proofing alternatives unviable. There are approximately 1,500 structures within the 0.002 AEP floodplain in the study area (Figure 22).

3.3.2 Retained Non-Structural Measures

The following non-structural measures were retained for alternative development:

Flood Warning System – Based on the both the flashiness and severity of certain potential floods caused by rain events, this measure was retained and could be recommended with or without structural measure implementation. It is always a prudent decision to have a warning system in place even if the risks associated with flooding are greatly reduced. Citizens need to know when an event is happening and what steps to take if the project does not perform as intended or the storm exceeds the design event for the project. A flood warning system, including gaging and response plans will be developed collaboratively between the USGS, the Non-Federal Sponsor, Emergency Services and the Municipality of Guayanilla and USACE.

Removal of Impediments to Flow – Based on observable conditions of the natural river channel and preliminary hydrology and hydraulic modeling, this measure was deemed necessary to maintain low to bank full flows in the natural river channel. Constrictions to the river channel and floodplain by manmade structures, and in particular bridge crossings, this measure was deemed necessary to ensure bank full flow conservation measures

3.3.3 Screened Structural Measures

The following nonstructural measures were screened out and removed from consideration:

Reservoirs – Constructing large reservoirs in montane river units to retain and detain rainwaters was eliminated from further consideration for the Guayanilla FRM study. Reasons for elimination include life-safety hazard creation, large scale and irrecoverable environmental damage, and the likely magnitude of cost associated with construction and mitigation. This was determined during the reconnaissance phase. Detailed consideration is provided in *Appendix A1* under Measure Screening.

Channelization – Channelizing the natural channel of the Río Guayanilla in montane and coastal plain for increased conveyance/capacity was eliminated from further consideration for the Guayanilla FRM study. Reasons for elimination of this measure include creating a life-safety hazard through the Municipality of Guayanilla and avoidance of large scale and irrecoverable environmental damage to amphidromous fishes. This was determined during the reconnaissance phase. Further information gleaned from feasibility

phase work indicates that the Río Guayanilla could not be deepened and widened enough to contain floodwaters due to Real Estate constraints.

Diversion Channels without Levees – Due to the large volume of floodwaters, the capacity of the diversion channel would be exceeded without confining banks, resulting in overbank flooding of the Municipality of Guayanilla and the agricultural fields on the west side of the river. Consequently, it was determined that the diversion channel measure should be combined with the Levee/Floodwall measure and the measure for a standalone diversion channel was eliminated.

Staged Greenway Terraces without Channel Excavation – Due to the quantity of flow, it is not possible to build a levee along the western border of the Municipality of Guayanilla and allow uncontrolled overbank flows to the west of the community. Without an excavated channel, a greenway would form over time due to the forces associated with flood flows. However, the flow paths would be highly unpredictable and could end up meandering into agricultural facilities and structures, roads not flooded before and into critical dry karst habitats. Consequently, this measure was eliminated.

3.3.4 Retained Structural Measures

The following structural measures were retained for alternative development based on hydrologic and hydraulic modelling of the system's existing conditions, geomorphology, open space/real estate availability and sustainability concepts:

Levees & Floodwalls – this measure is very flexible in terms of shapes, widths and heights. This measure can provide containment of flood waters and can be combined with other features to maximize effectiveness.

Engineered Diversion Channels w/ Levees – this measure would facilitate the movement of flood waters around the affected damage areas. Based on numerical modelling of the existing conditions and study area geomorphology, diversion channels would not be effective without combining with a retaining type feature, such as a levee or berm.

Staged Greenway Terraces w/ *Excavation* – this natural diversion channel measure would facilitate the movement of flood waters around the affected damage areas while maximizing natural processes and habitat. Based on hydrologic modelling of the existing conditions, geomorphology and open space availability, this measure would be effective in certain reaches, but not in others that have a greatly reduced open space foot print. Site conditions dictate that this measure would need to be combined with reaches of the engineered diversion channel.

Rehabilitate Phase I (DNER Constructed) – this measure is necessary in order to bring up the existing Phase I project to engineering standards and functionality, while ensuring it functions seamlessly with any potential new flood risk measures/features upstream.

Bridge & Conveyance Modifications – for any diversion channel measures, this measure is necessary to address road crossings that need to remain in their current alignment for local and regional transportation purposes. This would ensure new or existing bridge structures and the cross sectional floodway is modified to improve in channel conveyance of flood flows.

Vegetation Control – this measure is necessary for any flood control feature to ensure structures are not degraded by tree and shrub root systems. This is especially important for study areas located within the tropic and sub tropic zones where vegetation growth and colonization is very rapid.

Utility Relocation – this measure is typically necessary for any flood control feature to ensure there is no loss of power, water or communications to the surrounding community.

Engineered Features & Bank Protection – this measure is typically necessary for any flood control feature to ensure there is no loss of functionality by preventing erosion induced by flows and runoff.

Minor Nature Based Features (Channel Stabilization) – this measure is typically necessary for any flood control feature to ensure there is no loss of functionality by preventing erosion induced by flows and runoff. This measure has a much lower impact on natural stream channels, and sometimes can actually have a benefit when designed to work with natural processes and mimic habitat.

3.4 Initial Alternative Array

One (1) No Action (Alt 0) alternative and six (6) with project alternatives (Alts 1 – 6) were developed from the list of measures that are listed in Sections 3.3.2 and 3.3.4.

Table 20: Alternatives & Measure Components

Measure Category	Measure Description	Alt 0	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
No Action	Existing & FWOP Conditions	X						
Nonstructural Measures	Flood Warning System		X	X	X	X	X	X
	Removal of Impediments to Flow		X	X	X	X	X	X
Structural Measures	Levees/Floodwalls Single Line Protection				X			X
	Levees/Floodwalls Double Line Protection			X		X	X	
	Bridge & Conveyance Modifications			X	X	X	X	X
	Engineered Features & Bank Protection			X	X	X	X	X
	Diversion Channel (North)					X		
	Diversion Channel (South)			X	X			
	Rehabilitate Phase I (DNER Constructed)			X	X	X	X	X
	Vegetation Control			X	X	X	X	X
	Utility Relocation			X	X	X	X	X
Nature-based Measures	Staged Greenway Terraces						X	X
	Minor Nature Based Features		X	X	X	X	X	X
	Vegetation Control				X		X	X

3.4.1 No Action

There would be no federal action taken at the Municipality of Guayanilla, which would remain subject to frequent flooding and associated damages, increased life safety risk and other social effects. The current natural and manmade resources of geology, soils, hydrology, river, karst forest, secondary growth shrub/grasslands, and agricultural fields would remain in their current state, as described in the Affected Environment chapter, and specifically the FWOP descriptions. A summary of key elements of the FWOP forecast is contained in Section 2.10.

3.4.2 Nonstructural Alternatives

Alt# 1 Flood Warning & Conveyance – The two (2) retained nonstructural measures were combined to create the nonstructural alternative. This alternative would reduce life safety risk, but would not affect the source of the problem.

Flood Warning System – Citizens of Guayanilla can get stranded during quick moving or unsuspecting storms outside the large hurricane events. This measure would be a collaborative effort between the USGS, USACE, the municipality, non-Federal sponsor and local emergency services to develop a system for flood warning that includes a warning system (hardware) as well as a response plan. The Municipality does not have a coordinated warning system that can take real time weather data and provide instant reports and alerts. It was recommended by USGS to set up real time alerts for flood warnings using the existing gage. The USGS currently has a phone and computer application available to the public that can be easily downloaded and used to provide warnings at any stage level. Another possibility for implementing a flood warning system is for a Wireless Emergency Alert (WEA) system to be established. WEA is a public safety system that allows customers who own compatible mobile devices to receive geographically targeted, text-like messages alerting them of imminent threats to safety in their area. Successful implementation of a WEA system would help ensure that individuals located in the vicinity of Guayanilla would be alerted prior to a storm event. At a minimum this information could help citizens to prepare for a flood event as early as possible. Emergency services and city officials would be responsible for alerting the entire community using emergency signals (sounds, flags, et cetera), messages and patrols, for citizens without access to digital messages, or during a cellular phone/Wi-Fi outage. The response plan would identify appropriate actions for citizens which could include shelter in place, or evacuation to an emergency shelter.

Removal of Impediments to Flow – Removal of impediments to flow is a nonstructural maintenance measure that involves the removal of vegetation, sediment, and debris that can accumulate in the channel and interfere with the conveyance of flood flows. Removing impediments to flow would be implemented on a priority-basis at the 3 bridge crossings on the natural channel of the Rio Guayanilla. Typically, materials of fluvial stone and large woody debris would need to be removed to maintain a) existing flows without implementation of structural measures or b) the bank full flows required to keep the Rio Guayanilla riverine ecosystem intact should a structural measure be implemented.

While a standalone nonstructural alternative comprised only of these measures would not provide the benefits necessary to be considered as the NED plan, the separable measures of this alternative are complimentary to the structural set of alternatives.

3.4.3 Structural Alternatives

The following structural Alternatives #2 – 6 include all of the following measures:

a. Rehabilitate Phase I
b. Bridge & Conveyance Modifications
c. Vegetation Removal
d. Utility Relocation
e. Minor Nature Based Features
f. Engineered Features & Bank Protection
g. Flood Warning System (NS)
h. Removal of Impediments to Flow (NS)

Alt# 2 Diversion Channel South with Double Line Protection – This alternative would involve the construction of an engineered diversion channel between the end of the montane unit and beginning of the coastal plain unit of the Rio Guayanilla near PR-2 (Figure 25). A concrete diversion structure would be set in place across the natural river channel to direct flows into the engineered diversion channel. Channel improvements (grading and shaping) would occur upstream of the diversion structure to provide conveyance into the diversion area. The double line of protection includes levees on both sides of the

diversion channel to ensure that flood flows stay within the diversion channel through the design flood event.

The alignment for this alternative directs flood water away from the Municipality and to the west along the confining mountain valley wall. The diversion channel would primarily cut through agriculture fields and join up with constructed Phase I project near PR-3336.

The length of the diversion channel is approximately 9,000 feet long. The diversion channel itself would be a trapezoidal construction with a bottom width of 100-feet and 2:1 side slopes. This alternative would have levees on both sides of the diversion channel. Material from the excavated channel would include gravel and sand, which is not ideal for levee construction from the perspective of erosion; however, the material would be suitable for concrete components, or another beneficial. For example, the material could also be used by local municipalities for landfill cover.

The levees would be constructed of project quarried crushed rock, or commercially sourced clay. All stone for construction would be quarried from the identified quarry areas (Figure 26). The levees and floodway would be kept free of woody vegetation via clearing or mowing, only allowing grasses and forbs to grow; no invasive plant species management would be done. Removal of impediments to flow in the existing channel would take place during project construction as well as periodically during O&M.

The Flood Warning System would be developed collaboratively by the USACE, USGS, the NFS, the municipality and Emergency Services.

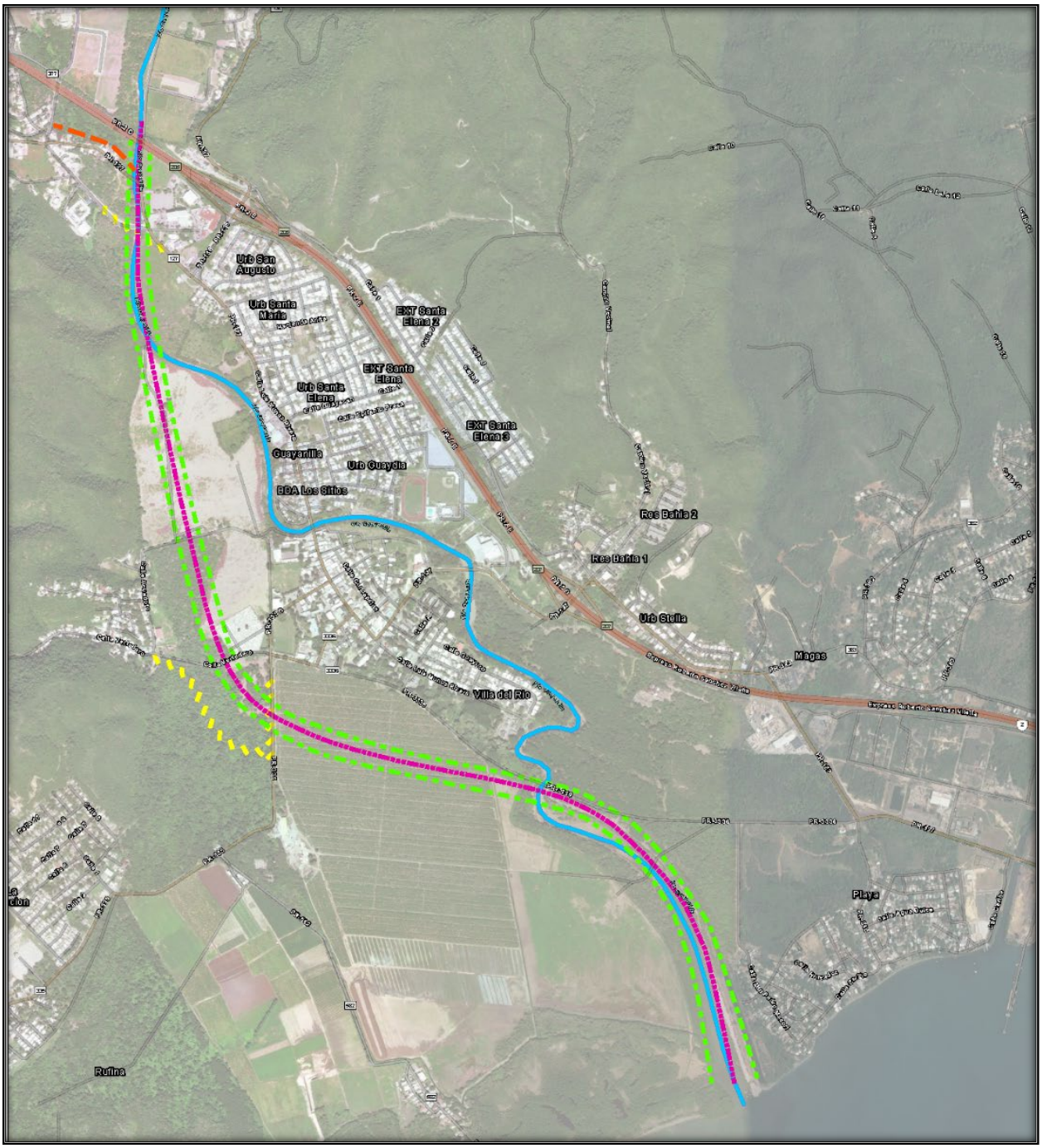

Figure 25: Alternative 2 Diversion Channel South w/ Double Line Protection

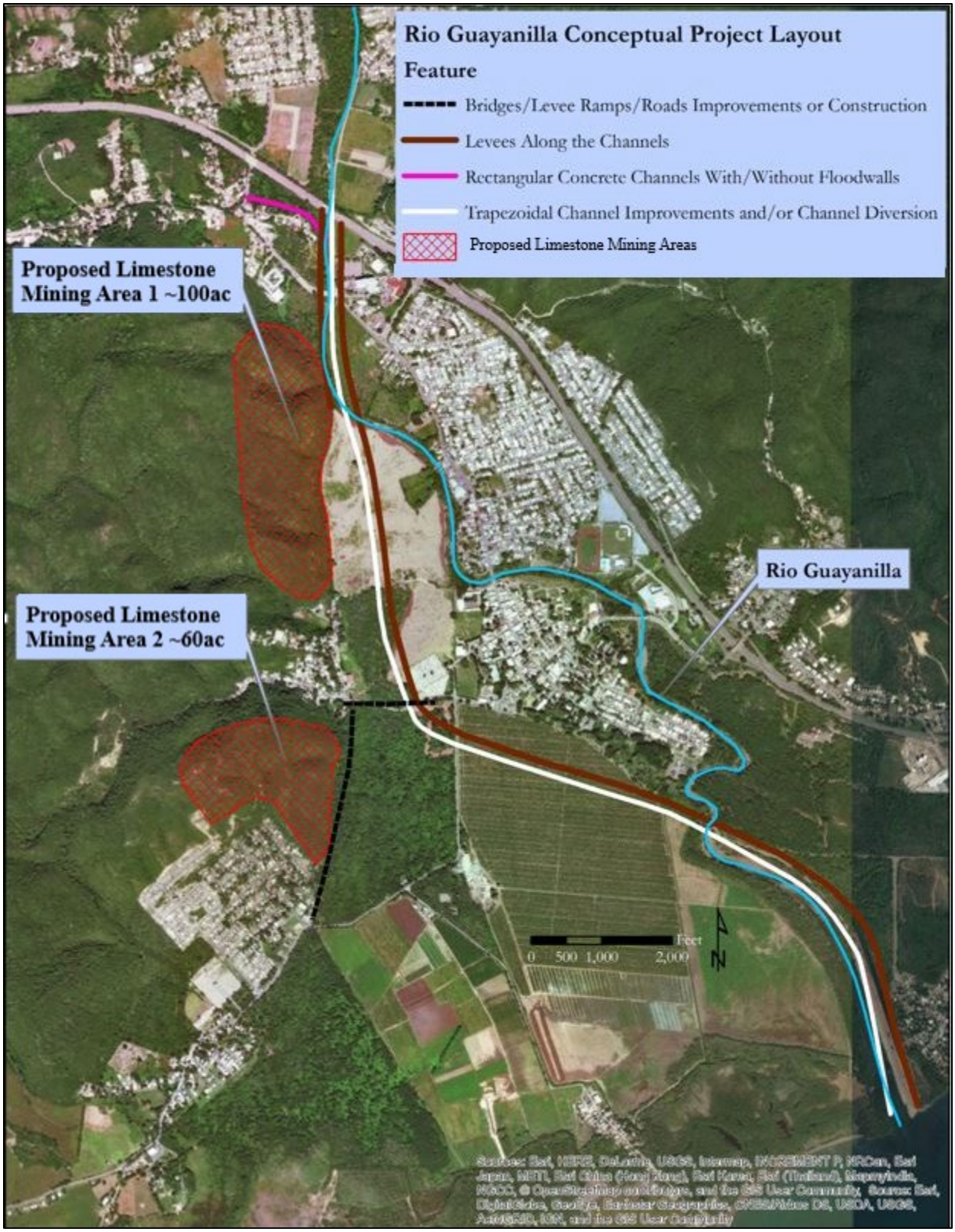

Figure 26: Quarries & Sourcing for Levees and Concrete Limestone Aggregates

Alt# 3 Diversion Channel South with Single Line Protection – This alternative (Figure 27) would be the same as Alternative #2 with the exception that this alternative would only include levees on one side of the new diversion channel, the Municipality side or east of the channel. The west side of the channel would be graded and/or bermed to certain elevations to ensure waters stay within the designated flowage.

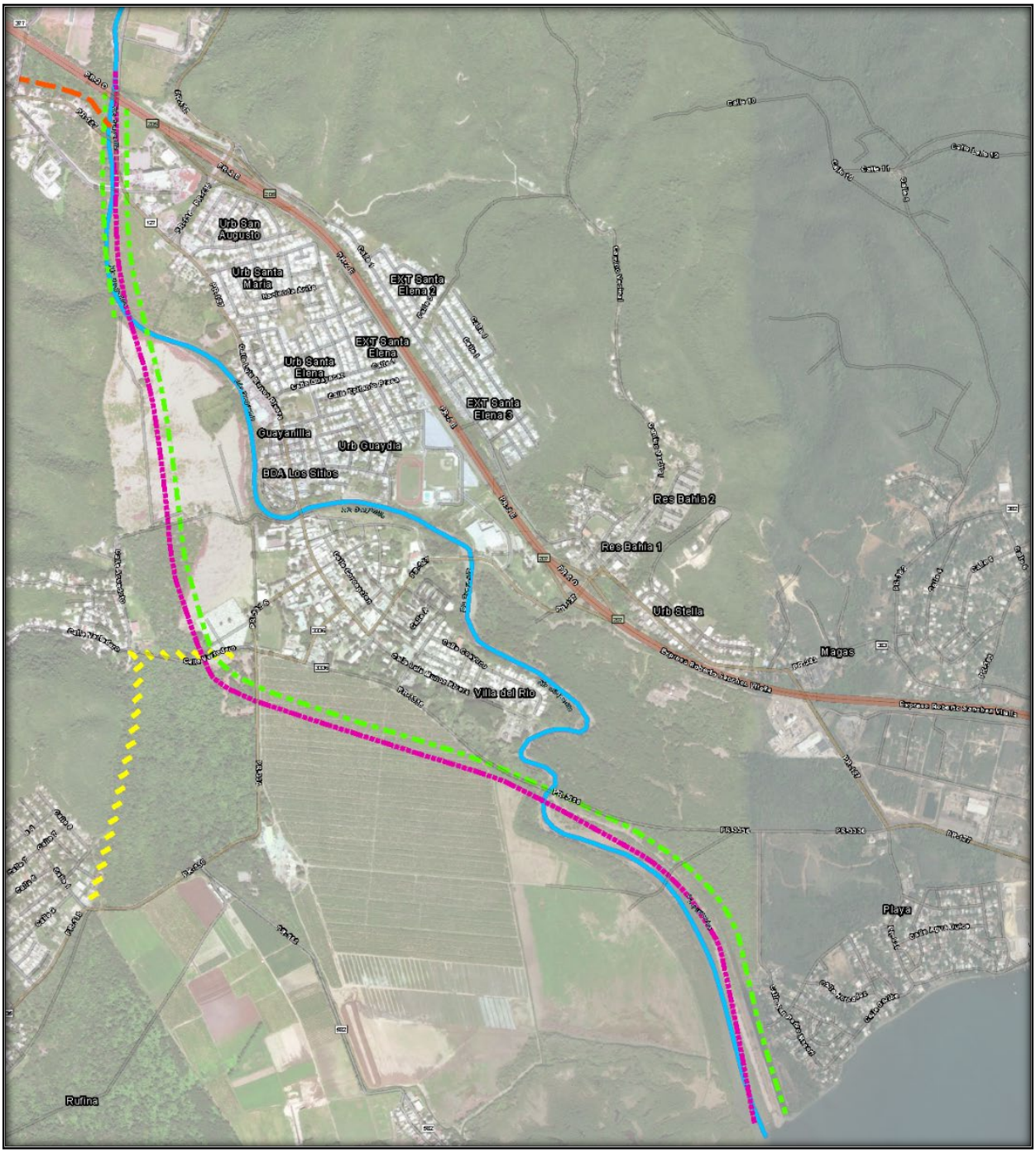

Figure 27: Alternative 3 Diversion Channel South w/ Single Line Protection

Alt# 4 Diversion Channel North with Double Line Protection – This alternative would involve the construction of an engineered diversion channel between the end of the montane unit and beginning of the coastal plain unit of the Rio Guayanilla near PR-2 (Figure 28). A concrete diversion structure would be set in place across the natural river channel to direct flows into the engineered diversion channel. Channel improvements (grading and shaping) would occur upstream of the diversion structure to provide conveyance into the diversion area. There will be several reaches where the natural channel would be abandoned.

The alignment for this alternative does not direct flood water away from the Municipality, but through it via a combination of new channel and channelization of the Rio Guayanilla. A new channel would be excavated north of the Municipality through forest habitat to connect to the constructed Phase I project near PR-3336.

The length of newly constructed diversion channel would be approximately 3,280 feet and the length of channelized river would be 1,980 feet. The diversion channel itself would be an engineered trapezoidal construction with a bottom width of 100-feet and 2:1 side slopes. This alternative would have levees on both sides of the diversion channel and channelized reaches of the Rio Guayanilla.

Channel materials and construction would be the same as Alternatives #2 and #3.

A robust woody debris and sediment/rock removal plan would need to be implemented to ensure the alternative would successfully convey floodwaters due to the channel flowing through the Municipality, where numerous bends and road crossing in the channel would become clogged with riverine debris. Removal of impediments to flow in the existing channel would take place during project construction as well as periodically during O&M.

The Flood Warning System would be developed collaboratively by the USACE, USGS, the NFS, the municipality and Emergency Services.

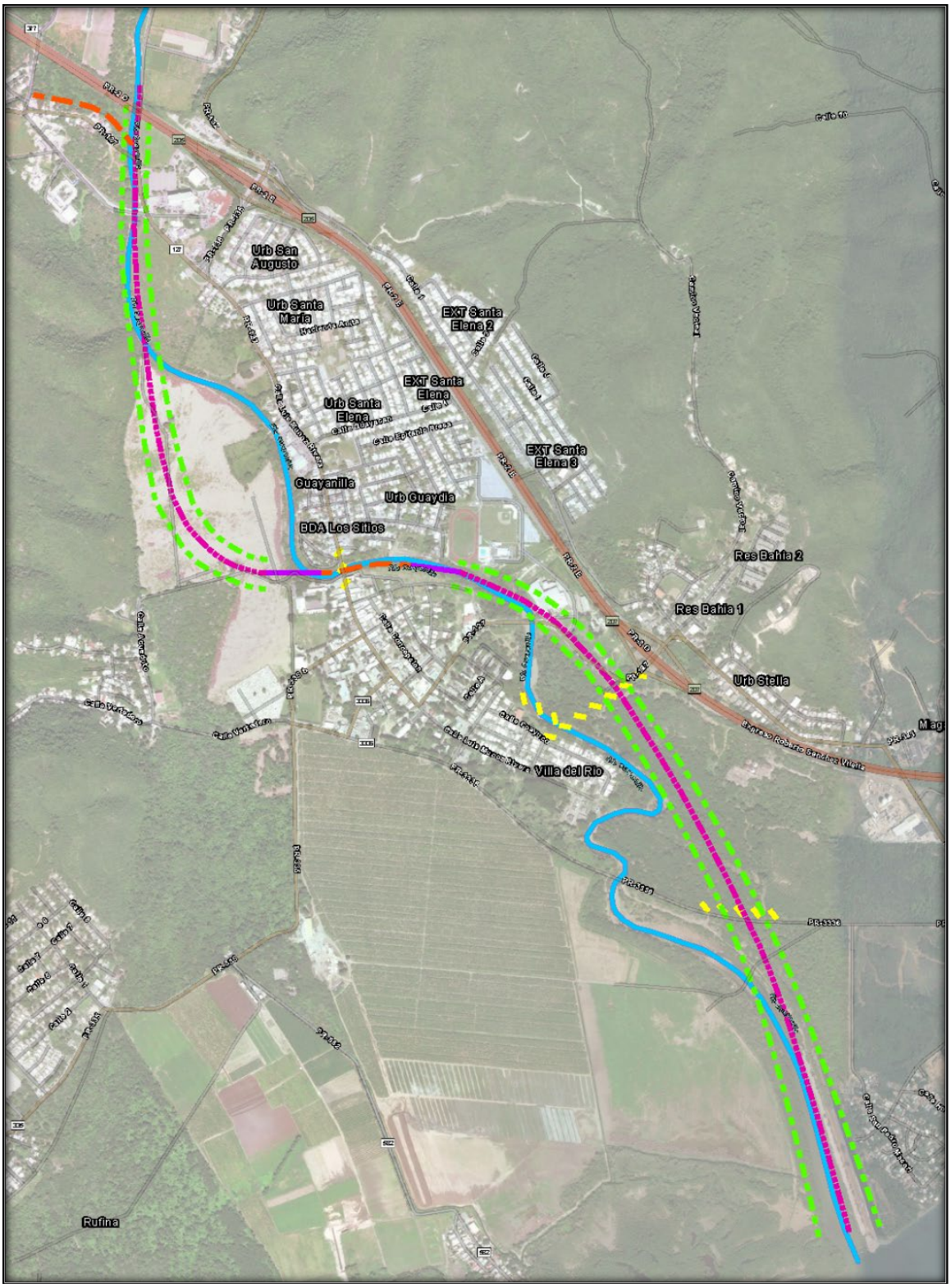

Figure 28: Alternative 4 Diversion Channel North w/ Double Line Protection

Alt# 5 Staged Greenway Terraces with Double Line Protection – This alternative would involve the construction of a naturalistic greenway diversion channel between the end of the montane unit and beginning of the coastal plain unit of the Rio Guayanilla near PR-2 (Figure 25). A robust diversion structure would be set in place across the natural river channel to direct flows into the greenway diversion channel. Channel improvements (grading and shaping) would occur upstream of the diversion structure to provide conveyance into the diversion area.

The alignment for this alternative directs flood water away from the Municipality and to the west along the confining mountain valley wall. The diversion channel would primarily cut through agriculture fields and join up with constructed Phase I project near PR-3336.

The length of the channel is approximately 9,000 feet long. The diversion channel itself would be a non-engineered, bowl and terrace shaped construction to allow channel morphology to be formed by flood pulses. This type of channel may be 6 to 7 times wider than Alternative #2 to ensure hydraulic forces do not degrade the integrity of the levees and terraces. The bottom width would range between 100-feet and 2:1 side slopes to 700-feet and 10:1 side slopes. Particular reaches, such as that next to the cemetery, would need to have engineering channel features due to the limited space available for greenway widths to be implemented. This alternative would have levees on 2 sides of the diversion channel.

Channel materials and construction would be the same as Alternatives #2 and #3. Removal of impediments to flow in the existing channel would take place during project construction as well as periodically during O&M. The Flood Warning System would be developed collaboratively by the USACE, USGS, the NFS, the municipality and Emergency Services.

Certain terrace reaches may require engineered features to prevent erosion at critical hydraulic points. The bottom of the channel would have erosion control features embedded at select points in the channel where hydraulic models indicate incision or meandering potential exists. Expectations for these features are that they could move as a result of hydraulic forces. Erosion protection requirements for the channel would be monitored since deposition would be greater than erosion in this wider channel. The terraced areas would receive different rates of deposition and material size depending on flow velocities. Once the system comes to dynamic equilibrium, erosion and deposition would be balanced and riverine ecosystem communities would develop. The low flow channel and levees would be kept free of woody vegetation via clearing or mowing only allowing grasses and forbs to grow; second or third terraces outside of the active flood areas could support sparse tree and shrub communities as their effects on flows and levee integrity would be negligible in these locations. Vegetation would need to carefully managed to ensure no loss of capacity in the diversion channel. Further, invasive plant species management would be done during construction, which includes keeping a short list of aggressive non-native species (African Guinea Grass, Canario Morado Falso) out of the project foot print while other native plant species establish.

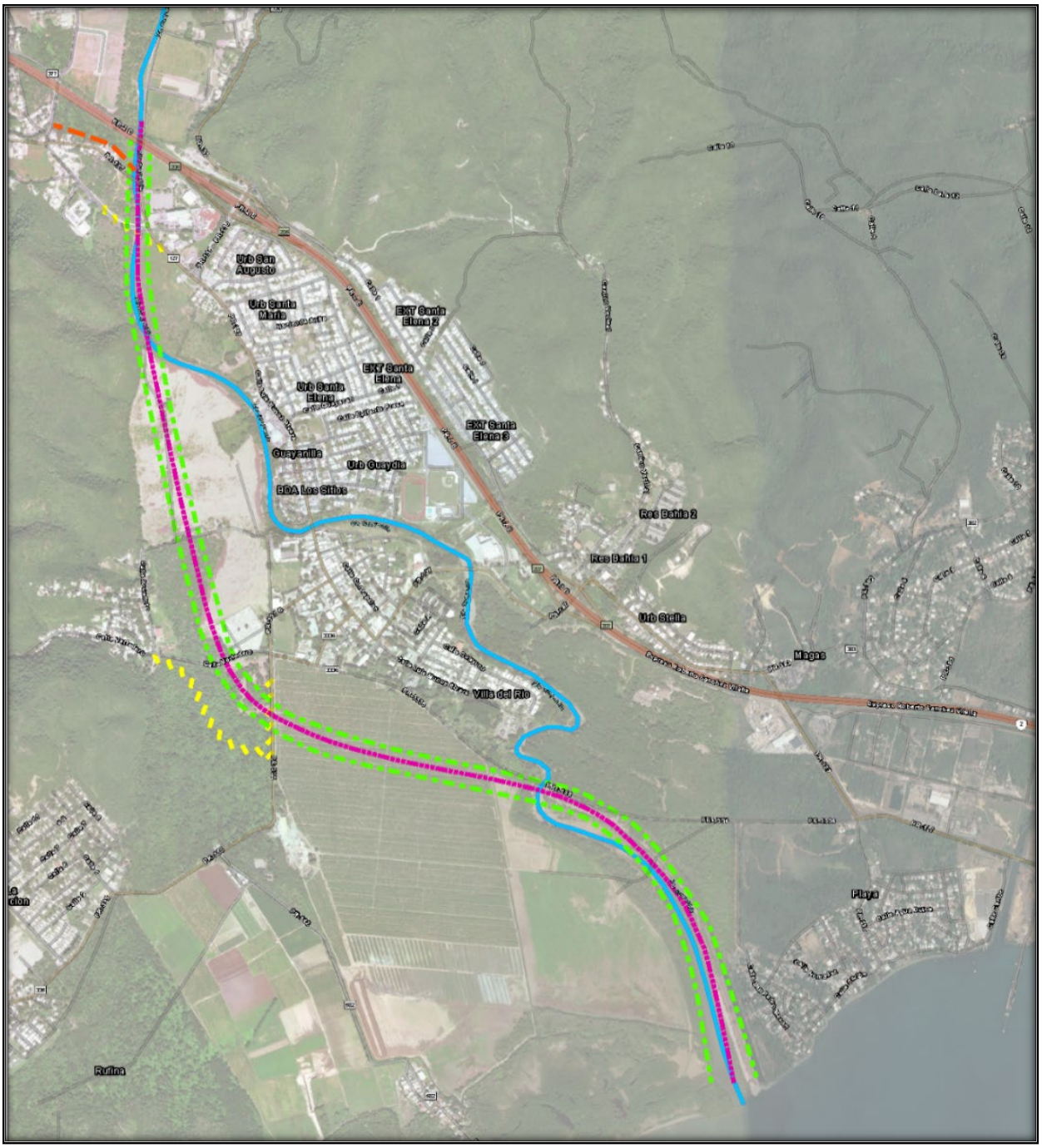

Figure 29: Alternative 5 Staged Greenway Terraces w/ Double Line Protection

Alt# 6 Staged Greenway Terraces with Single Line Protection – This alternative (Figure 30) would be the same as Alternative #5 except for the following. This alternative would have levees on one side of the new diversion channel only, the Municipality side or east of the channel. The west side of the channel would be graded to certain elevations to ensure waters stay within the designated flowage. The terraced greenway footprint for this alternative would be very wide in certain sections, about 780-feet based on current hydrologic and hydraulic modeling. Removal of impediments to flow in the existing channel would take place during project construction as well as periodically during O&M. The Flood Warning

System would be developed collaboratively by the USACE, USGS, the NFS, the municipality and Emergency Services.

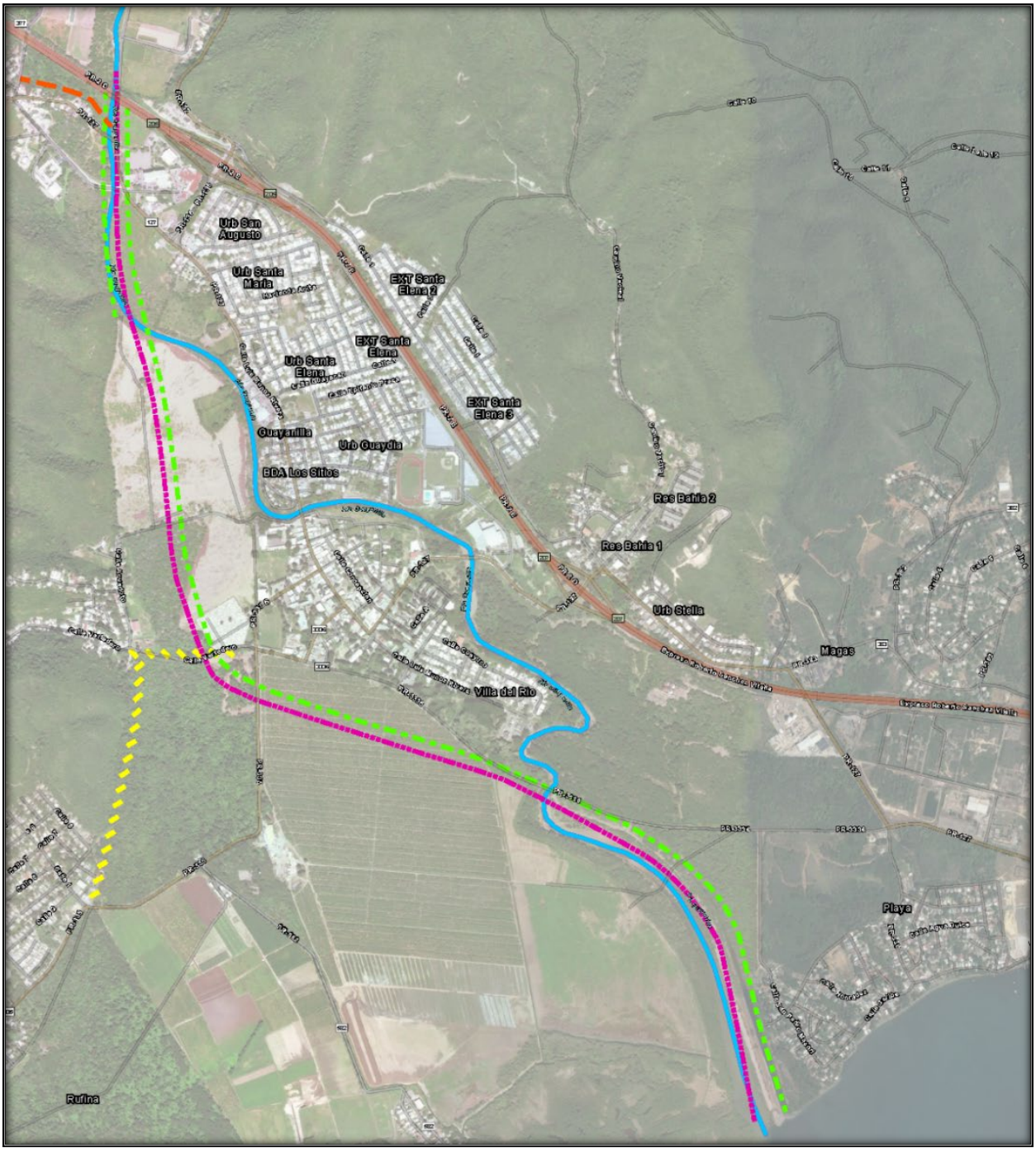

Figure 30: Alternative 6 Staged Greenway Terraces w/Single Line Protection

3.4.4 *Alternative Screening*

The six action alternatives (Alt #1–6) were screened utilizing relevant USACE planning guidance and compared against the No Action alternative (Alt #0) (Tables 21 and 22). Table 21 depicts the final array of alternatives after the completion of the screening process. Table 21 depicts the screened and retained alternatives including the measures that compose each of the alternatives. The ten criteria applied during the screening process included: Completeness (C), Effectiveness (E), Efficiency (Ef), Acceptability (A) (the four criteria established in the P&G (1986)), as well as Life-Safety (LS), Natural Resources Effects (NR), Hazardous-Toxic-Radiological Waste (HTRW) considerations, Real Estate requirements (RE), Utility Relocation (U), and Sustainability O&M requirements (O&M). These screening criteria are defined and presented in *Appendix A1*, and illustrated below in Table 22. Each of the 10 screening criterion was assigned a qualitative score from 0–4 to differentiate between alternative plans, having a maximum score possibility of 40. Detail on screening rationale and scoring is provided in *Appendix A* as the Alternative Screening Matrix and summarized as follows.

Table 21: Alternatives Screening Summary; Green Retained, Red Eliminated

Measure Category	Measure Description	Alt 0	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
No Action	Existing & FWOP Conditions	X						
Nonstructural Measures	Flood Warning System		X					
	Removal of Impediments to Flow		X					
Structural Measures	Levees/Floodwalls Single Line Protection				X			X
	Levees/Floodwalls Double Line Protection			X		X	X	
	Bridge & Conveyance Modifications			X	X	X	X	X
	Engineered Features & Bank Protection			X	X	X	X	X
	Diversion Channel (North)					X		
	Diversion Channel (South)			X	X			
	Rehabilitate Phase I (DNER Constructed)			X	X	X	X	X
	Vegetation Control			X	X	X	X	X
	Utility Relocation			X	X	X	X	X
Nature-based Measures	Staged Greenway Terraces						X	X
	Minor Nature Based Features		X	X	X	X	X	X
	Vegetation Control						X	X

This screening analysis as numerically depicted in (Table 22) was used to guide decisions on which of the developed alternatives would be retained for further detailed economic and environmental analyses. In general the alternatives, with the exception of Alternative #4, resulted in total scores within five points of one another (between 24 and 29 points of a possible 40). Structural Alternatives #2 and #5 included the same suite of measures with one exception. Alternative #2 incorporated a double line of protection with the engineered channel; while Alternative #3 included a single line of protection on the north side of the channel. There is a similar distinction between the two greenway alternatives: Alternative #5 includes a double line of protection, while Alternative #6 includes a single line of protection. Preliminary analyses determined that potential risks associated with structures to the south of the engineered channel would not warrant the construction of the additional line of protection. The screening process also identified areas where additional design consideration would be needed to address concerns identified for each of the alternatives. sRetaining Alternatives #1, #3 and #6 basically came down to being the most Efficient, Cost Effective, and Environmentally Acceptable. A summary of the screening analysis, by alternative follows Table 22.

Table 22: Alternative Screening Score Summary

Alt #	Alternative Name	Score	C	E	Ef	A	LS	NR	HTRW	RE	U	O&M
0	No Action	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	Nonstructural Measures	28	2	2	4	4	1	4	2	4	4	1
2	Diversion Channel South w/ Double Line Protection	24	3	4	2	2	3	1	3	3	2	1
3	Diversion Channel South w/ Single Line Protection	25	3	4	3	2	3	1	3	3	2	1
4	Diversion Channel North w/ Double Line Protection	9	3	2	0	1	0	0	3	0	0	0
5	Staged Greenway Terraces w/ Double Line Protection	28	3	4	2	4	4	2	3	1	2	3
6	Staged Greenway Terraces w/ Single Line Protection	29	3	4	3	4	4	2	3	1	2	3

Alternative #0 No Action: This alternative is always retained to depict the future without project conditions and is required by NEPA.

Alternative #1 Nonstructural Measures: Although this alternative would not provide adequate levels of hazard or vulnerability protection on its own, it was retained for further evaluation. Having a flood warning system in place is always prudent in terms of public awareness for both the "with" and "without" project scenarios. Also, this alternative would ensure the natural channel of the Rio Guayanilla would provide sufficient conveyance for both flood risk reduction support and ecosystem connectivity, this alternative was retained as an important Efficiency and Life Safety plan component.

Alternatives #2 Diversion Channel South w/ Double Line Protection: This alternative entails the use of two levees designed to USACE specifications, one on each side of the diversion channel. Hydrologic and hydraulic modeling (*Appendix B*) found that it is necessary to have a levee on the east side, or Municipality side of the diversion channel, whereas natural topography and land use to the west precludes the need for one. This alternative was screened out on the basis of Cost-Effectiveness due to the increased cost associated with the additional line of protection versus Alternative #3. Therefore, Alternative #2 was not retained for further detailed economic and environmental evaluation. This alternative also includes two non-structural measures.

Alternative #3 Diversion Channel South w/ Single Line Protection: This alternative had the second highest score in terms of providing positive aspects to the given criteria components, as it shows merit in terms of Cost Effectiveness, minimizing Real Estate needs and being an efficient plan. This alternative also includes the two non-structural measures contained in Alternative #1.

Alternative #4 Diversion Channel North w/ Double Line Protection: This alternative was screened from further analysis due to the significant damage it would cause to natural resources and therefore result in high mitigation costs and low levels of acceptability to resource agencies. This alternative would also result in an unacceptable level of residual risk to life safety, increased Real Estate needs from multiple parcel owners and have technical and feasibility issues in terms of engineering and sustainability.

Alternatives #5 Staged Greenway Terraces w/ Double Line Protection: This alternative concept is different in that it would create a wide naturalistic channel for the diversion of water. This alternative would entail the use of two levees designed to USACE specifications, one on each side of the diversion channel or terraced greenway. Hydrologic and hydraulic modeling (*Appendix B*) found that it is necessary to have a levee on the east side, or municipality side of the greenway diversion, whereas natural topography and land use to the west precludes the need for one. This alternative was screened out on the basis of Cost-Effectiveness due to the increased cost associated with the additional line of protection versus Alternative #6. Therefore, Alternative #5 was not retained for further detailed economic and environmental evaluation. This alternative also includes two non-structural measures.

Alternative #6 Staged Greenway Terraces w/Single Line Protection: This alternative had the highest score in terms of providing positive aspects to the given criteria components, as it shows merit in terms of Cost Effectiveness and Acceptability, providing increased habitat and being an efficient plan.

3.5 Focused Array of Alternatives

Screening of the initial alternative analysis resulted in the three alternatives, plus the No-Action Alternative, being carried forward as the Final Array of Alternatives. Alternative #3 and #6 are not combinable. Alternative #1 was combined with Alternative #3 and #6, but can also be implemented on its own without addressing flood hazards or their effects. More detail in terms of costs, benefits, indirect benefits, regional economic benefits, environmental effects and other social effects were developed for each of these alternatives in order to support plan selection:

- No Action Plan
- Alternative #1 Non-Structural Measures
- Alternative #3 Diversion Channel South w/ Single Line Protection
- Alternative #6 Staged Greenway Terraces w/ Single Line Protection

3.5.1 Focused Array Conservation Planning & Optimization

On March 01, 2019 a project evaluation document was provided to the USFWS-CESFO that described the formulation and results of measures and subsequent alternatives presented above (*Appendix A4*). In response, the USFWS provided the following guidance for engaging avoidance and minimization planning to reduce effects to fish and wildlife habitat and T&E species to less than significant.

Disposal Areas – It was recommended to 1) place all excavated material in upland locations to avoid impacts associated filling lowland and wetland land types; 2) to utilize excavated material for ecosystem restoration purposes; and 3) to make these materials accessible should beneficial reuse or commercial need arise. To avoid affects/effects, engineering investigations were based on these requirements. Three (3) upland locations for Alternative #3 (Figure 31) and one (1) lowland location that had been previously impacted by industry for Alternative #6 (Figure 32) were located and added to respective alternatives.

Diversion Structure & Natural River Channel – It was recommended to avoid or minimize the effects associated with placing a diversion structure across the natural channel of the Río Guayanilla. The main impacts of concern associated with placing this diversion structure across the channel include 1) fish and aquatic organism passage; 2) sediment transport and substrate sorting; and 3) river channel hydrology. To reduce effects to less than Significant, the diversion channel structure design was modified to include features that would allow water, sediment (substrates) and animal passage through the structure during low and high flows. The team determined that a set of culverts, either with no bottom or half buried in the substrates of the river, would be the most cost effective means. This method has effectively been used in the past globally. To be in harmony with the flood risk management alternative, the culverts would be sized to only allow the passage of near bank full flow or less through to the existing channel. This would keep all flows in the natural channel in-bank while still producing enough force to induce sediment transport through the culverts and downstream to the bay. This conservation measure was deemed negligible in terms of cost or its effects on the diversion structure itself and/or other alternative components. This conservation measure is the same for Alternatives #3 and #6.

Levees & Mangrove Coastal Zone – It was recommended to avoid cutting off freshwater floods and sediment from entering the 240-acre mangrove coastal zone between the Río Guayanilla mouth and the El Faro neighborhood. The configuration of the berms as depicted in Alternative #3 (Figure 29) and Alternative #6 (Figure 30) show that the initial alignment extended all the way to the ocean on the west side of the DNER Phase I project. This would effectively cut off a source of freshwater and sediment supply that mangrove communities require. To avoid significant adverse impact to 240 acres of interior basin mangrove swamp, the team evaluated other options for providing flood risk reduction to the El Faro neighborhood. Through a series of iterations, an optimized measure was developed for this portion of the project area. The optimized measure developed included truncating the western riverside berms on the diversion channel just downstream of the beginning of the Phase I project and a smaller set-back levee located at El Faro (Figure 30 & Figure 31). This would effectively allow overbank flooding and sediment inputs into the 240 acre mangrove zone, while protecting the neighborhood of El Faro. In addition, this optimization measure eliminated adverse tail water conditions in this lower reach by opening up the river outlet to a more natural flow condition. This conservation measure was deemed negligible in terms of cost impacts and positive in terms of alternative functionality and preserves the natural and beneficial uses of this portion of the floodplain. This conservation measure is the same for Alternatives #3 and #6.

Rock Quarry & Subtropical Dry Forest – It was recommended to avoid and minimize high quality Dry Forest Habitat in the mountain range on the west side of the study area. This area had been identified to provide habitat and life requisites for at least five (5) federally listed species and over 20 endemic rare plants. It was recommended to avoid as much high quality habitat as possible while reducing the affected area as much as possible. The initial two sites considered shown in Figure 26 were quite large (between 60 – 100 acres) and located in an area of high biodiversity with the likelihood of five federally listed species being present. In order to reduce effects considerably, the PDT with assistance from the USFWS-CESFO both reduced the size of the quarry's affected acreage and located a formerly used quarry site that was within the study area. Utilizing topography and geologic information of the new abandoned quarry site, civil and geotechnical investigations reduced the borrow area size to about 7-acres. The reduced size and effects quarry site is shown in Figure 33. This avoidance planning change was deemed negligible in terms of cost impacts and alternative functionality for both Alternatives #3 and #6. This optimized alternative for fish and wildlife and federally listed species would be the starting point for the endangered species effects determination discussed in Section 5.6.8.

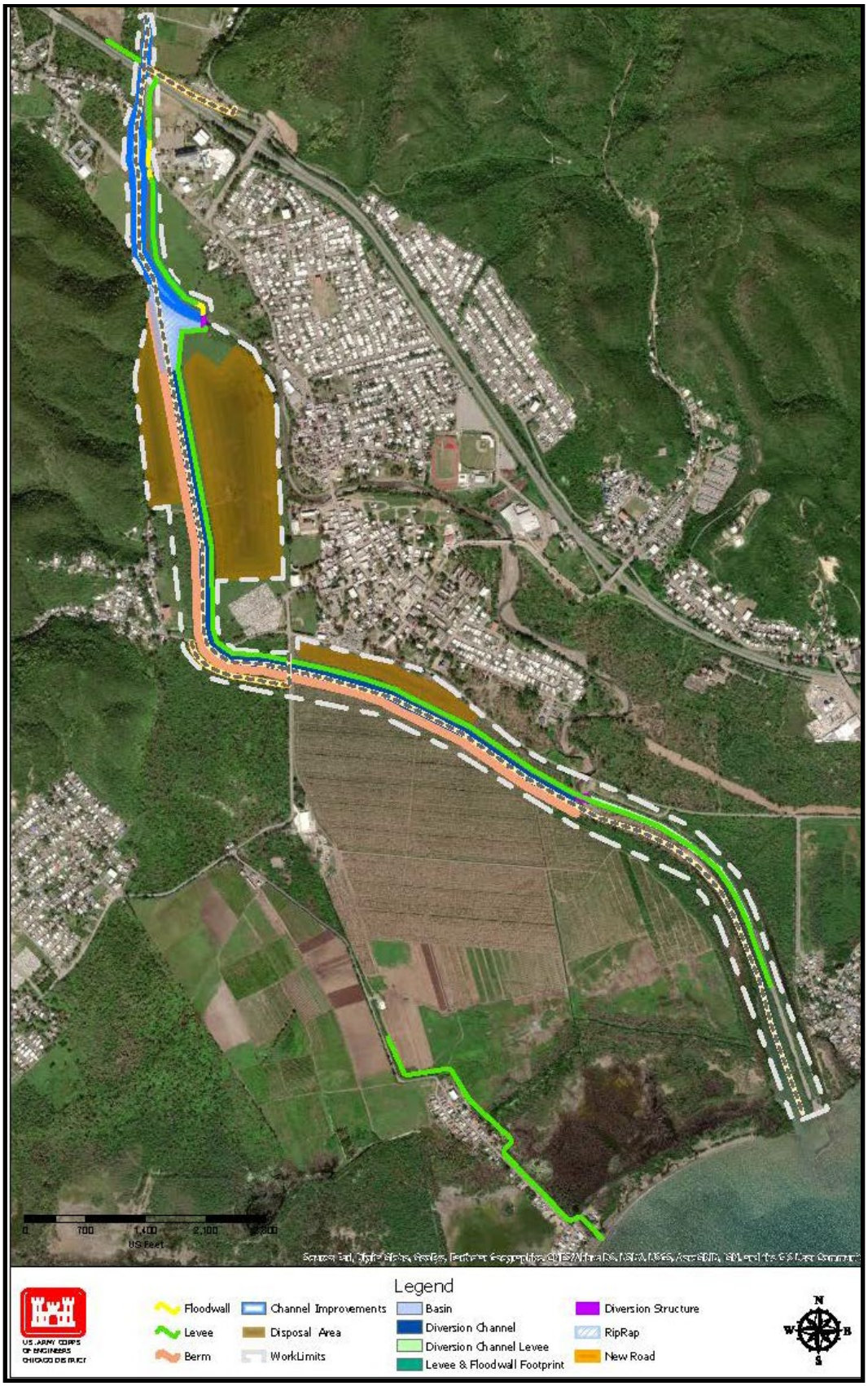

Figure 31: Alt#3 Diversion Channel South w/ Single Line Protection - Detailed

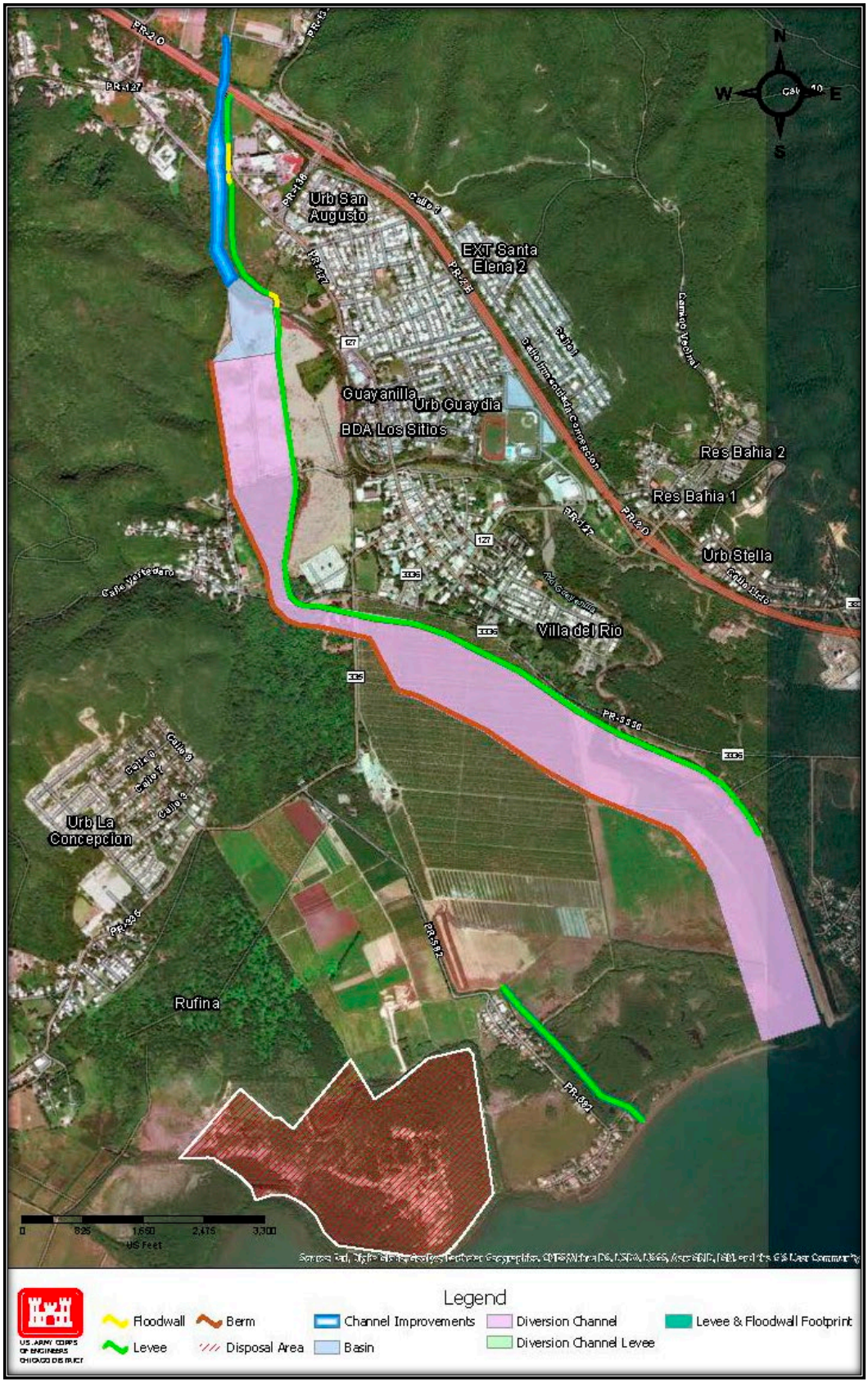

Figure 32: Alt#6 Staged Greenway Terraces w/ Single Line Protection - Detailed

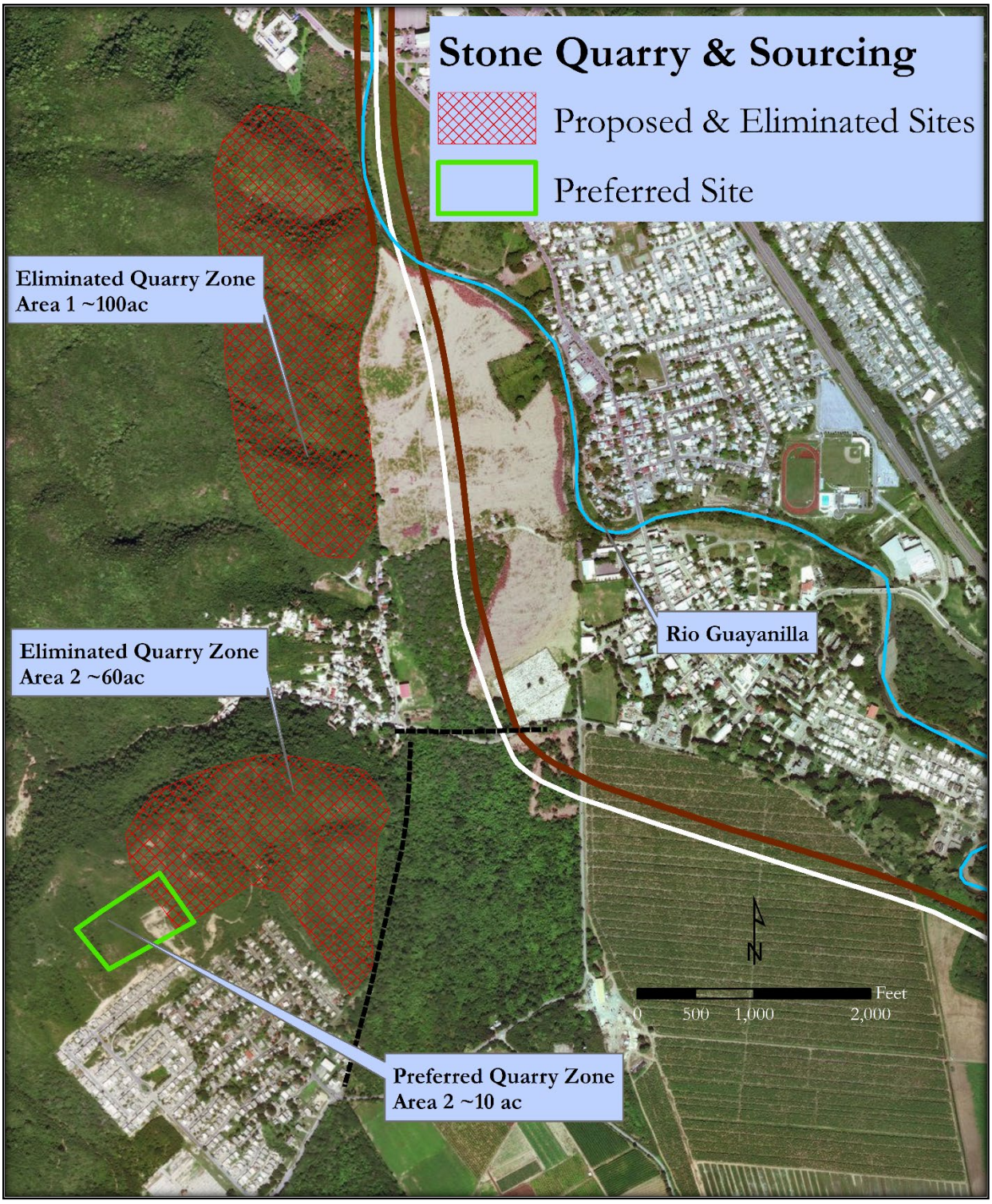

Figure 33: Stone Quarry Alternatives

4.0 Economic Comparison of Final Alternative Array*

4.1 Study Reaches

Numerical modeling was utilized to establish with- and without-project conditions that formed the basis of the economic comparison of the final array of alternatives. Hydrologic modeling was accomplished using HEC-HMS models. Riverine hydraulics were evaluated with HEC-RAS models. Detailed discussion on the development of these models, and the results of the with- and without-project simulations are included in *Appendix B, Hydrology and Hydraulics*.

Economic evaluation of flooding impacts were conducted using an HEC-FDA model for with- and without-project conditions for base and future years, with a base year of 2026 and a period of analysis of 50 years. The HEC-FDA model resulted in no change for future year damages from the base year, and thus expected annual damage estimates presented below are equivalent in the base and future year. The model included depreciated structure and content replacement values for the study area. Study reaches were delineated by H&H in HEC-RAS to separate flows and water surface elevations by area. Channel damage reaches are shown below. Note that Reach 1R is excluded from damage tables below since there are no structural damages expected to occur in this reach. Output from the various HEC-RAS simulations (with and without project) were input into the HEC-FDA model and used to evaluate flood damages. Additional information on the development of the economic modeling is included in *Appendix C, Economic Analyses.* Evaluations were completed for the without project condition and Alternative #3 and Alternative #6.

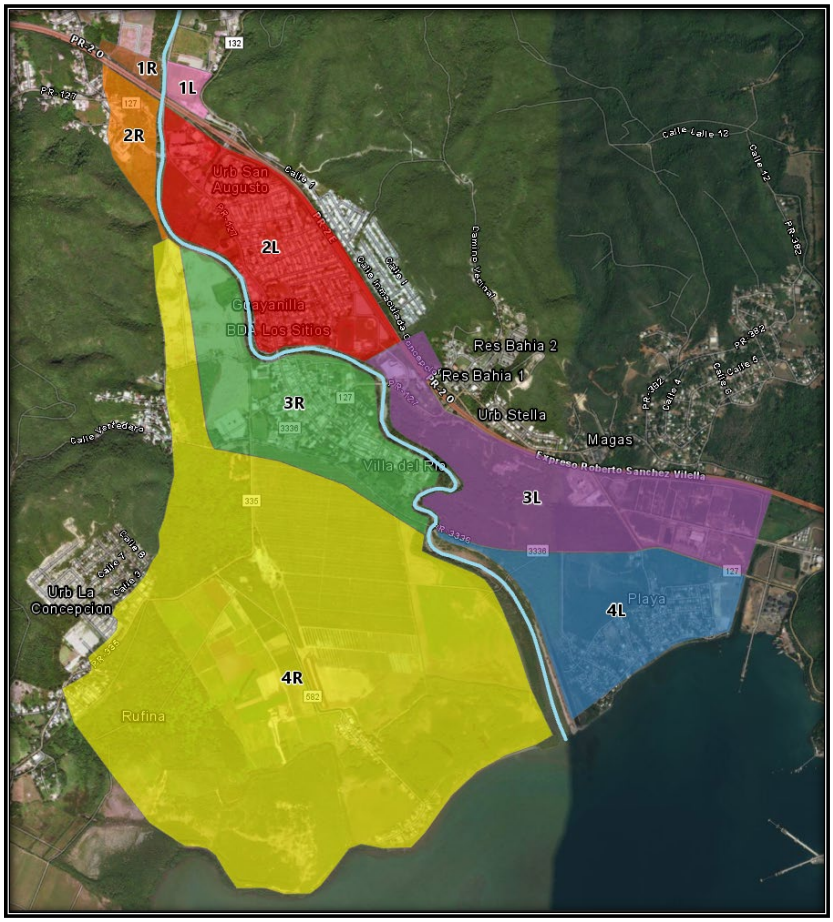

Figure 34: Study Area Channel Reaches for Damages Analyses

4.2 Expected Annual Damages and Benefits for Existing and Alternative

Table 23 presents expected annual damages for the without project condition, and for Alternatives #3 and #6.

Table 23: Expected Annual Damages (EAD), $000, FY 2020 Price Level

Reach	Without Project EAD	Alternative 3 EAD	Alternative 6 EAD
1L	52	33	33
2R	122	17	17
2L	4,387	309	315
3R	5,915	56	62
3L	77	0	0
4R	6,605	164	107
4L	2,686	0	13
Total	19,844	579	548

Note: Includes damages to structure and structure contents, vehicles, emergency and clean-up costs, and agricultural damages.

Expected annual damages under existing conditions are estimated to exceed $19 million over a 50-year period of analysis. Under with project conditions expected annual damages are reduced to $579,000 and $548,000, for Alternative #3 and Alternative #6, respectively.

Table 24 and Table 25 display with project benefits, which include structure and structure contents, other related flood damage categories (damages to vehicles and agriculture, and emergency and clean-up costs), and National Flood Insurance Program costs. Estimates shown are for both Alternative #3 and Alternative #6.

Table 24: With-Project Benefits Alternative 3, $000 FY 2020 Price Level

Reach	Structure and Structure Contents	Other Related Flood Damage Categories	National Flood Insurance Program	Underemployed Labor Resources	Total Average Annual Benefits
1L	16	3	0	-	19
2R	93	11	1	-	106
2L	3,546	532	94	-	4,174
3R	5,346	512	63	-	5,913
3L	74	4	1	-	78
4R	5,180	1,262	25	-	6,513
4L	2,179	507	88	-	2,741
Total	16,434	2,832	272	485	20,022

Total average expected annual benefits for Alternative #3 are $20 million. Structure and content benefits account for $16 million of that sum, while other flood related damage categories account for $2.8 million in benefits. Annual national flood insurance program benefits, which are costs avoided in flood insurance as a result of the project, equate to $272,000 annually. Underemployed labor resource benefits are $485,000 annually.

Table 25. With-project Benefits Alternative 6, $000 FY 2020 PL

Reach	Structure and Structure Contents	Other Related Flood Damage Categories	National Flood Insurance Program	Underemployed Labor Resources	Total Average Annual Benefits
1L	16	4	0	-	20
2R	93	11	1	-	106
2L	3,541	531	94	-	4,166
3R	5,341	512	63	-	5,916
3L	74	4	1	-	78
4R	5,231	1,267	25	-	6,523
4L	2,168	505	88	-	2,761
Total	16,464	2,833	272	696	20,265

Average expected annual benefits for Alternative #6 are $20.3 million. The difference in average annual benefits between Alternative #3 and #6 is due to slight differences in structures and contents damages reduced, and higher underemployed labor resource benefits under Alternative #6.

Table 26: Number of Structures Damaged by Flood Event and Structure Type

AEP Event	0.2		0.02		0.01		0.002	
Condition	Existing	With Project	Existing	With Project	Existing	With Project	Existing	With Project
Residential	220	0	868	3	1,065	17	1,187	736
Public	16	0	72	1	88	3	96	62
Commercial	59	0	227	0	286	4	316	205
Total	295	0	1,167	4	1,439	24	1,599	1,003

Table 25 displays the number and type of structures damaged by flood event and project condition. With project includes either Alternative #3 or Alternative #6. Under existing conditions, a total of 1,599 structures are estimated to be damaged in a 0.002 AEP flood event.

4.3 Cost Estimates for Alternatives #3 and #6

Preliminary cost estimates were developed for Alternatives #3 and #6 (Table 27). The largest difference between costs for these alternatives include the access bridge that will be built over the diversion channel (the bridge will be longer and more costly due to channel width under Alternative #6), and the operations and maintenance costs.

Table 27: Costs by Alternative, 2.75% ($) FY 20 Price Level

	Alternative #3	Alternative #6
Investment Cost		
Construction Cost	128,526,000	203,258,000
LERRDs	25,815,000	27,145,000
Subtotal First Cost	154,341,0000	230,403,000
Interest During Construction	8,501,000	12,691,000
Total Gross Investment	162,843,000	243,094,000
Annual Cost	6,032,000	9,004,000
OMRR&R	39,000	340,000
Average Annual Cost	6,070,000	9,344,000
Average Annual Benefits	20,022,000	20,265,000
Net Annual Benefits	13,951,000	10,920,000
Benefit to Cost Ratio	3.3	2.2

Costs shown in Table 27 are calculated at the current federal discount rate of 2.75 percent, with a four-year construction schedule. Total firsts costs exceed $154 million for Alternative #3, and first costs are approximately $230 million for Alternative #6. Average annual costs are $6 million for Alternative #3 and $9.3 million for Alternative #6. Annualized first costs and annual O&M costs are lower for Alternative #3 than Alternative #6.

4.4 Selection of a Recommended Plan

Per USACE Guidance, the PDT tentatively selects the alternative that maximizes net benefits as the recommendation for this Flood Risk Management Study; this is also called the NED Plan. In order to determine which alternative is the NED Plan, the costs and benefits for the Final Array of Alternatives were compared. The alternative with the greatest net benefits is the NED Plan, and thus the Recommended Plan.

Table 28: Plan Comparison Summary 2.75% ($)

	Alternative 3	**Alternative 6**
Total First Costs	154,341,000	230,403,000
Average Annual Costs	6,070,000	9,344,000
Average Annual Benefits	20,022,000	20,265,000
Average Annual Net Benefits	13,951,000	10,920,000
BCR	3.3	2.2

Table 28 shows that average annual net benefits for Alternative #3 are $14 million at the 2.75 discount rate and $11 million for Alternative #6. Since Alternative #3 has the highest net NED benefits, it is the Recommended Plan. Alternative #3 has a BCR of 3.3 and Alternative #6 has a BCR of 2.2 at the 2.75 percent discount rate.

5.0 Environmental Effects*

5.1 Introduction

This chapter presents the effects associated with implementing any of the alternatives identified in Section 3.5 – Focused Array of Alternatives. The No Action Alternative is required by NEPA and other laws and regulations; and is briefly described as the Future Without Project Conditions presented under each resource category in Chapter 2–Affected Environment*. The evaluation of effects is based upon a comparison of what the federal action alternative would have on resource categories considering historic, existing and future without project conditions. The Future with Project Condition describes what is anticipated to prevail in the future if a particular alternative is implemented. As well, this analysis makes distinction between adverse and beneficial effects. This Chapter mirrors the resources categories presented in Chapter 2.

5.1.1 Impact Analysis

A consequence, or effect (the terms "effects" and "impacts" may be used synonymously (40 C.F.R. § 1508.8)), is defined as a modification to the human or natural environment that would result from the implementation of an action. The three types of effects that may occur when an action takes place are direct, indirect, and cumulative. Direct effects are caused by an action and occur at the same time and place. Indirect effects are caused by an action and are realized at a later point in time or at a greater geospatial distance, but are logically foreseeable. Cumulative effects result from the collection of federal and non-federal actions taking place over the same period of time.

Effects may be temporary (short-term), long lasting (long-term), or permanent. Temporary effects are defined as those that would occur during construction of one of the alternatives. Long-term effects are defined as those that would extend from the end of the construction period through some point within the project life-cycle. Permanent effects are assumed to be present throughout the period of analysis.

Significance thresholds for each resource are used to categorize effects (Figure 35). The effects on each resource may be significant and unavoidable, significant, less than significant, or have no effects. Significant impacts are those that would result in substantial changes to the environment and receive the greatest attention in the decision-making process. Where significant effects are identified, recommended mitigation measures, best management practices (BMPs), and/or other environmental commitments are provided in order to avoid, minimize, or reduce environmental impacts to less than significant.

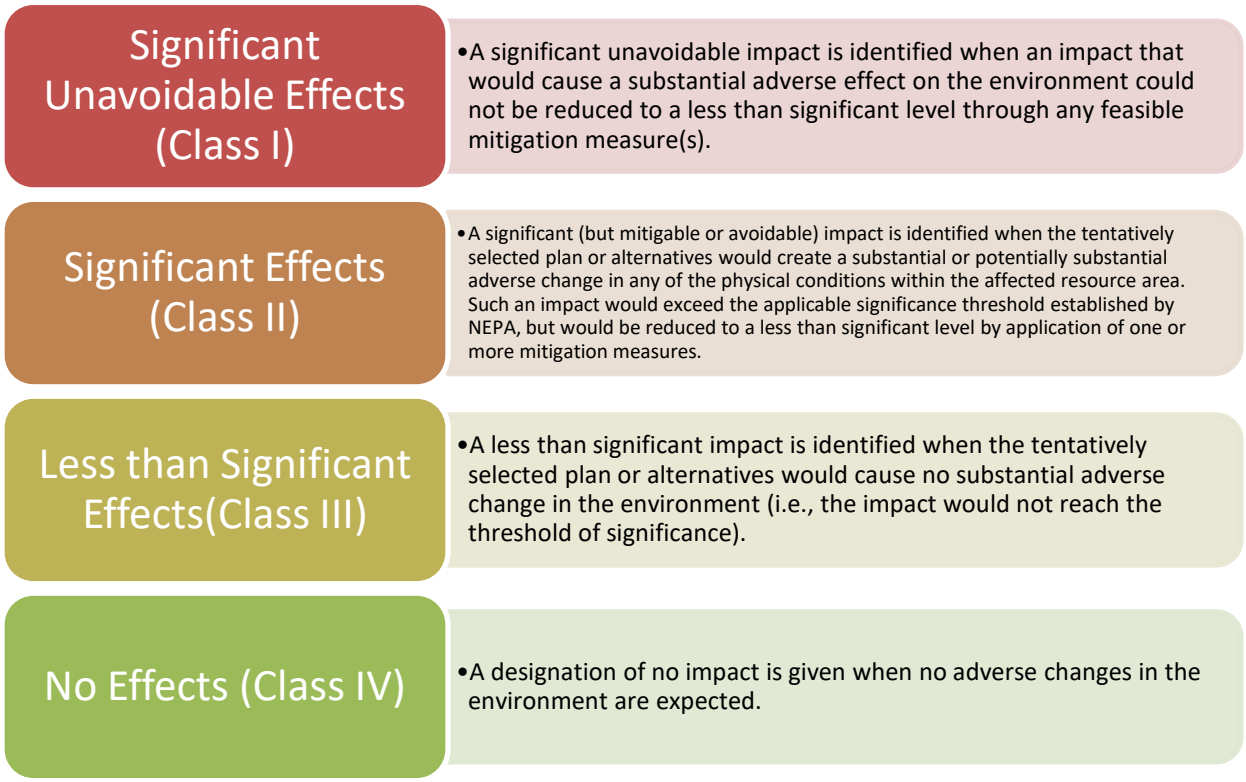

Figure 35: Classification of Effects Thresholds Based on CEQ Guidelines

5.1.2 Alternatives Assessed for Effects

The following tentatively selected alternatives, as described and mapped in Section 3.4, are assessed for effects/impacts to study area resource categories:

- No Action Plan

Assumes the Future without Project condition as if no Federal Action would occur. These conditions are described in Chapter 2.0 – Affected Environment*.

- Alternative #3 Diversion Channel South w/ Single Line Protection

Effects are assessed for excavation of a diversion channel, disposal of excavated material, construction of levee and floodwalls, quarrying of rock, placement of structures in and maintenance of the natural channel of the Río Guayanilla, other associated construction activities, and future operations and maintenance considerations (Figure 31).

- Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Effects are assessed for excavation of a diversion channel, disposal of excavated material, construction of levees and floodwalls, quarrying of rock, placement of structures in and maintenance of the natural channel of the Río Guayanilla, other associated construction activities and future operations and maintenance considerations (Figure 32).

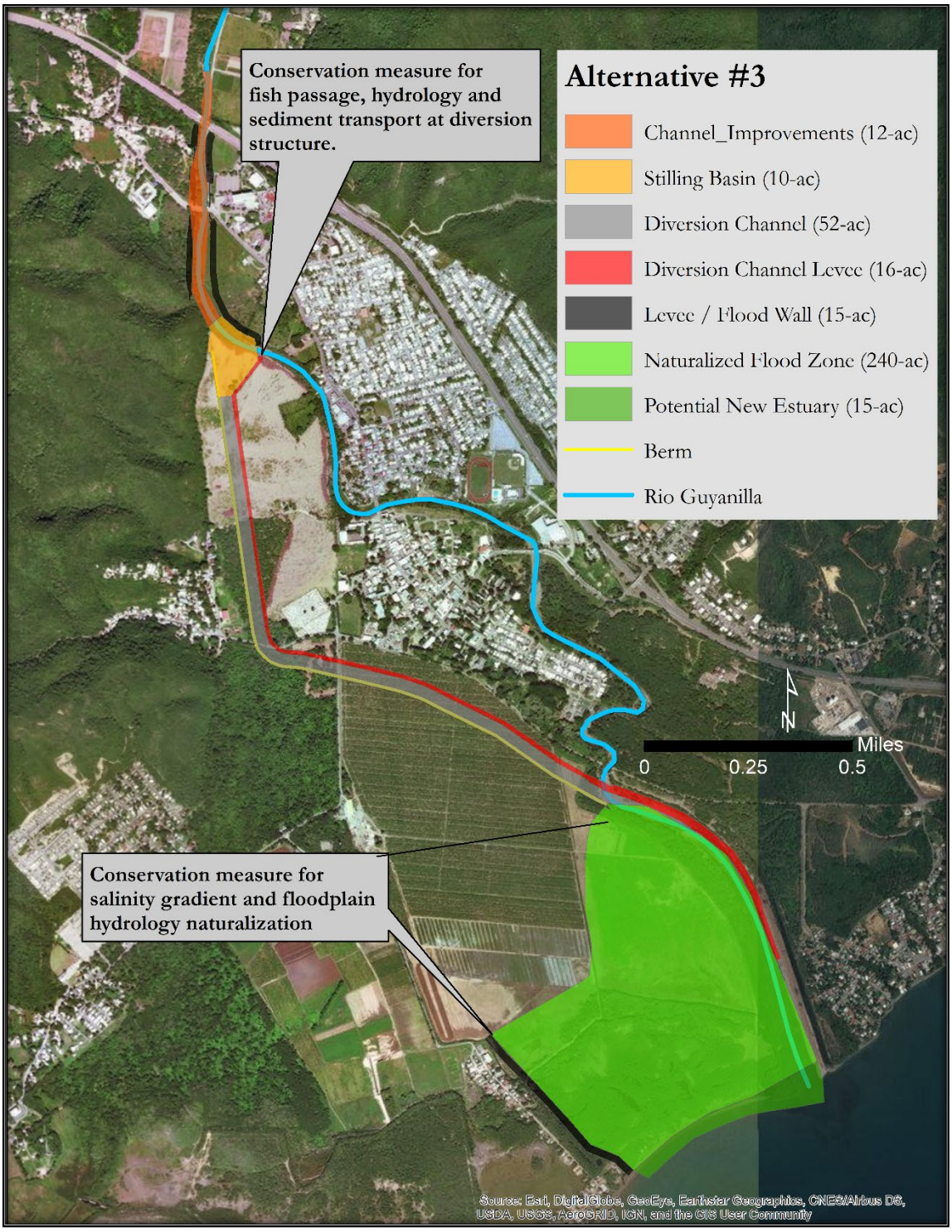

Figure 36: Recommended Plan Alternative #3 Areas and Acres of Affected Environment

5.2 Earth Resources Effects Determination

5.2.1 Geology & Topography

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have irreversible, long-term effects to a portion of the local geology and topography within the study area. Looking at the context and intensity of these effects, however, they are not significant since valued formations would remain intact. Excavation of the diversion channel would change geologic stratigraphy and topography of the alluvial fan formation within the constructed diversion channel and levee footprint. Layers of deposited riverine materials of sand, gravel and silt would be excavated and removed. These conditions would not recover, as a permanent diversion channel would be in its place. Topography would permanently change as well, from a relatively flat surface, to a constructed channel with raised embankments. Special measures are not recommended to offset geologic and topographic changes; all excavated geologic materials would be reutilized beneficially and are discussed further under the mineral resource category. Disposal and stockpile areas are identified in Figure 31.

Rock and concrete materials would be sourced from a former quarry now abandoned that was used to build the neighborhoods of Beldum and Los Indios (Figure 26). The geology and topography of this quarry has been modified from its natural state. A review of mapping shows disturbance on the site since 2003. Disturbed areas have re-vegetated. Additional quarrying activities and removal of materials would be considered minor to the already large scale change that has occurred to the geology and topography at this site.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects as Alternative #3 with the exception that the diversion channel footprint would be between 300-500 feet wider in some sections; however, not as deeply excavated. A portion of the excavated geologic material would remain on site and contoured to create floodplain terraces. Disposal and stockpile areas are identified in Figure 32. Also, due to the wider and more natural channel design, riverine processes would deposit some sands and gravels in the outer extremities of the channel, this would not occur with Alt #3.

5.2.2 Soils

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have irreversible, long-term effects to a portion of the local soils within the study area. Looking at the context and intensity of these effects, however, they are not significant since there is no apparent dependency on the soils by significant ecological or human needs. Also, the soil structure and composition of the soils have been greatly altered by intensive agricultural practices, altered hydrology and infrastructure. Excavation of the diversion channel would remove mostly Constantia, and to a lesser degree Machuelo and Teresa soils from the diversion channel and levee footprint. These soils would be excavated and removed from the area. These conditions would not recover, as a permanent diversion channel would be in its place. Special measures are not recommended to offset spatial loss of soil series; all excavated soil materials would be reutilized beneficially on and off-site.

Rock and concrete materials would be sourced from a former quarry now abandoned, used to build the neighborhood of Beldum and Los Indios. The Aguilita stony clay loam of this area was stripped away when the quarry was first in production. Additional quarrying activities and removal of remaining soils would be considered minor to the already large scale change that has occurred to the soils at this site.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects as Alternative #3 with the exception that the diversion channel footprint would be between 300-500 feet wider in some sections; however, not as deeply excavated. Also, a portion of the excavated soils would remain on site and contoured to create the floodplain terraces that could support native vegetation.

5.2.3 Faults, Seismic Activity & Tsunami

Large faults are common in southern Puerto Rico. Puerto Rico has experienced 4 major earthquakes. Larger earthquakes can lead to tsunamis along the coast but Guayanilla has tsunami evacuation zones identified. None of the alternatives have implications for affecting or aggravating faults, seismic activity or tsunami. All alternatives are considering these natural processes for design and implementation.

5.2.4 Liquefaction & Landslides

Liquefaction is not an issue in the area of the project and most landslides occur in the mountains above the Municipality. None of the alternatives have implications for affecting or aggravating liquefaction or landslides. All alternatives are considering these natural processes for design and implementation.

5.2.5 Hurricane

Typically, 6 to 10 hurricanes develop yearly near Puerto Rico. None of the alternatives have implications to affecting or aggravating hurricane development. All alternatives are considering this natural process for design and implementation.

5.3 Water Resources & Quality Effects Determination

5.3.1 Hydrology & Hydraulics

Climate Change

None of the alternatives have implications for affecting or aggravating climate change. All alternatives consider this concept and USACE guidance for modeling, design and implementation.

Sea Level Rise

None of the alternatives have implications for affecting or aggravating sea level rise. All alternatives consider this concept and USACE guidance for modeling, design and implementation.

Precipitation

None of the alternatives have implications for affecting or aggravating precipitation. All alternatives consider this concept and USACE guidance for modeling, design and implementation.

Land Use

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have irreversible, long-term change to a portion of the agricultural and old field land use within the study area where a permanent diversion channel would be constructed. However, these effects are not significant because of the context in which they occur. Specifically, the alternative does not impact a significant portion of the agricultural land in the region, and the alternative would reduce flood risks to other agricultural areas and residential areas in the local area.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative is similar to Alternative #3, but would take much more agricultural land out of production since the Greenway diversion channel footprint would be between 300-500 feet wider than Alternative #3 in some sections. A portion of the excavated soils would remain on site and contoured to create native planting mediums on the terrace extremities, or could even be utilized as low-impact farming that could cope with being subjected to flooding.

5.3.2 Flooding

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have significant or long-term beneficial effects to human social, health and economic properties of the study area. Removing flood waters from the currently impacted areas achieves study objectives by eliminating risks associated riverine flooding.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have significant or long-term beneficial effects to human social, health and economic properties of the study area. Removing flood waters from the currently impacted areas achieves study objectives by eliminating risks associated with riverine flooding.

5.3.3 Water Quality

Alternative #3 Diversion Channel South w/ Single Line Protection

It is not anticipated that this alternative would degrade water quality. All measures and features nested within this alternative would not impair water quality due to the utilization of clean and natural materials, as well as utilizing best management practices and sediment and erosion management plans during construction. Most of the construction would occur during the dry season, and would avoid adverse conditions more susceptible to rain water induced erosion and subsequent surface waters being affected.

Water quality for estuarine communities may be improved by this alternative. Alternative design for discharge at the mouth to the ocean allows fresh riverine waters to spread out in a delta formation and flush accumulating salinity from the former Cañaveral area and estuary zones at the coastline.

A Section 401 Water Quality certification from the Commonwealth of Puerto Rico would be required for project implementation.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

It is not anticipated that this alternative would degrade water quality. All measures and features nested within this alternative would not impair water quality due to the utilization of clean and natural materials, as well as utilizing best management practices and sediment and erosion management plans during construction. Most of the construction would occur during the dry season, and would avoid adverse conditions more susceptible to rain water induced erosion and subsequent surface waters being affected.

Water quality for estuarine communities may be improved by this alternative. Alternative design for discharge at the mouth to the ocean allows fresh riverine waters to spread out in a delta formation and flush accumulating salinity from the former Cañaveral area and estuary zones at the coastline.

A Section 401 Water Quality certification from the Commonwealth of Puerto Rico would be required for project implementation.

5.3.4 Groundwater

Alternative #3 Diversion Channel South w/ Single Line Protection

Based on geotechnical subsurface investigations, effects to the groundwater are not expected from excavating the diversion channel. Diversion channel inverts are currently designed above the existing groundwater table in the study area and would not influence changes in elevations or gradients. The current foot print of the diversion channel is mostly agricultural fields that are tiled and drained, therefore, there would also be minimal to no change in infiltration with the change of land use from agricultural fields to diversion canal.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Based on geotechnical subsurface investigations, effects to the groundwater are not expected from excavating the greenway diversion. Greenway diversion channel inverts are currently designed above the existing groundwater table in the study area and would not influence changes in elevations or gradients. The current foot print of the diversion channel is mostly agricultural fields that are tiled and drained, therefore, there would also be a moderate change in infiltration of freshwater with the change of land use from agricultural fields to the rock bottom greenway diversion.

5.4 Air Quality Effects Determination

5.4.1 Regional Climate

None of the alternatives have implications for affecting or aggravating regional climate. All alternatives consider this concept and USACE guidance for modeling, design and implementation.

5.4.2 Regional Air Quality

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects to the air quality of the region. The project proposes no new facilities or features that have on-going energy needs or atmospheric emissions. Operation and maintenance activities are designed to be minimal, short, and infrequent.

Construction activities will cause minor, temporary air quality impacts in the vicinity of the project due to emissions from construction equipment and haul trucks, as well as fugitive dust from grading, construction, quarrying, and driving. All equipment will comply with federal vehicle emission standards, and dust control measures will be implemented throughout construction including watering graded soil and unpaved roads, applying soil stabilizers on inactive construction areas, limiting vehicle speeds on unpaved roads, and minimizing earthmoving operations to the extent feasible during high wind events. The temporary, mobile source emissions from this project are expected to be *de minimis* in nature according to the terms of the National Ambient Air Quality Standards, and are not expected to affect attainment status.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects to air quality of the study area just as Alternative # 3. This alternative exposes more soil during construction due to a wider diversion channel and larger disposal area, however dust controls and best management practices will minimize impacts to air quality.

5.5 Noise Effects Determination

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects to the noise climate of the study area. Noise levels during construction would be noticeable as large cranes, excavators and dump trucks would be moving materials. The loudest noises would be from loading dump trucks with rock or driving sheet pile. Residences and schools are far enough away to avoid effects thresholds to hearing, however, noises could disturb daily activities that require concentration, such as reading or studying. On site construction workers would be required to follow regulations for hearing exposure and protection to avoid adverse effects. Once the project is complete, noise concerns are negligible as the project would operate silently. Operations and maintenance activities for repairing rock, concrete and sheet pile require similar activities as construction, but are considered short-term and isolated incidences, much more so that the initial construction period.

The Beldum neighborhood in which the abandoned rock quarry would be reopened would experience increased noises levels associated with this operation. The duration of the operation would continue through construction of the diversion channel, levees and concrete features, which could be between 4 and 6 years. The noise levels would be a significant increase from Normal Conversation (60 db) to Jackhammer (130 db) levels, which is about a 70 decibel increase. This is considered a significant short term effect of implementing this alternative. In compliance with conservation measures associated with the Puerto Rican Night Jar, quarrying operations would not take place between February and August.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alternative # 3.

5.6 Biological Resources Effects Determination

5.6.1 Riverine Ephemeral Communities

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have permanent, long-term effects to a portion of the Río Guayanilla's connectivity, structure and natural riverine processes within the study area. The connectivity of the river would be permanently affected by the construction of the diversion structure within the existing channel affecting fish passage, sediment transport and river flows. The diversion structure placed will be located downstream of PR-2 bridge. To minimize the loss and adverse effects, culverts in the diversion structure would be sized to allow for fish passage, sediment transport and near bank-full flows to the existing river channel. Flows that exceed the existing channel's capacity would be diverted to the constructed channel.

As example, the suite of ephemeral fishes found within the Río Guayanilla during the wet season would not be subsequently effected by this alternative. Cues (bank-full flows), connectivity (culvert passage) and habitat (sediment transport/substrates) would remain no less intact than the existing condition, especially for species in which physical fragmentation of the river is not an issue i.e. Sirajo Goby, Spinycheeked Smallscaled Sleeper, American Eel. Further, conveyance improvements to remove debris and sediment accumulation at bridges and other locations in the channel would be infrequent and not significantly affect the ephemeral communities.

The diversion structures have a combined footprint of less than 0.1 acres in the existing river channel. Consequently, it was determined that no compensatory mitigation under Section 404 of the Clean Water Act would be required for the loss of this small quantity of ephemeral riverine habitat. A Section 401 Clean Water Act Permit will be obtained for the project.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alternative # 3.

5.6.2 Essential Fish Habitat (EFH)

The USACE provided NOAA with an evaluation and request for determination 09 May 2019. Based on the information provided, the National Marine Fisheries Service (NMFS) believes adverse effects occurring from this project to NOAA trust resources would be minimal due to best management practices for maintaining river flows, controlling erosion, and managing stormwater. The project area does not include essential fish habitat (EFH) designated by the Caribbean Fishery Management Council or the NMFS. As a result, the NMFS had no EFH conservation recommendations pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, and no recommendations under the Fish and Wildlife Coordination Act.

5.6.3 Subtropical Dry Forest – Abandoned Quarry Site

Alternative #3 Diversion Channel South w/ Single Line Protection

The abandoned quarry just north of the Beldum neighborhood was selected as the rock source through a collaborative planning effort between the USACE and USFWS (*Appendix A4 ESA*). This site was clear cut, stripped of soils and quarried for rock in the early 2000s. Portions of the area have not recovered in

terms of native vegetation cover since. Quarrying will be limited to approximately 7 acres that was previously disturbed. The effects under NEPA are considered to be less than significant for the native vegetation community component of the site.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alternative # 3.

5.6.4 Dry Grassland & Riparian Vegetation

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects to secondary growth and old field vegetation within the Dry Grassland and Riparian zones and associated fauna.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alt# 3; however, would further increase acres of Sub Tropical Dry Forest Community. The larger Greenway footprint while still maintaining flood risk effectiveness, provides opportunity for a more natural condition. Select vegetation compatible with the anticipated flow requirements would be allowed to colonize the Greenway The wide channel would eventually take on the character of the natural Río Rio Guayanilla channel during drought/no flow periods. The benefits to the ecosystem would be the conversion of agricultural lands to riverine environment including compatible native vegetation.

5.6.5 Grassland & Abandoned Sugar Cane Plantation (Cañaveral)

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects to secondary growth and old field vegetation within the Grassland and Abandoned Cañaveral zones and associated fauna.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alt# 3; however, would further increase acres of Sub Tropical Dry Forest Community. The larger Greenway footprint while still maintaining flood risk effectiveness, provides opportunity for a more natural condition. Select vegetation compatible with the anticipated flow requirements would be allowed to colonize the Greenway The wide channel would eventually take on the character of the natural Río Rio Guayanilla channel during drought/no flow periods. The benefits to the ecosystem would be the conversion of agricultural lands to riverine environment including compatible native vegetation.

5.6.6 Brackish Swamp

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects the Brackish Swamp zone and associated fauna, as conditions for this area would not be changed by this alternative since it is located on the east side of the Rio Guayanilla.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alternative # 3.

5.6.7 Interior Mangrove Basin & Edge at Guayanilla Beach

Alternative #3 Diversion Channel South w/ Single Line Protection

An iterative process was employed to address potential impacts to significant aquatic habitat located adjacent to the proposed diversion channel. The initial alignment included a levee on the east side of the diversion channel and a raised berm on the west side. The berm limited overtopping of the diversion channel to less frequent events. However, based on modeling and an assessment of the surrounding habitat indicated that the loss of overbank flooding from Rio Guayanilla would adversely affect 240 acres of interior mangrove basin and fringe swamp. Further, the proposed diversion channel configuration did not result in a fully functional channel downstream of the junction of the diversion channel and the existing channel.

The alternative was modified to remove the western berm of the diversion channel just upstream of the confluence with Rio Guayanilla. This will allow overland flow of water and sediment through the interior 240 acre mangrove basin to continue, which eliminates the impact. This feature of the project acts as a conservation measure. However, due to continued overbank flooding of the interior area, a setback levee to protect El Faro, located to the west and south of the diversion channel at Guayanilla Bay was added to this alternative. Because the El Faro Levee would have direct impact on the mangrove swamp, various configurations were evaluated to minimize the levee footprint. Six 6 acres of compensatory mitigation to address 5.8 acres of impact will be needed. The alternative design was refined through a collaborative planning process between USFWS, NOAA and USACE that considered methods to avoid and minimize impacts to significant aquatic habitat.

The analysis of compensatory mitigation (40 C.F.R. § 230.93) for the loss of 5.8 acres of perennial estuarine interior basin mangrove wetland/habitat and associated fauna for Clean Water Act compliance is contained in the 404(b)(1) Analysis (*Appendix A2*) and USFWS FCAR (*Appendix A4*). The effects under NEPA are considered to be lowered to less than Significant by the application of the conservation measure and compensatory mitigation as described in *Appendix A3 Mitigation, Monitoring and Adaptive Management Plan*.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alternative # 3.

5.6.8 Federal Listed Species

Alternative #3 Diversion Channel South w/ Single Line Protection

The initially proposed iteration of this alternative would potentially result in adverse effects to six (6) federally listed species associated with the clearing of about an estimated 100 acres of dry forest habitat to quarry limestone. Avoidance and minimization planning was undertaken by USACE and USFWS to both reduce the size (~100-acres) of the affected acres of T&E species habitat and avoid those areas of known high quality habitat. Through this collaborative process, an abandoned quarry was located and about 7 acres of it was found to be sufficient to provide a cost effective rock source for the two structural alternatives. The size of the borrow area was drastically reduced once more detailed design information became available. This avoidance and minimization planning reduced the amount of habitat affected

(~100 to ~7 acres), the number of T&E species potentially affected to two (the plant species were removed from consideration) and the quality of habitat affected (high quality native dry forest to secondary growth / dry grassland.

The abandoned quarry that was identified as a source of limestone includes a secondary growth plant community that is somewhat degraded; however, this area still provides sufficient habitat for the Puerto Rican Nightjar (FE) and the Puerto Rican Boa (FE). The use of the area by these two species was confirmed by USFWS field work. Activities associated with quarry operations could result in adverse effects to the two species of concern. To further reduce possible adverse effects, conservation measures provided in the February 2020 CAR would be implemented during the implementation phase in conjunction with the USFWS Caribbean Office.

Based upon avoidance and minimization planning and the incorporation of USFWS prescribed conservation measures (*Appendix A4 ESA*), the USACE has therefore concluded that a "May Affect, but not likely to Adversely Affect" determination for the Puerto Rican Boa and Puerto Rican Nightjar is appropriate for Alternative #3. The USFWS concurred with this determination on February 24, 2020. Because the proposed project is not likely to adversely affect the Puerto Rican Boa and the Puerto Rican Nightjar, it will not significantly affect threatened and endangered species for NEPA purposes.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects and conditions as Alternative # 3.

5.6.9 State Listed Species & Species of Special Concern

The DNER does not have a state level threatened/endangered species list for the Guayanilla study area. The DNER was contacted on 07 July 2019 requesting information on critical habitats or species in which the state is aware of or has management plan for within the study area. In 2009, the USFWS (Monsegur 2009) confirmed (47) plant taxa that correspond to species designated by the DNER as Critical Elements; seven of them are protected by the USFWS. On November 4, 2019 the DNER accompanied the USFWS on T&E habitat, vegetation and animal surveys; it is assumed information provided by the USFWS includes input from the DNER.

It is anticipated that none of the alternatives would have adverse, long term effects to state species of concern. Applied conservation measures and compensatory mitigation is currently considered sufficient to also cover any state species of concern present in any of the affected study area habitats. This determination will be updated should the DNER provide information in response to this Final EA.

5.6.10 Nature Preserves & Conservation Areas

The Bosque Estatal de Guánica natural area's official boundaries do not include the study area; however it does share connectivity with the Sub Tropical Dry Forest within the study area. Based on location and types of activities associated with the proposed alternatives, effects are not anticipated.

5.6.11 Coastal Barriers

After reviewing the Coastal Barrier Resources System (CBRS) mapper no portion of the project falls within a CBRS system unit. This investigation was conducted based on the Coastal Barrier Resources Act of 1982, 16 U.S.C. 3501; therefore, effects are not anticipated.

5.6.12 Clean Water Act Section 404

A Section 404(b)(1) Analysis was completed for those alternative components subject to the Clean Water Act. The Alternative #3 and #6 component of the set-back El Faro levee would fill/impact about 5.8-acres of interior basin mangrove swamp. It was determined that six (6) acres compensatory mitigation (40 C.F.R. § 230.93) would be implemented for the loss of 5.8 acres of perennial estuarine interior basin mangrove wetland/habitat and associated fauna as described for Clean Water Act compliance in the 404(b)(1) Analysis (*Appendix A2*) and USFWS FCAR (*Appendix A4*). The effects under NEPA are considered to be lowered to less than Significant by the application of the conservation measure and compensatory mitigation as described in *Appendix A3 Mitigation, Monitoring and Adaptive Management Plan*.

The diversion structures have a combined footprint of less than 0.1 acres in the existing river channel. Consequently, it was determined that no compensatory mitigation under Section 404 of the Clean Water Act would be required for the loss of this small quantity of ephemeral riverine habitat. A Section 401 Clean Water Act Permit will be obtained for the project.

5.7 Cultural Resources Effects Determination

Analysis of potential impacts to historic and cultural resources considered both direct and indirect effects (see Section 2.7). 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 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. In the case of a flood risk management projects, indirect effects would include those that may occur as a result of removing flood effects from large portions of agricultural lands and fallow fields, which in turn could induce construction of residences and population growth. 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, state, 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 November 1, 2018. SHPO concurred with the USACE's determination of the APE by letter dated May 22, 2019. The USACE submitted a research design for proposed methods of identifying historic properties within the APE on July 18, 2019. The results of the Phase I cultural resources assessment and the USACE's determination of no adverse effect to historic properties was submitted to SHPO and the Instituto de Cultura Puertorriqueña (ICP) on January 28, 2020. Comments were received from the ICP and SHPO on February 25 and 28, 2020 respectively. These comments have been incorporated into the final report. The Puerto Rico State Historic Preservation Office

(SHPO) concurred with the USACE's determination of no adverse effect on March 26, 2020. Consultation with the Puerto Rico State Historic Preservation Office (SHPO) pursuant to Section 106 of the NHPA is complete. All correspondence relevant to cultural resources is provided in Appendix A5.

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would cause ground disturbance by construction of a diversion channel, disposal of excavated material, building levees, quarrying of rock, placement of structures within the natural channel of the Río Guayanilla, and other associated construction, access, operations, and maintenance activities. Ground disturbing activities have the potential to effect cultural resources and historic properties within the APE. This alternate would also have visual effects to a portion of the valley's natural riverine vista. Historic properties located within the viewshed of the proposed concrete and stone diversion channel running have the potential to be adversely effected by a change from the current rural aesthetic.

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no effect to cultural resources or historic properties within the APE. Removing large woody debris, foreign debris, and rocky sediment accumulation at bridges and other structural constrictions may help to preserve historic buildings, structures, or objects vulnerable to flooding within the APE.

Based on a background review and the location of previously identified cultural resources adjacent to the APE, the archaeological probability of the project area was determined to be high. In order to identify historic properties within the APE, the USACE, in consultation with the Puerto Rico SHPO, has contracted a cultural resources survey of undisturbed portions of the proposed Alternative. The Phase I cultural resources survey conducted consisted of a pedestrian reconnaissance, an architectural survey, excavation of 689 shovel tests at 30-, 15-, or 60-meter intervals, and deep testing of areas with heavy sediment accumulation using a backhoe. As a result of this survey, one prehistoric site (GL0100006), four isolated archaeological occurrences (AOs) relating to early twentieth-century irrigation features (AO 8-11), and three twentieth-century sites (GL0100030, GL0100037, and GL0100043) associated with the irrigation system for Central Rufina (a large sugar plantation located outside of the project area) were identified adjacent to the project footprint.

Site GL0100006 is a rock shelter containing four anthropomorphic and geometric/abstract prehistoric petroglyphs located 15 meters from the edge of Río Guayanilla. Although the petroglyphs show evidence of erosion and vandalism, the site retains its significance and integrity and the USACE determined that site GL0100006 is eligible for listing in the NRHP under Criteria C and D. A field visit after the earthquake that struck near Guayanilla on January 7, 2020 did not show any damage to site GL0100006. Both site GL0100030, a canal and levee site, and sites GL0100037 and GL0100043, two irrigation pump sites, indicate that there is the potential that further research could provide information on water conveyance systems and their importance to the sugarcane industry in Puerto Rico during the nineteenth and early twentieth centuries. Additionally, AOs 08-11 are scattered subterranean elements of the larger irrigation system for Central Rufina, which has not been adequately investigated. Additional evidence of a broad historic irrigation system for the area was not identified in the 30-m grid of shovel tests across the project area. Their relationship to other previously recorded irrigation-related sites is uncertain. Based on this information the USACE has determined there is not currently enough information to determine the NRHP eligibility of AOs 8-11 or sites GL0100030, GL0100037, and GL0100043.

Alternative #3 has been refined to avoid impacts to AOs 8-11 and sites GL0100006, GL0100030, GL0100037, and GL0100043. During construction, Project plans and drawings will label the area as an environmentally sensitive area of avoidance and exclusionary fencing and signage will be placed

around the site to ensure avoidance. Based on current construction plans and levee heights, the viewshed analysis did not identify any impacts to the current rural and agricultural aesthetic of the cultural resources within or adjacent to the project area. Based on this analysis and the avoidance of site AOs 8-11 and sites GL0100006, GL0100030, GL0100037, and GL0100043, the USACE has determined that Alternative #3 poses no adverse effect to historic properties. The SHPO concurred with the USACE's determination of no adverse effect on March 26, 2020. Consultation with the Puerto Rico SHPO on the determination of effects pursuant to Section 2016 of the NHPA is complete.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same effects as Alternative #3 with the exception that the diversion channel footprint would be between 600-700 feet wider in some sections. Although the proposed diversion channel would not be excavated as deeply as Alternative #3, this Alternative has the potential to effect historic properties. Conversely, this Alternative creates a naturalistic Greenway, as opposed to a concrete and rock channel. A more natural channel would better preserve the valley's natural riverine vista, thereby lessening visual effects to historic properties, if present.

5.8 Socioeconomic/Environmental Justice

5.8.1 Demographic Survey

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would result in permanent, long-term land use changes, but since land use change would occur on what is currently agricultural land, it would not decrease the population, nor change the demographic composition of the population in the study area. This alternative would significantly reduce inundation for the 0.002 AEP event, and reduce economic losses as a result. Floodwaters would no longer inundate schools and businesses during frequent flood events, and thus education and business operations would not be as negatively impacted, in an area where income levels are nearly one-fourth of the national average.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same socioeconomic impacts as Alternative #3.

5.9 Other Human Resources Effects Determination

5.9.1 Hazardous, Toxic, and Radioactive Waste

Alternative #3 Diversion Channel South w/ Single Line Protection

Project implementation will not result in a significant or long-term release of HTRW. The risk of encountering HTRW in the project area has been reduced with the completion of a HTRW Phase I Environmental Site Assessment (see attached Appendix H – Hazardous, Toxic and Radioactive Waste (HTRW) Report). The project alignment was selected to avoid industrial areas east/northeast of the Rio Guayanilla and urbanized areas in the Municipality of Guayanilla, where the risk of encountering HTRW is elevated. One Recognized Environmental Condition (REC) was identified within the project area: a banana farm where uncontrolled releases of pesticides to the atmosphere in 1996-1997 may have resulted in residual levels of hazardous substances in soils. Due to site constraints, the proposed diversion channel

must be routed through banana fields and avoidance is not practical. Although the farm may contain residual levels of fertilizer or pesticides in surficial soils, subsequent enforcement actions, including a 2001 consent decree, resolved pesticide application violations and future HTRW response actions are not anticipated. In addition, implementation of this alternative will include management of all excavated material on-site. Erosion and sediment controls will be maintained during construction to reduce movement of soil from the site by storm water runoff or vehicular traffic. No additional impacts from this REC or off-site HTRW are expected to affect project implementation.

Impacts could also occur from unintended release of hazardous or toxic construction equipment fluids, including fuel and oil spills or leaks during project implementation. These risks are mitigated by requiring construction contractors to develop an accidental spill prevention and response plan for all hazardous materials that may be used onsite, develop a solid and hazardous materials and waste management plan prior to starting work, and comply with all applicable local, regional, state, and Federal laws, policies, and regulations regarding the transportation, storage, handling, management, and disposal of hazardous materials and wastes. In the event of a spill or release of hazardous substances at the construction site, the contaminated soil would be immediately contained, excavated, and treated per Federal and state regulations developed by the USEPA, as well as local hazardous waste ordinances.

All suitable excavated material will be re-used for construction of project features and unsuitable excavated material will be managed within the project boundaries. If decisions were made to move the material off-site for disposal or beneficial use, additional testing would be required. The testing would determine if material contains hazardous substances for management in accordance with applicable laws and regulations of the relevant regulatory agencies. No significant or long-term effects to the HTRW condition of the project area are anticipated.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have similar activities, features, and subsequent effects and conditions as Alternative #3, with a somewhat elevated risk of encountering HTRW during project implementation due to greater amounts of land-disturbing activity for construction and disposal. No significant or long-term effects to the HTRW condition of the project area are anticipated.

5.9.2 Agricultural Lands

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have irreversible, long-term effects to a portion of the agricultural lands within the study area where a permanent diversion channel would be constructed. However, these effects are not significant because of the context in which they occur. Specifically, the alternative does not impact a significant portion of the agricultural land in the region, and the alternative would reduce flood risks to other agricultural areas and residential areas in the local area.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would take much more agriculture out of production since the Greenway diversion channel footprint would be between 300-500 feet wider than Alternative #3 in some sections. A portion of the excavated soils would remain on site and contoured to create native planting mediums on the terrace extremities, or could even be utilized as low-impact farming including crops that could tolerate inundation.

5.9.3 Aesthetic Quality

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have irreversible, long-term effects to a portion of the valley's natural riverine vista. Bordering agricultural lands that add a rural aesthetic to riverine communities would have a concrete and stone diversion channel running through it. This diversion channel would contain limited flow during dry seasons. During large events and rainy seasons, the channel will be substantially full.

Implementing this alternative would have relatively moderate and short-term effects to the abandoned quarry site. Rock and concrete materials would be sourced from a former quarry now abandoned, used to build the neighborhood of Beldum and Los Indios. Although this site was formerly clear-cut and quarried, vegetation has recovered to some extent. Opening up this area would remove the forest aesthetic and create an active quarry for the duration of the construction period. After the construction period, it would be closed and returned to natural area.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would lessen the effects of Alternative #3 in most areas by creating a large, naturalistic Greenway, as opposed to a concrete and rock channel. The channel would be contoured to mimic a natural waterway including a limited number of plants of various species. This alternative would provide result in a more natural aesthetic quality than the engineered diversion channel.

Implementing this alternative would have the same effects as Alternative #3 for the abandoned quarry site near the Beldum neighborhood.

5.9.4 Public Health & Safety

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have beneficial effects to public health and safety within the study area by reducing flood risks. Conversely, there would be safety hazards during floods within and along the diversion channel. High channel flows and velocities along with the smooth sides of channel would pose a significant risk of drowning. Flood warning systems developed with the USGS and the municipalities will include consideration of the risks associated with the diversion channel for area residents.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have beneficial effects to public health and safety within the study area by reducing flood risks. Conversely, there would be safety hazards during floods within and along the diversion channel. High channel flows and velocities along with the smooth sides of channel would pose a significant risk of drowning. These hazards would be lessened in the wider, more natural parts of the Greenway. Flood warning systems developed with the USGS and the municipalities should include the risks associated with portions of the Greenway channel for area residents.

5.9.5 Traffic and Transportation

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would significantly decrease flooding, particularly in reaches 2L and 3R, which encompass the main part of municipality and the most populated area of the floodplain. Principal transportation and evacuation routes, including PR-127 in Reaches 2L, 3R, and 3L, would still experience reduced flowing during the 0.002 AEP, but flooding along PR-127 would be almost nonexistent for the more frequent events up to the 0.01 AEP (100-year event). Flood depths would be significantly reduced along PR-127 for the 0.005 AEP and 0.002 AEP events.

During quarrying and project construction, contractors will utilize constructed haul roads and major area arterials. Quarrying will occur only between the months of September through January. The contractor will be required to manage traffic during construction periods, and local roads should not be utilized. The contractor will be required to restore used roadways to preconstruction conditions. While it is anticipated that there will be some impacts to traffic and transportation in the community during the estimated four year construction period, the impacts will be limited due to restrictions on quarrying, requirements for traffic management, and the use of haul roads and major arterials. No long term impacts are expected as haul roads must be restored to pre-construction conditions by contractors.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same transportation impacts as Alternative #3.

5.9.6 Utilities

Any of the alternatives would move or replace utilities in-kind should it be required. There would be no long-term or permanent loss of utilities or subsequent services. Temporary facilities or lines would be utilized should certain utilities need to be reconfigured and replaced. Temporary outages during utilities connections (hours) may be experienced as normal system maintenance would.

5.10 Cumulative Effects

NEPA requires the consideration of cumulative effects of the proposed action combined with those of other projects. NEPA defines a cumulative effect as an environmental affect that results from the incremental effect of an action when combined with other past, present, and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes such other actions (40 C.F.R. 1508.7).

Methodology and Geographic Scope of the Analysis – If a resource category is effected by alternative-specific actions, a cumulative analysis is conducted. The cumulative effects analysis takes into consideration whether the separate actions identified in combination with each other would have the potential to affect the same resources. If there is not a combined effect, then a finding of no cumulative impact is made. If there would be a combined effect, then a determination is made if that combined effect is a significant cumulative effect or not. Finally, a determination is made as to whether environmental commitments recommended for the project-specific effects would reduce the contribution to the cumulative effect to a less than significant level; therefore, resulting in a less than significant cumulative effect. Mitigation of significant cumulative effects could be accomplished via technical (i.e. ecosystem restoration) or project management methodologies (i.e. scheduling).

Geographic Scope – The context of the cumulative analysis varies by resource category. The cumulative context for each technical issue area is further defined by the specific geographic area affected. For example, air and water resources extend beyond the confines of the project footprint since effects on these

resources would not necessarily be confined to the project area. When the effects of the project are considered in combination with those of other past, present, and future projects to identify cumulative effects, the other projects that are considered may also vary depending on the type of environmental effects being assessed. Table 29 presents the general geographic areas associated with the different resources categories being addressed in this analysis.

Table 29: Geographic Affected Environment by Río Guayanilla FRM Study Alternatives

Resource Category	Geographic Area
Earth Resources	Vicinity of the individual sites of construction activity, inclusive of staging areas, stockpile areas, disposal areas, haul/trucking routes and proposed rock quarry.
Water Resources	Includes the Río Guayanilla and the near shore Guayanilla Bay.
Air Quality & Greenhouse Gas Emissions	The municipality of Guayanilla (global for GHG emissions)
Noise & Vibration	Immediate vicinity of the individual sites of construction activity and haul routes. The Beldum Neighborhood for the rock quarry and T&E Species.
Biological Resources	The Río Guayanilla, Subtropical Dry Forest Communities, near shore estuarine communities and various ruderal habitats.
Cultural Resources	Immediate vicinity and viewshed of construction footprint, including the footprint of structural measures, disposal areas, access roads and construction staging areas.
Aesthetic Quality	Landscapes and vistas within the vicinity of the study area.
HTRW Materials	Vicinity of the individual sites of construction and excavation activity.
Traffic & Transportation	Roadway network within the study area, including PR-2, PR-127 and other connecting minor roads.
Utilities & Service Systems	Local utilities and facilities near construction and excavation sites.

5.11 Cumulative Effects Determination

Based on recent natural and anthropogenic history, demographics of the study area and considering adjacent municipalities as well, it is not anticipated that non-federal, state or municipal projects would occur within the affected environment that are of magnitude or spatial size to add cumulative effects to any of the proposed alternatives. The direct and indirect effects analysis took into consideration the past effects of the Phase I DNER flood project at the mouth of the Río Guayanilla and current agricultural, commercial and residential practices. Current actions under any of the alternatives would not cumulatively increase adverse effects that had previously occurred, but in some instances would promote recovery of lost resources/services.

5.12 Unavoidable Significant Environmental Effects

Unavoidable, significant environmental effects were not identified during the effects assessment for the two (2) federal action alternatives. All resources initially identified to potentially accrue significant effects underwent additional avoidance and minimization planning and/or received conservation measures or identified compensatory mitigation to ultimately avoid, minimize and mitigate the effects to cumulatively less than significant.

5.13 Growth Inducing Impacts

NEPA defines indirect effects as those that include growth-inducing effects or other effects related to induced changes in population density or growth rate (40 C.F.R. § 1508.8). An action is defined as growth-inducing when it:

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

Growth inducement is generally dependent upon the presence or lack of existing utilities and public services in the area. The provision of new utilities and services can induce growth in an undeveloped area. Growth inducement can also occur if a proposed action makes it feasible to increase the density of development in surrounding areas. 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. However, the action alternatives would reduce flood risks from large portions of agricultural lands and old fields, which in turn could induce development or investment in areas currently impacted by flooding. However, based upon projected landuse changes, these areas are expected to remain in agricultural production. Consequently the implementation of either of the alternatives is not likely to induce growth based on current plans. In the event that future landuse changes, and these areas are considered for development, the reduction in flood risk should be considered as an inducement for future growth.

5.14 Irreversible and Irretrievable Commitment of Resources

The irreversible and irretrievable commitments of resources are the permanent loss of resources for future or alternative purposes. Irreversible and irretrievable resources are those than cannot be recovered or recycled or those that are consumed or reduced to unrecoverable forms. Project implementation would result in the irreversible and irretrievable commitments of the following:

- Construction materials, including such resources as soil and rock (however, these could be reutilized);
- Land area committed to project footprint;
- Energy expended in the form of electricity, gasoline, diesel fuel, and oil for equipment and transportation vehicles that would be needed to project construction, operations and maintenance (O&M); and
- Water used for dust abatement.

The use of these nonrenewable resources are expected to account for only a small portion of the region's resources and would not affect the availability of these resources for other needs within the region. Construction activities would not result in inefficient use of energy or natural resources.

5.15 Compliance with Applicable Laws & Policies

The proposed alternatives are in compliance with appropriate statutes, executive orders, memoranda and USACE regulations. Applicable laws, statutes and executive orders are provided in *Appendix A2*. Applicable federal compliance components include the Natural Historic Preservation Act of 1966; the Endangered Species Act of 1973; the Fish and Wildlife Coordination Act; EO 12898 (environmental justice); EO 11990 (protection of wetlands); EO 11988 (floodplain management); and the Rivers and Harbors Act of 1899. The potential project is in compliance with the Clean Air Act; the Clean Water Act, and the National Environmental Policy Act of 1969. There were no adverse environmental effects

identified which cannot be avoided should the proposal be implemented. The proposed alternatives would have localized and short-term effects to uses of the study area coastal zone environment.

5.15.1 *Endangered Species Act*

Pursuant to section 7 of the Endangered Species Act of 1973, as amended, the U.S. Army Corps of Engineers coordinated with the U.S. Fish and Wildlife Service on potential impacts of the recommended plan. To avoid impacts to **4** federally endangered species, coordination between the USACE and the USFWS identified an abandoned quarry as an alternate site for obtaining stone for the project. Based on initial surveys, areas within the abandoned quarry had been previously cleared of vegetation and quarried, but still provide habitat for the Puerto Rican Nightjar and Puerto Rican Boa.

Based on further assessment of the abandoned quarry site on November 4, 2019 by USFWS, and inclusion of the prescribed conservation measures, the USACE has determined that the proposed project is not likely to adversely affect the following federally listed species or their designated critical habitat: *the Puerto Rican Nightjar (Antrostomus noctitherus) and the Puerto Rican Boa (Epicrates inornatus).* The U.S. Fish and Wildlife Service (FWS) concurred with the Corps' determination on February 24, 2020.

5.15.2 *Fish & Wildlife Coordination Act*

Pursuant to Section 2(b) of the Fish and Wildlife Coordination Act, as amended, the U.S. Army Corps of Engineers coordinated with the U.S. Fish and Wildlife Service on potential natural resource impacts of the recommended plan.

USFWS determined in the Final Coordination Act Report received on 28 February 2020 that USACE complied with the recommendation to allow normal bankfull flow in the natural river channel minimizing impacts to native aquatic species found in the Rio Guayanilla. Use of the abandoned quarry and applying conservation measures for the Puerto Rican boa and Puerto Rican nightjar during construction ensure that the proposed project is not likely to adversely affect these species or their designated critical habitat. It was determined that 6 acres of compensatory mitigation (40 C.F.R. § 230.93) would be implemented for the loss of 5.8 acres of perennial estuarine interior basin mangrove wetland/habitat and associated fauna as described for Clean Water Act compliance in the 404(b)(1) Analysis (*Appendix A2*) and USFWS FCAR (*Appendix A4*). Further coordination with the service will continue to refine project specifics.

5.15.3 *National Historic Preservation Act*

Pursuant to Section 106 of the National Historic Preservation Act, the USACE has conducted an assessment on cultural resources within the area of potential effects. The USACE has determined that the recommended plan will have no adverse impacts on historic properties listed or eligible for listing on the National Register of Historic Places. The Puerto Rico State Historic Preservation Office (SHPO) concurred with the USACE's determination of no adverse effect on March 26, 2020. Consultation with the Puerto Rico State Historic Preservation Office (SHPO) pursuant to Section 106 of the NHPA is complete.

5.15.4 *Clean Water Act Section 404 Compliance*

Pursuant to the Clean Water Act of 1972, as amended, the discharge of dredged or fill material associated with the recommended plan will be compliant with section 404(b)(1) Guidelines (40 C.F.R. 230).

The diversion structures have a combined footprint of less than 0.1 acres in the existing river channel. Consequently, it was determined that no compensatory mitigation under Section 404 of the Clean Water Act would be required for the loss of this small quantity of ephemeral riverine habitat. A Section 401 Clean Water Act Permit will be obtained for the project.

It was determined that 6 acres of compensatory mitigation (40 C.F.R. § 230.93) would be implemented for the loss of 5.8 acres of perennial estuarine interior basin mangrove wetland/habitat and associated fauna as described for Clean Water Act compliance in the 404(b)(1) Analysis (*Appendix A2*) and USFWS FCAR (*Appendix A4*). The effects under NEPA are considered to be lowered to less than Significant by the application of the conservation measure and compensatory mitigation as described in *Appendix A3 Mitigation, Monitoring and Adaptive Management Plan*.

5.15.5 *Clean Water Act Section 401 Compliance*

401 WQC – The Commonwealth of Puerto Rico provided a letter on 27 May 2020 indicating that the recommended plan appears to be consistent with and not likely to compromise Puerto Rico water quality standards. A state water quality certification pursuant to Section 401 of the Clean Water Act will be obtained from the Puerto Rico Environmental Quality Board prior to construction after the development of detailed construction drawings and specifications.

CZMA CONSISTENCY – In a letter dated 13 February 2020 the Puerto Rico Planning Board stated that the recommended plan appears to be consistent with state Coastal Zone Management plans, pending confirmation based on information to be developed during the pre-construction engineering and design phase. All conditions of the consistency determination shall be implemented in order to minimize adverse impacts to the coastal zone.

5.15.6 NOAA & NMFS Compliance

The USACE provided NOAA with an evaluation and request for determination 09 May 2019. Based on the information provided, the National Marine Fisheries Service (NMFS) provided in a letter dated 13 May 2019, that adverse effects occurring from this project to NOAA trust resources would be minimal due to best management practices for maintaining river flows, controlling erosion, and managing stormwater. The project area does not include essential fish habitat (EFH) designated by the Caribbean Fishery Management Council or the NMFS. Thusly, the NMFS had no EFH conservation recommendations pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, and no recommendations under the Fish and Wildlife Coordination Act.

5.15.7 Coastal Barrier Resources Act of 1982, 16 U.S.C. 3501

After reviewing the Coastal Barrier Resources System (CBRS) mapper no portion of the project falls within a CBRS system unit. This investigation was conducted based on the Coastal Barrier Resources Act of 1982, 16 U.S.C. 3501.

Table 30: Applicable Federal, State & Local Legal Compliance Summary

Reference	Environmental Statutes/Regulations	Project Compliance
Federal		
42 U.S.C. 7401, et seq.	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, as amended	C
42 U.S.C. 9601, et seq.	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980	C
16 U.S.C. 1531, et seq.	Federal Endangered Species Act of 1973, as amended	C
16 U.S.C. 661, et seq.	Fish and Wildlife Coordination Act, as amended	C
EO 11990	Protection of Wetlands	C
EO 11988	Floodplain Management	C
EO 12898	Federal Actions to Address Environmental Justice in Minority and Low-Income Populations	C
EO 13045	Protection of Children from Environmental Health Risks and Safety Risks	C
16 U.S.C. 1801, et seq.	Magnuson-Stevens Fish Conservation and Management Act	C
16 U.S.C. 703, et seq.	Migratory Bird Treaty Act of 1918, as amended	C
54 U.S.C. 300101, et seq.	National Historic Preservation Act, as amended	C
42 U.S.C. 6901, et seq.	Resource Conservation and Recovery Act of 1976, as amended	C
Commonwealth		
12 L.P.R.A. 8001 et seq.	Environmental Public Policy Act of 2004, as amended	C

[a] NA = not applicable, C = Compliance, P = Pending, and NC = Non-Compliant

6.0 Public Involvement, Review and Coordination*

This chapter summarizes public and agency involvement undertaken by USACE that were conducted to date, are ongoing, and/or will be conducted for this project and that satisfy NEPA requirements for public scoping and agency consultation and coordination.

6.1 Public Involvement under NEPA

This section describes key elements of the public involvement process for this feasibility study. This report was prepared as an Integrated Feasibility Report (IFR) which combines the Feasibility Report (FR) and Environmental Assessment (EA) into a single document. USACE is the lead agency for the IFR and NEPA compliance. The Puerto Rico DNER is the non-federal sponsor.

Study Scoping Letters

State and federal agencies and Tribal Nations were notified with a letter dated 01 November 2018 of the intent by the U.S. Army Corps of Engineers to prepare a National Environmental Policy Act (NEPA) document (Appendix A). It was indicated that this document would evaluate the potential effects of alternatives to manage risks associated with flooding at Guayanilla, Puerto Rico. The study would investigate overbank flooding and erosion threating infrastructure along the Río Guayanilla, focusing on prioritizing high risk areas and developing a range of possible structural and non-structural alternatives to reduce flood risk. Measures and alternatives that could be evaluated to reduce flood risk and erosion included: floodwater storage, levees or floodwalls, diversion channels, channel modifications, flow control structures, flood proofing, structure elevations, and buyouts. As part of the NEPA scoping process, the Chicago District requested comments, concerns or information associated with these preliminary concepts.

Agency Planning Charrette

The Planning Charrette for the Río Guayanilla Flood Risk Management (FRM) Study was conducted on 28 November 2018. The ultimate purpose of the Planning Charrette was to solicit critical information from the agencies and citizens of Guayanilla, and provide an opportunity for the agencies and citizens to review and comment on the conceptual plans moving forward into alternative analyses. Topics discussed included existing information and data, items of coordination and compliance, plan formulation, conceptual design considerations, and the goal, problems, opportunities, objectives and constraints presented in the slide deck. Critical information garnered and discussed at the Charrette were documented in a Memorandum for Recorded to aid in guiding study development.

Public & Agency Scoping Meeting

The Chicago District, in collaboration with the Corps' Jacksonville District and the study's nonfederal sponsor, Puerto Rico Department of Natural and Environmental Resources, hosted a public scoping meeting on Nov. 28, 2018, from 2 p.m. – 6 p.m. Information for the meeting was provided at the following webpages: (https://www.lrc.usace.army.mil/) (http://www.saj.usace.army.mil/) (http://drna.pr.gov/cat/programas-y-proyectos/). Comments were requested to be received no later than 15 December 2018 for incorporation into the NEPA document, but were generally accepted after the period closed to ensure all useful information is acquired. Approximately 230 citizens of Guayanilla attended the public meeting, with a subset of about 10 citizens providing spoken comments. The meeting was recorded in Spanish by a stenographer as well as recorded digitally. Comments were processed and translated into English. Currently, two (2) comments in email format were received and eleven written comments were

submitted at the scoping meeting. All comments give details of losses incurred due to the flooding and overwhelming support for a solution that would help eliminate flooding in the future (*Appendix A5 Agency & Public Coordination)*.

Public & Agency Review Meeting

Notification that the Draft IFR was available for review was published on August 27, 2019 and circulated for a 30-day review period to federal, state and local agencies, organizations and individuals who have an interest in the project. Two public meetings were held during the review period to provide additional opportunities to discuss and comment on the draft report. A public meeting took place on September 18, 2019 at Costa Bahia Hotel and Convention Center from 2pm – 6pm and an open house was hosted September 19, 2019 from 9am – 2pm at Museo de Historia de Guayanilla Calle Luis Muñoz Rivera. All comments received during the public review period were considered and incorporated into the final report, as appropriate. All comments are provided in *Appendix A5 Agency & Public Coordination*.

Public review of the draft IFR/EA and FONSI was completed on **4 October 2019**. All comments submitted during the public review period were considered in the Final IFR/EA and FONSI. The project was submitted to the Puerto Rico Permit Management Office through the Single Business Portal website on October 25, 2019.

7.0 Recommended Plan*

Based on analyses of the final array of alternatives, Alternative #3 is the NED plan, and it is also the Recommended Plan. This plan is estimated to result in approximately $20 million of average annual benefits at an average annual cost of $6 million, and a total first cost of $154 million. The benefit-cost ratio (BCR) of this plan is 3.3 at the current federal discount rate of 2.75%.

Table 31: NED/Recommended Plan Summary 2.75% ($)

	NED/Recommended Plan*
Total First Cost	$154,341,000
Average Annual Cost	$6,071,000
Average Annual Benefits	$20,022,000
Net Average Annual Benefits	$13,951,000
Benefit to Cost Ratio (BCR)	3.3

*FY 20 Price Levels

7.1 Mitigation

Mitigation includes all measures that would avoid, minimize, offset or compensate for potential environmental effects. When considered under the ESA, these measures may be referred to as conservation measures. Wetland mitigation of 6 acres of special aquatic habitat are included in the Recommended Plan as detailed in the 404(b)(1) Analysis (*Appendix A2*) and USFWS FCAR (*Appendix A4*). The effects are considered to be lowered to less than Significant by the application of the conservation measure and compensatory mitigation as described in *Appendix A3 Mitigation, Monitoring and Adaptive Management Plan*.

7.1.1 Environmental Commitments

Environmental commitments are relatively standardized and compulsory best practices that represent sound and proven methods to avoid or reduce potential effects. Although environmental commitments fall within the NEPA definition of mitigation through avoidance and minimization, the costs for implementing these measures are accounted for within the PED or Construction accounts, as appropriate, and are not included in the fish and wildlife habitat mitigation account. The environmental commitments identified in Table 32 would be implemented to avoid or reduce short-term construction-related effects.

Table 32: Environmental Commitments

Environmental Commitment	Timing	Responsible Party
T&E species survey at proposed quarry site	Feasibility/Complete	USFWS
Develop conservation measures for habitat and T&E species	Feasibility/Complete	USFWS & USACE
Develop compensatory mitigation for wetland loss	Feasibility/Complete	USACE
Noise-reducing construction practices	During construction	USACE, in coordination with the construction contractor

Environmental Commitment	Timing	Responsible Party
Traffic control and road maintenance plan	During construction	USACE, in coordination with its contractor and the cities and county public works departments
Construction area closure notification	Prior to construction	USACE, in coordination with construction contractor
Storm water Pollution Prevention Plan	Prior to construction	USACE, in coordination with construction contractor
Spill Prevention, Control, and Countermeasure Plan	Prior to construction	USACE, in coordination with construction contractor
Soil hazards testing and soil disposal	Prior to construction	USACE, in coordination with construction contractor
Install exclusion fencing along the perimeter of the construction work area (where necessary) and implement general measures to avoid effects on sensitive natural communities and special-status species.	Prior to and during construction	USACE, in coordination with construction contractor
Conduct mandatory contractor/worker awareness training for construction personnel	Prior to and during construction	USACE, in coordination with construction contractor

7.1.2 Compensatory Mitigation

Compensatory mitigation means the restoration (re-establishment or rehabilitation), establishment (creation), enhancement, and/or in certain circumstances preservation of wetlands, streams and other aquatic resources for the purposes of offsetting unavoidable adverse impacts which remain after all appropriate and practicable avoidance and minimization has been achieved.

It was determined that 6.0 acres of compensatory mitigation (40 C.F.R. § 230.93) would be implemented for the loss of 5.8 acres of perennial estuarine interior basin mangrove wetland/habitat and associated fauna as described in Sections 2.6.8 and 5.6.7, for Clean Water Act compliance in the 404(b)(1) Analysis (*Appendix A2*) and USFWS FCAR (*Appendix A4*). The effects under NEPA are considered to be lowered to less than Significant by the application of the conservation measure and compensatory mitigation as described in *Appendix A3 Mitigation, Monitoring and Adaptive Management Plan*.

7.2 Operation, Maintenance, Repair, Replacement, and Rehabilitation

Once construction activities are completed, the project will be turned over to the NFS. Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) of the levees, floodwalls, conveyance improvements, diversion structure, diversion channel, and the bridges/roads will be the responsibility of the Department of Natural and Environmental Resources (DNER). OMRR&R activities would include periodic inspections, vegetation control, removal of impediments to flow and repair of structures as needed, in addition to supporting emergency efforts during flood events. DNER and local municipalities will be responsible for outreach to communities, residents, and businesses in the floodplain about project risks and the development of an emergency action/ response plan. The project features in the area will be inspected at least once a year and following major flooding events.

7.3 Real Estate Considerations

Real estate interests within the project footprint include predominately agricultural lands with some residential, industrial and commercial parcels. Permanent easements for channel improvement and flood reduction will need to be acquired along with temporary work area easements. There are approximately nine residences associated with this project that will require relocation assistance benefits under Public Law 91-646. No business relocations are anticipated.

Additional details regarding real estate considerations are available in *Appendix I – Real Estate*.

7.4 Costs

7.4.1 Project Costs

Preliminary project cost estimates for the final array of alternatives are provided below. Construction costs include costs for utility relocations, roads and bridges, channels and canals, levees and floodwalls, and flood control and diversions structure. Lands, easements, rights-of-way, relocation, and disposal (LERRDs) costs include real estate costs. Interest during construction is calculated based on a four-year construction schedule. Table 32 includes a breakdown of the costs for the Recommended Plan.

Table 33: Recommended Plan Breakdown Details

	Cost Breakdown ($000)
Investment First Costs	
Construction Cost	$128,526
LERRDs	$25,815
Subtotal First Cost	$154,341
Interest During Construction	$8,501
Total Gross Investment	$162,843
Average Annual Cost	$6,032
OMRR&R	$39
Total Average Annual Cost	$6,071
Note: Construction costs include contingency of 35%. *Interest during construction is calculated at 2.75% for a 4-year construction period.* *Costs are in FY 2020 Price Level, annualized over the 50-year period of analysis.*	

7.5 Risk Analysis

Per the guidance included in "Incorporating Life Safety in to Planning Studies" (PB 2019-04), the project team evaluated potential life safety risks during the development of the Recommended Plan. The evaluation identified future work during PED to reduce potential life risk such as but not limited to the following: collecting additional site characteristics, refining the 2-D H&H model to inform design, and refining design features. The evaluation also identified OMRR&R activities that would be required by the NFS and that have an impact on potential life risk. Those OMRR&R activities include but are not limited to the following: maintaining the existing channel clear of vegetation and debris; maintaining the levee

free of problem vegetation and encroachments; and, monitoring for maintenance needs before and after a storm or seismic event to ensure proper functioning of the system.

7.5.1 Uncertainty and Associated Risks

Uncertainty is inherent in economic and engineering assumptions that impact project performance. In general, the ability of the plan to reduce flood risk depends on assumptions about variability in storm water discharge, water surface elevations, levee performance, structure elevations, structure and structure content values, and depth-damage relationships. This uncertainty is described in detail in the economics appendix.

Under the Recommended Plan, there is an estimated 97 percent reduction in economic damages due to floodwaters. The section below describes project performance and residual risk in more detail.

7.5.2 Residual Risk

Residual risk is the risk that is still present when the proposed flood risk management project is implemented. Residual risk includes the consequences of capacity exceedance under the with-project condition, and consideration of project performance, robustness, and resiliency. Guidance contained in "Risk Assessment for Flood Risk Management Studies" (ER 1105-2-101, 17 July 2017) clearly defines two types of residual risks to consider when comparing the with-project condition to the without-project condition. These subsets of residual risk are identified as transformed and transferred.

- Transformed risk – a risk that emerges or increases as a result of mitigating another risk.
- Transferred risk – a relocated or increased risk from one region within a study area to another region of a study area as a result of an action within the study area.

This study considered both types of residual risk for the with-project condition. The recommended plan does not transform risk, or transfer risk from one area of the study to another.

Transformed risk in the Recommended Plan is avoided by a project design that reduces flood risk for existing structures only. The plan does not encourage development in the floodplain near levees or channels that could overtop, resulting in increased future flood risk.

Transferred risk is avoided by implementing conveyance modifications at the downstream end of the project first, and ensuring the additional upstream flow will be contained in the upstream reaches. Likewise, downstream reaches are not negatively impacted by upstream improvements.

While reducing flood risk was a part of the plan formulation and preliminary design processes, flood risk is not completely eliminated for the with-project condition. For the Recommended Plan, flood risk is significantly reduced for the 0.01 AEP (100-year event), and the number of structures at least partially inundated decreases from 1,439 to 24. Floodwaters for events up to the 50-year event are contained with 95 percent confidence. For the 0.002 AEP (500-year event), there are still 1,003 structures at risk of partial inundation. (See Appendix J Figure 3-5 and Figure 3-7.)

The conditional probability of non-exceedance, or assurance, refers to the probability that no flooding occurs, given the occurrence of a specific flood event. For example, the probability that the 0.01 AEP event (100-year event) would be contained by the existing levee for reach 3R is just 1%. Inversely, that means there is a 99% chance that the 0.01 AEP event would exceed the channel capacity (either through breach or overtopping) and inundate the leveed area. The probability that no flooding occurs for the 0.02 AEP (100-year event) is increased to 98 percent when the Recommended Plan is implemented.

The following tables display the project performance statistics by reach for the without-project and with-project condition. The columns in the table below are defined as:

- Reach: This refers to the economic reaches, or impact areas
- AEP: The annual exceedance probability, or probability that a flood will inundate the specified impact area in any given year
- Long-Term Risk
  - 10 year: The probability that the top of bank will be exceeded at least once in a 10 year period
  - 30 year: The probability that the top of bank will be exceeded at least once in a 30 year period
  - 50 year: The probability that the top of bank will be exceeded at least once in a 50 year period
- Assurance
  - 2.00%: The probability that the existing infrastructure (levee or channel) will contain, or not be exceeded by a 2.00% AEP flood event (50 year recurrence interval)
  - 1.00%: The probability that the existing infrastructure (levee or channel) will contain, or not be exceeded by a 1.00% AEP flood event (100 year recurrence interval)
  - 0.20%: The probability that the existing infrastructure (levee or channel) will contain, or not be exceeded by a 0.20% AEP flood event (500 year recurrence interval)

Table 34: Without project performance (%)

		Long Term Risk[2]			Assurance[3]		
Reach	AEP[1]	10 year	30 year	50 year	2.00%	1.00%	0.20%
1L	99.9	99.00	99.00	99.00	1.00	1.00	1.00
2L	99.9	99.00	99.00	99.00	1.00	1.00	1.00
2R	99.9	99.00	99.00	99.00	1.00	1.00	1.00
3L	20.67	89.97	99.00	99.00	2.28	1.77	1.00
3R	66.77	99.00	99.00	99.00	1.00	1.00	1.00
4L	1.56	42.97	81.46	93.97	51.28	38.79	4.92
4R	99.9	99.00	99.00	99.00	1.00	1.00	1.00

1Probability that flooding will occur in any given year

[2]Probability the target stage is exceeded during the period of time listed below

[3]Probability that no flooding occurs, given that a flood event of the frequency listed has occurred

Table 35: With-project performance (%)

		Long Term Risk[2]			Assurance[3]		
Reach	AEP[1]	10 year	30 year	50 year	2.00%	1.00%	0.20%
1L	21.35	90.97	99.99	99.00	1.00	1.00	1.00
2L	99.90	99.00	99.00	99.00	1.00	1.00	1.00
2R	17.81	86.48	99.75	99.99	2.00	2.00	1.00
3L	0.29	3.50	10.01	16.12	99.29	94.09	44.18
3R	0.22	2.19	6.43	10.49	99.95	98.44	57.99
4L	0.01	0.10	0.30	0.50	99.99	99.97	99.96
4R	7.33	61.13	94.13	99.11	13.52	8.77	3.34

1Probability that flooding will occur in any given year

[2]Probability the target stage is exceeded during the period of time listed below

[3]Probability that no flooding occurs, given that a flood event of the frequency listed has occurred

7.6 Plan Implementation

This section describes the remaining steps to potential authorization of the proposed project by Congress.

7.6.1 Report Approval

After its review of the Final Integrated Report and EA, including consideration of public comments, USACE HQ will prepare the Chief of Engineers' Report (Chief's Report). This report will be submitted to the ASA(CW), who will coordinate with the Office of Management and Budget (OMB) and submit the report to Congress when the appropriate reviews are completed.

7.6.2 Project Authorization and Construction

Upon completion of the final report, the ASA(CW) transmits the Chief's Report to the Office of Management and Budget (OMB) for review. Upon completion of the OMB review, the report is submitted to Congress for Authorization. If the project is authorized by Congress, PED would begin, followed by real estate acquisition, if necessary, and construction.

7.6.3 Division of Responsibilities

Federal Responsibilities

Following authorization of the proposed project, USACE would enter the PED phase to develop detailed design and cost estimates for the approved project. Once the project is authorized and funds are appropriated, a Project Partnership Agreement (PPA) would be signed with Department of Natural and Environmental Resources as the NFS. After the sponsor provides its cash contribution, lands, easements, rights-of-way, relocations, and disposal areas, as well as assurances, the Federal Government would begin construction of the project.

Non-Federal Responsibilities

A list of responsibilities of the NFS is included in Section 7.8.

Views of 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. Throughout development of this feasibility report, there has been coordination with the DNER, relevant federal agencies, the Commonwealth of Puerto Rico, the Municipality of Guayanilla and other stakeholders.

Financial Capability of Sponsor

The total estimated non-federal first cost (35% minimum minus the $484,000 Territory Credit) of the project is $53,535,000 for the NED Plan including LERRDs, at the 2020 price level. Actual costs may be slightly greater at the time of construction due to inflation. The total estimated value for the project lands, including LERRDs, for the NED Plan is $25,815,000.

The NFS has provided a self-certification of financial capability for the final report as required by USACE guidance.

Project Cost-Sharing Agreements

Prior to PED, a Design Agreement must be executed between USACE and the NFS in order to cost share the development of detailed plans and specifications. Before construction is started, USACE and the NFS would execute a PPA. This agreement would define responsibilities of the NFS for project construction as well as OMRR&R, and other assurances. The scope for this project includes OMRR&R directly required for project features defined in this report as well as indirectly required to ensure the ongoing operation of the project as designed. As part of signing the PPA, DNER would assume eventual OMRR&R responsibilities for the completed project.

Table 36: Rio Guayanilla FRM Project Cost Sharing, FY 20 Price Level

Cost Items	Total Costs	Fed Costs	Non-Fed Costs
Flood Risk Management			
PED	$19,135,000	$12,438,000 (65)	$6,697,000 (35)
LERR&D	$ 25,815,000	$ 0	$25,815,000
Flood Risk Management	$109,391,000	$ 87,884,000	$21,507,000
Subtotal	**$154,341,000**	**$100,322,000 (65)**	**$54,019,000 (35)**
WRDA 2014 Section 1156 Credit		**$ 484,000**	**$ -484,000**
Total First Costs	**$154,341,000**	**$100,806,000 (65)**	**$53,535,000 (35)**
5% cash*			$ 7,233,000
LERRDS			$25,815,000
Additional Cash			$20,487,000

*Section 1156 credits are applied to the 5% cash requirement.

7.6.4 Schedule

Table 37: Study schedule.

Item	Date
Feasibility Cost Sharing Agreement Signed	24 September 2018
Alternatives Milestone Briefing	18 December 2018
Alternative Milestone Approved	07 January 2019
TSP Milestone	18 June 2019
Final Report Released for Public Review	27 August 2019
Agency Decision Milestone	19 November 2019
Senior Leader Briefing	11 June 2020*
Chief of Engineer's Report Signed	23 July 2020*
Finding of No Significant Impact Signed	TBD

**Tentative dates*

7.7 Project Implementation

7.7.1 Design & Construction

The Feasibility Phase will be completed when the IFR and Integrated EA is finalized and a Chief's Report is issued. After this point the recommended project would need to receive funding to move into the PED

phase. During PED, detailed design work would result in detailed design documentation, final construction documents and a final detailed cost estimate.

During the PED Phase, the project team will develop design documentation and complete additional surveys and engineering analyses to increase the level of design. Additional surveys will include new topographic data along the coastline to verify ground surface elevations, as subsidence due to the recent earthquakes is expected. Due to the uncertainties associated with site conditions following the earthquakes, the certified costs included an increased amount of contingency.

7.7.2 Project implementation strategy

A preliminary best-case construction schedule was developed for the Recommended Plan and resulted in an estimate of 4 years of continuous construction for project completion, assuming availability of funding.

7.7.3 Operation, Maintenance, Repair, Replacement, and Rehabilitation

Once construction activities are completed, the project will be turned over to the NFS. Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) of the levees, floodwalls, conveyance improvements, diversion structure, diversion channel, and the bridges/roads will be the responsibility of the Department of Natural and Environmental Resources (DNER). OMRR&R activities would include periodic inspections, vegetation control, removal of impediments to flow and repair of structures as needed, in addition to supporting emergency efforts during flood events. DNER and local municipalities will be responsible for outreach to communities, residents, and businesses in the floodplain about project risks and the development of an emergency action/response plan. The project features in the area will be inspected at least once a year and following major flooding events.

7.8 Items of Cooperation

This section describes the Items of Cooperation for the proposed flood risk management project. Two plans have been identified that meet the objectives of the study and could potentially be recommended for implementation.

Alternative #3 is the NED Plan and the Recommended Plan. The estimated first cost (2020 price level) of the Recommended Plan is $154,341,000 with an estimated maximum federal cost of $100,806,000. This would equate to an estimated non-federal cost of $53,535,000 to implement the NED Plan, with an estimated annual OMRR&R cost of $39,000 (2020 price levels).

Federal implementation of a recommended plan would be subject to the NFS complying with applicable Federal laws and policies, including but not limited to:

a. Provide a minimum of 35 percent, but not to exceed 50 percent of total project costs, subject to a reduction of up to $484,000 as further specified below:

    1. Provide 35 percent of design costs in accordance with the terms of a design agreement entered into prior to commencement of design work;

    2. Provide, during construction, a cash contribution of funds equal to 5 percent of total project costs;

    3. Provide all lands, easements and rights-of-way, including those required for relocations, the borrowing of material and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all modifications required on lands, easements and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction and O&M of the project;

    4. Provide, during construction, any additional funds necessary to make its total contribution equal to at least 35 percent of total project costs, subject to a reduction of up to $484,000;

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

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

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

e. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-federal interest to prepare a floodplain management plan within 1 year after the date of signing a project cooperation agreement, and to implement such plan not later than 1 year after completion of construction of the project;

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

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

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

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

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

k. Hold and save the U.S. free from all damages arising from the construction, OMRR&R of the project and any betterments, except for damages due to the fault or negligence of the U.S. or its contractors;

l. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of three years after final accounting;

m. Comply with all applicable federal and State laws and regulations, including but not limited to: Section 601 of the Civil Rights Act of 1964 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; the Age Discrimination Act of 1975 (42 U.S.C. 6102); the Rehabilitation Act of 1973, as amended (29 U.S.C. 794) and Army Regulation 6007 issued pursuant thereto; and 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (labor standards originally enacted as the Davis-Bacon Act, the Contract Work Hours and Safety Standards Act, and the Copeland Anti-Kickback Act);

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

o. Assume, as between the Federal Government and the NFS, 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 O&M of the project;

p. Agree, as between the Federal Government and the NFS, that the NFS shall be considered the operator of the project for the purpose 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; and

q. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the 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.

8.0 Recommendations*

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to Congress as proposals for authorization and implementation funding. However, prior to transmittal to Congress, the sponsor, the State, interested federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further. The Finding of No Significant Impact (FONSI) can be found on the pages following this recommendation and is available as a separate document.

05/27/2020
Date

Aaron W. Reisinger
Colonel, U.S. Army
District Commander

9.0 FINDING OF NO SIGNIFICANT IMPACT

Rio Guayanilla Flood Risk Management Study – Integrated Feasibility Report & Environmental Assessment
Municipality of Guayanilla
Commonwealth of Puerto Rico

The U.S. Army Corps of Engineers, Chicago District (Corps) has conducted an environmental analysis in accordance with the National Environmental Policy Act of 1969, as amended. The Final Integrated Feasibility Report and Environmental Assessment (Final IFR/EA) dated **24 March 2020**, for the **Rio Guayanilla Flood Risk Management Study** addresses **flood risk management** opportunities and feasibility in the **Municipality of Guayanilla, the Commonwealth of Puerto Rico**. The final recommendation is contained in the report of the Chief of Engineers, dated **DATE OF CHIEF'S REPORT TBD**.

The final IFR/EA, incorporated herein by reference, evaluated various alternatives that would **reduce risk of flood damages to structures and infrastructure and reduce risks to life safety** in the study area. The recommended plan is the **National Economic Development (NED) Plan** and includes:

- Construction of an engineered diversion channel with a bottom width of 100-feet and 2:1 side slopes. The 9,000 foot engineered channel will extend from a new diversion structure, constructed across the existing river approximately 2,000 feet downstream of PR-127. The diversion structure will direct the majority of flood waters to the trapezoidal diversion channel while maintaining a bank-full flow to the Rio Guayanilla. The diversion structure will maintain riverine connectivity for sediment transport and fish passage. A levee will be built on the eastern side of the diversion channel. The riverside slope of the levee will be lined with riprap to prevent erosion. The diversion channel and existing channel will be reconnected upstream of the Phase I project with an additional diversion structure.
- Upstream of the diversion channel, a combination of levees and floodwalls will be installed on the east side of the river channel at designated locations. The levees will be constructed from local limestone that will be excavated from an abandoned quarry in the project area. A 2,750 foot long earthen levee will also be constructed to reduce flood risk for El Faro community from overbank riverine flooding.
- Improvement of conveyance under PR-2 and PR-127 and removal of flow impediments.
- Due to impacts associated with the El Faro levee, wetland mitigation of 6 acres is also included in the Recommended Plan. Conservations measures for two special status species will be implemented during quarrying of levee materials to minimize potential impacts to less than significant.
- Project features impact three local roads that will require them to be relocated. A road at the northern part of the project will be moved north of PR-2 and two roads that intersect the diversion channel will be replaced with a bridge over the channel and connecting roadway that follows the southern edge of the diversion channel as it curves to the east.
- A flood warning system/response plan.
- Implementation of any required environmental compensatory mitigation and associated monitoring and mitigation area adaptive management plan, when applicable and appropriate.

Monitoring will continue until any required mitigation has been determined to be successful based on the identified criteria within **the Rio Guayanilla Mangrove Mitigation, Monitoring & Adaptive Management Plan** included in Appendix **A3**. Monitoring is expected to last no more than 10 years.

In addition to a "no action" plan, three action alternatives were evaluated. The alternatives included: Alternative #1 Non-Structural Measure – Natural Channel Conveyance and Flood Warning System; Alternative #3 Diversion Channel South w/ Single Line Protection; Alternative #6 Staged Greenway Terraces w/ Single Line Protection. Non-structural alternatives were considered and were generally eliminated due to economic and logistical infeasibility. The non-structural alternatives of a Flood Warning System and Natural Channel Conveyance were incorporated into the Recommended Plan.

For all alternatives, the potential effects were evaluated, as appropriate. A summary assessment of the potential effects of the recommended plan are listed in Table 1:

Table 1: Summary of Potential Effects of the Recommended Plan

	Insignificant effects	Insignificant effects as a result of mitigation*	Resource unaffected by action
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	☒	☐	☐
Socio-economics	☒	☐	☐
Environmental Justice	☒	☐	☐
Soils	☒	☐	☐
Water Quality	☒	☐	☐
Climate Change	☒	☐	☐

All practicable and appropriate means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. Best management practices (BMPs) as detailed in the IFR/EA will be implemented, if appropriate, to minimize impacts. In addition, avoidance planning, conservation measures and compensatory mitigation as discussed below were incorporated as part of the Recommended Plan to render effects to insignificant.

Aquatic Resources/Wetlands and Fish & Wildlife Habitat – *Channel Improvements & Diversion Structure*: To minimize effects to riverine components of connectivity, substrate transport and sorting, and ephemeral hydrology, conservation measures were applied to the diversion channel structure. These include culverts sized to facilitate fish passage, maintenance of low to bank full flows in the natural channel (0-2-year flood events), and gravel and cobble substrate transport and sorting for channel morphology and habitat. Additional conservation measures incorporated into the design of the stilling basin include a low flow channel and with associated stream morphology above the diversion structure. (Section 3.5.1 of the Integrated Feasibility Report)

Aquatic Resources/Wetlands and Fish & Wildlife Habitat – *Wetland Impact Avoidance, Minimization & Enhancement Opportunities*: To avoid effects to the existing mangrove swamp due to the construction of the diversion channel, avoidance and enhancement of mangrove wetlands was included in the Recommended Plan. To provide a net benefit to estuarine wetlands, the western berm of the engineered diversion channel was eliminated which will allow for continued overbank flooding of the inner mangrove swamp. Overbank floods provide freshwaters that flush excess salinity from the 240 acre greater coastal mangrove zone between El Faro and Rio Guayanilla. Floodwaters are also a source of required sediment from the upper portions of the watershed to the interior swamp. Flood risk management protection for El Faro will be provided by a set-back levee. The set-back levee configuration is more conducive to promoting a naturalistic hydrogeomorphic setting for river mouth delta and estuarine wetlands to regenerate. (Section 3.5.1 of the Integrated Feasibility Report).

Fish & Wildlife Habitat – *Rock Sourcing*: To avoid impacts to **4** federally endangered species and over 20 endemic rare plants, coordination between the USACE and the USFWS identified an abandoned quarry as an alternate site for obtaining stone for the project. Based on initial surveys, it was determined that areas within the abandoned quarry had been previously cleared of vegetation and quarried, but still provide habitat for the Puerto Rican Nightjar and Puerto Rican Boa. Implementation of the prescribed conservation measures lead to a determination of not likely to adversely affect the Puerto Rican Nightjar and the Puerto Rican Boa. (Section 3.5.1 and Section 5.6.8 of the Integrated Feasibility Report).

Aquatic Resources/Wetlands and Fish & Wildlife Habitat – *Wetland Compensatory Mitigation*: Construction of the El Faro levee results in an unavoidable impact. The recommended plan will result in unavoidable adverse impacts to **5.8 acres of Interior Basin Mangrove Swamp that requires compensatory mitigation.** To mitigate for these unavoidable adverse impacts, the U.S. Army Corps of Engineers will **provide** 6 acres of compensatory mitigation (40 C.F.R. § 230.93) for the loss of 5.8 acres of perennial estuarine interior basin mangrove wetland/habitat and associated fauna due construction of the setback levee. Full description can be found in Section 5.6.7 and 5.6.12 of the Environmental Assessment, and the Mitigation, Monitoring & Adaptive Management Plan in Appendix A3.

Public review of the draft IFR/EA and FONSI was completed on **4 October 2019**. All comments submitted during the public review period were responded to in the Final IFR/EA and FONSI. The project was submitted to the Puerto Rico Permit Management Office through the Single Business Portal website on October 25, 2019 and a response was received on January 14, 2020.

Pursuant to section 7 of the Endangered Species Act of 1973, as amended, the U.S. Army Corps of Engineers coordinated with the U.S. Fish and Wildlife Service on potential impacts of the recommended plan. To avoid impacts to **4** federally endangered species, coordination between the USACE and the USFWS identified an abandoned quarry as an alternate site for obtaining stone for the project. Based on initial surveys, areas within the abandoned quarry had been previously cleared of vegetation and quarried, but still provide habitat for the Puerto Rican Nightjar and Puerto Rican Boa. Based on further assessment of the abandoned quarry site on November 4, 2019 by USFWS, and inclusion of the prescribed conservation measures, the USACE has determined that the proposed project is not likely to adversely affect the following federally listed species or their designated critical habitat: *the Puerto Rican Nightjar (Antrostomus noctitherus) and the Puerto Rican Boa (Epicrates inornatus).* The U.S. Fish and Wildlife Service (FWS) concurred with the Corps' determination on February 24, 2020.

Pursuant to section 106 of the National Historic Preservation Act of 1966, as amended, the U.S. Army Corps of Engineers determined that historic properties would not be adversely affected by the recommended plan. The **State Historic Preservation Officer for Puerto Rico** concurred with the determination on **March 26, 2020**

Pursuant to the Clean Water Act of 1972, as amended, the discharge of dredged or fill material associated with the recommended plan has been found to be compliant with section 404(b)(1) Guidelines (40 CFR 230). The Clean Water Act Section 404(b)(1) Guidelines evaluation is found in **the 404(b)(1) Analysis presented in Appendix A2** of the IFR/EA.

A water quality certification pursuant to section 401 of the Clean Water Act will obtained from the **Puerto Rico Environmental Quality Board** prior to construction. In a letter dated **27 May 2020**, the **Commonwealth of Puerto Rico** stated that at this time, the recommended plan is consistent with and not likely to compromise Puerto Rico Water Quality Standards. A final determination will be based on information developed during the pre-construction engineering and design phase. All conditions of the water quality certification will be implemented in order to minimize adverse impacts to water quality.

A determination of consistency with the **Commonwealth of Puerto Rico** Coastal Zone Management program pursuant to the Coastal Zone Management Act of 1972 was obtained from the **Puerto Rico Planning Board.** All conditions of the consistency determination shall be implemented in order to minimize adverse impacts to the coastal zone.

All applicable environmental laws have been considered and coordination with appropriate agencies and officials has been completed.

Technical, environmental, and economic criteria used in the formulation of alternative plans were those specified in the Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on this report, the reviews by other Federal, State and local agencies, Tribes, input of the public, and the review by my staff, it is my determination that the recommended plan would not cause significant adverse effects on the quality of the human environment; therefore, preparation of an Environmental Impact Statement is not required.

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Date

Aaron W. Reisinger
Colonel, Corps of Engineers
District Commander

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