# RÍO GUAYANILLA FLOOD RISK MANAGEMENT STUDY

## DRAFT INTEGRATED FEASIBILITY REPORT

## & ENVIRONMENTAL ASSESSMENT

## MUNICIPALITY OF GUAYANILLA

## the COMMONWEALTH OF PUERTO RICO

**August 2019**

US Army Corps of Engineers®
Chicago District

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# COVER SHEET*
# Río Guayanilla Flood Risk Management Study, Guayanilla, Puerto Rico
# Draft Integrated Feasibility Report & Environmental Assessment

The lead federal agency responsible for the planning and design of a flood risk management project, including addressing the 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 a draft Environmental Assessment report (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 Draft 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 was developed to a feasibility level of detail sufficient to determine the most cost effective and environmentally compliant plan(s), which is termed the Tentatively Selected Plan (TSP). Additional detailed design, cost estimating, and effects assessments would be completed for the TSP should significant information or concerns be received from this public and resource agency review, as well as from concurrent internal technical reviews. Each of the alternatives, including the TSP, were formulated to be complete, effective, efficient and acceptable.

The study area is located in Guayanilla, Puerto Rico, beginning near highway PR-2 and continuing until the river's confluence with the Caribbean Sea. Preliminary analysis shows that flooding overtops the existing natural river channel of Rio Guayanilla in the study area at the 0.5 annual chance of exceedance (ACE) storm event (which corresponds to a 2-year storm 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 the 500 year (0.002 ACE) event would cause an estimated $270 million in structural and other damages. Study analyses focused on various diversion channel types that would divert flood waters greater than the 2-year ACE flow around the Town of Guayanilla to the west.

Of the three action alternatives, Alternative #3 Diversion Channel South w/ Single Line Protection is the TSP, supported by non-structural Alternative #1 Non-Structural Measures (flood warning & natural channel conveyance). This plan generally includes an engineered diversion channel, a robust diversion structure, a levee along one side of the diversion channel, bridge modifications, berms, a rock quarry, haul roads, staging, and disposal areas. As a result of nature based features and conservation measures included in the alternative to minimize and mitigate project impacts, the TSP will not have a significant impact on the human environment. Compatible nonstructural measures (Alt #1) were also included in the TSP for debris clearing within the natural channel of the Rio Guayanilla and to implement a flood warning system to reduce the life safety risk associated with flooding in the project area. It is estimated the TSP would reduce average annual expected damages by $18.8 million.

The estimated first cost of the TSP is $146 million and it has a benefit-to-cost ratio (BCR) of 3.3 / 1 at the current Fiscal Year 2019 (FY19) federal discount rate of (2.875%).

This Draft IFR is available for public review beginning 27 August 2019. The official closing date for the receipt of comments is 27 September 2019, 30 days from being posted on USACE and supporting agency websites. Comments may be mailed or emailed to the address listed below.

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# HOJA DE CUBIERTA *
# Estudio de Gestión de Riesgos de Inundaciones de Río Guayanilla, Guayanilla, Puerto Rico
# Estudio 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 de Viabilidad Integrado (IFR, por sus siglas en inglés) que incluye un Informe de Viabilidad y el Borrador del Informe de 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 borrador del Informe 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 Tentativamente Seleccionado (TSP, por sus siglas en inglés). En el caso de que información significativa o preocupante surja de los comentarios del público y agencias concernidas, así como de los exámenes técnicos internos se llevaran a cabo otros diseños en detalle, estimación de costos y evaluación de esos efectos para el Plan Tentativamente Seleccionado. Cada una de las alternativas, incluyendo el TSP, se formuló para que fuera completo, eficaz, eficiente y aceptable.

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 análisis preliminar muestra que las inundaciones sobrepasan el cauce natural del Río Guayanilla en el área de estudio a una probabilidad anual de superación 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 demuestra que el flujo de recurrencia de 500 años (0.002 ACE) causaría un estimado de $270 millones en daños estructurales y de otro tipo. El estudio se enfocó en varios tipos de canales de desviación que desviarían aguas de inundación hacia el oeste del pueblo de Guayanilla con flujos de recurrencias mayores a 2-años.

De las tres alternativas de acción, la Alternativa #3 Canal de Desvío al Sur con Una Línea de Protección es el TSP, apoyado por la Alternativa #1 de Medidas No-estructurales (aviso de inundación y transporte de canal natural). En terminos generales este plan incluye un canal de desviación, una estructura de desviación robusta, un dique a lo largo de un lado del canal de desviación, modificaciones de puentes, bermas, una cantera de roca, carreteras de transporte de material y zonas de estadificación y eliminación. Como resultado de las características naturales y las medidas de conservación incluidas en la alternativa para minimizar y mitigar los impactos del proyecto, el TSP no tendrá un impacto significativo en el medio ambiente humano. También se incluyeron medidas no-estructurales compatibles (Alt #1) en el TSP para remover escombros en el cauce natural del Río Guayanilla y la implementación de un sistema de

advertencia de inundaciones para reducir el riesgo a la vida humana asociado con las inundaciones en el área del proyecto. Se estima que el TSP reduciría los daños en un promedio anual de $18.8 millones.

El primer costo estimado del TSP es de $146 millones y tiene una relación beneficio-costo (BCR por sus siglas en inglés) de 3.3 / 1 en el actual año fiscal 2019 (FY19) a una tasa de descuento federal de (2.875%).

El borrador de IFR está disponible al público a partir del 27 de agosto de 2019. Los comentarios deberan ser recibidos en o antes del 27 de septiembre de 2019, 30 días después de su publicación en el portal de USACE. Los comentarios pueden ser enviados por correo electrónico a la dirección indicada a continuación.

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# EXECUTIVE SUMMARY

## Río Guayanilla Flood Risk Management Study, Guayanilla, Puerto Rico Draft 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 town. Heavy rainfall combined with very steep slopes in the upper catchment can produce high peak discharges in a relatively short period of time. This discharge can be in the magnitude of 30,000-40,000 cubic-feet-per-second (cfs). The 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 establishes a significant need for action. The 1975 flood, caused by Tropical Storm (later classified as Hurricane) Eloise, caused over $1.7 million 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, 1998, and 2017 floods. In addition to the damaged structures and lives lost, flood-induced waters and sediment (rock and silt) deposition have induced 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 overtopping of the Rio Guayanilla and the floodwaters washed out a major bridge, and caused significant damage to: the largest supermarket, a pharmacy, a bakery, and 106 homes. 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 and security of people would otherwise be adversely affected. The 1990 Recon Study presented that Federal Interest was warranted based on the potential benefits derived from five different structural alternatives. The 1990 recommended plan combined 6.5 kilometers (4 miles) of earthen levee, 3.6 kilometers (2.25 miles) of trapezoidal channel improvements (stream channelization), 1.3 kilometers (.8 miles) of trapezoidal channel diversion, 300 meters (984 feet) of rectangular concrete channels, and the replacement of three vehicular bridges. In 1990, the total first cost of this plan was $12.5 million and total annual costs were estimated at $1.2 million; with annual benefits at $2.5 million. Implementation of the project would have resulted in a benefit-to-cost ratio of 2.1. Though the plan would contribute $0.5 million of annual location benefits, it was also justified independently on existing inundation damages prevented with a benefit-to-cost ratio of 1.7. The positive benefit-to-cost ratios established by the 1990 Recon Study further established the project as being economically beneficial.

The purpose of 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 in terms of life safety and economic losses, with a primary hazard of flash flooding. 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). This natural condition is driven by topography and naturally impervious ground surfaces; these conditions are not exacerbated by man such as you would find in an urbanized watershed. This natural flooding regime once helped created a diverse ecosystem within the coastal floodplain and estuary. Since the town was built, the flooding has become a problem for citizens in the town of Guayanilla, other local homesteads, and the agriculture lands situated within the floodplain. The 100-year flood can inundate over 8-square kilometers within the municipality and rural areas of Guayanilla. The potential for these floods to occur is high, while the resulting consequences are considered large in terms of life safety, economic, and social resources. A high potential for these floods, exacerbated by a high (large) consequences results in this event to be considered high-risk.

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. The success by which a solution would meet this objective would be measured by a net reduction in estimated annual damages, under the with-project condition. The affected location would be within the study area specifically focused on residential, public, and commercial structures, utilities, transportation infrastructure, and agricultural fields in production. Beneficial effects commence accruing at completion of the construction phase and last the duration of the project life cycle.

*Reduce Risks to Life Safety* – To lower the risks to life safety induced by flooding and associated effects this objective seeks to 1) properly inform the public of pending floods, and 2) reduce the depth, duration, and likelihood of flooding. Success would be measured by 1) how quickly and reliably the public can be informed of pending floods, and 2) reducing the risk of being caught in a structure or an evacuation route during a flood event, and thus reducing the population at risk. The affected location would be within the study area specifically focused on the Municipality of Guayanilla. Beneficial effects commence accruing at completion of the construction phase and last the duration of the project life cycle.

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 pool of six (6) non-structural measures and eleven (11) structural measures were developed to address study needs. Based on concepts of technical merit, environmental effects and policies, 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 tested with USACE core planning concepts, life safety, environmental effects, real estate, utilities and sustainability concepts. Based on this testing, or screening, 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

Alternative #3 is the TSP. The estimated first cost of the TSP is $146 million and it has a benefit-to-cost ratio (BCR) of 3.3 / 1 at the current Fiscal Year 2019 (FY19) federal discount rate of (2.875%).

It reduces average annual expected damages by $18.8 million. This plan generally includes an engineered diversion channel, a robust diversion structure, a levee along one side of the diversion channel, bridge modifications, berms, a rock quarry, haul roads, staging, and disposal areas. This alternative also includes nature based features and conservation measures to minimize and mitigate project impacts from the disturbance of 10 to 15 acres of formerly disturbed karst dry forest habitat and several acres of the Rio Guayanilla natural channel. Compatible nonstructural measures were also included in the TSP for debris clearing within the natural channel of the Rio Guayanilla and to implement a flood warning system to lessen the life safety risk associated with flooding in the project area.

**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; the 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, a tertiary highway, the land use and topography was modified for agriculture, residential, commercial and to a much lesser degree light industrial. 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; inclusive of 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 for the Rio Macaná.

The 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 impairments, 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 Town of Guayanilla itself is nestled in the upper portion of the coastal floodplain valley, where the valley is narrower. This location makes the town 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 town, 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 over one thousand 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 changed from residential to primarily agriculture and naturalistic open-space areas, with the exception of the small coastal towns of El Faro and Playa de Guayanilla. The river in this reach was channelized and leveed under the Phase I DNER project for flood control at Guayanilla. Based on the calculated flows entering the coastal alluvial plain at PR-379, large floods have filled up the entire valley in the past, inducing many braided and overland flowages that would temporally flush and maintain estuarine habitats along the Bay of Guayanilla coast.

Based on the natural deep depth of the bay shallow estuary wetland habitat was naturally limited, but is noted as currently present in some areas, while noted as unnaturally lost in others. Outside of the deep natural bay 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.

**ENVIRONMENTAL CONSEQUENCES AND MITIGATION**

For all alternatives, the potential effects were evaluated, as appropriate. A summary assessment of the potential effects of the TSP follows:

| | 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.

Coordination is still ongoing with the USFWS regarding threatened and endangered species within the preferred abandoned quarry site; however, based on avoidance planning between USFWS and USACE, and subsequent conservation measures nested within the alternatives, it is not anticipated that mitigation will be required as part of ESA compliance.

Modifications to the natural channel of the Rio Guayanilla requires assessment under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. Features requiring assessment included the diversion structure across the entire channel just downstream of PR-2, placement of dolomitic limestone, steel sheet pile, and other erosion features in the channel improvement area. The 404(b)(1) assessment is located in Appendix A. The proposed project includes measures to both minimize impacts and mitigate unavoidable impacts to the riverine habitat.

## 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. There were no 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 (42 U.S.C. § 4332(2)(c)(iv); 40 C.F.R. 1502.16). There have been no irreversible and irretrievable commitments of resources identified resulting from the proposed action should it be implemented (42 U.S.C. § 4332(2)(c)(v); 40 C.F.R. 1502.16).

**Applicable Federal, State & Local Legal Compliance Summary**

| Reference | Environmental Statutes/Regulations | Project Compliance |
|---|---|---|
| **Federal** | | |
| 42 U.S.C. 7401 | Clean Air Act of 1970, as amended | P |
| 33 U.S.C. 1251, et seq. | Clean Water Act of 1977, as amended | P |
| 16 U.S.C. 1451, et seq. | Coastal Zone Management Act of 1972, as amended | P |
| 42 U.S.C. 9601 | 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 | P |
| 16 U.S.C. 661 | Fish and Wildlife Coordination Act, as amended | P |
| EO 11990 | Protection of Wetlands | P |
| 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 | P |
| 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 | P |
| | | |

| | | |
|---|---|---|
| | | |
| | | |
| **Local** | | |
| | | |

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

**PRELIMINARY RECOMMENDATION**

Of the three action alternatives, Alternative #3 Diversion Channel South w/ Single Line Protection is the TSP, supported by non-structural Alternative #1 Non-Structural Measures (flood warning & natural channel conveyance). This plan generally includes an engineered diversion channel, a robust diversion structure, a levee along one side of the diversion channel, bridge modifications, berms, a rock quarry, haul roads, staging, and disposal areas. Compatible nonstructural measures (Alt #1) were also included in the TSP for debris clearing within the natural channel of the Rio Guayanilla and to implement a flood warning system to reduce the life safety risk associated with flooding in the project area. This plan also includes nature based features and conservation measures to minimize and mitigate project impacts from the disturbance of 10 to 15 acres of formerly disturbed karst dry forest habitat and several acres of the Rio Guayanilla natural channel. The estimated first cost of the TSP is $146 million and would reduce average annual damages by $18.8M. Therefore, it has a benefit-to-cost ratio (BCR) of 3.3 / 1 at the current Fiscal Year 2019 (FY19) federal discount rate of (2.875%).

# Resumen Ejecutivo

# Estudio de Gestión de Riesgos Inundaciones del Río Guayanilla, Guayanilla, Puerto Rico
# Borrador del Estudio 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. Esta descarga puede tener una magnitud de 30,000-40,000 pies cúbicos por segundo (cfs, por sus siglas en inglés). En el área del estudio un flujo de recurrencia de 100 años puede inundar más de 8 kilómetros cuadrados de terreno.

Se dieron inundaciones significativas en la llanura inundable del Río Guayanilla en los años: 1975, 1979, 1982, 1985, 1996, 1998, 2004, 2008, 2012 y 2017. Esta trayectoria de inundaciones establece claramente una necesidad significativa de acción. La inundación del 1975, provocada por la tormenta tropical (posteriormente clasificada como huracán) Eloisa, causó más de $1.7 millones en 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 del: 1975, 1979, 1985, 1998 y 2017. Además de las estructuras dañadas y las vidas perdidas, las inundaciones y sedimento (roca y limo) han provocado el cierre de las carreteras principales de la zona y han impedido 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 provocó el desbordamiento del Río Guayanilla y la crecida destruyó un puente de mayor importancia, y causó daños significativos a: el supermercado principal de la ciudad, una farmacia, una panadería y 106 hogares. 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 lo establecido en la Ley de Control de Inundaciones del 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 la vida y la seguridad de las personas se ven 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 combino 6.5 kilómetros (4 millas) de dique de tierra, 3.6 kilómetros (2.25 millas) de mejoras en el canal trapezoidal (canalización de flujo), 1.3 kilómetros (.8 millas) de desviación del canal trapezoidal, 300 metros (984 pies) de canales de hormigón rectangulares, y la sustitución de tres puentes vehiculares. En el 1990 el primer costo total de este plan fue de $12.5 millones y los gastos anuales totales se estimaron en $1.2 millones, con beneficios anuales de $2.5 millones. La ejecución del proyecto hubiese dado lugar a una relación beneficio-a-costo de 2.1. Aunque el plan contribuiría con $0.5 millones en beneficios de ubicación anuales, también fue justificado independientemente por daños de inundación

existentes prevenidos con una relación beneficio-a-costo de 1.7. Las relaciones positivas del beneficio-a-costo establecidas por el estudio de "Reconnaissance" del 1990 establecieron además que el proyecto era económicamente beneficioso.

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 de la 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 en este estudio son la seguridad a la vida humana y pérdidas económicas, con un riesgo principal de inundaciones repentinas. Las lluvias fuertes combinadas con laderas empinadas en la cuenca de la montaña superior pueden producir altas descargas en la magnitud de 30,000-40,000 cfs en un período de tiempo relativamente corto (horas). Estas condiciones no son exacerbadas por el hombre como se encontraría en una cuenca hidrográfica urbanizada, sino que es una condición natural, motivada por la topografía y las superficies del suelo naturalmente impermeables. Este régimen de inundación natural una vez ayudó a crear un ecosistema diverso dentro del llano costanero y el estuario. Desde que se construyó el pueblo, las inundaciones se han convertido en un problema para los ciudadanos de Guayanilla, estructuras y terrenos agrícolas ubicados dentro de la llanura de inundación. La inundación del municipio con un flujo de recurrencia de 100 años puede causar inundaciones de más de 8 kilómetros cuadrados expandiéndose a zonas rurales de Guayanilla. La probabilidad de inundaciones es alta y las consecuencias se consideran significativas respecto al riesgo a la vida humana y los recursos socioeconómicos. El potencial alto de inundaciones, exacerbado por grandes consecuencias resulta en este evento ser considerado de alto riesgo.

Los objetivos de planificación que se presentan a continuación están directamente relacionados con los problemas identificados en las secciones anteriores.

*Reducir el Riesgo de Daños por Inundación a Estructuras e Infraestructura* – Para reducir el riesgo de daños provocado por inundaciones y los efectos asociados, este objetivo busca reducir la profundidad, duración y probabilidad de inundación. El éxito mediante el cual una solución cumpliría este objetivo se mediría mediante una reducción neta en los daños anuales estimados, bajo la condición de un proyecto. El lugar afectado estaría dentro del área de estudio específicamente enfocada en estructuras residenciales, públicas y comerciales, servicios públicos, infraestructura de transporte y campos agrícolas en producción. Los efectos beneficiosos comienzan a verse al finalizar la fase de construcción y duran el ciclo de vida completo del proyecto.

*Reducir el Riesgo a la Vida Humana* – Para reducir los riesgos a la vida humana provocados por las inundaciones y los efectos asociados, este objetivo busca 1) informar adecuadamente al

público de las inundaciones pendientes, y 2) reducir la profundidad, duración y probabilidad de inundación. El éxito se mediría por 1) la rapidez y fiabilidad con que el público puede ser informado de las inundaciones pendientes, y 2) reducir el riesgo de quedar atrapado en una estructura o una ruta de evacuación durante un evento de inundación, reduciendo así la población en riesgo. El lugar afectado estaría dentro del área de estudio específicamente enfocada en el Municipio de Guayanilla. Los efectos beneficiosos comienzan a verse al finalizar la fase de construcción y duran el ciclo de vida completo 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 abordar 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. Basado en los conceptos de mérito técnico, los efectos ambientales y las políticas, se mantuvieron dos (2) medidas no estructurales y siete (7) medidas estructurales para seguir desarrollando en planes alternativos. Se elaboraron y ensayaron seis (6) planes de acción alternativos con conceptos básicos de planificación de USACE, seguridad a la vida humana, efectos ambientales, bienes raíces, servicios públicos y conceptos de sostenibilidad. Basado en estas pruebas se recomendó la no-acción y tres (3) alternativas de acción para ser analizadas económicamente y ambientalmente en más detalle:

- 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

Alternativa #3 es el TSP. El primer costo estimado del TSP es de $146 millones y tiene una relación beneficio-costo (BCR por sus siglas en inglés) de 3.3 / 1 en el actual año fiscal 2019 (FY19) a una tasa de descuento federal de (2.875%). Esta alternativa reduce el promedio esperado de daños anuales en $18.8 millones. En terminos generales este plan incluye un canal de desviación, una estructura de desviación robusta, un dique a un lado del canal de desviación, modificaciones de puentes, bermas, una cantera de roca, carreteras de transporte de material y zonas de estadificación y eliminación. Esta alternativa también incluye características basadas en la naturaleza y medidas de conservación para minimizar y mitigar los impactos del proyecto en la perturbación de 10 a 15 cuerdas de hábitat del bosque seco cárstico anteriormente perturbado y varias cuerdas del cauce natural del Río Guayanilla. También se incluyeron medidas no-estructurales compatibles en el TSP para remover escombros en el cauce del Río Guayanilla e implementar un sistema de advertencia de inundaciones para reducir el riesgo a la vida humana asociado con las inundaciones en el área del proyecto. Actualmente no se prevé la mitigación de la pérdida de recursos ambientales; sin embargo, incluye medidas menores de conservación para abordar la perturbación de 7 a 10 cuerdas de bosque seco kársticos anteriormente perturbado y varios acres del canal natural de Río Guayanilla.

**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.

Como el río desemboca en la llanura costera cerca de la carretera PR-379, el uso del suelo y la topografía fue modificada para uso agrícola, residencial, comercial y en menor grado industrial. 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 para 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.

La ciudad 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 la ciudad sea susceptible tanto a las inundaciones fluviales como a lavados de quebradas desde pared montañosa del valle al este. El río generalmente fluye hacia el oeste de y por el centro de la ciudad, manteniendo un patrón serpenteante. 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 mil 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 del terreno hacia el sur de la carretera PR-3337 cambió de un área residencial a un espacio abierto principalmente agrícola y naturalista, con la excepción de los pequeños barrios costeros, El Faro y Playa. Bajo la Fase I del Proyecto del Departamento de Recursos Naturales y Ambientales, el río fue canalizado en esta área y se agregaron diques para el control de inundaciones. Basado en los flujos que se calcularon entrando la llanura aluvial costera de la carretera 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, el hábitat del estuario era naturalmente limitado, pero se observa como actualmente está presente en unas zonas y ausente de forma no natural en otras. Fuera de esta bahía profunda se encuentran varios arrecifes de coral del verdadero medio marino, que se consideran adyacentes al área de estudio. Estas pueden o no ser influenciadas por las plantas de licuefacción de gas ubicadas juntas.

## CONSEQUENCIAS AMBIENTALES Y MITIGACIÓN

Para todas las alternativas, se evaluaron los posibles efectos, según le aplica. A continuación se ofrece una evaluación resumida de los posibles efectos del TSP:

| | 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 | ☒ | ☐ | ☐ |

Fueron analizados e incorporados al plan recomendado todos los medios prácticos y apropiados para evitar o minimizar los efectos ambientales adversos. Las mejores prácticas de gestión que se detallan en el IFR/EA se aplicarán, si procede, para minimizar los impactos.

Continúa la coordinación con el USFWS en relación a las especies amenazadas y en peligro de extinción dentro del área de la referida cantera abandonada; sin embargo, sobre la base de la planificación de evitación entre USFWS y USACE y subsiguientes medidas de conservación anidadas en las alternativas, no se prevé que la mitigación sea necesaria como parte del cumplimiento de la ESA.

Modificaciones al canal natural del Río Guayanilla exigen una evaluación en virtud del artículo 404 de la Ley de Aguas Limpias y el Artículo 10 de la Ley de Ríos y Puertos de 1899. Entre las características que requieren evaluación figuran la estructura de desviación a través de todo el canal justo después de la

carretera PR-2, la colocación de piedra caliza dolomítica, pila de chapa de acero y otras características de erosión en el área de mejora del canal. La evaluación de la antidegradación 404(b)(1) se encuentra en el apéndice A. El proyecto propuesto incluye medidas para minimizar y mitigar los impactos inevitables en el hábitat ribereño.

## CUMPLIMIENTO CON LAS LEYES, REGLAMENTOS, POLITICAS Y PLANES

Las alternativas propuestas cumplen con los estatutos apropiados, las órdenes ejecutivas, los memorandos y las reglamentos de la USACE. Las leyes, estatutos y órdenes ejecutivas aplicables se encuentran en el Apéndice A. Los componentes de cumplimiento federal aplicables incluyen la Ley de Preservación Histórica Natural de 1966; la Ley de Especies Amenazadas de 1973; la Ley de Coordinación de Pesca y Vida Silvestre; EO 12898 (justicia ambiental); EO 11990 (protección de los humedales); EO 11988 (gestión de llanuras de inundación); y la Ley de Ríos y Puertos de 1899. El proyecto potencial cumple con la Ley de Aire Limpio; la Ley de Agua Limpia y la Ley de Política Ambiental Nacional de 1969. No se detectaron efectos ambientales adversos que no pudieran minimizarse o evitarse si se aplicara la propuesta. Las alternativas propuestas tendrían efectos localizados y a corto plazo en los usos del entorno de la zona costera del área del estudio (42 U.S.C. - 4332(2)(c)(iv); 40 C.F.R. 1502.16). No ha habido compromisos irreversibles e irrecuperables de recursos identificados como resultado de la acción propuesta en caso de que se aplique (42 U.S.C. 4332(2)(c)(v); 40 C.F.R. 1502.16).

**Resumen de Cumplimiento Legal Federal, Estatal y Local Aplicable**

| Referencia | Estatutos/Reglamentos Ambientales | Cumplimiento del Proyecto |
|---|---|---|
| **Federal** | | |
| 42 U.S.C. 7401 | Ley de Aire Limpio de 1970, según enmendada | P |
| 33 U.S.C. 1251, y siguientes. | Ley de Aguas Limpias de 1977, según enmendada | P |
| 16 U.S.C. 1451, y siguientes. | Ley del Manejo de la Zona Costanera de 1972, según enmendada | P |
| 42 U.S.C. 9601 | 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 | P |
| 16 U.S.C. 661 | Ley de Coordinación de la Pesca y la Fauna Silvestre, según enmendada | P |
| EO 11990 | Protección de los Humedales | P |
| 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 | P |
| 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 | P |
| | | |
| **Local** | | |
| | | |

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

**RECOMENDACIÓN PRELIMINAR**

De las tres alternativas de acción, Alternativa #3 Canal de Desvío al Sur con Una Línea de Protección es el TSP, apoyado por la Alternativa #1 Medidas No-Estructural (advertencia de inundación y transporte de del cauce natural). Este plan generalmente incluye un canal de desviación, una estructura de desvío robusta, un dique a un lado del canal de desvío, modificaciones de puentes, bermas, una cantera de rocas, caminos de acarreo, escenificación y áreas de eliminación. También se incluyeron en el TSP medidas no-estructurales compatibles (Alt #1) para la limpieza de escombros dentro del cauce natural del Río Guayanilla y para implementar un sistema de advertencia de inundaciones para reducir el riesgo de seguridad a la vida humana asociado con las inundaciones en el área del proyecto. Este plan también incluye características basadas en la naturaleza y medidas de conservación para minimizar y mitigar los impactos del proyecto en la perturbación de 10 a 15 cuerdas de hábitat del bosque seco cárstico anteriormente perturbado y varias cuerdas del cauce natural del Río Guayanilla. El primer costo estimado del TSP es de $146 millones y reduciría el promedio anual de daños en $18.8 millones. Por lo tanto, tiene una relación beneficio-costo (BCR) de 3.3 / 1 en el año fiscal actual (FY19) a una tasa de descuento federal de (2.875%).

# Table of Contents

# Figures:

# Tables:



# Appendices:

E. Mitigation Plan
F. Civil Engineering
G. Cost Engineering
H. Geotechnical Engineering
I. Real Estate
J. Hazardous, Toxic, and Radioactive Waste (HTRW) Report
K. Structural Engineering

# LIST OF ACRONYMS

| | | | |
|---|---|---|---|
| in ( " ) | Inch(es) | mm | Millimeters |
| ft ( ' ) | Foot, feet | cm | Centimeters |
| yds | Yard(s) | m | Meters |
| mi | Mile(s) | km | Kilometers |

| | | | |
|---|---|---|---|
| dB | Decibels | ft/s | Foot-per-second |
| °F | Degrees, Fahrenheit | cfs ($ft^3/s$) | Cubic-foot-per-second |
| °C | Degrees, Celsius | cms ($m^3/s$) | Cubic-meter-per-second |
| | | $\mu g/m^3$ | Micro-gram-per-cubic-meter |
| $O_3$ | Ozone | Pb | Lead |
| CO | Carbon Monoxide | $PM_{2.5}$ | Particulate Matter 2.5 |
| CO2 | Carbon Dioxide | $PM_{10}$ | Particulate Matter 10 |
| CO2e | Carbon Dioxide equivalent | $SO_2$ | Sulfur Dioxide |
| $NO_2$ | Nitrogen Dioxide | ppb | Parts-per-billion |
| | | ppm | Parts-per-million |

| | |
|---|---|
| CEQ | Council on Environmental Quality, Division of the Executive Office |
| FEMA | Federal Emergency Management Agency |
| NMFS | National Marine Fisheries Services |
| NOAA | National Oceanic and Atmospheric Agency |
| NRCS | Natural Resources Conservation Service |
| PRASA | Puerto Rico Aqueduct and Sewer Authority |
| PRDNER, DNER | Puerto Rico Department of Natural and Environmental Resources |
| PREQB | Puerto Rico Environmental Quality Board |
| PREPA | Puerto Rico Electric Power Authority |
| USACE | U.S. Army Corps of Engineers |
| USACE-HQ | Headquarters |
| USACE-IWR | Institute of Water Resources |
| USEPA, EPA | U.S. Environmental Protection Agency |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| USGCRP | U.S. Global Change Research Program |

| | | |
|---|---|---|
| CAA | Clean Air Act | 42 U.S.C. § 7401 et seq. |
| CBRA | Coastal Barrier Resource Act | 16 U.S.C. § 3501 et seq. |
| CWA | Clean Water Act | 33 U.S.C. § 1251 et seq. |
| FCA | Flood Control Act | 33 U.S.C. § 701 et seq. |
| NEPA | National Environmental Policy Act | 42 U.S.C. § 4321 et seq. |
| NHPA | National Historic Preservation Act | 16 U.S.C. § 470 et seq. & 54 U.S.C. § 300101 |
| WRDA | Water Resources Development Act | 33 U.S.C. § 2261 et seq. |

| | |
|---|---|
| AAE | Average Annual Equivalent |
| ACS | American Census Survey |
| ADM | Agency Decision Milestone |
| AL | Aquatic Life |
| Alt | Alternate |
| AM | Alternative Milestone |
| APE | Area of Potential Effects |
| ASA(CW) | Assistant Secretary of the Army (Civil Works) |
| BCR | Benefit-to-Cost Ratio |
| BMP(s) | Best Management Practice(s) |
| C | Completeness |
| CBRS | Coastal Barrier Resource System |
| C.F.R. | Code of Federal Regulations |
| DW | Drinking Water |
| E | Effectiveness |
| EA | Environmental Assessment |
| EAD | Expected Annual Damages |
| ECB | Engineering and Construction Bulletin |
| Ef | Efficiency |
| EFH | Essential Fish Habitat |
| EIS | Environmental Impact Statement |
| EO | Executive Order |
| EQ | Environmental Quality |
| ER | Engineer Regulations |
| ESA | Environmental Site Assessment |
| FCSA | Feasibility Cost Sharing Agreement |
| FDR | Federal Discount Rate |
| FE | Federally listed as “Endangered” |
| FONSI | Finding of No Significant Impact |
| FR | Feasibility Report |
| FRM | Flood Risk Management |
| FWOP | Future Without-Project Conditions |
| FY | Fiscal Year |
| GHG | Greenhouse Gas(ses) |
| H&H | Hydraulic and Hydrologic |
| HEC-RAS | Hydrologic Engineering Center’s River Analysis System |
| HTRW | Hazardous, toxic, and radioactive waste |
| IFR | Integrated Feasibility Report |
| LERRD | Land, Easements, Rights-of-Way, Relocation, and Disposal (Areas) |
| LPP | Locally Preferred Plan |
| LS | Life-Safety |
| NA (N/A) | Non-Applicable |
| NAAQS | National Ambient Air Quality Standards |
| NED | National Economic Development |
| NEI | National Emission Inventory |
| NFS | Non-Federal Sponsor |
| NPDES | National Pollutant Discharge Elimination System |
| NR | Natural Resource Effects |
| NRHP | National Register of Historic Places |
| O&M | Operations and Maintenance |
| OMRR&R | Operation and Maintenance, Repair, Replacement and Rehabilitation |
| OSE | Other Social Effects |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PB | Planning Bulletin |
| PDT | Project Delivery Team |
| P&G | Principles and Guidelines |
| P.L. | Public Law |
| PR | Puerto Rico |
| PVC | Polyvinyl Chloride |
| RE | Real Estate |
| REC | Recognized Environmental Concerns |
| RED | Regional Economic Development |
| RSLC | Relative Sea Level Change |
| Sec. | Section |
| SHPO | State Historic Preservation Officer |
| SIP | State Implementation Plans |
| SMART | Specific, Measureable, Attainable, Risk-Informed, and Timely |
| T&E | Threatened and Endangered (Species) |
| TMDL | Total Maximum Daily Load |
| TSP | Tentatively Selected Plan |
| U | Utility Relocation |
| U.S.C. | United States Code |
| VT | Vertical Team |
| w/ | With |
| w/o | Without |
| WQS | Water Quality Standards |
| # R | Reach, # Right |
| # L | Reach, # Left |

# 1.0 Introduction*

This document is a draft Integrated Feasibility Report and Environmental Assessment known as an Integrated Feasibility Report (IFR) for the Rio Guayanilla Flood Risk Management (FRM) Study located in Guayanilla, Puerto Rico. This IFR 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 tentatively selected plan (TSP).

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. Guayanilla River Basin, Puerto Rico.*

*(a) The Secretary shall conduct a feasibility study on providing flood protection in the Guayanilla River 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 Draft IFR 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.), as well as 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)/leadership 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 Corps' Civil Works Transformation efforts. A key tenet of Planning Modernization is bringing increased efficiency and efficacy to the processes USACE uses to make decisions and produce planning decision documents. Collectively, these processes are referred to as Specific, Measurable, Attainable, Risk-Informed, and Timely (SMART) Planning, and is derived from the Principles and Guidelines (P&G) and the USACE Planning Guidance Notebook, ER

1105-2-100. Under SMART Planning, a Feasibility Study works progressively through the six-step planning process, but also includes three key decision points or 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; this is referred to as the 3x3x3 rule.

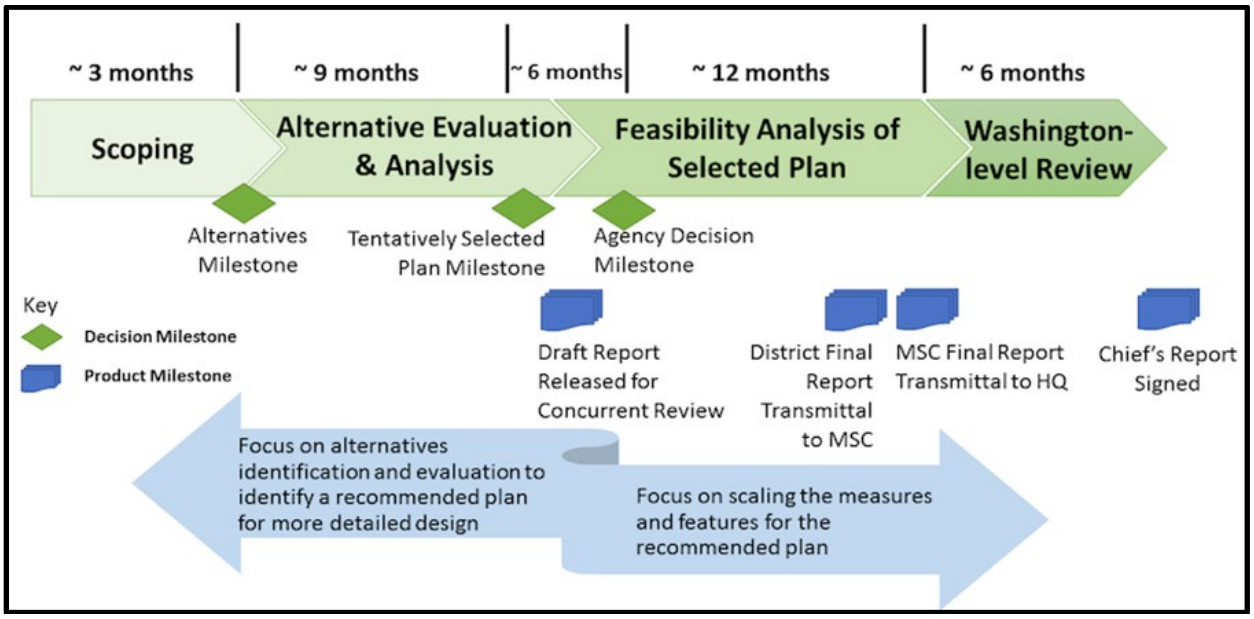


**Figure 1: SMART Planning key decision and product milestones.**

### *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 Town 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 in the 1990 Reconnaissance Report; this project entailed the channelization of the lower Guayanilla River at the estuary mouth for better evacuation of floodwaters in the Guayanilla floodplain. Major activities included excavation and dewatering for a diversion channel and main river channel; various types of stone revetment, filter materials; and core stones were mechanically processed at a quarry 20 miles away from the project site. 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 for investigations. Studies must be federally authorized in order to be eligible to be undertaken using Supplemental Investigations funds. 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 investigation funds. A Feasibility Cost Sharing Agreement (FCSA) was signed by the DNER on 6 September 2018 and by USACE on 24 September 2018.

The Rio Guayanilla Feasibility Study is a new SMART Planning study (PL 115-123 SUPPLEMENTAL PROGRAM Rio Guayanilla, PR INVESTIGATIONS – NEW START) investigating FRM measures and alternatives within the Guayanilla riverine and coastal floodplain, specifically focusing on the Town of Guayanilla. This report (Draft IFR) includes integrated National Environmental Policy Act (NEPA) documentation that assesses the effects of any recommended Federal actions. An EA with a Mitigated Finding of No Significant Impact (FONSI) for minor and short-term impacts is integrated into this document.

### *1.1.5 Report Organization*

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

*Executive Summary*:* Summarizes the Draft IFR, provides a brief overview of major conclusions, and brief description of the tentatively selected plan.

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

*1* - Introduction:* Describes lead agencies, guiding regulations, study authority, statement of purpose and need, proposed project area and scope, study participants and coordination. Identifies problems and opportunities, project objectives and planning constraints, prior reports, and report organization.

*2* - Affected Environment:* Describes the existing, potentially affected environment in the Río Guayanilla study area.

*3* - Plan Formulation:* Identifies 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; and establishment of focused alternative plans that adequately address the objectives established. Chapter 3 also describes the evaluation process leading to the final array of alternatives, summary comparison of effects of the alternatives, and the identification of a TSP that best meets the study objectives.

*4*- Comparison of the Final Array of Alternatives:* Quantitatively and qualitatively compares the costs and benefits of the Final Array of Alternatives.

*5* - Environmental Consequences:* Discloses the potential environmental impacts of implementing each of the alternatives in the final array. This chapter also identifies conservation measures to avoid or minimize impacts. Mitigation needs are addressed in this chapter, as applicable.

*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, as well as a list describing the study's compliance status for each.

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

*9* - Recommendation:* Identifies the TSP and next steps leading to the final feasibility report.

*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 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.

### *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 town. Heavy rainfall combined with very steep slopes in the upper catchment can produce high peak discharges in a relatively short period of time. This discharge can be in the magnitude of 30,000-40,000 cubic-feet-per-second (cfs). The 100-year flood event 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 clearly establishes a significant need for action. The 1975 flood, caused by Tropical Storm (later classified as Hurricane Eloise), caused over $1.7 million in damages. Several hundred residents were required to vacate their homes as 99 houses were destroyed and 276 additional houses were damaged. Fatalities were reported in the: 1975, 1979, 1985, 1998, and 2012 flood events. In addition to the damaged structures and fatalities, flood-induced waters and sediment (rock and silt) deposition induced closures of major area roadways and impeded access to critical facilities. These facilities include a regional hospital and the local fire, and other emergency services and police stations. In 2017 Hurricane Maria caused significant overtopping of the Rio Guayanilla; the floodwaters washed out a major bridge, and caused significant damage to: the largest supermarket, a pharmacy, a bakery, and 106 homes. 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 average annual benefits over the period of analysis exceed estimated average annual costs, and if the lives and security of people would otherwise be adversely affected. The 1990 Reconnaissance Study established Federal Interest based on the estimated benefits derived from five different structural alternatives. The 1990 recommended plan combined 6.5 kilometers (4 miles) of earthen levee, 3.6 kilometers (2.25 miles) of trapezoidal channel improvements (stream channelization), 1.3 kilometers (.8 miles) of trapezoidal channel diversion, 300 meters (984 feet) 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 Town of Guayanilla is located, portions of the mountains to the west, and to a lesser degree, the marine/estuarine coastline (Figure 3).


**Figure 2: Guayanilla River Watershed**


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

## 1.4 Prior Reports & Existing Projects

### *1.4.1 Report & Studies*

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

1988. Municipality of Guayanilla. *Hydrologic and Hydraulic Study for the Construction of a Public Transportation Terminal and Recreation Facilities at the Town 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[2].

**Photo 1: Phase I Construction Activities**

2010. *DNER Mitigation* – The Army Corps of Engineers (USACE) required that a mitigation plan must be established by the Puerto Rico Department of Natural and Environmental Resources to compensate for the loss of 7.57 acres of forested wetland and salt flat, as a result of Phase I of the Channelization of Guayanilla River Flood Control Project. The compensatory mitigation for the impacted wetland was completed on 8.5 acres. This included mitigation for the 1.5 acres of wetland that were impacted outside the scope of the December 2000 USACE's permit.

## 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 in terms of life safety and economic losses, with a primary hazard of flash flooding. 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). This natural condition is 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 town of Guayanilla was built, flooding has been a problem for its

citizens, other local homesteads, and the agriculture lands situated within the floodplain. These high-risk flood events are characterized by the high potential flooding and high (large) consequences. The 100-year flood event can inundate over 3 square miles (8-square kilometers) within the municipality and rural areas of Guayanilla (Figure 4). The potential for these floods to occur is high, while the resulting consequences are considered large in terms of life safety, economic, and social resources.

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 (Figure 4). Fatalities were reported in the 1975, 1979, 1985, 1998, and 2012 floods.


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

*Evacuation Problems* – Flood-induced water depths, 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. (Figure 5 & Photo 3).

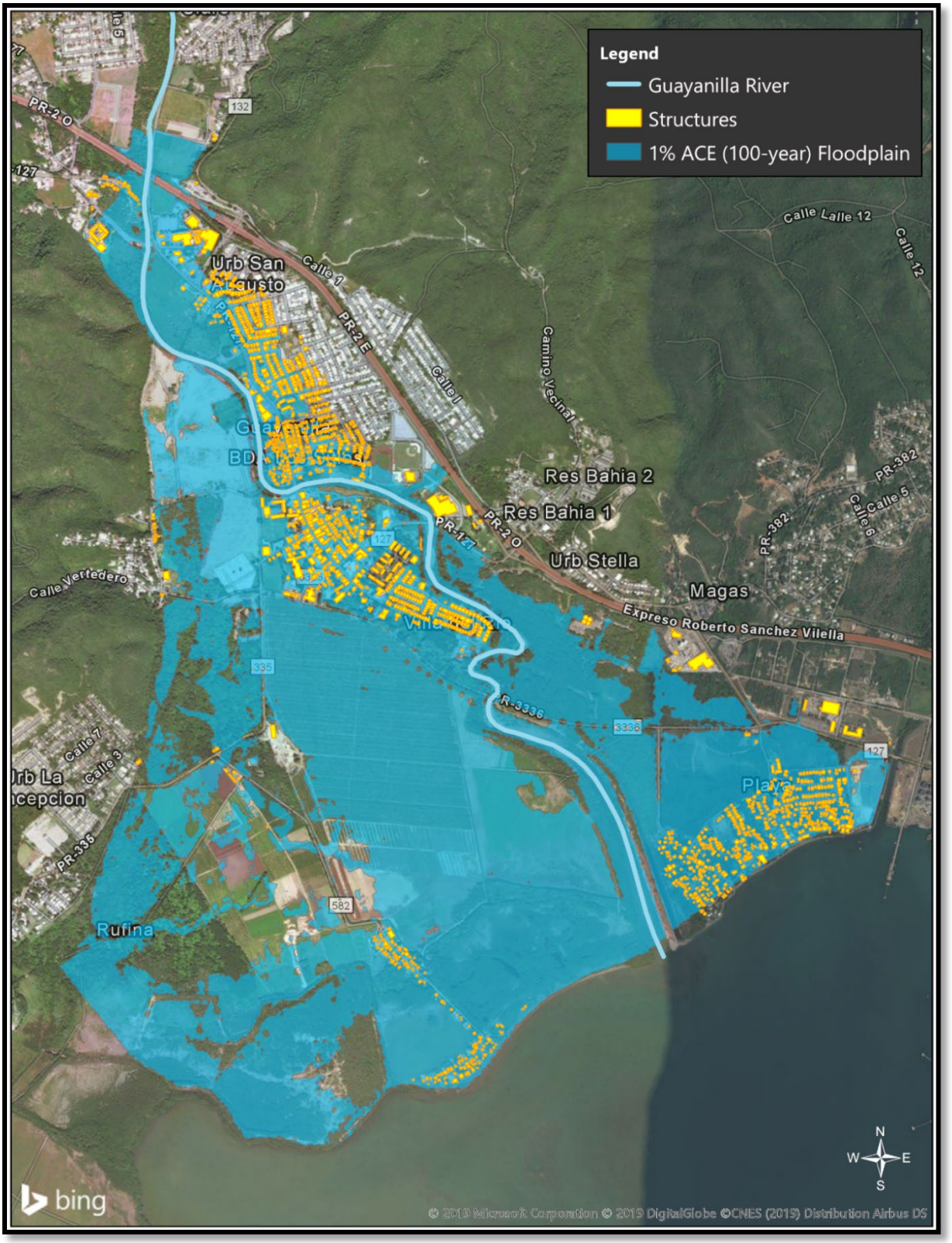


**Figure 4: Floodplain Map to Show Affected Area & Structures in the 1% ACE (100-yr) Floodplain**

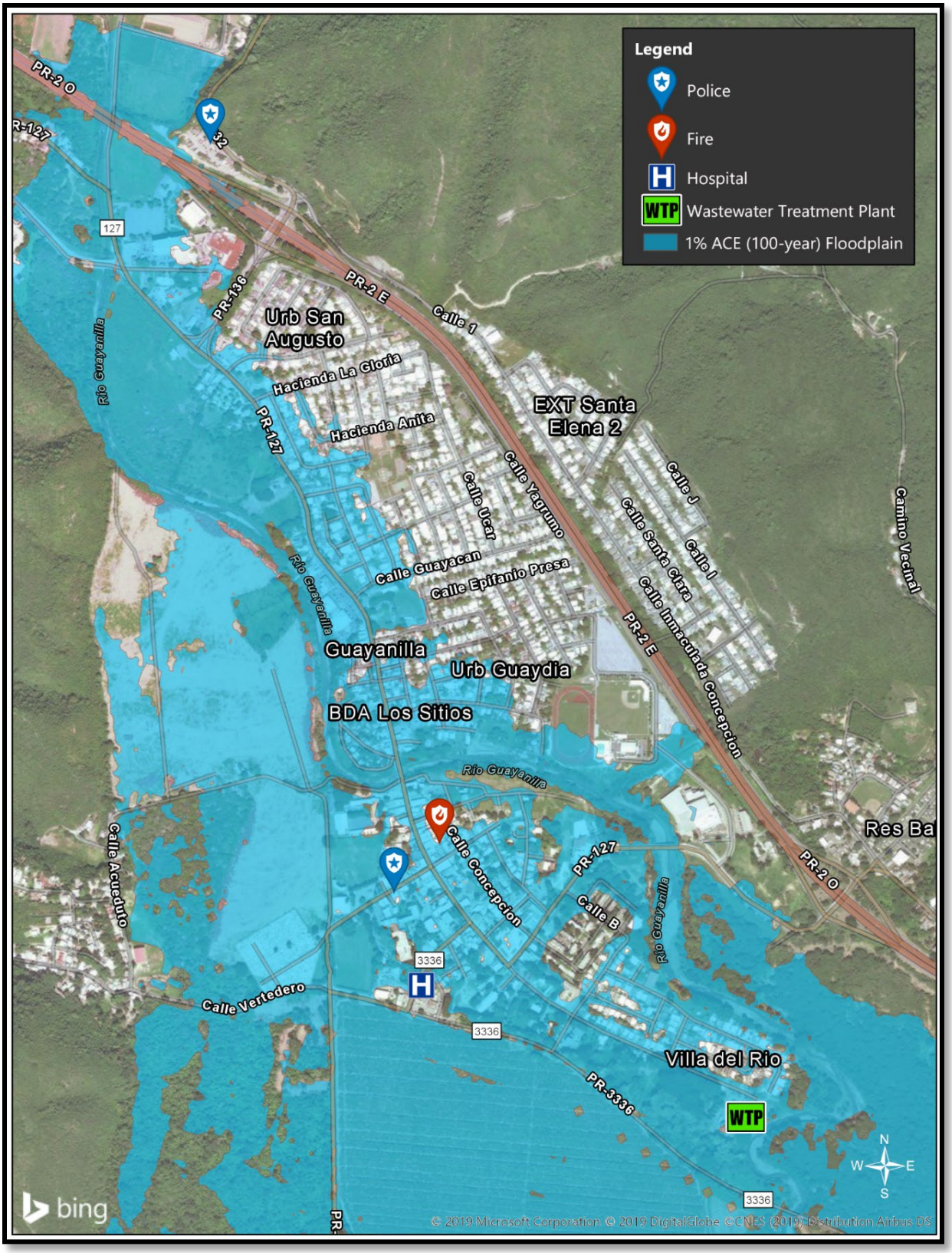


**Figure 5: Emergency Facilities Affected by Flooding**

*Emergency Facilities Problems* – Flood-induced water depths, 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 disabled in past floods due to flooding. The loss of this critical structure increases life-safety risk to community residents during flood evacuations. 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. Flood impacts result in a loss of these critical life requisites, including food, water, and pharmaceuticals, as well as the commercial facilities. Damages to the Guayanilla pharmacy are illustrated in Photo 3, below.

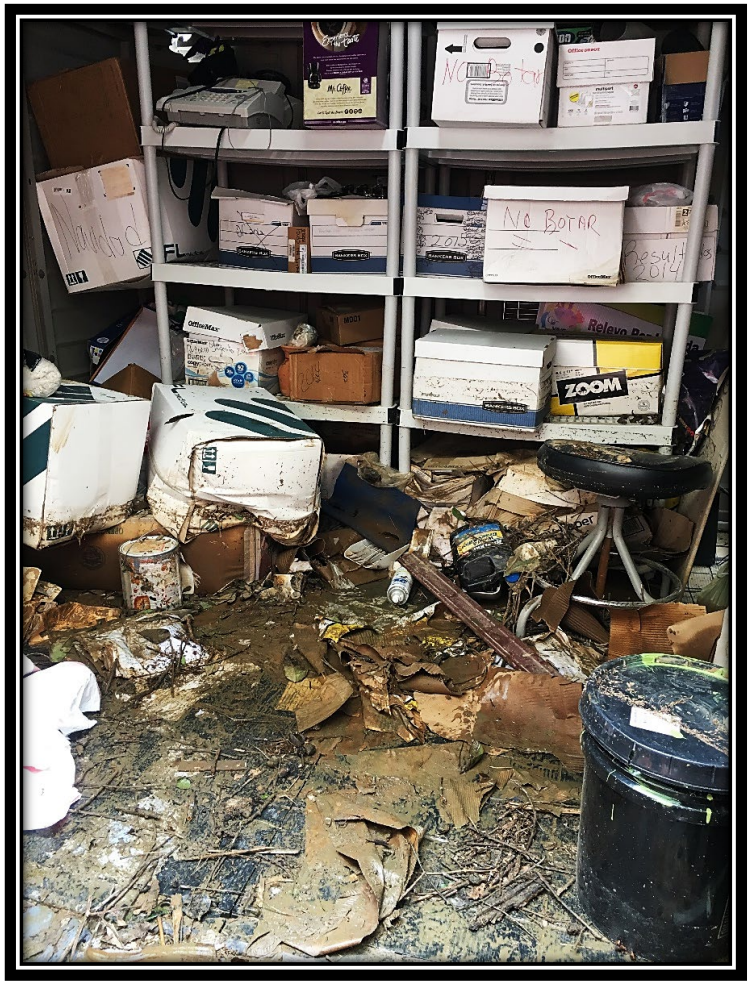


**Photo 3: Rio Guayanilla Flood Damages to Critical Businesses (Pharmacy)**

*Health Problems* – Flood-induced water depths, currents, velocities, erosion, and sediment deposition have the ability to impact the municipal wastewater treatment plant. Large events could inundate the wastewater treatment plant with the potential for the discharge of wastewater into the Río Guayanilla and eventually reach the Guayanilla Bay. In addition, flood waters flowing through industrial, commercial, and agricultural areas can become contaminated. Discharge of these 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) (Figure 4). Table 1 displays the 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**

| ACE 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 ACE events correspond with the 5-yr, 50-yr, 100-yr, and 500-yr flood events, respectively

*Delays in Transportation* – Flood-induced water depths, currents, velocities, erosion, and sediment deposition have induced closures of major area roadways and bridges, which impeded access to critical businesses and the conveyance of commercial and agricultural goods and services. No transportation delay analysis will be undertaken for this study.

*Damages to Agriculture* – Flood impacts to agricultural lands include inundation, sediment depositions, and erosive velocities, which 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 2019 price levels) in agricultural damages (Photo 4). See the Economics Appendix for estimation methodology.

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

### *1.5.2 Opportunities*

Opportunities are benefits, or positive aspects for the community or environment that can be achieved in addition to the study objectives. Opportunities may not necessarily be related to the problems we are attempting to solve, but they may be achieved in the process of meeting the objectives. Below are major 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

## 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 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. The success by which a solution would meet this objective would be measured by a net reduction in estimated annual damages, under the with-project condition. The affected location would be within the study area specifically focused on residential and commercial structures, utilities, transportation infrastructure, and agricultural fields in production (Figure 4). Beneficial effects begin to accrue at completion of the construction phase and last the duration of the project life cycle.

- *Reduce Risks to Life Safety* – To lower the risks to life safety induced by flooding and associated effects this objective seeks to 1) properly inform the public of pending floods, and 2) reduce the depth, duration, and likelihood of flooding. The success by which a solution would meet this objective would be measured by 1) how quickly and reliably the public can be informed of pending floods, and 2) reducing the risk of a person or persons being caught in a structure or an evacuation route during a flood event, and thus reducing the population at risk. The affected location would be within the study area specifically focused on the Town of Guayanilla (Figure 4, Figure 5). Beneficial effects commence accruing at completion of the construction phase and last the duration of the project life cycle.

### *1.6.4 Planning Constraints*

Planning constraints represent restrictions that actually limit the study's ability. 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 provides habitat for 5 federally endangered species and over 20 endemic plant species
- Avoid the fragmentation of riverine habitat for ephemeral migratory amphidromous fishes

### *1.6.5 Planning Considerations*

- Minimize project lifecycle costs by considering features with lower maintenance requirements; rapid vegetation growth, woody debris, rocky debris and sedimentation
- Consider the use of nature-based features that mimic, enhance or restore natural and beneficial riverine, floodplain, estuary or other ecosystem values
- 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).

## 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; the 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, a tertiary highway, the land use and topography was modified for agriculture, residential, commercial and to a much lesser degree light industrial. 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; inclusive of 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 for the Rio Macaná.

The 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 impairments, 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 Town of Guayanilla itself is nestled in the upper portion of the coastal floodplain valley, where the valley is narrower. This location makes the town 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 town, 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 over one thousand 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 changed from residential to primarily agriculture and naturalistic open-space areas, with the exception of the small coastal towns of El Faro and Playa de Guayanilla. The river in this reach was channelized and leveed under the Phase I DNER project for flood control at Guayanilla. Based on the calculated flows entering the coastal alluvial plain at PR-379, large floods have filled up the entire valley in the past, inducing many braided and overland flowages that would temporally flush and maintain estuarine habitats along the Bay of Guayanilla coast.

Based on the natural deep depth of the bay, shallow estuary wetland habitat was naturally limited, but is noted as currently present in some areas, while noted as lost in others. Outside of the deep natural bay 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 near and within the study area has low elevation alluvial plains that fringe the foot of the steep-sloped upland (Kaye, 1959).

Monroe (1980) describes these coastal plains as nearly flat areas that slope very gently upward from the shore to the foothills and grade into the alluvial plains of the larger rivers. The plains consist of a wide belt of coalescing alluvial fans composed of deposits from the Quaternary age and consist of sand, clay, and gravel deposited in floodplains and alluvial fans of rivers, in coastal and river swamps, on beaches, and as dunes of beach sand blown up by the wind.

Monroe (1980) describes the mountainous area as deeply eroded by streams, and valley sides with steep slopes of 30° to 45°. The rocks in the mountainous core consist predominantly of Lower Cretaceous to middle Eocene volcanic formations and are bordered by a fringe of sedimentary rocks of Oligocene and Miocene age along the south coast. Most of the Lower Cretaceous rocks are submarine, deep-water volcanic-ash deposits interspersed with pillow lava. The Cretaceous rocks are 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 older complex is deformed by faulting and to a lesser extent by folding (Kaye, 1959). The Cretaceous and early Tertiary rocks have been folded into an anticlinorium and have been intensely faulted into hundreds of fault blocks (Briggs & Akers, 1965). The younger rocks consist of conglomerate, sand, clay, chalk, and limestone of late Oligocene to early Miocene age (Kaye, 1959). These overlie the older complex unconformably and are locally folded and faulted (Kaye, 1959).

Three formations of middle Tertiary age are recognized in southern Puerto Rico by the USGS (Monroe, 1973) (Figure 7). At the bottom is the Juana Diaz Formation, consisting of a very thick mass of intertonguing mudstone, conglomerate, limestone, and a small amount of unconsolidated sand and lignite (Monroe, 1980).

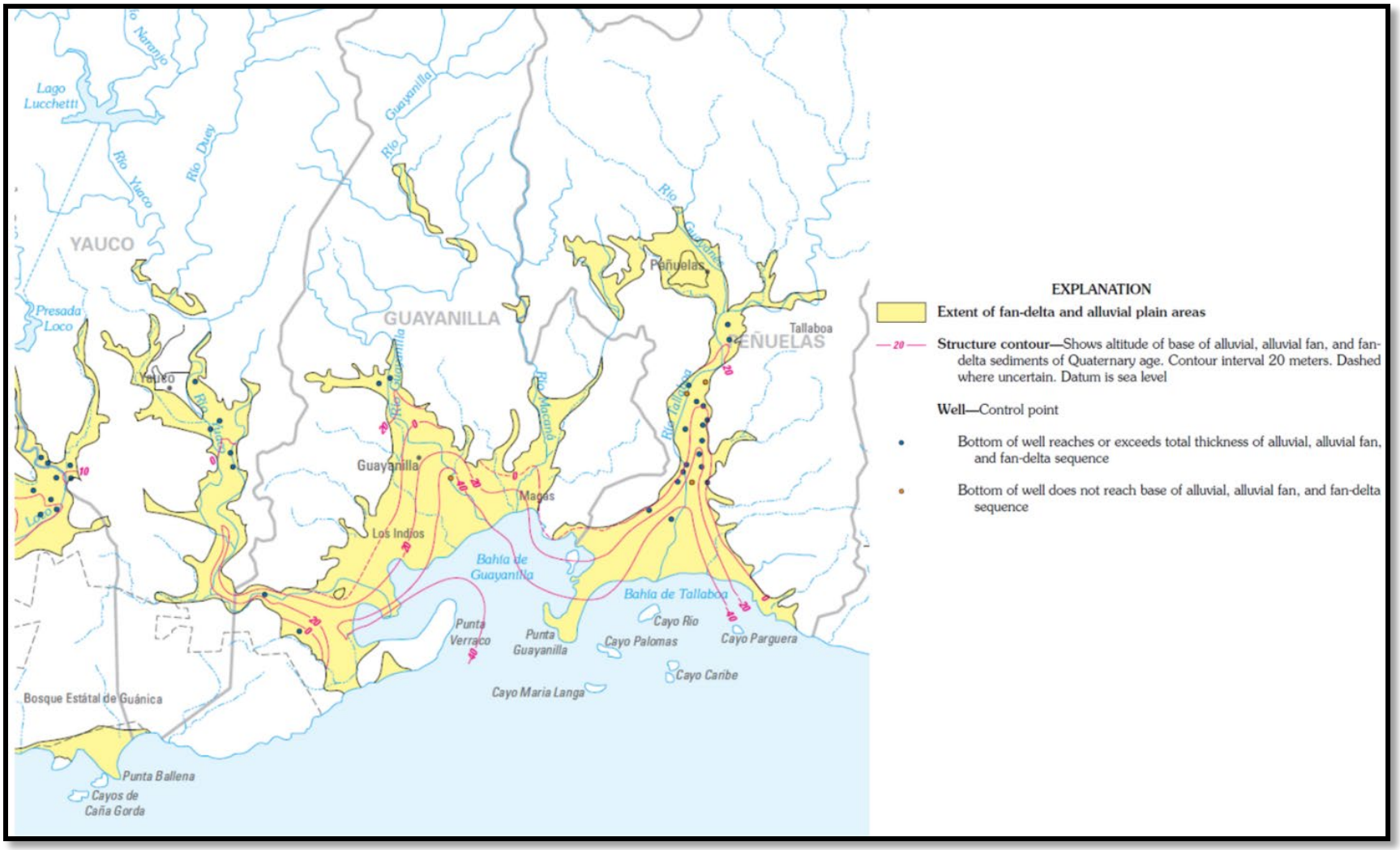


**Figure 6: Bedrock Surface Underlying Alluvial-Fan & Fan-Delta Sediments (Renken et al, 2002)**

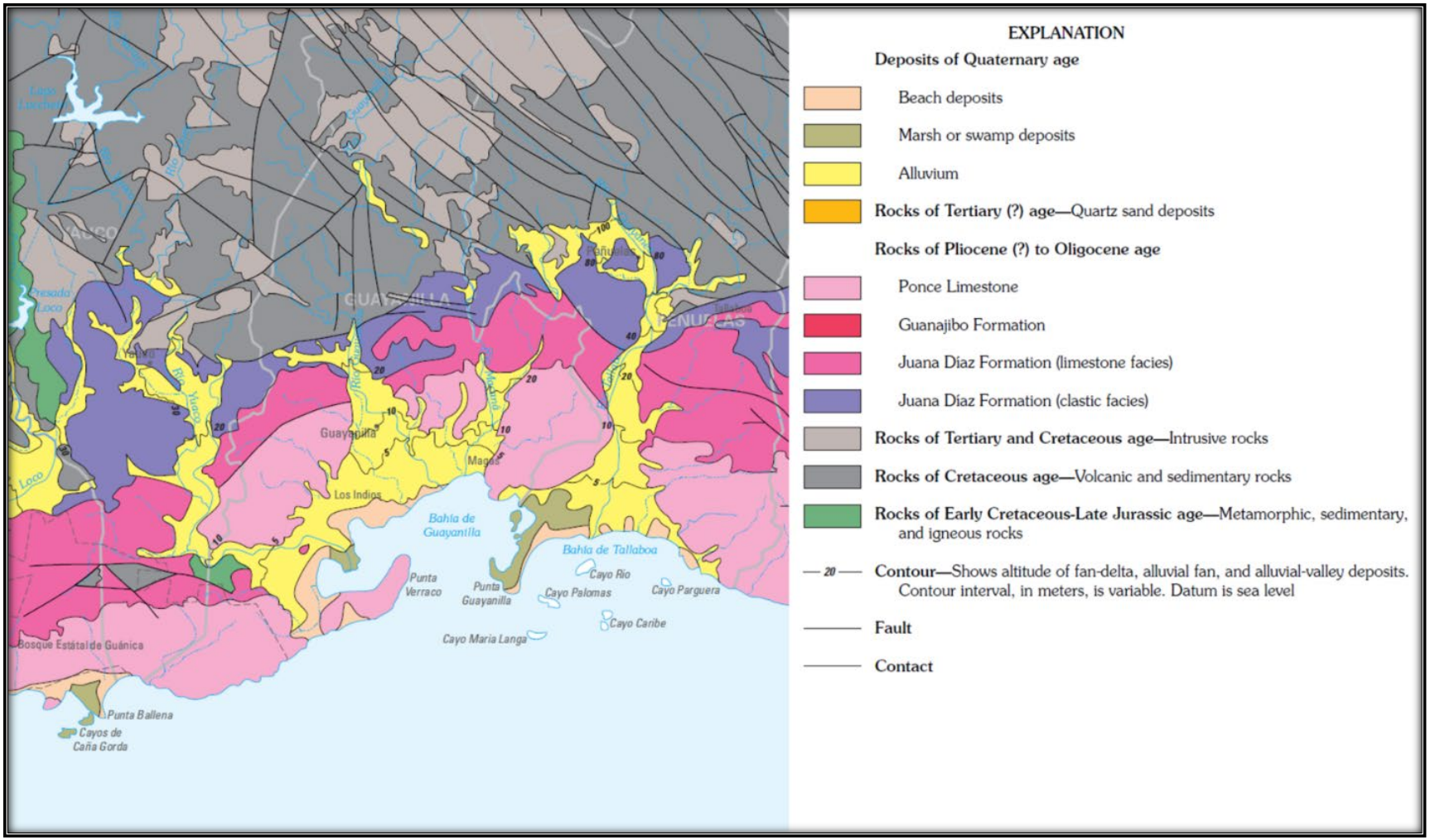


**Figure 7: Geologic Map of Tertiary Rocks (Renken et al, 2002)**

The Juana Díaz is overlain unconformably by the Ponce Limestone. The Ponce Limestone was named by Berkey (1915) and is an organic reef deposit characterized by various kinds of corals, algae, and mollusks (Monroe, 1980). It probably formed as a fringing reef on the southern coast of Puerto Rico during the Miocene age and became thicker as the coastal shelf slowly subsided (Monroe, 1980). The Guanajibo Formation consists of light-yellow to gray limestones, sandy or earthy and ranging from soft to fairly hard, and sands, silts, and clays; probably from late Miocene or Pliocene age (Monroe, 1980).

There are karstic formations near Guayanilla. Though Guayanilla is officially outside of the known area of southern coastal karst, the USGS report states that karstic formations exist south of Peñuelas extending to the Río Macaná. (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 and subsequent meandering to protect town and agricultural lands and infrastructure.

### *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 Conditions: 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. Certain areas have already lost these, such as those that used to support the large Cañaveral in the southern part of the study area. Those 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.

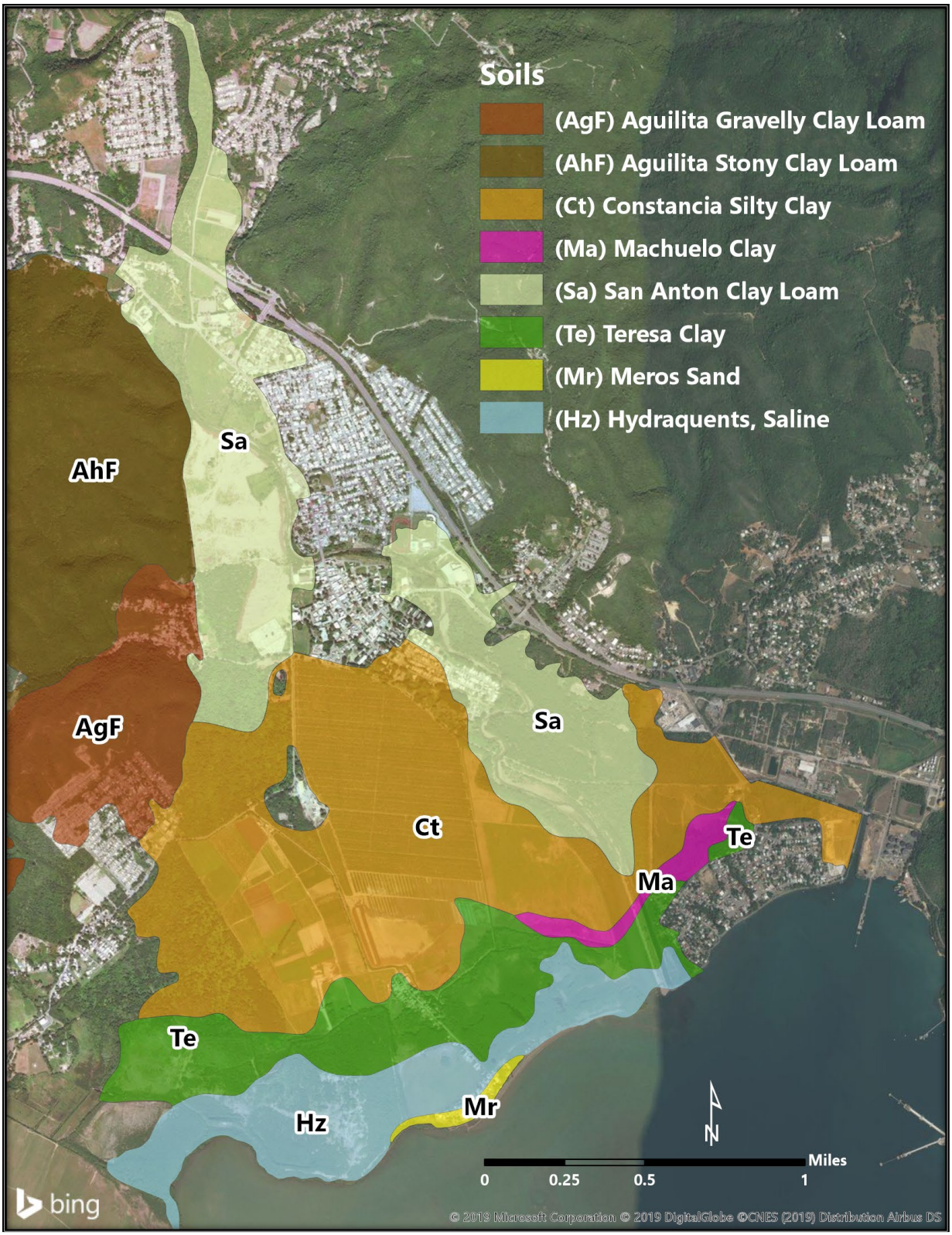


**Figure 8: Río Guayanilla Study Area Soils**

### *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 USGS, there have been four major earthquakes between the first colonization of the island and today. The most recent earthquake occurred in October of 1918 and measured 7.5 on the Richter scale. This 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.

Tsunamis are giant 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).

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

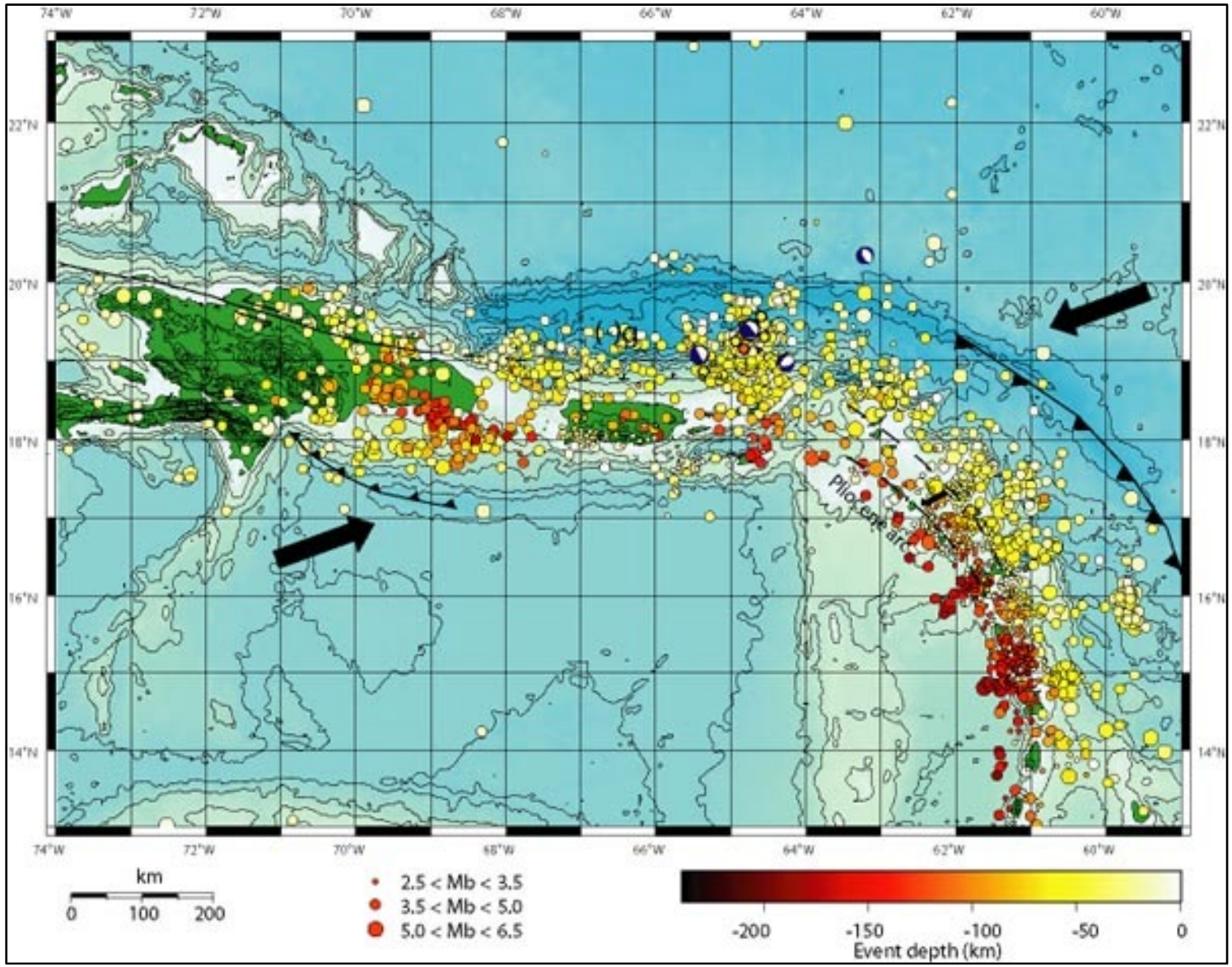


**Figure 9: USGS Map of Puerto Rico Trench, Tectonic Plate Direction and Occurrence & Magnitudes of Resulting Earthquakes**

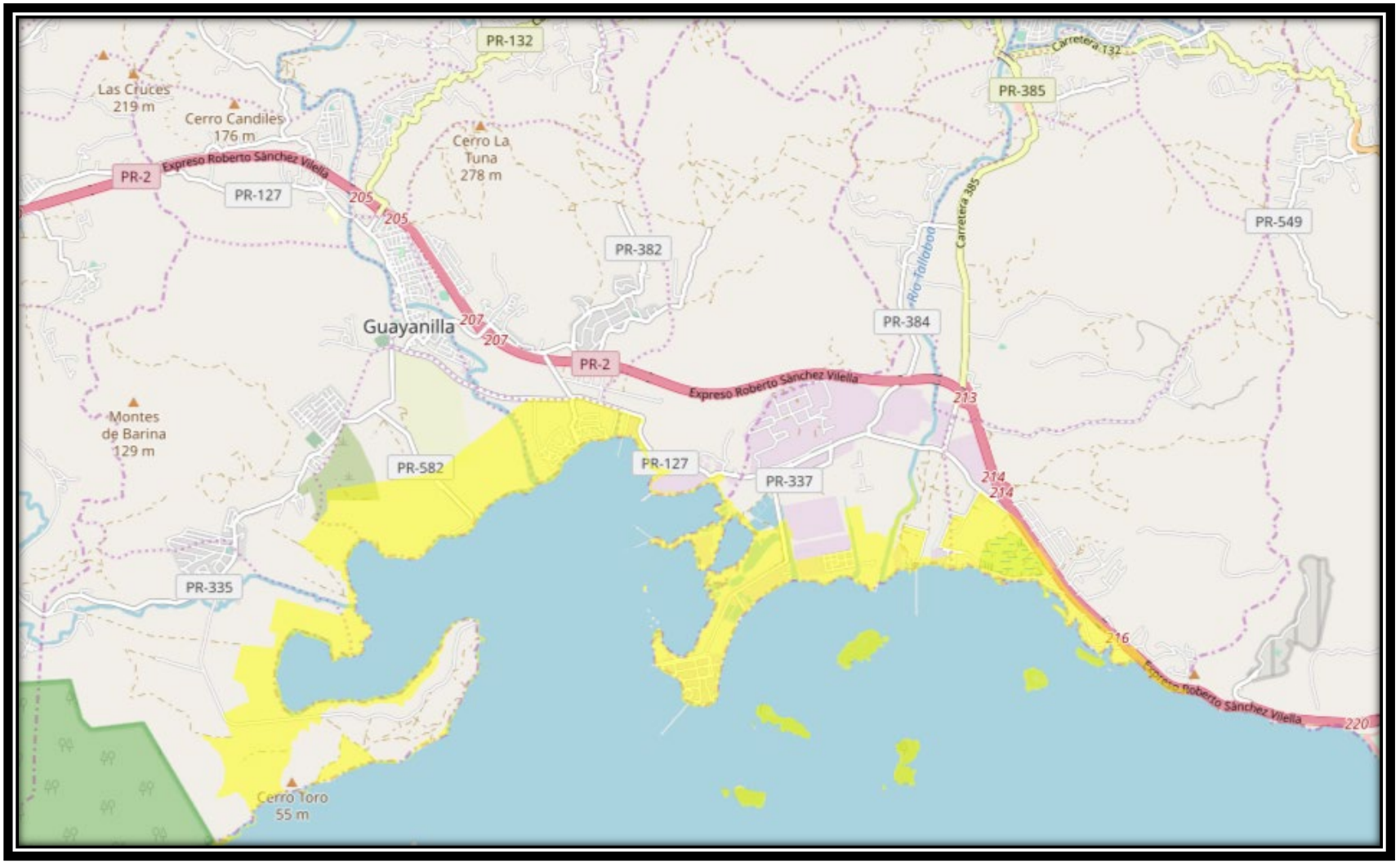


**Figure 10: Tsunami Evacuation Zone**

### *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.

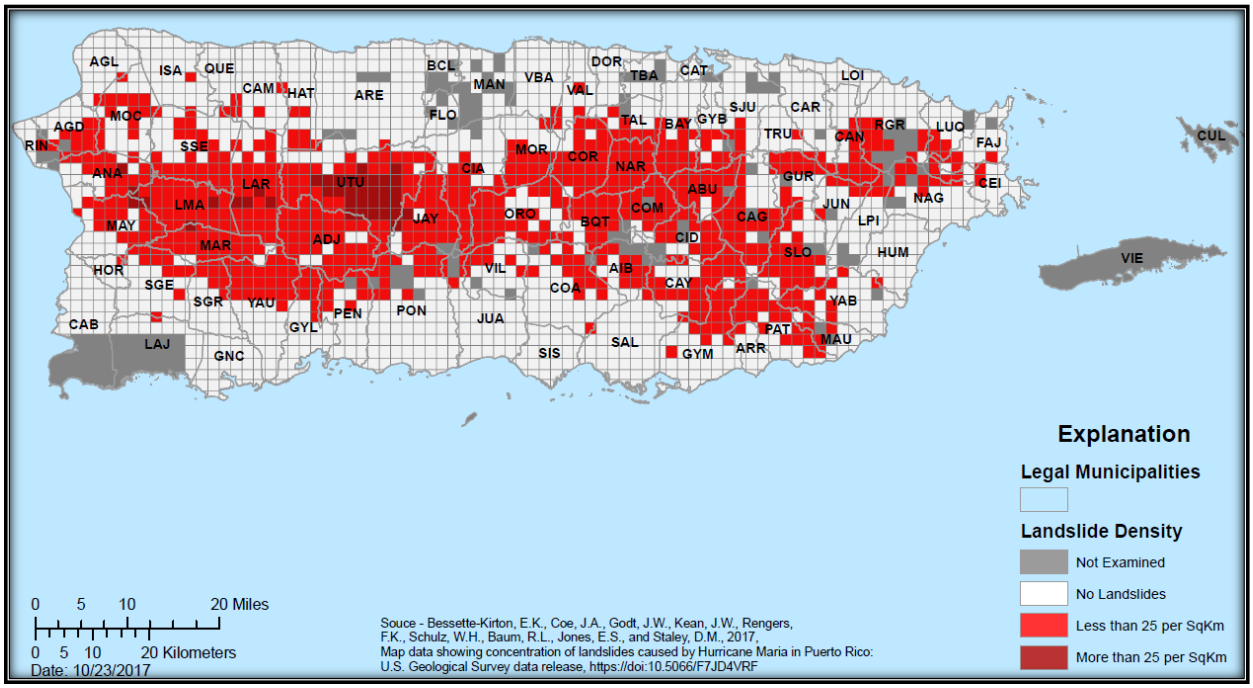


**Figure 11: USGS Map of Landslides Caused by Hurricane Maria (2017)**

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. There are no known areas within the project area that experienced liquefaction.

Future Without Project Conditions: 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.

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

### *2.2.6 Mineral Resources*

Puerto Rico was part of the "Black Arc" in the Caribbean, that ring of petroleum production that rims northern South America to eastern Mexico. The only known seeps of petroliferous materials are in Cretaceous rocks in the south central portion of Puerto Rico (Schellekens, 1991).

Mining has not been a major source of income for Puerto Rico. The Spaniards mined gold placer deposits during 1509-1579, and extracted an estimated 1,200,000 troy ounces of gold (Beard, 1993). However, economics at the time discouraged further mining, and richer sources of gold and silver had been found elsewhere in the New World. The labor source, which was chiefly the native populace, was also decimated, mainly through disease. The chief source of the placer gold was in the Rio Mavilla, about 30 km southwest of San Juan (Beard, 1993). The nickel-bearing laterites in Puerto Rico are located on the southwestern end of the island and overlie serpentinized ultramafic rocks (Beard, 1993). The Central Volcanic-Plutonic Province can be subdivided into three sub-provinces. These are the Southwest Igneous Sub-province, the Central Igneous Sub-province, and the Northeast Igneous Sub-province. The Southwest Igneous Sub-province is characterized by the presence of large bodies of serpentinite and extensive thick marine limestone. The serpentine provides the bedrock source for the nickel, iron, and cobalt laterite deposits. Plutonic bodies of any size are rare in this Sub-province (Beard, 1993). Although occurrences of precious metals are found in each of the igneous Sub-provinces, the majority of the occurrences, and the largest known deposits, are in the Central Igneous Sub-province (Beard, 1993).

In 2013, the value of the nonfuel mineral production in the Commonwealth of Puerto Rico decreased to $66.3 million, 0.09% of the total U.S. nonfuel mineral production, ranking it 48th if compared with the 50 States (USGS, 2016). The value of nonfuel mineral production in Puerto Rico for the years 2006 through 2013 was as follows (in millions of dollars): $84.1 (2006), $105 (2007), $90.0 (2008), $84.7 (2009), $69.4 (2010), $78.9 (2011), $79.6 (2012), and $66.3 (2013) (USGS, 2016).

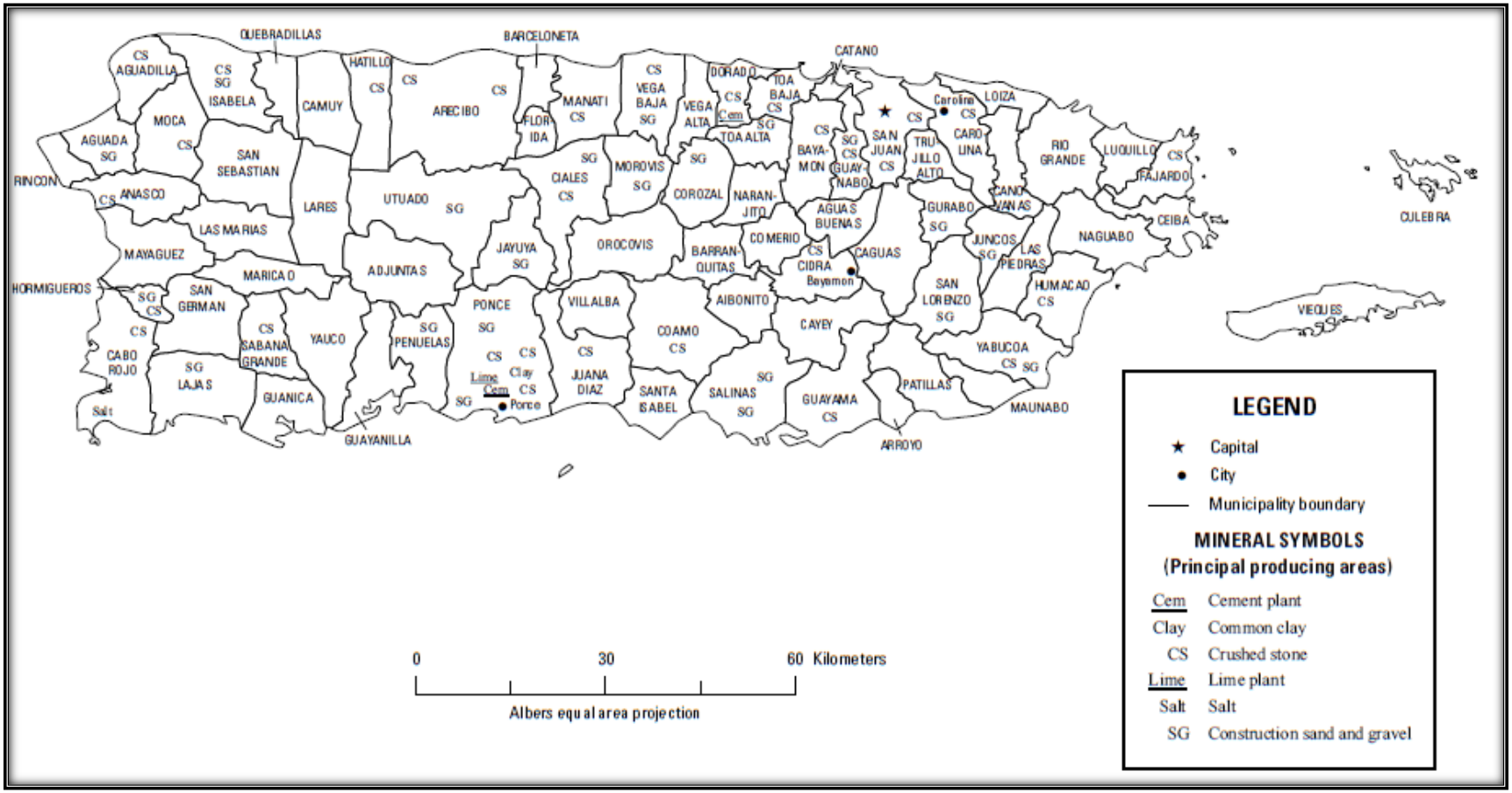


**Figure 12: DNR Map of Nonfuel Mineral Producing Areas**

Puerto Rico had two cement plants that produced masonry and portland cement; one of these cement companies also had a lime plant that produced high-calcium hydrated lime and high-calcium quicklime (USGS, 2016). Cement was both imported and exported from Puerto Rico; on balance more cement was consumed in Puerto Rico than produced, despite relatively low capacity utilization. Most cement in Puerto Rico was shipped to building material dealers as bagged cement. There was one salt operation in Puerto Rico that produced solar salt from sea water and had markets in the Eastern United States and the Caribbean for chemical, ice-control, industrial, and water softening applications (Puerto Rico International Salt Corporation, [undated]). Some common clay was also produced.

Guayanilla does not produce non-fuel minerals.

Future Without Project Conditions: In the absence of a federal project, mineral resources would not be affected or produced.

## 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, 50124500, within the watershed that has been operated continually by the USGS on the Río Guayanilla since 1961 (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. This discharge is equivalent to a recurrence interval, defined as the probability that the given event will be equaled or exceeding in any given year, of about two years.

The following discussions integrate concepts of the Future Without-Project Condition to illustrate the potential changes in hydrologic and hydraulic parameters that equate to more intense/larger storms and sea level rise, making flooding potential worse within the study area.

Climate Change

Puerto Rico has a typical tropical climate resulting in year-round warm temperatures (see Section 2.4.1 for more details). However, the mountains that generally run along the center of island act as a control on local temperature and precipitation. Temperatures can and do vary between the coast and inland mountains by as much as 10°F.

It has been documented in several studies and reports, such as the 4th National Climate Assessment's (NCA), that the average annual and monthly air temperature on the island are increasing. The climate in Puerto Rico is changing. Average annual temperature on the island has increased more than 1.5°F since 1950, rainfall during heavy storms has increased by 33% since 1958, and surrounding waters have warmed almost 2°F since 1901. Regionally within the island of Puerto Rico, there are indications that the southern region of Puerto Rico has experiences positive trends in annual rainfall while the western and a portion of the northern region showed decreases (USACE, 2015). Depending on future greenhouse gas emissions scenarios, average annual temperatures in Puerto Rico are expected to continue to increase

(Figure 13) and precipitation from extreme events are projected to increase, with associated increases in the intensity and frequency of flooding. (Runkle et. al., 2018).

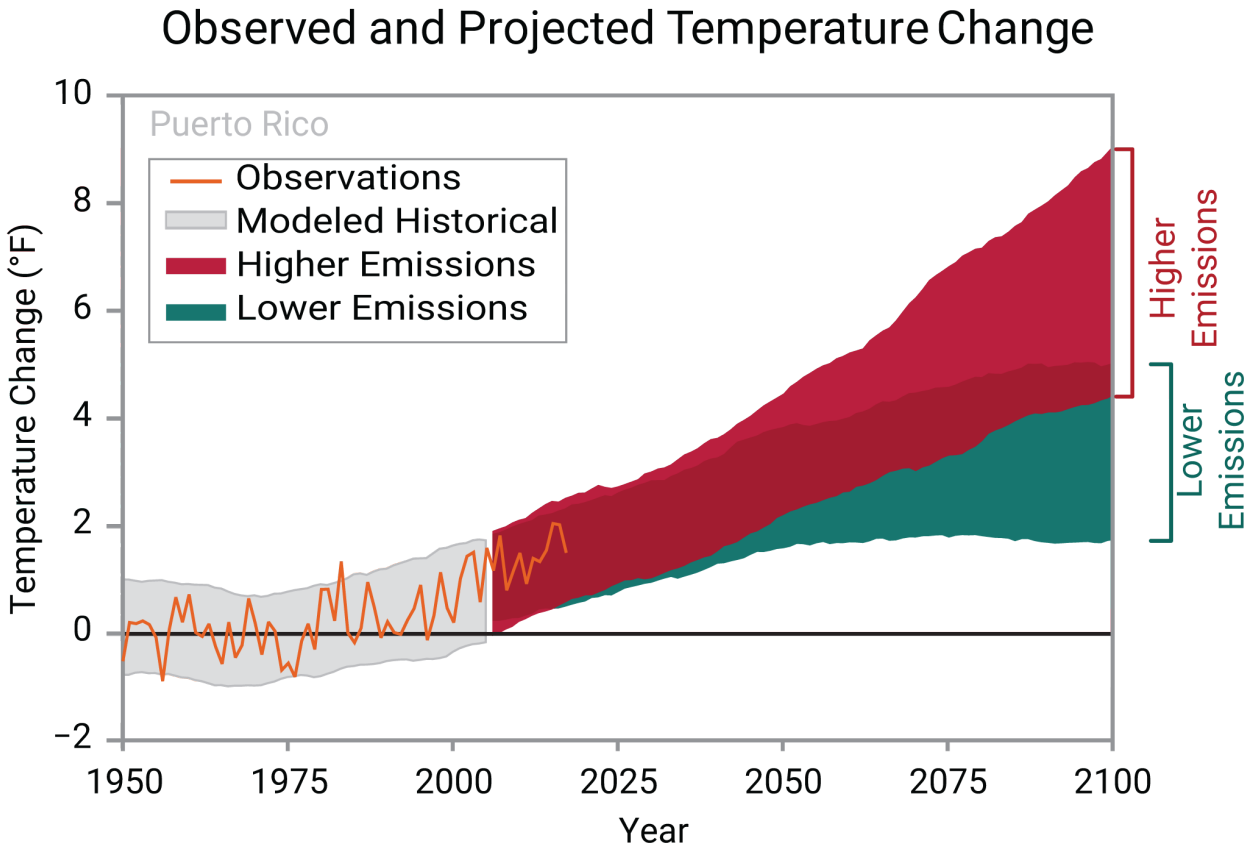


**Figure 13: Observed and projected changes (compared to the 1951 – 1980 average) in near-surface air temperature for Puerto Rico (Runkle et. al., 2018).**
Observed data are from 6 long term reporting sites for 1950 – 2017, and projected changes are for 2006 – 2100 from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions).

Sea Level Rise

Historically, the study area has not been flooded by hurricane or storm tides, although heavy wave action has occurred during the passage of some storms. High storm tides may cause disastrous flooding in the low-lying coastal areas, specifically in the Playa de Guayanilla and El Faro sectors. In addition to the direct effect on the coastal areas, storm tides may cause backwater in the Rio Guayanilla which increases the adverse effects of the channel's lack of capacity. Unlike future precipitation and temperature trends, there is much more confidence that sea levels are rising and will continue to do so. The unknown with regards to areas effected by sea level change is when the change will occur and by how much. Using the USACE Sea Level Change Calculator, Figure 14 shows that for a 50 year planning horizon with sea level rise estimates ranging from 0.310 to 2.565 feet above current mean sea level by the year 2070.

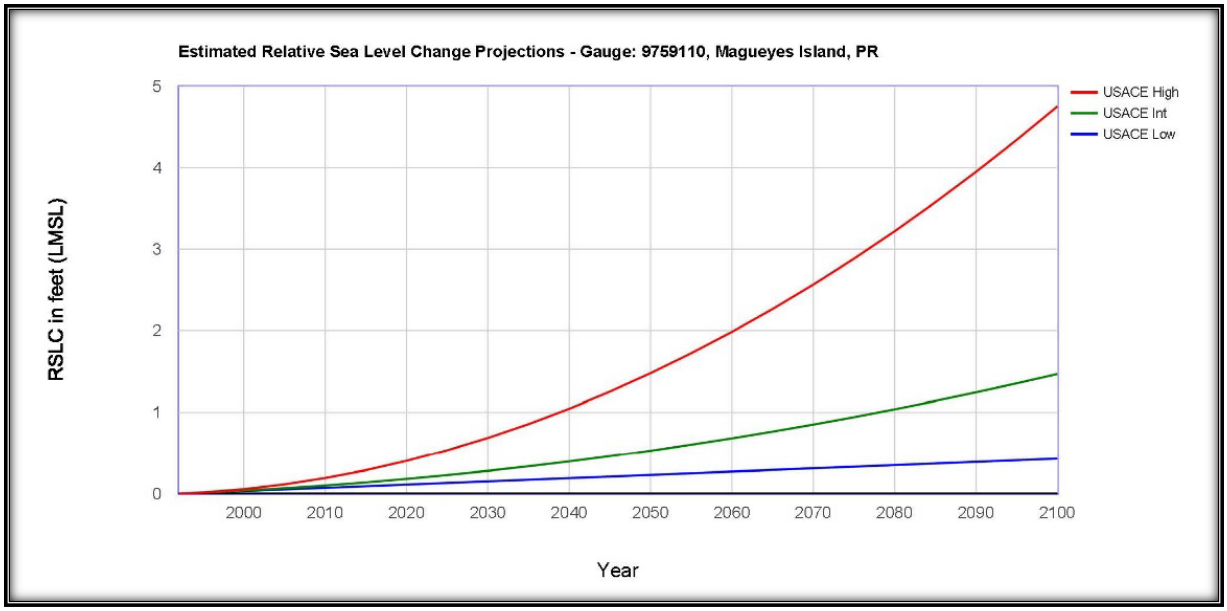


**Figure 14: USACE Sea Level Change Curve Calculator for gage closest to Guayanilla**

Precipitation

Similar to climate, precipitation also varies across the island based on the island's topography, urban population and vegetation cover. As documented in several studies, analysis of weather station data for the period 1948 to 2007 found no clear trends in total annual rainfall for the island as a whole. However, there is evidence for changes in the spatial distribution of rainfall. There was an indication that the southern region of Puerto Rico, which is also the driest region, had positive trends in annual rainfall while the western and a portion of the northern region showed decreases (Mendez, 2010). With regards to projected precipitation changes, there is a lot of uncertainty and no clear trend with regards to precipitation for the island. One trend that has been documented is the increasing frequency and intensity of heavy downpours. In fact, from 1958 to 2007, Puerto Rico experienced a 37% increase in very heavy precipitation (USGCRP, 2009).

Land Use

Present land (Figure 15) use in the Rio Guayanilla basin are as follows: About 69 percent is uncultivated or virgin 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.

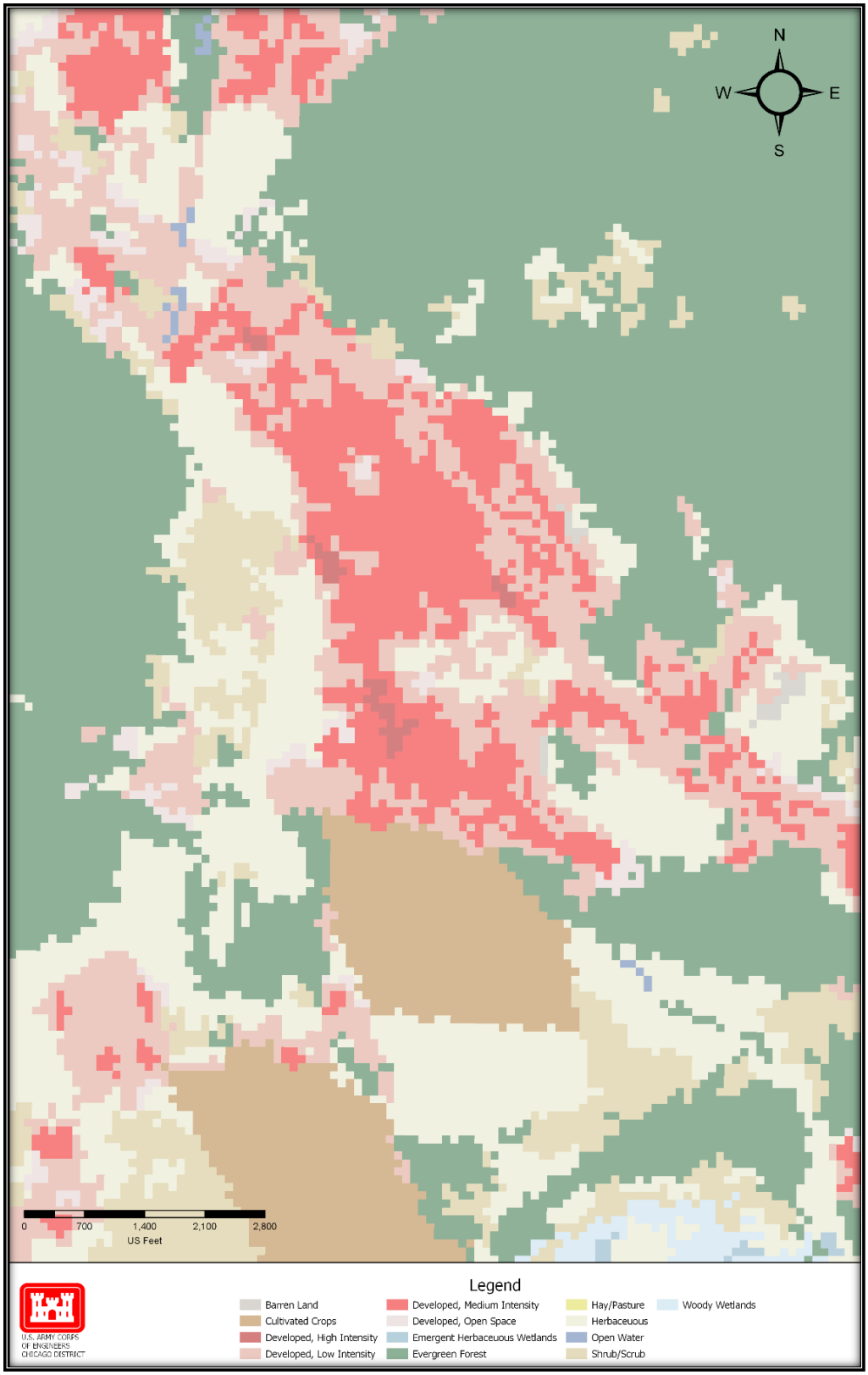


**Figure 15: Study Area Land Use as Utilized by HEC-RAS Modeling**

About 22 percent is or has been cultivated. Typical crops are bananas in the flood plain and foot hills, coffee, grazing pasture, and some minor crops in the hills and mountain slopes. About 7 percent is urban developed land and more than 3 percent is occupied by roads and highways and another 1 percent is swampy mangrove land at the bay front. 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 town of Guayanilla and to some extent east of the town 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 to the town and residents of Guayanilla. Due to the steep slopes in the basin, this flooding is often caused by flash floods that result with little warning time to the people. 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. The USGS has not yet published the peak flow data for Hurricane Maria in September 2017.

**Table 3: 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) obtains data for the Guayanilla River 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 4 (PREQB, 2018a).

**Table 4: 2018 Guayanilla River and Guayanilla Bay 303(d) listed pollutants.**

| Water body (river/coast length) | Designated Uses | Impairments | TMDL Development Priority (projected submittal date) | Sources |
|---|---|---|---|---|
| | Contact and non-contact | Ammonia | High | Agriculture, Collection System |
| | | Enterococci | High | |

| | | | | |
|---|---|---|---|---|
| Guayanilla River / Río Guayanilla (60 miles) | water recreation (REC-1, REC-2), preservation and propagation of aquatic life including T&E species (AL), drinking water supply (DW) | Fecal Coliform | Already Established (Approved September 2012) | Failure, Landfills, Minor Industrial Point Source, Minor Municipal Point Source, Onsite Wastewater Treatment Systems, Urban Runoff/Storm Sewers |
| | | 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 Guayanilla River 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 Guayanilla River 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 resuspension, 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 Guayanilla River 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).

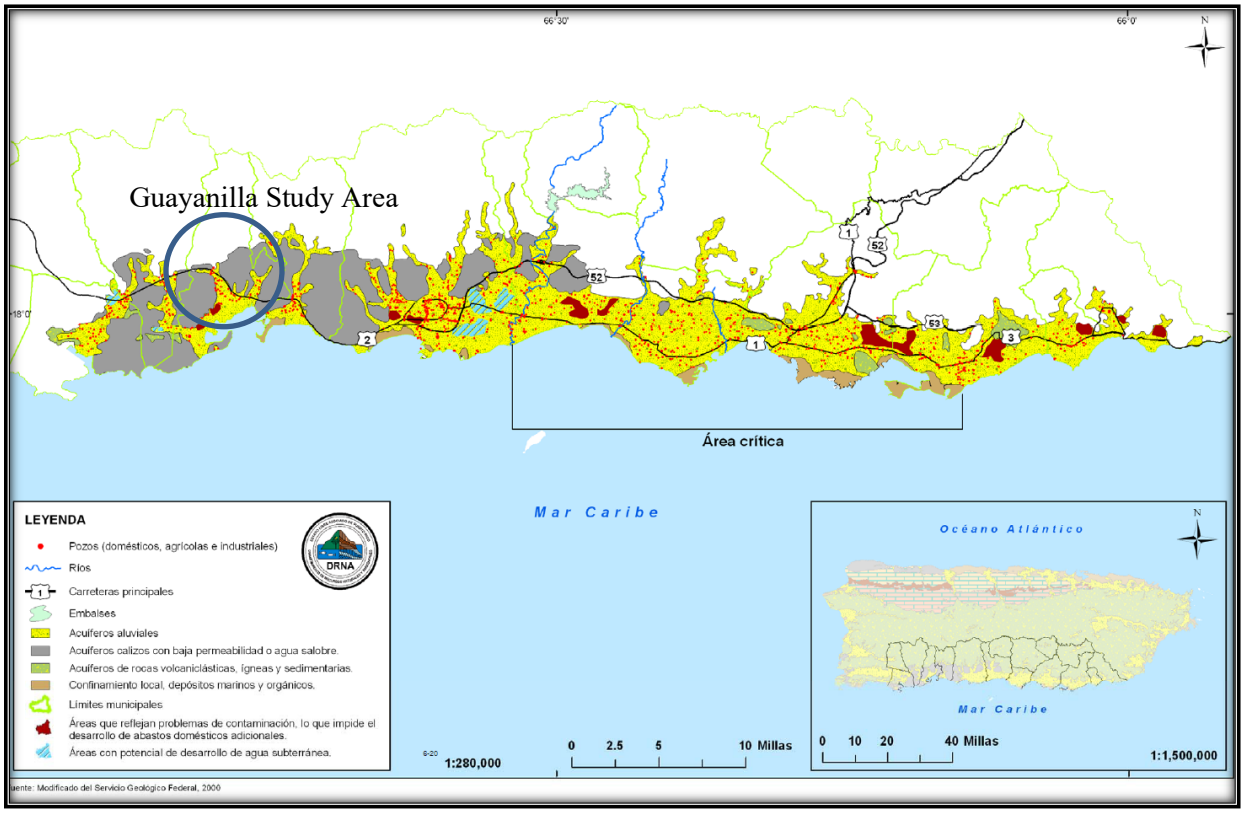


**Figure 16: PR South Coast Aquifers, with Critical Areas of Saline Intrusion Highlighted in Red**

Future Without Project Conditions: 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.

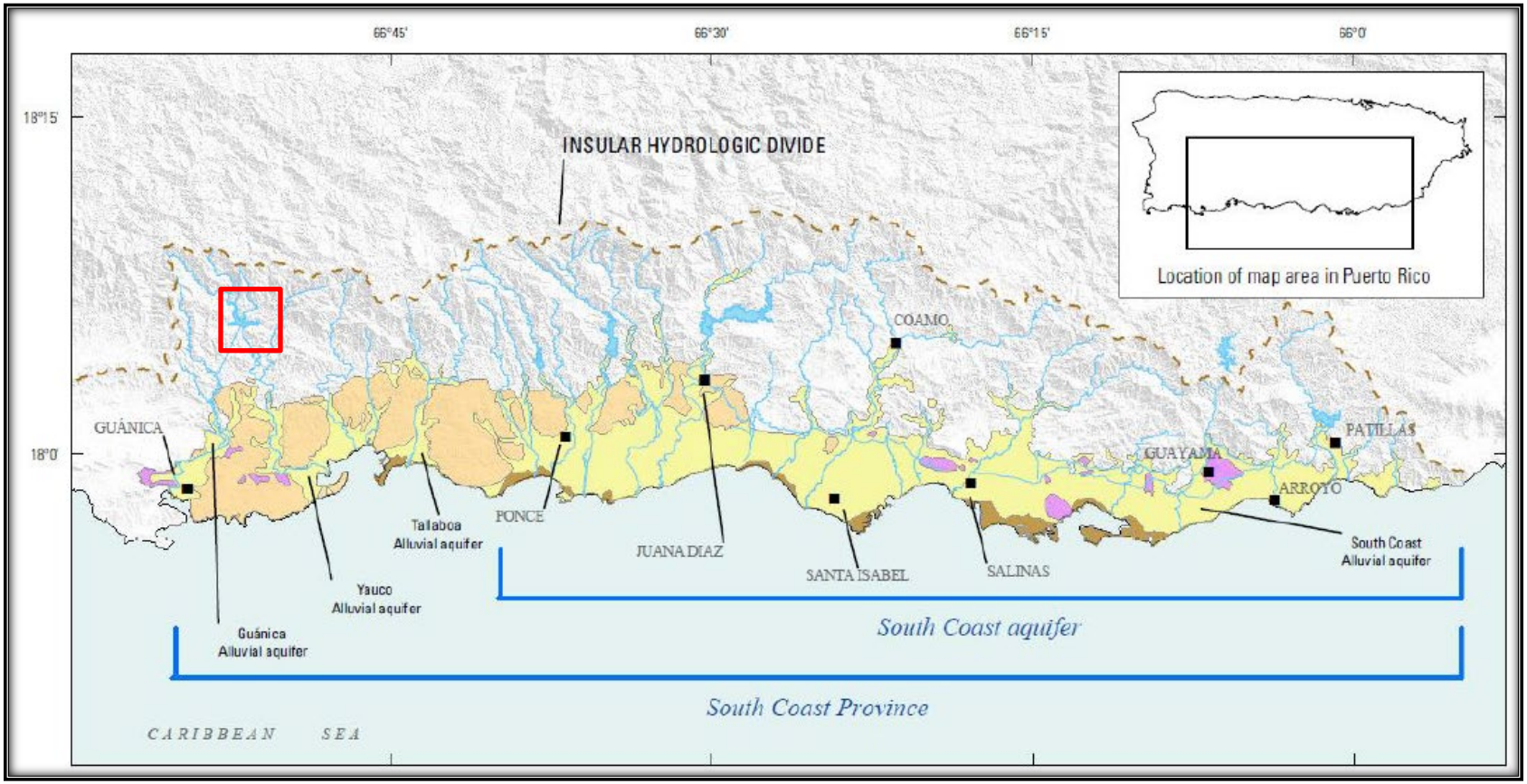


**Figure 17: USGS Location Map of Aquifers within and surrounding the Study Area**

## 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).

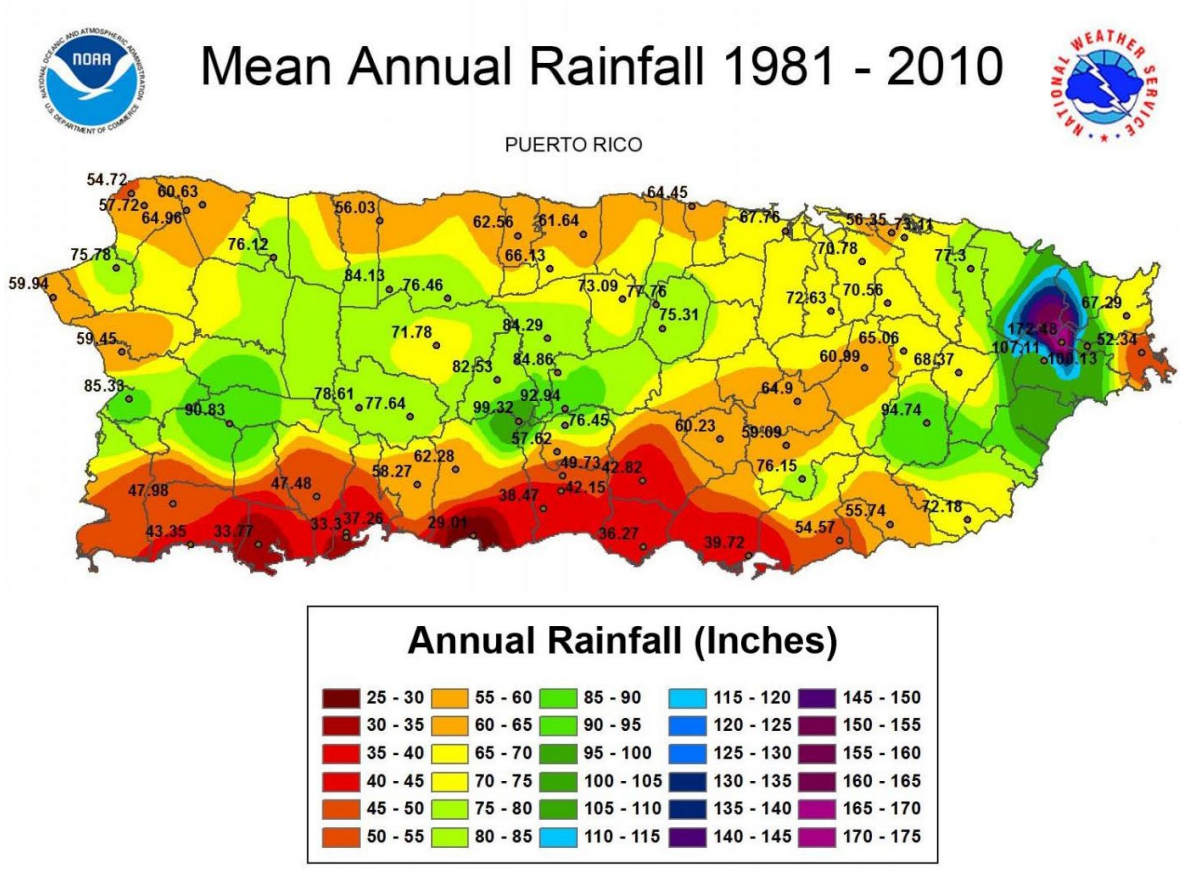


**Figure 18: Mean Annual Rainfall for Puerto Rico 1981 – 2010. Source: National Weather Service**

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 Conditions: 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 5) 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 5: 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 6 & Table 7). 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 6: 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 7: 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).

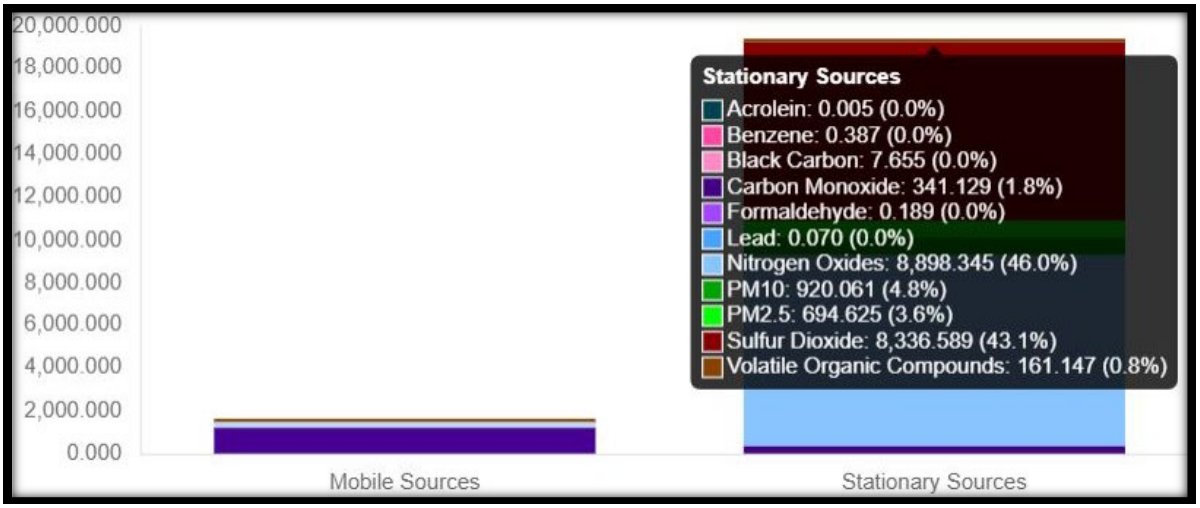


**Figure 19: Guayanilla County 2014 Total Emissions (tons) of Multiple Pollutants**
Source: USEPA National Emissions Inventory 2014 ver. 2

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 8: 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 Conditions: 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 was a natural ephemeral river (drying out completely for months at a time) in the lower segment, but probably having standing pools and low flows provided by groundwater discharge in the upper montane segment. 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. Sirajo Goby *Sidydium plumeri* (Photo 5). There may be several distinct 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 correlating existing fish communities to historic, based on the fluviogeomorphic and hydrologic inputs that are seemingly moderately modified to unchanged, they were most likely the same.

The existing condition of the Río Guayanilla is moderately in its historic state based on land use, hydrologic inputs and highly active fluviogeomorphic characteristics (eroding banks, large active point bars, sediment transport and sorting); except for the channelized reach at the mouth, bridge crossings and several areas of bank armoring/channel modification. There has been some change in the upper segment; however, it is generally protected from change by steep karst slopes. In the lower segment, land use change for agriculture and residential along the coastal plain segment of the river has adversely affected habitat, but more 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 river was channelized as part of a potentially greater project. This subsequently removed all fluviogeomorphic processes and degraded various interactions with estuary zone.

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. In November 2006, during the rainy season, six (6) native and one (1) invasive species were collected (Table 9) from the Río Guayanilla at PR-127 Bridge crossing in Guayanilla (Kwak 2007). 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. 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 9: 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 |

Future Without-Project Condition: In the absence of a federal project, there is no apparent reasons to indicate decline or improvement in terms of riverine habitat and resulting aquatic communities; however, it is anticipated that without a project, the conditions in the river would slightly improve as community groups address minor and localized water quality issues. There may or may not be additional ecosystem improvements at the mouth of the river, where the estuarine conditions were previously degraded.

**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 history requirements of 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 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.

### *2.6.3 Subtropical Dry Forest Zone*

By the 1970s most of the world's dry forests had already been severely altered. Some estimates indicate that up to 42 percent of forests in the tropics were originally dry forests. In addition, about 60 percent of current scrub forest and savanna may have been dry forests prior to human alterations. In some areas today, dry forests are only historical remnants, whereas many other areas have only 1 to 5 percent of their initial areas remaining. This trend is reflected for dry forests located on the Island of Puerto Rico as well.

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.

Existing Conditions: The Subtropical Dry Forest community 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 in that 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 having 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, as water deficits may occur up to 10 months of the year.

*Floral Inventory of Study Area*

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 A* with map and species lists.

In 1988, at the time of this cited survey, most of the land reflected a recent agricultural use, as the predominant vegetation type was considered Sugar Cane, or Cañaveral, (now abandoned) and old fields. Since then, agriculture still dominates the landscape and based on aerial observations, not much if anything has seemingly changed since 1988 except for the implementation of the Phase I flood control project by the DNER. There is remnant mangrove forest surrounding the "Playa de Guayanilla "

community adjacent to the coast, located between the Río Guayanilla and Río Macána mouths. It was noted that on the east bank of the river mouth, there was a brackish swamp dominated by Giant Grass (*Fimbristylis spadicea*), which was impacted and mitigated for by the Phase I project.

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 A*. Most of the species encountered were shrubs and annual herbs of widespread or weedy distribution, noted as being ruderal, or induced by man.

Dry Grassland & Riparian Vegetation

The vegetation within the channel was 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.

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.

Brackish Swamp

In the brackish swamps, from road PR-336 to the river are 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 Guayanilla River, are used as grazing pastures. Trees occur widely scattered among the dominant grasses and sedges, making 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*).

Mangrove Basin & Edge at Guayanilla Beach

The mangrove stand to the north of Playa is mostly dominated by Black Mangrove (*Avicennia germinans*), although it exists some White Mangrove (*Laguncularia racemosa*). 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 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*).

Despite showing evidence of frequent flooding by brackish waters (and occasional tidal flood), the mangrove does not appear to be in contact with the river very frequently except for the mangrove stand near the river mouth. It is possible that brackish water reaches this area by intrusion and percolation. During visits by DNER technical staff, the river was almost dry; however, the mangrove swamp and surrounding swamp were wet. The Rio Guayanilla is ephemeral and experiences a seasonal flow. Also, adjacent wetlands and the Phase I canal at the mouth of the river reflect the strong influence of saline intrusion in both surface waters and the aquifer.

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 CommonvWarbler (*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 study area plant communities would remain relatively similar to the existing condition. Puerto Rico's forested ecosystems have been highly altered in the last 200 years owing to introduction of various economically important plants such as Sugar Cane, Coffee, Bananas, Tobacco, Pineapples, and others. Considerable forest clearing also took place for pasturage and charcoal production. Today, forests and old agricultural lands are disappearing as a result of construction of highways, transmission lines, ports, refineries, mines, powerplants, industrial developments, and many other activities associated with extensive urbanization. Trends toward urbanization and industrialization are producing an opportunity in Puerto Rico to study what happens to large areas of a tropical island when reverted back from intensive agricultural to open fields. Successional sequences are being documented to understand natural recovery of forested ecosystems in areas massively degraded in the past.

### *2.6.4 Subtropical Dry Forest – Abandoned Mine Quarry Site*

This area was naturally Subtropical Dry Forest community as described in the previous section. The USFWS carried out a field visit and rapid assessment of the area on August 5, 2019. The site is composed of four hills separated by three drainages. Although the area was previously cleared, some forested areas were left intact. These remnant forested areas remained relatively undisturbed to the present day. These

areas could contain listed plant species typical of sub-tropical dry forest. However, these patches of undisturbed vegetation are relatively small when compared to the original quarry proposals. Future Service surveys will concentrate on forested areas. In addition, there still exists the possibility of the Puerto Rico nightjar within this site since the area of karst hills in Guayanilla is known to harbor a population of this federally listed ground nesting bird; and it has been known to nest in previously disturbed areas. Information on habitat, vegetation and species will be updated and provided by the USFWS via coordination through Fish & Wildlife Coordination Act Report.

### *2.6.5 Federal Listed Species*

The USFWS advised that the karst hills and forests immediately west of the project site are within the range of four (4) federally listed species to consider during plan development (Table 10). These are the Puerto Rican Nightjar (bird) (FE), the Puerto Rican Boa (snake) (FE), *Eugenia woodburyana* (evergreen tree) (FE) and *Trichilia tricantha* (evergreen tree) (FE).

**Table 10: Federal Listed Species Potentially within the Project Area.**

| Common Name | Scientific Name | Federal Status | Potential to Occur |
|---|---|---|---|
| Guabairo or Puerto Rican Nightjar | *Antrostomus noctitherus* | Endangered | High potential to occur in mountainous dry subtropical forest, especially over karst parent material |
| Puerto Rican Boa | *Chilabothrus inornatus* | Endangered | High potential to occur everywhere, as is a generalist species including ruderal habitats |
| NA | *Eugenia woodburyana* | Endangered | |
| Bariaco | *Trichilia tricantha* | Endangered | |

The first species likely to occur within the study area is *Antrostomus noctitherus*; the common name in English is the Puerto Rican Nightjar, 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 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. Based on the species' natural history, surveys will need to be conducted for ground nests containing eggs from February thru July. As part of protection of this species, USFWS will be conducting inventories and providing subsequent conservation measures to be implemented during construction.

The second species likely to occur within the study area is *Chilabothrus inornatus* (recently (2013) changed from *Epicrates inornatus*, which is now a binomial synonym); 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. As part of protection of this species, plans during construction should include measures to eliminate the risk of physically entraining or crushing mothers in parturition (in labor) and new born through adult life stages. Various conservation measures can be implemented to move snakes from the area before earthwork or mining occurs. Other potential mitigation for habitat disturbance could include planting conspecific tree and shrub species after construction. Also, it is very

possible that if significant cave structures are found within the potential limestone mining zone, these could be avoided.

The third species likely to occur within the study area is *Eugenia woodburyana*, which has no common name. This plant is a small evergreen tree belonging to the family Myrtaceae (Myrtles: Eucalyptus, Tea Tree), a large family that includes from 100 to 140 genera and 3,000 or more species of trees and shrubs, mostly of tropical and subtropical regions. The species is specifically noted to occur within the Guánica Commonwealth Forest located in southwestern Puerto Rico; including the municipality of Guayanilla. *Eugenia woodburyana* is found in the semi-evergreen forests of the bottoms of mesic canyons. The parent material for canyon soils are Tertiary limestone rock. Soils are derived from limestone and are shallow, well-drained, and alkaline in nature. Also, water runs through these canyons during heavy rainfall, but they are dry to mesic the remainder of the year. Silty alluvial soils are left behind from the flowing and eroding water where pockets form among large limestone rock outcrops. These pockets retain a greater moisture content and support greater tree growth. Historic reasons for listing included deforestation and selective cutting for urban and industrial development, agriculture, charcoal production, and fence posts. Current reasons include residential and industrial development, as well as forest management practices. Various conservation measures can be implemented to exclude discovered plots of this species from mining activities, particularly within ravine/gully/canyon valleys. Other potential mitigation for this species could include propagation and reintroduction.

The fourth species likely to occur within the study area is, *Trichilia triacantha*; the common name is Bariaco. This plant is a small evergreen tree belonging to the family Meliaceae (Mahogany). The species is specifically noted to occur within the Guánica Commonwealth Forest located in southwestern Puerto Rico; including the municipality of Guayanilla. Bariaco occurs in the same habitat as described for *Eugenia woodburyana*. Historically, the most important factors limiting the distribution have been deforestation and selective cutting for urban and industrial development, agriculture, charcoal production, and the cutting of wood for fence posts. Today residential and industrial development, as well as forest management practices, threaten this species. Various conservation measures can be implemented to exclude discovered plots of this species from mining activities, particularly within ravine/gully/canyon valleys. This species seems to prefer disturbance regimes, especially those established by streams. Its appearance along road ways also lends to this. It seems characterizing and mimicking the specific disturbance regime post karst mining for this species could be a conservation measure for replanting and propagation.

### *2.6.6 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 PRDNER 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.

### *2.6.7 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 to be listed 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.

### *2.6.8 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 USC 3501.

## 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 Guayanilla River. 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 in 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 town 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; however, 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 11 provides a list of the major plantations in the nineteenth century by *barrio* within Guayanilla (Sievens Irizzarry 1983).

**Table 11: 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 town'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 12). 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 potions of this study overlap with the current APE.

**Table 12: 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, Guayanilla River Channel Project, Guayanilla, Puerto Rico* | 1994 | G.A. Pantel |
| *Guayanilla River Channel Improvements, Archaeological Mitigation Program, Data Recovery Draft 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 13). Of these nine sites, only one resource (GL0100046) has been evaluated for eligibility for inclusion in the NRHP. Site 8GL0100046 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 13: 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 Guayanilla River Basin. There are approximately 8,800 residents in the study area (Table 14 ). The age distribution of the study area is shown below.

**Table 14: 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 15 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 15: 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 16.[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 16: 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 17 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 town. 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 town. 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 17: 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 Conditions

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. The U.S. Census Bureau estimates that the population in the municipality of Guayanilla decreased by 18 percent between 2010 and 2018. 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 Guayanilla River. Review of historical topographic maps and aerial photographs suggest the project area was largely undeveloped and used for agricultural purposes. Based on land-use and a historic (1996-1997) release of pesticides to air, fertilizer and pesticide residues are likely in the soil of study area at the tropical fruit plantation. Soils may contain *de minimis* concentrations of PAHs and metals due to proximity to the developed Municipality of Guayanilla. Petrochemical facilities at an industrial area in southeast Guayanilla (Barrio Magas) have impacted local soils, 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. A Phase I Environmental Site Assessment (ESA) was used to identify HTRW or non-HTRW recognized environmental conditions impacting the project area; full details are provided in Appendix J: Hazardous, Toxic, and Radioactive Waste (HTRW) Report.

Future Without Project Conditions: 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 Conditions: In the absence of a Federal project, agricultural spatial occupancy would generally remain the same. Most agricultural lands would remain in the 1% ACE (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 Conditions: 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 caused significant road closures, damage to existing roadbeds, flood damages to vehicles and other

portable property. Closures at flooded roadways impedes access to critical emergency facilities (Figure 5).

The emergency shelter where the community gathers during evacuations was disabled by past floods, causing issues with evacuation cohesiveness and accountability for individual citizens. Key municipal facilities (fire and police) are impacted, causing issues to evacuation and safety assistance as well as weakening law enforcement. Second tier emergency support such as pharmacies (Photo 3), food, clothing and supply shops are impacted and have been heavily damaged by past floods. These include a regional hospital, local fire and police stations, emergency services, shelters, and other during frequent storm events. Also of concern is the Waste Water Treatment Plant, which impacted, 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, both spreading them overland and into the Rio Guayanilla and Guayanilla Bay. This 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 Conditions: In the absence of a Federal project, the existing condition would remain, with potential to increase public health and safety concerns from flooding due to predicted increase in storm and flooding intensities due to climate change.

### *2.9.5 Traffic and Transportation*

Flooding causes road closures along PR-127 in the center of town, which becomes a passageway 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, which was not rebuilt until 2016 due to lack of government funds. In 2017, Hurricane Maria caused significant damage to the PR-127 bridge on the southeast side of town, making the bridge impassible for months and causing traffic delays. Road closure impacts evacuation routes, and creates a public safety concern as individuals are unable to evacuate the area and/or reach medical facilities, which significantly increases life safety risk.

Future Without Project Conditions: In the absence of a Federal project, the existing condition would remain, with potential to increase transportation complications from flooding due to predicted increase in storm and flooding intensities due to climate change.

### *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 18: 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 Conditions Summary

The future without-project condition (FWOP) represents the most likely (forecasted) future conditions in absence of a federal project. The FWOP is synonymous with the No Action Alternative. Each alternative plan that is formulated is compared to the FWOP. The following is a summary of FWOP for elements that could have the most direct effect on plan formulation.

- Flash floods and over topping of the Río Guayanilla natural channel would continue with existing climate patterns (Section 2.3.1) within the Guayanilla riverine and coastal floodplain. Also, it is predicted climate pattern change would increase local precipitation, further increasing the magnitude and risk of inundation. Risk to public safety and health would continue to remain high; evacuation routes and emergency services remain impacted. Risks to structure damages would continue to remain high. Vulnerable populations would continue to at high risk of flooding.
- The Río Guayanilla would be expected to continue to experience natural fluviogeomorphic processes, which includes erosion of banks, deposition of point bars and large amounts of sediment transport, primarily of rock substrate. 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. Critical facilities, including emergency responders would continue to be at risk.
- Earthquakes/seismic events, especially those associated with the Puerto Rico Trench would continue to occur in an unpredictable manner, which if strong enough could induce surface rupture and/or liquefaction of natural and manmade resources within the study area, in particular the bordering karst mountains to the west. The last major earthquake to strike Puerto Rico was magnitude 6.5 in 2014. Tsunamis may result from these earthquakes; however, to date, only one landed on the northern side of the island in 1918, which resulted from an 8.1 earthquake in the Puerto Rico Trench.
- 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, and has only been moderately impacted 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 decline since the year 2000. Residents explain that due to the frequency of flooding, many individuals and businesses have left the area. Census.gov estimates that the population in the municipality of Guayanilla decreased by 18 percent between 2010 and 2018. 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, as flooding is a huge inhibitor of the growth of the area.
- 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*

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 shows effects on ecological, cultural, and aesthetic attributes of significant natural and cultural resources that cannot be measured in monetary terms. The OSE account shows urban and community impacts and effects on life, health and safety. The NED account shows effects on the national economy. The RED account shows 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 below the poverty line, while flash floods pose risks to the life and safety of those in the community. In light of the affected environment, the effects and benefits under all four accounts - NED, RED, EQ and OSE - were used to support plan selection.

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. 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 results from analyses apparent, the process is refined and updated in cycles until the answer is clear.

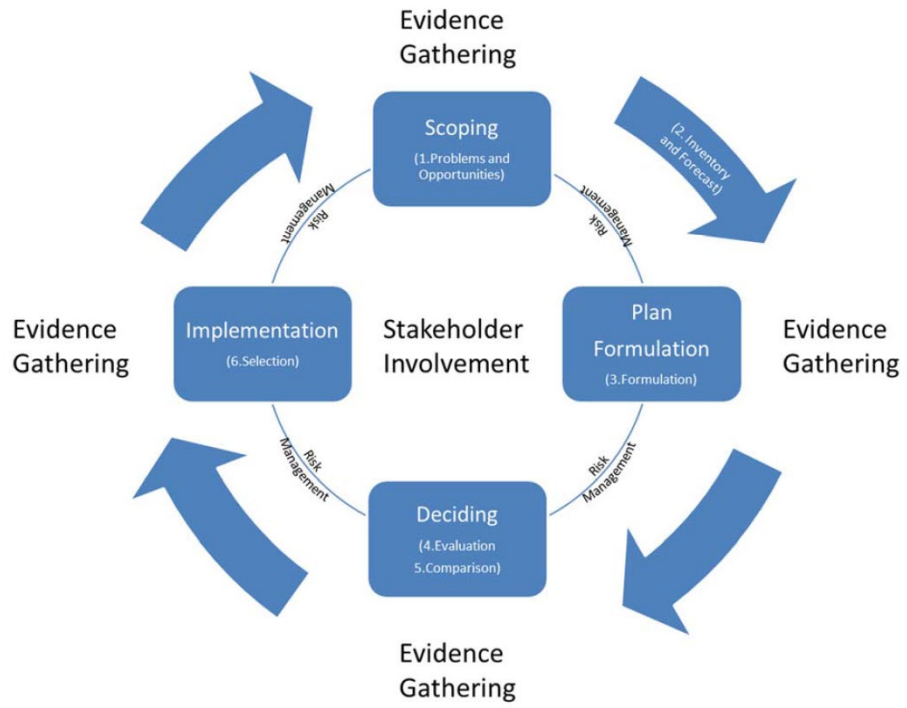


**Figure 20: USACE Risk-informed planning process.**

### *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 and each term is discussed more completely in ER 1105-2-101 “Risk Assessment for Flood Risk Management Studies” dated 17 July 2017.

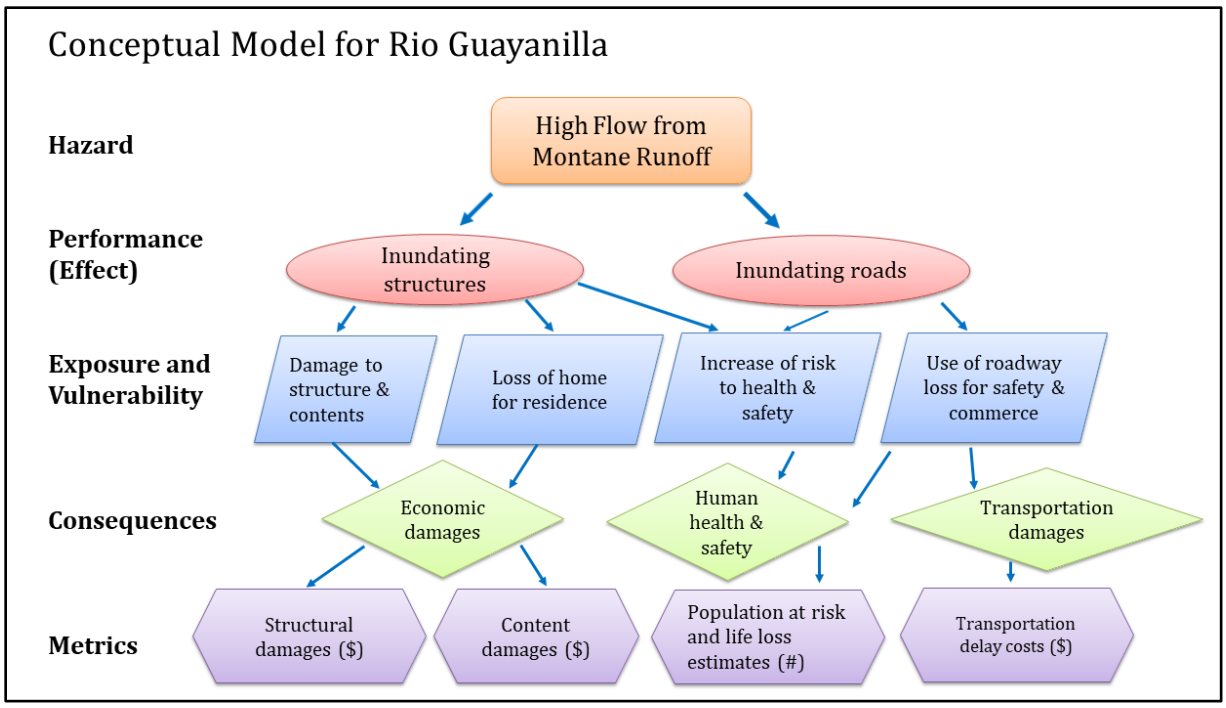


**Figure 21: Flood Risk Management Model for the Río Guayanilla Study**

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% ACE (500-year) and 1% ACE (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 H – Geotechnical Engineering*.

Consequence

Consequence refers to the potential economic and socioeconomic impacts that results from a single occurrence of the hazard, including risks to life safety, damages to residential and commercial structures and public infrastructure, and time lost due to traffic delays caused by flooded transportation routes. Consequences are summed as quantified damages.

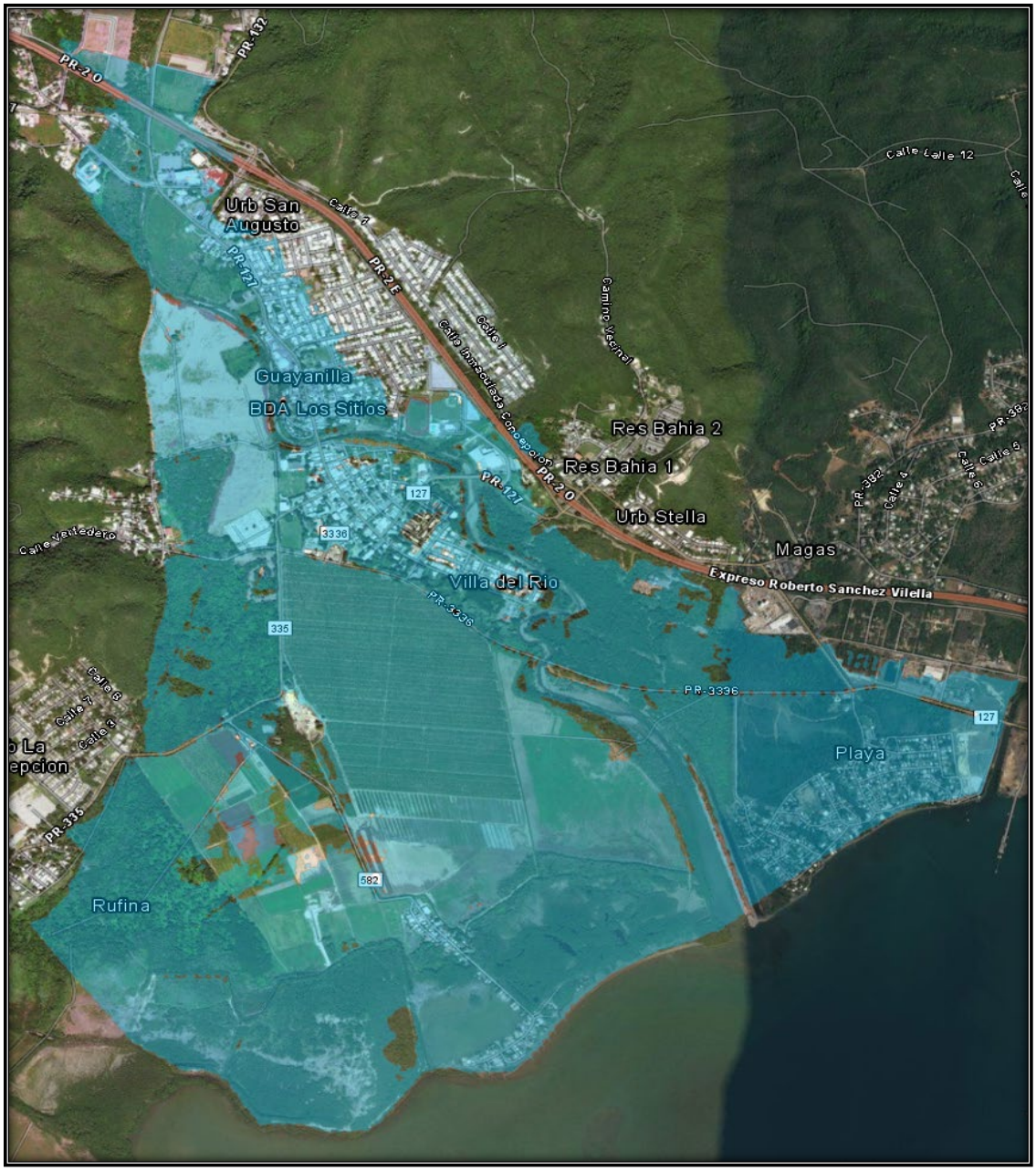


**Figure 22: 0.2% ACE (500 year) Anticipated Study Area Flooding under Current FWOP**

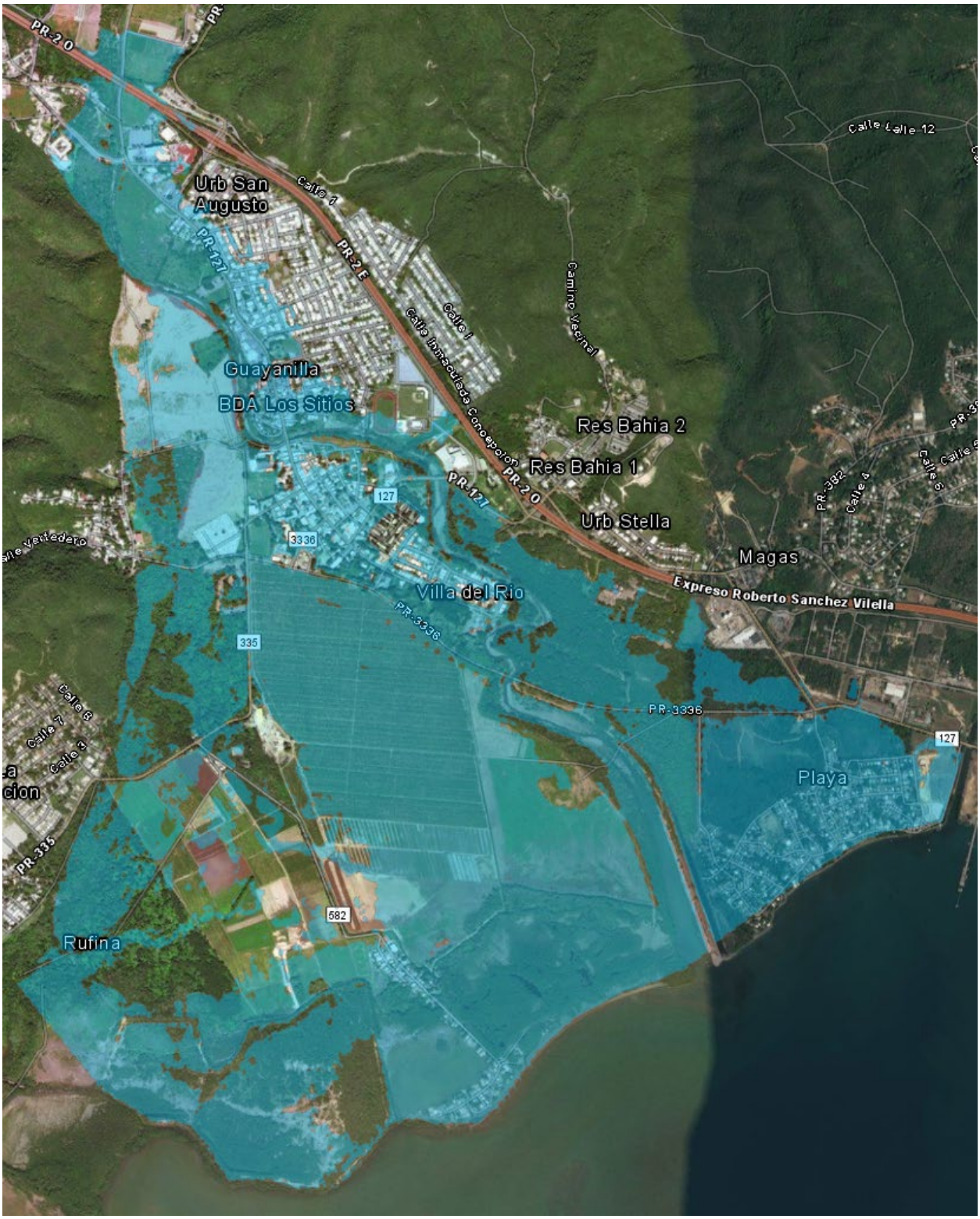


**Figure 23: 1% ACE (100 year) Anticipated Study Area Flooding under Current FWOP**

## 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 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 exposed people and properties are to damage and harm from the 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 solve the issue of flooding; rather it seeks to provide for public safety and spot treatment of problem areas. 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. 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 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* – also called canalization, involves deepening, widening and straightening of a river's natural channel in order to contain and hasten rainwaters to the sea. The alignment for this type of measure would generally be through the existing natural channel adjacent floodplain terraces.

*Levees & Floodwalls* – involve construction of earthen, stone, and or concrete berms (levees) or 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 such as clay and stone, 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.

*Diversion Channels without Levees* – Due to the likely quantity of flow, which is on the magnitude of 30,000-40,000 cfs, it is not possible to allow the Rio Guayanilla flood waters to freely flow to the west in a diversion channel without levees. The quantity of water would be so great during significant flood events that the Town of Guayanilla, as well as agricultural fields on the west side of the river would still become inundated under a range of flow conditions.

*Staged Greenway Terraces* – involves rerouting flood water away from the Municipality of Guayanilla, but instead of an engineered channel that induces high velocities, the greenway channel would be widened in order to reduce these velocities and provide habitat and open space during the long periods between flood events. Due to landform and open space constraints, this measure would need to be supported by engineered channel features in certain segments of the diversion. This measure evolved from the agency planning Charrette (28 November 2018) discussion between USACE, USFWS, and NOAA. This greenway diversion would require real estate and easements greater than the engineered channel measure, both for footprint and excavated material (sand, gravel, et cetera) disposal and beneficial reuse.

*Rehabilitate Phase I (DNER Constructed*) – involves repairing damage to the existing levees, clearing tree and shrubbery vegetation from levees, 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 a) removing vegetation per USACE standards for levee construction; 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 excluded from removal requirements; and b) includes concepts of native vs non-native species for incidental habitat and erosion control.

*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 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 implementing 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.

### *3.3.1 Screened Nonstructural Measures*

*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.

*The National Nonstructural Committee's Flood Damage Reduction Matrix* – This matrix was used to evaluate the feasibility of multiple nonstructural measures. Nonstructural measures which were not screened out using the matrix were economically evaluated to compare the net benefits with structural alternatives.

*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). The reaches with lower flood velocities, less than 3 fps, generally contained agricultural or open land; consequently, elevation was not considered to be effective.

*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. Effective implementation is still being explored at this time.

*Flood Warning System* – Currently there is no flood warning system in place. The possibility of implementing a flood warning system is being considered.

*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 make dry and wet flood proofing alternatives unviable. There are approximately 1500 structures within the 0.002 ACE floodplain in the study area (Figure 22). Nonstructural solutions will be considered on a more localized basis, in combination with other measures, if they are likely to increase the net benefits produced by the various alternative plans. Similarly, flood proofing of critical facilities will be considered if protection of said facilities would be likely to improve response and recovery, or decrease risks to life safety, in the study area.

### *3.3.2 Screened Structural Measures*

*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 magnitudes of cost. This was determined during the reconnaissance phase.

*Channelization* – Channelizing the natural channel of the Río Guayanilla in montane and coastal plain units to contain and hasten rainwaters to the sea was eliminated from further consideration for the Guayanilla FRM study. Reasons for elimination include creating a life-safety hazard through downtown 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 space restrictions.

*Diversion Channels without Levees* – Due to the likely quantity of flow, which is on the magnitude of 30,000-40,000 cfs, it is not possible to allow the Río Guayanilla flood waters to freely flow to the west in a diversion channel without levees. The quantity of water would be so great during significant flood events that the Municipality of Guayanilla would still become inundated, as well as additional agricultural fields on the west side of the river.

*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 flows to go west. A greenway would form over time from the 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.

### *3.3.3 Separable Measures*

Nature-Based Features are the only separable structural measures that can address the threatened structures along the Rio Guayanilla's natural channel. Nature-Based Features can be implemented with or without addressing flood hazards and their associated effects. When considering non-structural measures, similar to Nature-Based Features, they can be implemented independently of the structural measures, and are not dependent upon them; for example, it is always a prudent decision to have a flood warning system in place with or without structural flood control features to warn citizens of pending hazards and vulnerabilities of high flow/high velocity channels. Nature based features and non-structural measures must be considered and evaluated appropriately as part of an economically justified alternative.

## 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 were strategized to address study problems.

**Table 19: 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 town 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 is considered independent and separable from the structural alternatives.

*Flood Warning System* – Citizens of Guayanilla can get stranded during quick moving or unsuspecting storms outside the large hurricane events. The town 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. 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 levels which can help to evacuate early. 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.

*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 of 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 in some fashion:

*a.* Rehabilitate Phase I
*b.* Bridge & Conveyance Modifications
*c.* Vegetation Removal
*d.* Utility Relocation
*e.* Minor Nature Based Features
*f.* Engineered Features & Bank Protection

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, approximately at PR-2. A robust diversion structure would be set in place across the river channel to split flows, sending all flood waters to the diversion channel while largely retaining bank-full flows in the Rio Guayanilla to maintain its ephemeral riverine ecology. The conceptual design of the diversion structure includes riverine connectivity for sediment transport and fish passage.

The alignment for this alternative directs flood water away from the town and to the west along the confining mountain valley wall through agriculture fields, where it bends east though banana fields to join up with constructed Phase I project near PR-3336 (Figure 24). The length of the diversion channel is approximately 9,000 feet long. 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.

Material from the excavated channel would be predominantly gravel and sand, which is not suitable for levee construction, but potentially suitable for concrete components; beneficial reuse of materials could be incorporated into the plan for wetland and ecosystem restoration or as a marketable commodity for potential contractors. The material could also be used by the municipalities of Ponce and/or Peñuelas for landfill cover. Figure 26 shows the areas designated for disposal and stockpiling of materials. The levees would be constructed of project generated or commercially sourced clay and rock. An abandoned quarry that has already incurred natural resource impacts would be utilized to generate rock and concrete materials (Figure 25). The bottom of the channel may have robust concrete, gabion, sheet-pile and/or riprap grade control structures embedded at select locations where hydraulic models indicate incision or meandering potential exists. 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. This alternative includes measures A–F, but will focus efforts and costs towards F: Engineered Features & Bank Protection.

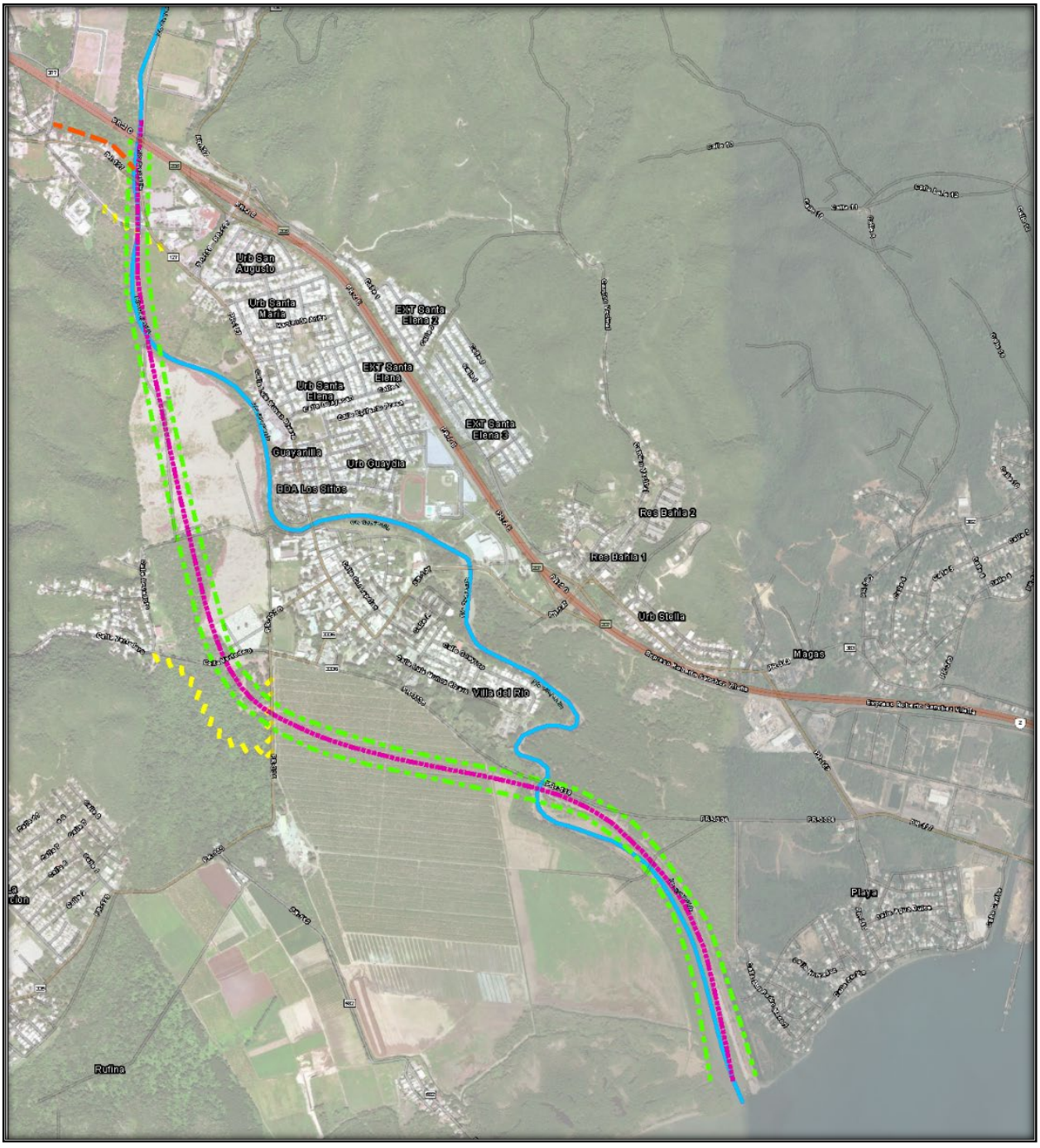


**Figure 24: Alternative 2 Diversion Channel South w/ Double Line Protection**

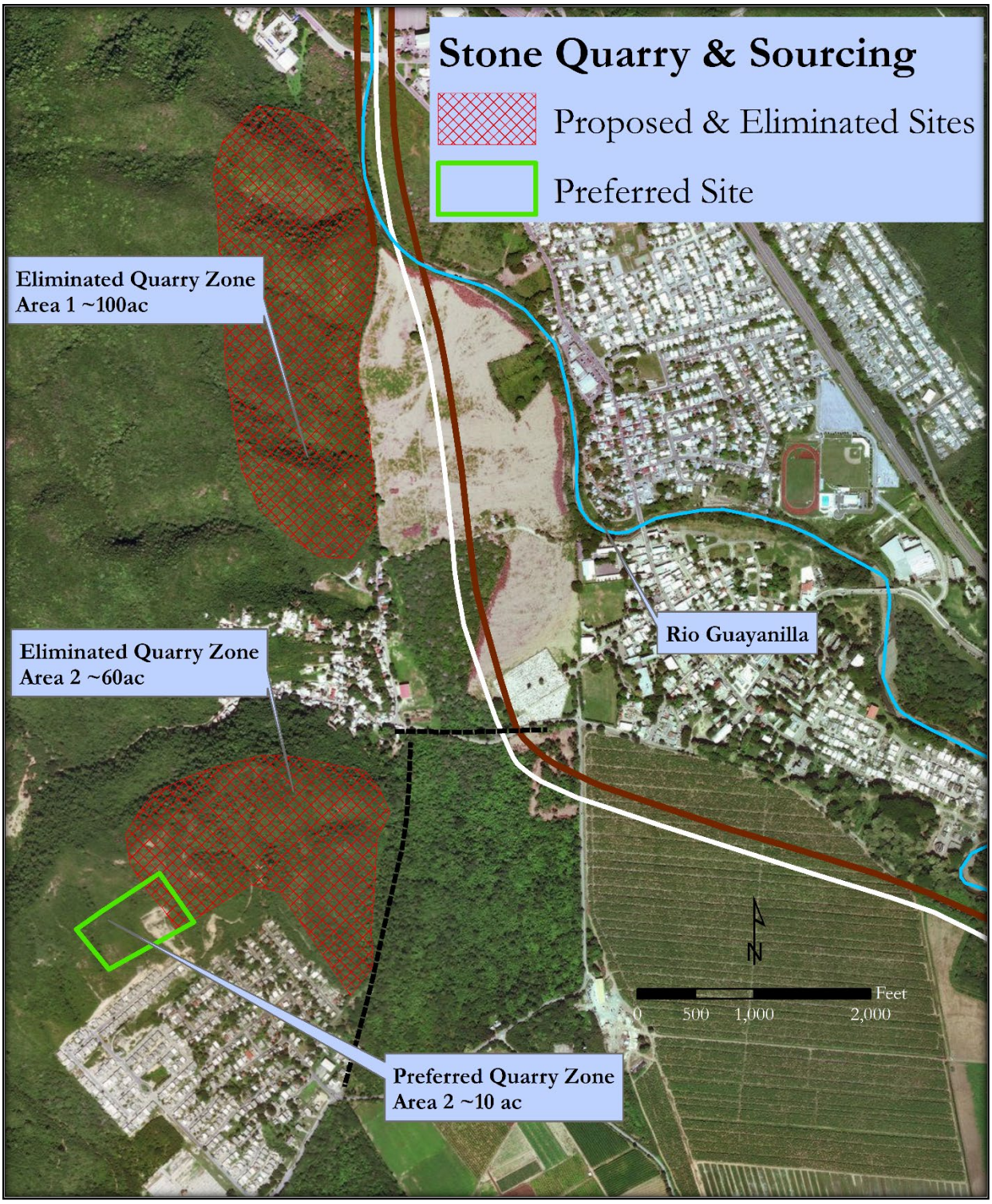


**Figure 25: Quarries & Sourcing for Levees and Concrete Limestone Aggregates**

Alt# 3 Diversion Channel South with Single Line Protection – This alternative (Figure 26) 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 town side or east of the channel. The west side of the channel would be graded/bermed to certain elevations to ensure waters stay within the designated flowage. The bottom of

the channel would have a robust concrete grade control structure embedded throughout due to the expected velocities.

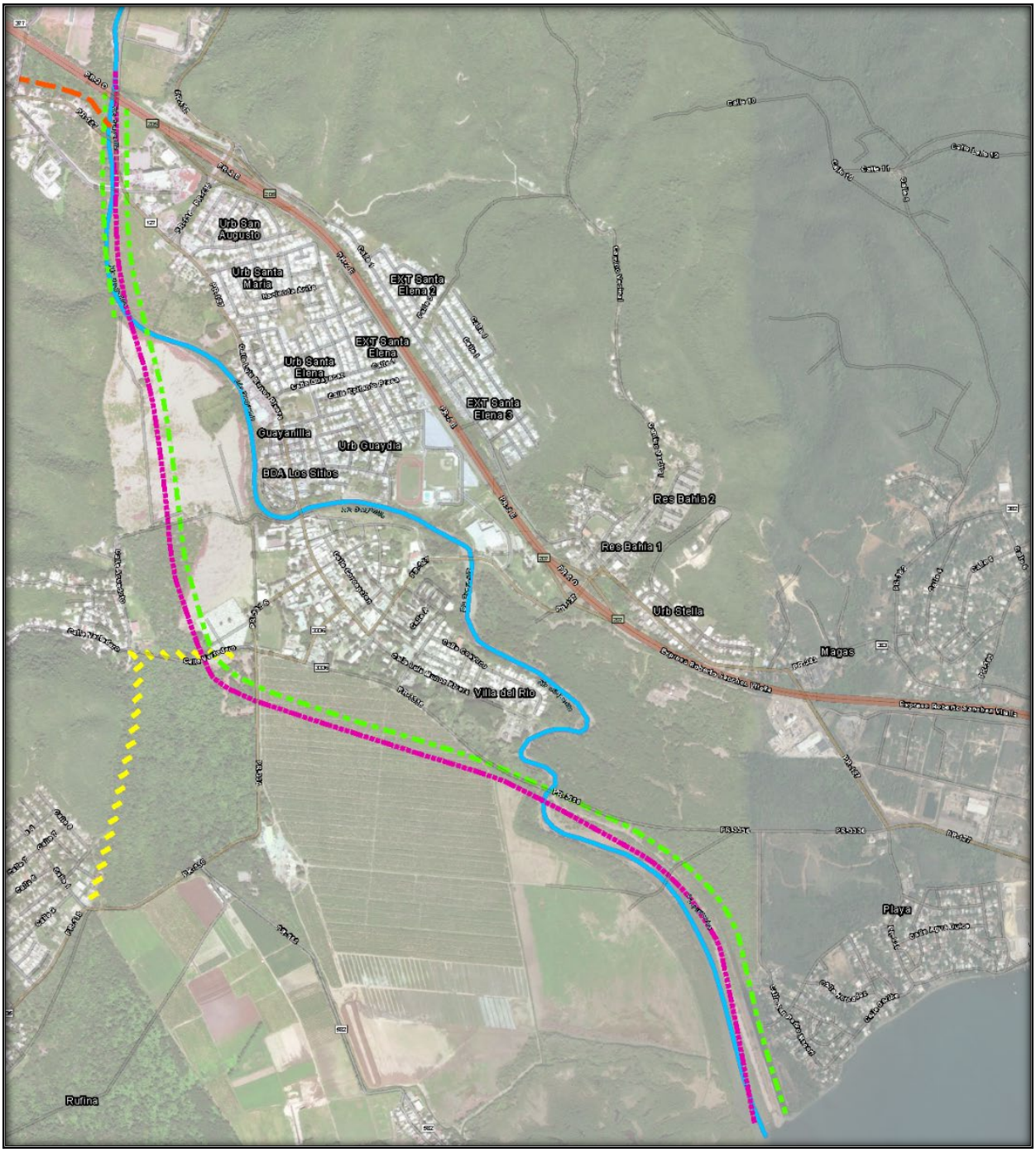


**Figure 26: Alternative 3 Diversion Channel South w/ Single Line Protection**

Alt# 4 Diversion Channel North with Double Line Protection – This alternative would involve construction of an engineered diversion channel along with channelization of the natural river channel at the end of the montane unit and beginning of the coastal plain unit of the Rio Guayanilla, approximately at PR-2. A robust diversion structure would be set in place across the river channel to send all flood

waters to the diversion channel and channelized portions of the natural river; there will be several reaches where the natural channel becomes abandoned.

The alignment for this alternative does not direct flood water away from the town, but through it via a combination of new canal and channelization of the Rio Guayanilla. A new canal would be excavated north of town through forest habitat to connect to the constructed Phase I project near PR-3336 (Figure 27). 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.

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

A large woody debris and sediment/rock removal plan would need to be implemented to ensure the alternative would successfully convey floodwaters. As indicated, this alternative includes measures A–F, but will focus efforts and costs towards F: Engineered Bank Protection. This alternative measure would exclude measure e: Minor Nature Based Features.

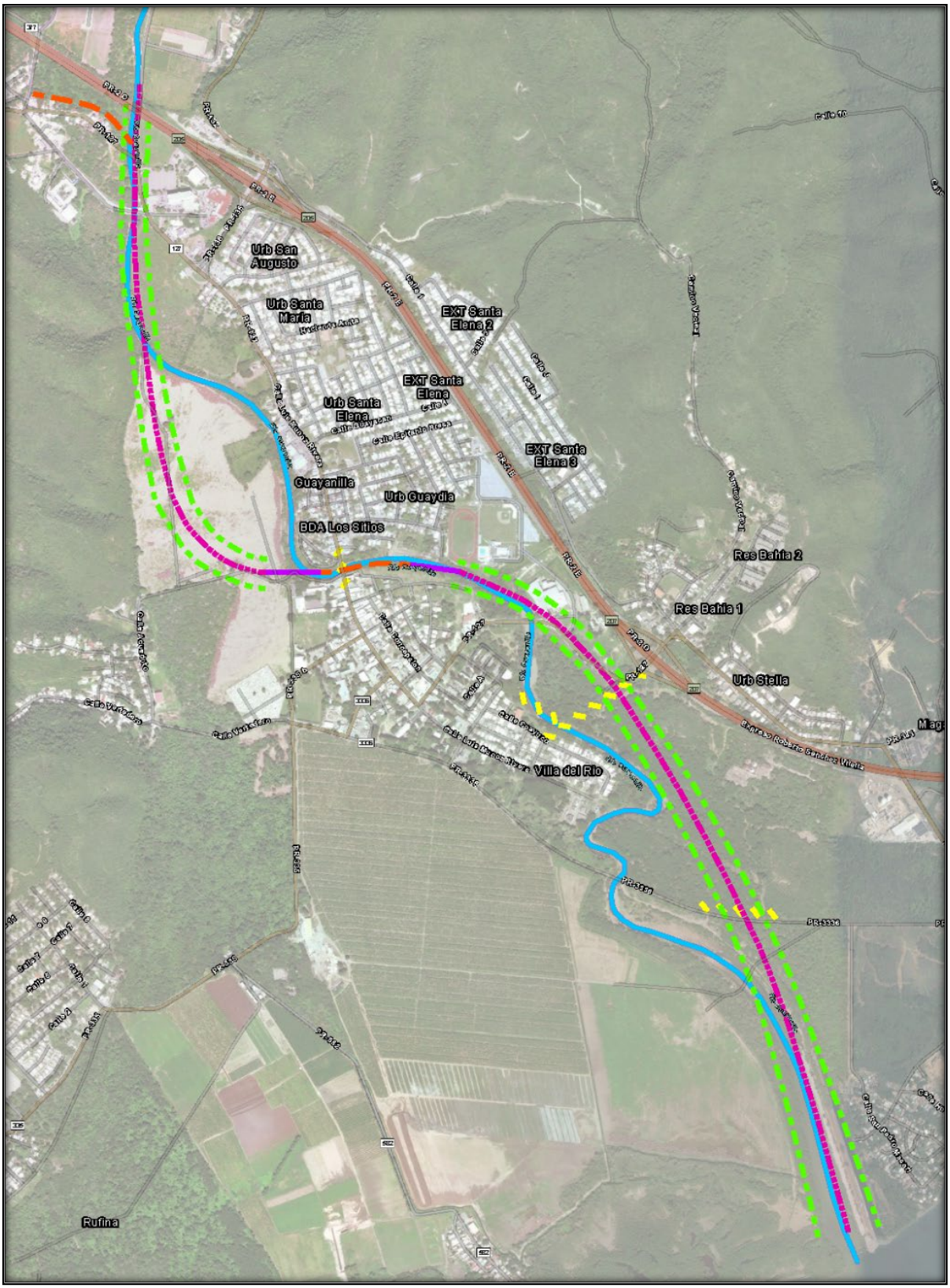


**Figure 27: Alternative 4 Diversion Channel North w/ Double Line Protection**

Alt# 5 Staged Greenway Terraces with Double Line Protection – This alternative would construct a terraced greenway diversion channel at the end of the montane unit and beginning of the coastal plain unit of the Río Guayanilla, downstream of PR-2. A robust diversion structure would be set in place across the river channel to split flows, sending all flood waters to the terraced greenway channel, but keeping almost bank-full flows to maintain the ephemeral riverine ecology of the Río Guayanilla. The diversion structure conceptual design includes riverine connectivity for sediment transport and fish passage. Upstream of the diversion structure would be channel improvements to maintain conveyance into the diversion area.

The alignment for this alternative directs flood water away from the town and to the west along the confining mountain valley wall, though agriculture fields, where it bends east though banana fields to join up with constructed Phase I project near PR-3336 (Figure 28). 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 2 to 3 times wider than Alternative #2 to ensure hydraulic forces do not degrade the integrity of the levees and terraces, with a bottom width ranging from 100-feet and 2:1 side slopes to 300-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.

Material from the excavated channel would be predominantly gravel and sand, which is not suitable for levee construction, but potentially suitable for concrete components; beneficial reuse of materials could be incorporated into the plan for wetland and ecosystem restoration or as a salable commodity for potential contractors (Figure 29). The levees would be constructed of project generated or commercially sourced clay and rock. An abandoned quarry that has already incurred natural resource impacts would be utilized to generate rock and concrete materials (Figure 25).

Certain terrace reaches may need stone and or engineered features as well to prevent erosion at critical hydraulic points. The bottom of the channel would have robust boulder and or tree structures embedded at select points in the channel where hydraulic models indicate incision or meandering potential exists. Expectations for these features are that they will move and change yearly, and will not be static looking features such as the gabions or sheet-pile would be; never the less performing the necessary function of grade and meander control. There would be no need to blanket the channel bottom with stone since deposition would be greater than erosion in this wider channel; terraces would receive different rates of deposition and material size based on water velocities; once the system comes to dynamic equilibrium, erosion and deposition would check and balance the system making it quite stable, yet dynamic enough for ecosystem communities to 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 could support sparse tree and shrub communities as their effects on flows and levee integrity would be negligible in these locations. 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. As indicated, this alternative includes measures A–F, focused efforts and costs would be directed towards C: Vegetation Removal (invasive species removal during construction only) and E: Minor Nature Based Features.

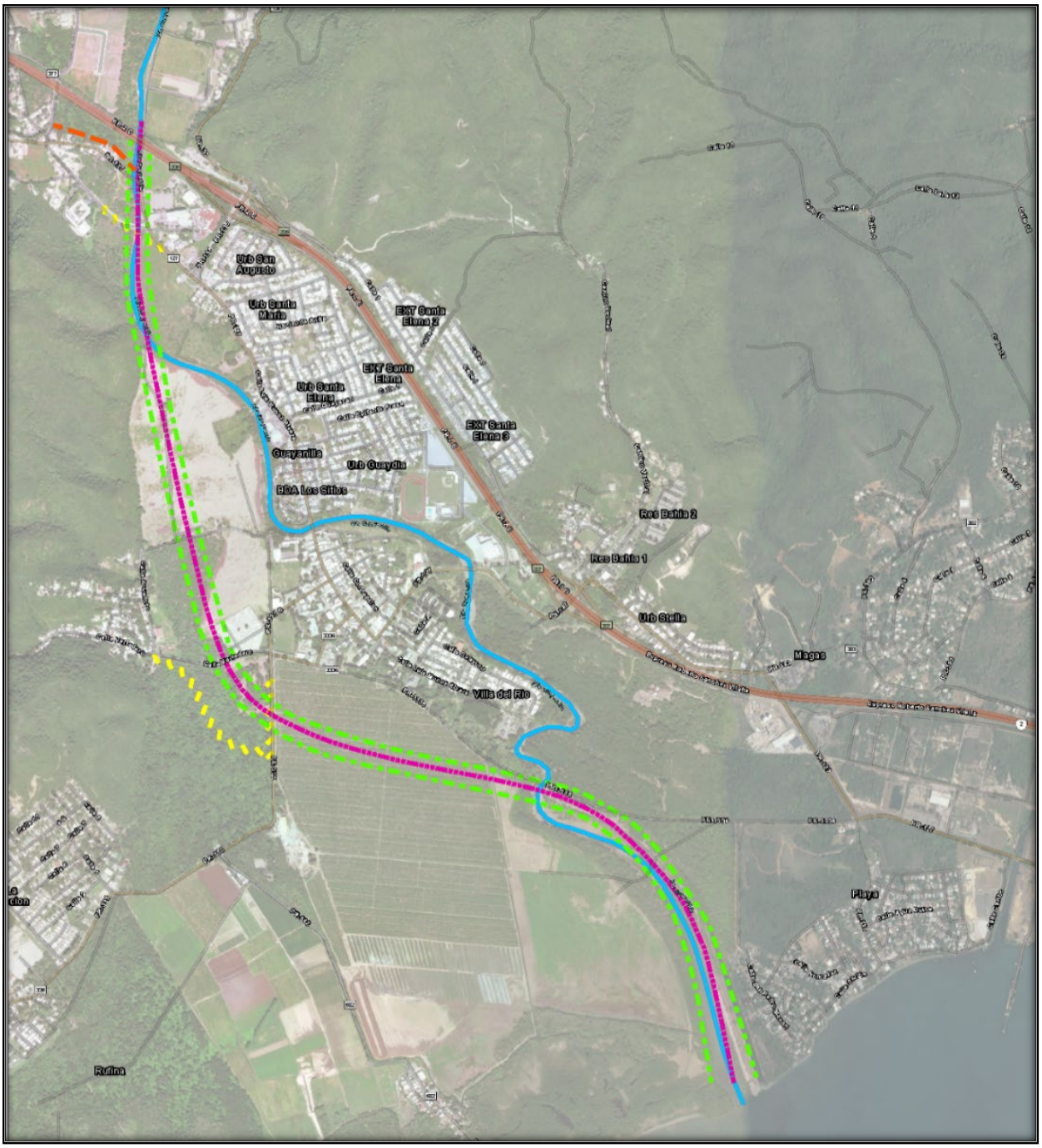


**Figure 28: Alternative 5 Staged Greenway Terraces w/ Double Line Protection**

Alt# 6 Staged Greenway Terraces with Single Line Protection – This alternative (Figure 29) 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 town 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.

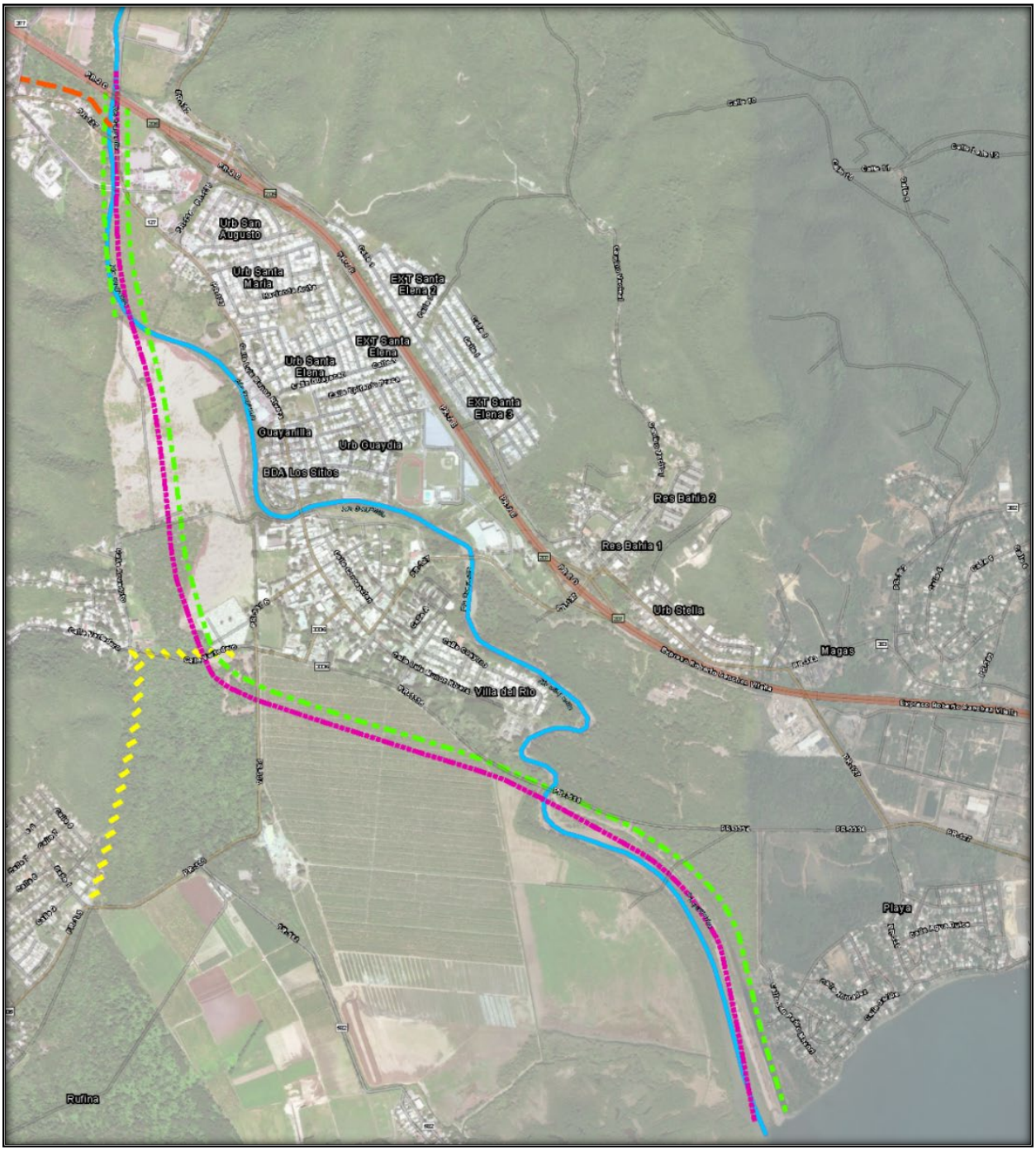


**Figure 29: Alternative 6 Staged Greenway Terraces w/Single Line Protection**

### *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) (Table 20). Ten screening criteria 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 A – Planning Information*. 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.

**Table 20: 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 |

Results from this preliminary screening analysis (Table 20) were used to determine the following alternatives would be retained for further analysis. Most of the alternatives, with the exception of Alternative #4 resulted in a total score within five points of one another (between 24 and 29 points of a possible 40). Alternative #4 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 and engineering feasibility aspects. Alternatives #2 and #5 both 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 town side of the diversion channel or greenway, whereas natural topography and land use to the west precludes the need for one. Therefore, Alternatives #2 and #5 were not retained for further evaluation due to as they were determined to include unnecessary features and were not cost effective. Although Alternative #1 would not provide adequate levels of hazard or vulnerability protection, it was retained for further evaluation because a flood warning system coupled with ensuring the natural channel of the Rio Guayanilla would provide sufficient conveyance for both flood risk reduction and ecosystem connectivity, and appears to be a highly effective component.

**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 |

## 3.5 Focused Array of Alternatives

The initial alternative analysis resulted in the following plans being carried forward as the Final Array of Alternatives. Alternative #3 and #6 are not combinable. Alternative #1 is combinable with Alternative #3 and #6, but can also be implemented on its own without addressing flood hazards or their effects. More detail (Figure 30 & Figure 31) in terms of costs, benefits, indirect benefits, regional economic benefits, environmental effects, 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

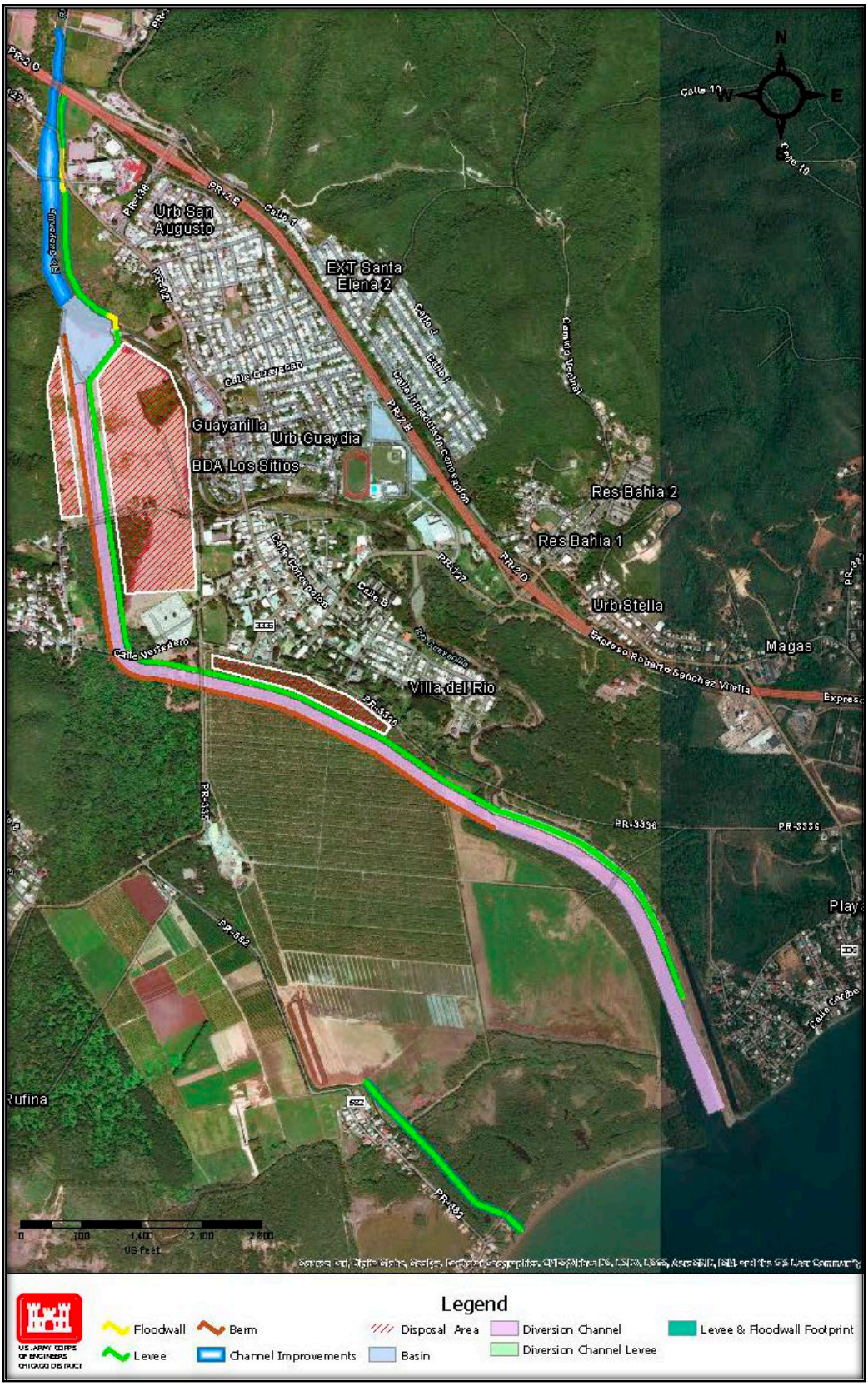


**Figure 30: Alt#3 Diversion Channel South w/ Single Line Protection - Detailed**

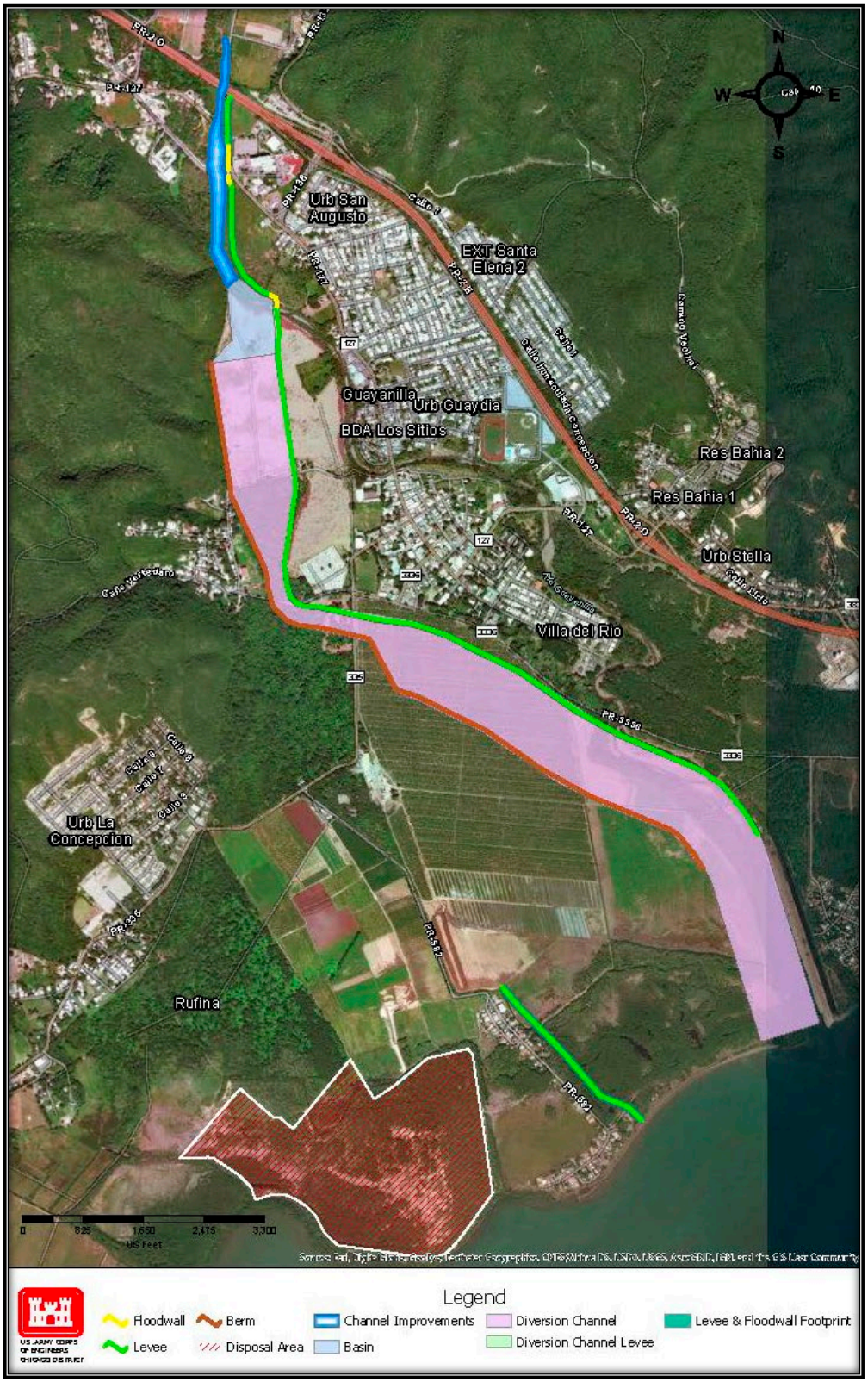


**Figure 31: Alt#6 Staged Greenway Terraces w/ Single Line Protection - Detailed**

# 4.0 Economic Comparison of Final Alternative Array*

The plan formulation process utilized the best available information at this phase of the study to identify a TSP. However, during the final phase of this feasibility study, additional analyses will be completed to refine hydrology and hydraulics (H&H), rock material sourcing, and the design and cost estimates of the features included in the TSP. Revised engineering data and costs will be incorporated after the TSP and could result in changes to the engineering features recommended for one or more reaches for the TSP.

## 4.1 Study Reaches

Study reaches were delineated by H&H in HEC-RAS to separate flows and water surface elevations by area, and quantify damages in the study 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.

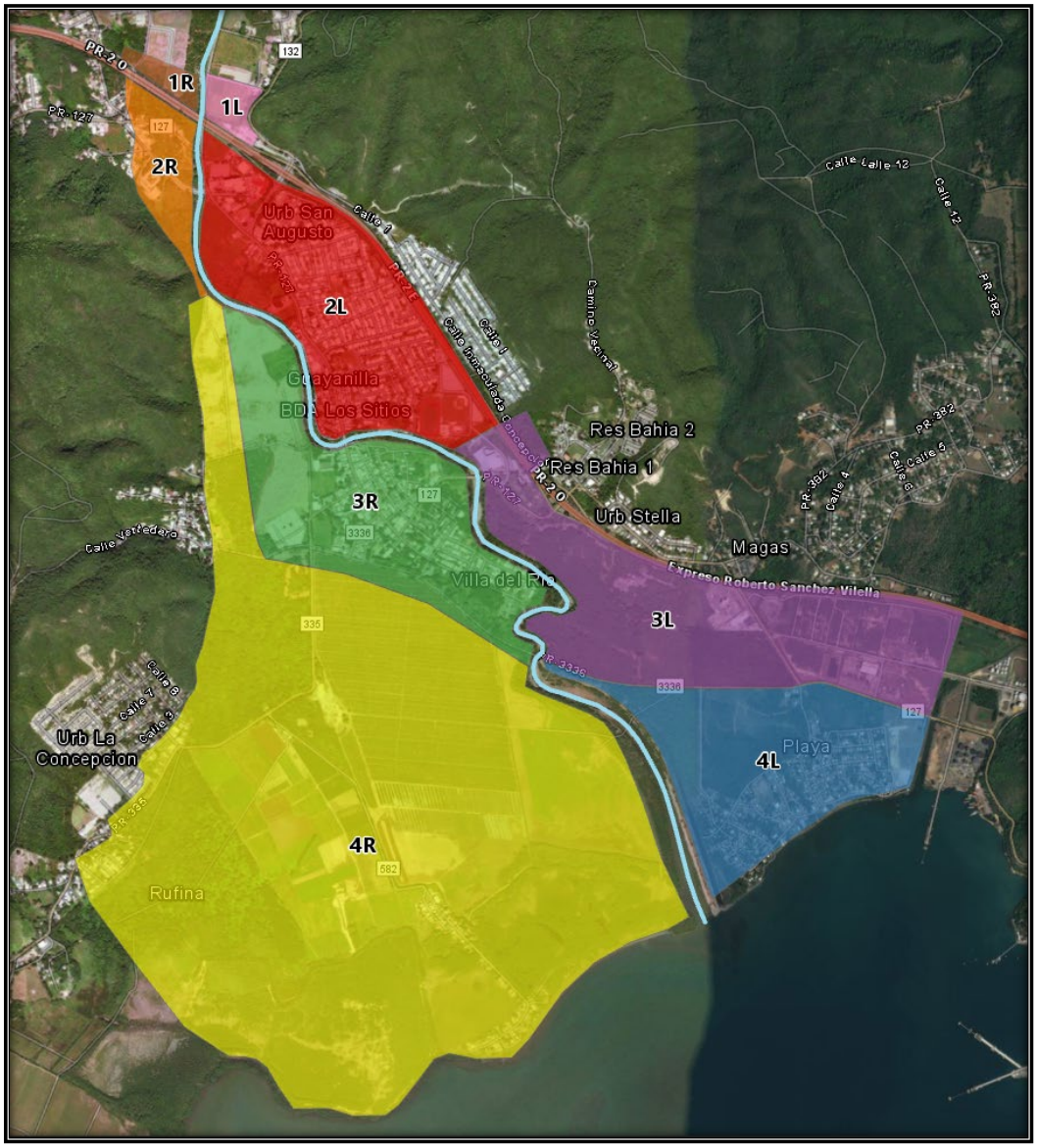

**Figure 32: Study Area Channel Reaches for Damages Analyses**

### 4.2 Expected Annual Damages and Benefits for Existing and Alternative

Table 22 presents expected annual damages for the without project condition, and for Alternatives #3 and #6. Since Alternatives #3 and #6 have the same estimated flow conveyance capacity and project performance, expected annual damages were calculated using the same hydraulic and hydrologic model. This results in the same quantity of expected annual damages for both alternatives.

**Table 22: Expected Annual Damages (EAD), $000, FY 2019 PL**

| Reach | Without Project EAD | Alternative 3 EAD | Alternative 6 EAD |
|---|---|---|---|
| 1L | 51 | 32 | 32 |
| 2R | 119 | 17 | 17 |
| 2L | 4,278 | 300 | 300 |
| 3R | 5,768 | 63 | 63 |
| 3L | 75 | 0 | 0 |
| 4R | 6,442 | 114 | 114 |
| 4L | 2,620 | 33 | 33 |
| Total | 19,353 | 559 | 559 |

*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 including either Alternative #3 or Alternative #6, expected annual damages are reduced to $559,000.

Table 23 and 24 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 23: With-project Benefits Alternative 3, $000 FY 2019 PL**

| Reach | Structure and Structure Contents | Other Related Flood Damage Categories | National Flood Insurance Program | Underemployed Labor Resources | Total Average Annual Benefits |
|---|---|---|---|---|---|
| 1L | 15 | 3 | 0 | - | 19 |
| 2R | 91 | 11 | 1 | - | 103 |
| 2L | 3,460 | 519 | 94 | - | 4,072 |
| 3R | 5,206 | 499 | 63 | - | 5,768 |
| 3L | 72 | 4 | 1 | - | 76 |
| 4R | 5,085 | 1,242 | 25 | - | 6,352 |
| 4L | 2,098 | 488 | 88 | - | 2,675 |
| Total | 16,027 | 2,766 | 272 | 497 | 19,562 |

Total average expected annual benefits for Alternative #3 are $19.6 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 $497,000, annually.

**Table 24. With-project Benefits Alternative 6, $000 FY 2019 PL**

| Reach | Structure and Structure Contents | Other Related Flood Damage Categories | National Flood Insurance Program | Underemployed Labor Resources | Total Average Annual Benefits |
|---|---|---|---|---|---|
| 1L | 15 | 3 | 0 | - | 19 |
| 2R | 91 | 11 | 1 | - | 103 |
| 2L | 3,460 | 519 | 94 | - | 4,072 |
| 3R | 5,206 | 499 | 63 | - | 5,768 |
| 3L | 72 | 4 | 1 | - | 76 |
| 4R | 5,085 | 1,242 | 25 | - | 6,352 |
| 4L | 2,098 | 488 | 88 | - | 2,675 |
| Total | 16,027 | 2,766 | 272 | 713 | 19,778 |

Average expected annual benefits for Alternative #6 are $19.8 million. The difference in average annual benefits between Alternative #3 and #6 is due to higher underemployed labor resource benefits under Alternative #6.

**Table 25: Number of Structures Damaged by Flood Event and Structure Type**

| ACE 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. Under existing conditions, a total of 1,599 structures are estimated to be damaged in a 0.002 ACE flood event.

## 4.2 Cost Estimates for Alternatives #3 and #6

Preliminary cost estimates were developed for Alternatives #3 and #6 (Table 26). 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 26: Costs by Alternative ($)**

| | Alternative #3 | Alternative #6 |
|---|---|---|
| Investment Cost | | |
| Construction Cost | 143,851,512 | 195,432,985 |
| LERRDs | 2,036,106 | 2,517,860 |
| Subtotal First Cost | 145,887,618 | 197,950,845 |

| | | |
|---|---|---|
| Interest During Construction | 8,409,461 | 11,410,563 |
| Total Gross Investment | 154,297,079 | 209,361,408 |
| | | |
| Annual Cost | 5,855,279 | 7,944,865 |
| OMRR&R | 39,000 | 340,000 |
| Average Annual Cost | 5,894,279 | 8,284,865 |
| | | |
| Average Annual Benefits | 19,561,839 | 19,778,358 |
| | | |
| Net Annual Benefits | 13,667,560 | 11,493,494 |
| Benefit to Cost Ratio | 3.3 | 2.4 |

Costs shown in Table 26 are calculated at a 2.875 percent discount rate, with a 4-year construction schedule. Total firsts costs are nearly $146 million for Alternative #3, and first costs are nearly $198 million for Alternative #6. Average annual costs are $5.9 million for Alternative #3 and $8.3 million for Alternative #6. Annualized first costs and annual O&M costs are lower for Alternative #3 than Alternative #6.

### 4.3 Selection of a Tentatively Selected 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 TSP.

**Table 27: Plan Comparison Summary ($)**

| | Alternative 3 | Alternative 6 |
|---|---|---|
| Total First Costs | 145,887,618 | 197,950,845 |
| Average Annual Costs | 5,894,279 | 8,284,865 |
| Average Annual Benefits | 19,561,839 | 19,778,358 |
| Average Annual Net Benefits | 13,667,560 | 11,493,494 |
| BCR | 3.3 | 2.4 |

Table 27 shows that average annual net benefits for Alternative #3 are $13.7 million at the 2.875 discount rate and are $11.5 million for Alternative #6. Since Alternative #3 has the highest net NED benefits, it would be the TSP. Alternative #3 has a BCR of 3.3 and Alternative #6 has a BCR of 2.4 at 2.875 percent.

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# 5.0 Environmental Assessment*

## 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 include 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 must remain 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 there for perpetuity.

Significance thresholds for each resource are used to categorize effects (Figure 33). 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.

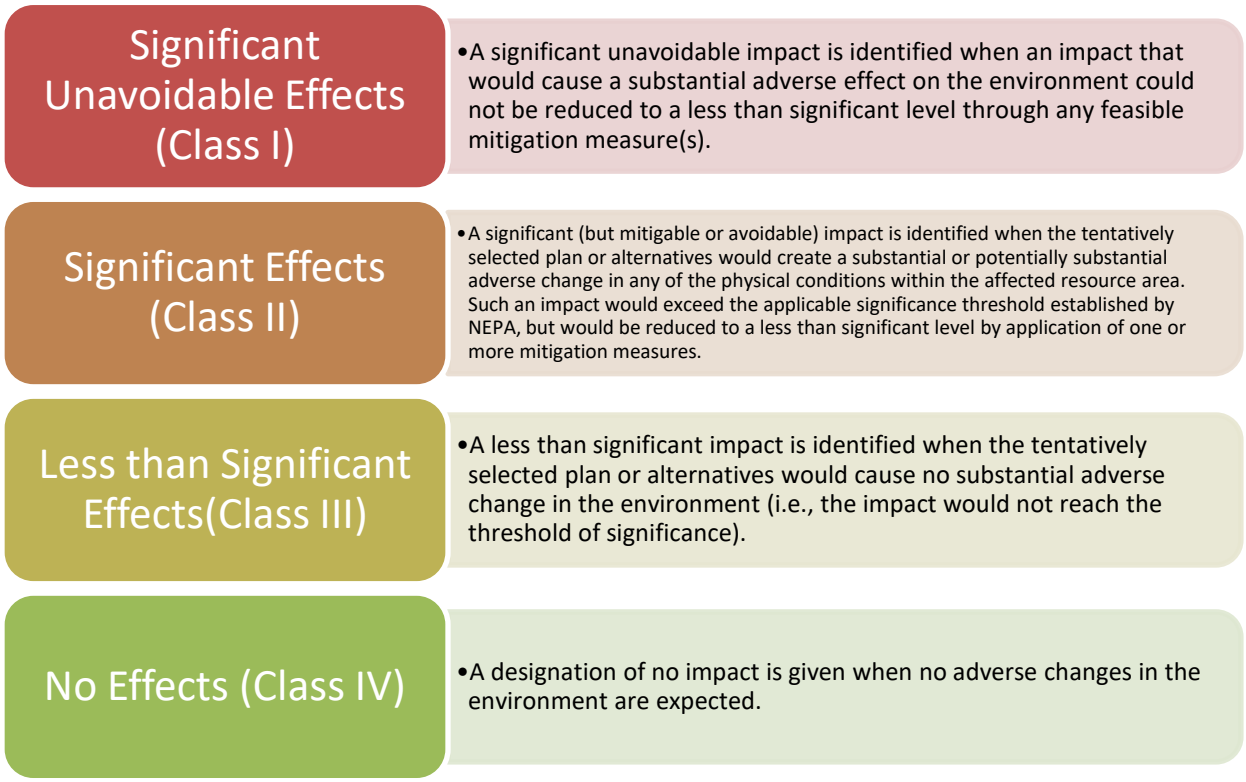


**Figure 33: Classification of Effects Thresholds Based on CEQ Guidelines**

### *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 #1 Non-Structural Measure – Natural Channel Conveyance

The two main components of this alternative are 1) develop a local flood warning system, and 2) implement physical measures of conveyance clearing of bridges on the natural channel of the Río Guayanilla. Effects associated with maintaining conveyance on the natural channel of the Río Guayanilla are assessed, however, establishing a flood warning system between the USGS and non-Federal partners is not.

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

Effects are assessed for excavation of a diversion channel, disposal of excavated material, building levees, quarrying of rock, placement of structures within the natural channel of the Río Guayanilla, other associated construction activities, and future operations and maintenance considerations (Figure 30).

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

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

## 5.2 Earth Resources Effects Determination

### *5.2.1 Geology & Topography*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the geology or topography of the study area. Removing large woody debris, foreign debris, and rocky sediment accumulation at bridges and other structural constrictions have no implications for altering geologic or topographic resources, stratigraphy or formations.

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 relative flat surface, to a large, somewhat trapezoidal canal with a trapezoidal levee on the east side. 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 30.

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 25). The geology and topography of this quarry has been modified from its natural state, most notably in 2003. 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 the terraces. Disposal and stockpile areas are identified in Figure 31. Also, due to the wider and more natural channel design, riverine materials 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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the soils of the study area. Removing large woody debris, foreign

debris, and rocky sediment accumulation at bridge points and other structural constrictions have no implication to altering mature, floodplain 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 ecologic or human need. 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 native planting mediums on the terrace extremities.

### *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 Town. 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.

### *5.2.6 Mineral Resources*

Mining is not a major source of income for Puerto Rico and Guayanilla does not produce non-fuel minerals.

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the mineral resources of the study area. Removing large woody debris, foreign debris, and rocky sediment accumulation at bridges and other structural constrictions have no implication to altering geologic or topographic resources, stratigraphy or formations. Should amounts of sand and gravel cleared from the channel be substantial, these materials could be beneficially reutilized or become salable.

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects to the mineral resources of the study area. Excavation of the diversion channel would produce significant amounts of top soil, clays, sand, gravel and potentially small cobble. All excavated materials could be reutilized beneficially or become salable.

Rock and concrete would be sourced from a former quarry now abandoned that was used to build the neighborhood of Beldum and Los Indios. This natural resource of karstic limestone would be utilized to construct the whole diversion channel and levee in Alt #3. The purpose and intent of a mineral resource such as limestone is consistent with project uses, as this material is quarried at different locations in Puerto Rico for similar projects.

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, which allows for less concrete and rock to be utilized by reducing hydraulic forces within the channel.

## 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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the land use of the study area.

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 Alt#3, but 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 that could cope with being subjected to flooding.

### *5.3.2 Flooding*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would be beneficial in reducing flood risk effects to the Municipality of Guayanilla and agricultural lands.

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 with rain storm induced 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 rain storm induced riverine flooding.

### *5.3.3 Water Quality*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

It is not anticipated that this alternative would degrade 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.

This alternative would acquire 401 Water Quality certification from the Commonwealth of Puerto Rico.

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.

This alternative would acquire 401 Water Quality certification from the Commonwealth of Puerto Rico.

### *5.3.4 Groundwater*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the groundwater of the study area. Removing large woody debris, foreign debris, and rocky sediment accumulation at bridges and other structural constrictions have no implications for altering groundwater infiltration, discharge or gradients.

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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the air quality of the study area. Operation and maintenance activities (removal of debris and sediment) would produce atmospheric emissions from crane and truck operation for only short (hours) infrequent (once a year) periods.

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 Alt# 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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the noise climate of the study area. Removing large woody debris, foreign debris, and rocky sediment accumulation at bridges and other structural constrictions are all short-

term (hours), infrequent (once a year) small activities that would be accompanied by the sounds of cranes and dump trucks removing debris from the river.

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 published laws and rules for hearing exposure and protection to avoid 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.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

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

## 5.6 Biological Resources Effects Determination

### *5.6.1 Riverine Ephemeral Communities*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the riverine ephemeral communities of the Río Guayanilla. Removing large woody debris, foreign debris, and rocky sediment accumulation at bridges and other structural constrictions are all short-term (hours), infrequent (once a year) small activities. Large woody debris and substrates within the Río Guayanilla would be left intact, removing only unnatural clogs in the river channel caused by manmade structures.

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have unchangeable, 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 receive a moderate interruption in fish passage, sediment transport and river flows by having a diversion structure placed across the channel just downstream of PR-2. To minimize this effect, one or a set of culverts would be sized and placed as part of the diversion structure. These culverts would allow for fish passage, sediment transport and near bank-full flows to continue downstream to the ocean; while maintaining effectiveness in transferring all out-of-bank flood stages to the constructed diversion 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.

Ecosystem improvements in the natural estuarine communities at the mouth of the river provide some level of compensatory mitigation within the watershed. Additional compensatory mitigation through enhancement or creation of riverine habitat in the channel improvement area and stilling basin will be considered, and incorporated as needed, to ensure compliance with 40 C.F.R. § 230.93.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same activities and structures, and subsequent effects and conditions as Alt# 3. As a result of the minimizing and mitigating measures described in Alt#3, no significant or long-term effects to the riverine ephemeral communities of the study area are anticipated.

### *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. 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.

### *5.6.3 Subtropical Dry Forest Zone*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the predominant Subtropical Dry Forest Zone and sub-community components.

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have no significant or long-term effects to the to the predominant Subtropical Dry Forest Zone and sub-community components of the study area. Also, this habitat type no longer occurs within the study area riparian zone or greater floodplain. All plant communities within the valley are now considered ruderal, or induced by man; stemming from deforestation, agriculture and urbanization.

*Natural floodplain communities* are cleared from the study area, as it has all been converted to agriculture or urban land uses. Therefore, the absences of high magnitude, low frequency floods during the wet season diverted for the project would not adversely affect the natural communities, as they are no longer present.

Natural *estuarine communities* documented include small plots of Brackish Swamp and Mangrove Basin & Edge (Section 2.6.3, Appendix A). These are the only perennial wetlands documented in the study area; however, these are not being adversely affected by project features. These areas were previously impacted by the DNER Phase I project. As a result of planning between USACE restoration ecologists and the USFWS and NOAA, certain conservation measures have been incorporated into the project which will beneficially impact these areas. These conservation measures include terminating elevations and berms short of the coastline on the west side of the diversion canal/old Phase I project (Figure 30 & Figure 31). This would allow flood waters to spread out at the mouth. The intent of this is twofold: 1) to flush accumulating salinity from intrusion within the soils and estuary waters; and 2) to induce a natural delta formation to rebuild the hydrogeomorphic setting for estuary and wetland formation.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same activities and structures, and subsequent effects and conditions as Alt# 3. This alternative, however, could 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, in which the extremities and other areas within the Greenway could be allowed to naturalize into dry forest, savanna or shrub communities dominated by native plants. The primary zone of flood forces would take on the character of the natural Río Guayanilla river channel during drought/no flow periods. The benefits to the ecosystem would be the conversion of agricultural lands to natural plant communities. No significant or long-term effects to the Sub Tropical Dry Forest communities of the study area are anticipated.

### *5.6.4 Subtropical Dry Forest – Abandoned Quarry Site*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla has no need of the rock quarry, nor would it have significant or long-term effects to the secondary growth Subtropical Dry Forest Zone and sub-community components present at the quarry site.

Alternative #3 Diversion Channel South w/ Single Line Protection

The abandoned quarry just north of the town of the Beldum neighborhood has been clear cut, stripped of soils and quarried for rock in the near past. Clear cutting was still highly evident in 2003, but the area has recovered in terms of vegetation cover since. Use of this site as a quarry is not anticipated to have significant adverse environmental impacts based on the coordination with USFWS and potential mitigating measures described in Section 5.6.5.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have the same activities and structure and subsequent effects and conditions as Alt# 3.

### *5.6.5 Federal Listed Species*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

There are no federally listed species for the Río Guayanilla river channel, therefore this alternative would have no effects to federal T&E species.

Alternative #3 Diversion Channel South w/ Single Line Protection

There are no federally listed species within the proposed alternative's footprint except for the proposed quarry site. It was initially proposed to quarry karstic limestone directly west of the diversion channel or greenway alignment (Figure 25). This area was identified by the USFWS to be an area of high biodiversity, inclusive of at least 5 federally endangered species and over 20 endemic rare plants. Avoidance planning between USACE and USFWS developed an alternate source of the same type of acceptable stone. The abandoned quarry just north of the town of the Beldum neighborhood was assessed as acceptable by USACE for material quality, accessibility and proximity to the construction site. USFWS and USACE both found this site preferable in terms of a greatly lessened effect on natural resources due to the fact that it had been clear cut, stripped of soils and quarried for rock in the near past. Clear cutting was still highly evident in 2003, but the area has greatly recovered in terms of vegetation cover since.

On 14 August 2019, USFWS provided an updated letter with the results of a preliminary exploration of the proposed quarry site. Initial indications are that most of the site was previously scraped clear of vegetation and does not appear to have listed plant species, but there will need to be an additional survey to see if the Puerto Rican nightjar (Caprimulgus noctitherus) is in the area since this species has been known to nest in previously disturbed areas. Potential conservation measures and mitigation for reducing direct physical impacts and habitat disturbance for the Puerto Rican nightjar could include moving birds from the mining zone during construction, preventing invasive species regrowth, and planting conspecific tree and shrub species after mining activities. Several areas of forest were left undisturbed and future efforts will focus on those areas to determine if T&E species exist within these small segments of native forest.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

There are no federally listed species within the proposed alternative's footprint except for the proposed abandoned quarry site in the karts hills to the west. Thus, implementing this alternative would have the same effects and conditions as Alt# 3.

### *5.6.6 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 PRDNER 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.

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. Currently, these species would only occur in the Sub Tropical Dry Forest located in the karstic mountain range to the west of the study area.

This determination will be updated should the PRDNER provide information, as well as information acquired from the USFWS inventory of the abandoned quarry site at Beldum. Based on discussions with the USFWS, effects to state listed plant species would be reduced or mitigated by conservation measures developed for Federally Listed plant species should they occur at the site. Plant conservation methods would inherently account for any and all species since the community approach would be taken instead of single species conservation.

### *5.6.7 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.

### *5.6.8 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.

### *5.6.9 Section 10 & Section 404*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

This alternative would be accomplished so that debris accumulated at bridges with a small amount of sediment would be removed from the river channel, and no such material would be returned to or other materials placed in the river channel.

Alternative #3 Diversion Channel South w/ Single Line Protection

This alternative, should it be implemented, would impart modifications to the natural channel of the Río Guayanilla that subject to assessment under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. Features requiring assessment include the diversion structure across the entire channel just downstream of PR-2, dolomitic limestone, steel sheet pile, and other erosion features. The detailed 404(b)(1) assessment is located in Appendix A. This alternative would permanently impact approximately 3-acres of ephemeral riverine rock bottom stream, including about .5-acres of permanent change by placing the concrete Diversion Structure across the river channel and about 2.5-acres of river channel morphology converted to an overly wide, rocky pool setting (7 of the 10 acres of Stilling Basin is considered upland). In addition, about 12-acres of the riverine habitat would be temporarily effected by the channel improvements activity. Channel morphology, vegetation and large woody debris would also be temporarily effected by clearing out the whole channel.

As further described in Appendix A, the diversion structure design minimizes the impacts to riverine connectivity for sediment transport and fish passage, and there is no apparent dependency on system parameters being lost for riverine ephemeral community species or components. In addition, this alternative includes ecosystem improvements in the natural estuarine communities which provides some level of compensatory mitigation within the watershed for the remaining impacts. Additional compensatory mitigation through enhancement or creation of riverine habitat in the channel improvement area and stilling basin will be considered, and incorporated as needed, to ensure compliance with 40 C.F.R. § 230.93.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

This alternative, should it be implemented, would impart modifications to the natural channel of the Río Guayanilla that require assessment under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. Features requiring assessment included the diversion structure across the entire channel just downstream of PR-2, placement of excavated alluvial material in coastal zone,

dolomitic limestone, steel sheet pile, and other erosion features. Implementing this alternative would have the same effects and conditions as Alt# 3.

## 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. Consultation is ongoing and will be finalized prior to submittal of a final EA. All correspondence relevant to cultural resources is provided in Appendix A.

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

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.

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.

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. If historic properties are identified within the APE as a result of the survey, USACE will consult with SHPO to avoid, minimize, or mitigate adverse effect. A determination of no adverse effect or a Memorandum of Agreement to mitigate adverse effects will be executed prior to submittal of a final EA.

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. Although the proposed diversion channel would not be excavated as deeply as Alternative #3, this Alternative has the potential to effect a greater number of historic properties, if present within the APE. 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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would not significantly reduce flood risk, and approximately 1,600 homes would continue to be at risk of inundation. With 57% of the floodplain population living below the national poverty line, loss of property due to flooding would continue to have significant adverse economic impacts on individuals. Under this alternative, it is also likely that schools and businesses would continue to be closed for significant periods of time after large storm events.

Alternative #3 Diversion Channel South w/ Single Line Protection

Implementing this alternative would have unchangeable, 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 ACE 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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the HTRW condition of the river. Minor impacts could occur from bringing hazardous materials onsite, including equipment fuels and oils, during short and infrequent debris and rocky sediment removal activities. No HTRW is expected to be encountered or released as a results of operations and maintenance activities. See attached Appendix J – Hazardous, Toxic and Radioactive Waste (HTRW) Report for results of the HTRW Phase I Environmental Site Assessment (ESA).

Alternative #3 Diversion Channel South w/ Single Line Protection

No significant or long-term effects to the HTRW condition of the project area are anticipated. Although there is potential for the project to encounter hazardous substances, the risk of exposing existing soil and groundwater contamination in the project area has been mitigated by completing a HTRW Phase I Environmental Site Assessment (see attached Appendix J – Hazardous, Toxic and Radioactive Waste (HTRW) Report for results of the HTRW Phase I ESA). Recognized Environmental Concerns (RECs) in the field and the surrounding area should not have an impact on implementation of the proposed project because construction will be avoided in HTRW contaminated areas where practicable, all excavated material will be managed on-site, and HTRW response actions are not expected prior to 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 material excavated for the diversion channel (predominantly gravel and sand) is proposed to be re-used or disposed of on portions of the project site. If the material would need to be taken off-site, or re-used as a salable commodity for potential contractors or by the municipalities of Ponce and/or Peñuelas for landfill cover, it would require additional testing to determine if material contains hazardous substances for management in accordance with applicable laws and regulations of the relevant regulatory agencies.

Alternative #6 Staged Greenway Terraces w/ Single Line Protection

Implementing this alternative would have similar activities, features, and subsequent effects and conditions as Alt# 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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to agricultural lands or practices of the study area. Removing large woody debris, foreign debris, and rocky sediment accumulation at bridge points and other structural constrictions have no implication in affecting farming.

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 that could cope with being subjected to flooding.

### *5.9.3 Aesthetic Quality*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have no significant or long-term effects to the aesthetic quality of the study area.

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 towns would have a concrete and stone diversion channel running through it. This diversion canal would remain dry nearly all the time except during large rainstorms during the wet season.

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 for the most part. 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 being able to have more

natural shape and limited amount of plant types and quantities, would give a more natural area aesthetic than and engineered one.

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 #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would have beneficial effects to public health and safety within the study area by reducing flood risks.

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. Velocities and channel geometry could create undertow currents, creating a potential risk of drowning. Flood warning systems developed between USGS and the municipalities should include the diversion channel.

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 Greenway channel. Velocities and channel geometry could create undertow currents in certain sections, creating a potential risk of drowning. These hazards would be lessened in the wider, more natural parts of the Greenway. Flood warning systems developed between USGS and the municipalities should include the Greenway channel.

### *5.9.5 Traffic and Transportation*

Alternative #1 Non-Structural Measure – Natural Channel Conveyance

Maintaining channel conveyance within the natural channel of the Río Guayanilla would not significantly reduce flood risk, and transportation and evacuation routes would continue to be heavily inundated.

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 town 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 high flood depths during the 500-year event, but flooding along PR-127 would be almost nonexistent for the more frequent events up to the 10-year event. Flood depths would be significantly reduced along PR-127 for the 25 through 100-year events.

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 CFR 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 28 presents the general geographic areas associated with the different resources categories being addressed in this analysis.

**Table 28: Geographic Area Effected 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. |
| 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. |

| Resource Category | Geographic Area |
|---|---|
| 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 and demographics of the study area, considering adjacent towns and municipalities as well it is not anticipated that non-federal, state or municipal projects would occur within the study 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. Current actions under any of the alternatives would not cumulatively increase adverse effects that had previously occurred, but in some instance would promote ecosystem recover of the mouth delta and estuarine system.

## 5.12 Unavoidable Significant Environmental Effects

Unavoidable, significant environmental effects were not identified during the effects assessment for the three (3) federal action alternatives. All resources initially identified to potentially accrue significant effects underwent additional planning and/or received conservation measures to avoid, minimize, or mitigate the effects, so that the proposed project will not significantly impact the human environment.

## 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 Federal Action alternatives do propose to remove flood effects from large portions of agricultural lands and old fields, which in turn could induce built-out of residences into the some areas. Therefore, implementation of any of the Federal Action alternatives could induce 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 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. 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 (42 U.S.C. § 4332(2)(c)(iv); 40 C.F.R. 1502.16). There have been no irreversible and irretrievable commitments of resources identified resulting from the proposed action should it be implemented (42 U.S.C. § 4332(2)(c)(v); 40 C.F.R. 1502.16).

**Table 29: Applicable Federal, State & Local Legal Compliance Summary**

| Reference | Environmental Statutes/Regulations | Project Compliance |
|---|---|---|
| **Federal** | | |
| 42 U.S.C. 7401 | Clean Air Act of 1970, as amended | P |
| 33 U.S.C. 1251, et seq. | Clean Water Act of 1977, as amended | P |
| 16 U.S.C. 1451, et seq. | Coastal Zone Management Act of 1972, as amended | P |
| 42 U.S.C. 9601 | 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 | P |
| 16 U.S.C. 661 | Fish and Wildlife Coordination Act, as amended | P |
| EO 11990 | Protection of Wetlands | P |
| 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 | P |
| 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 | P |
| | | |
| | | |
| | | |
| **Local** | | |
| | | |

[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 a draft Integrated Feasibility Report (IFR) which combines the draft 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. Comments were requested to be received no later than 15 December 2018 for incorporation into the draft NEPA document, but will generally be accepted after the period closes to ensure all useful information is acquired. No responses were received to date.

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 1) extract critical information from the Agencies and citizens of Guayanilla and 2) provide an opportunity for the Agencies and citizens to review and comment on the conceptual plans moving forward into detailed 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 are 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, and future public coordination will be, provided on 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 draft NEPA document, but will generally be accepted after the period closes 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.

### *6.1.1 Next Steps in the Environmental Review Process*

A Notice of Availability for the draft report will be published on 27 August 2019, and circulated for a 30-day public review period to federal, state and local agencies, organizations and individuals who have an interest in the project. Two public meetings will be held during the review period to provide additional opportunities to discuss and comment on the draft report. The public meetings will be held on 18th September 2019 at Costa Bahia Hotel and Conventions Center from 2pm – 6pm and 19th September 2019 9am – 2pm at Museo de Historia de Guayanilla Calle Muñoz RIVERA. All comments received during the public review period will be considered and incorporated into the final report, as appropriate.

# 7.0 Tentatively Selected Plan*

Based on the benefit-cost analysis of the final array of alternatives, Alternative #3 is the NED plan, and it is also the TSP. This plan is estimated to result in approximately $19.6 million of average annual benefits at an average annual cost of $5.9 million, and a total first cost of $146 million. The benefit-cost ratio (BCR) of this plan is 3.3 at the current federal discount rate of 2.875%.

**Table 30: NED/TSP Summary**

| | NED/TSP |
|---|---|
| Total First Cost | 145,887,618 |
| Annual Cost | 5,894,279 |
| Annual Benefits | 19,561,839 |
| Net Annual Benefits | 13,667,560 |
| Benefit to Cost Ratio | 3.3 |

## 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. As required under NEPA, potential mitigation and conservation measures for each resource are currently being developed by the USFWS and the USACE.

### *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 31 would be implemented to avoid or reduce short-term construction-related effects.

**Table 31: Environmental Commitments**

| Environmental Commitment | Timing | Responsible Party |
|---|---|---|
| T&E species survey at proposed quarry site | Feasibility | USFWS |
| Develop conservation measures should T&E species occur at proposed quarry site | Feasibility | USFWS & USACE |
| Conservation measures as part of proposed TSP for riverine, estuarine and dry forest habitats | Feasibility | USACE |
| Noise-reducing construction practices | During construction | USACE, in coordination with the construction contractor |
| Traffic control and road maintenance plan | During construction | USACE, in coordination with its contractor and the cities and county public works departments |

| Environmental Commitment | Timing | Responsible Party |
|---|---|---|
| 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.

Coordination is still ongoing with the USFWS regarding threatened and endangered species within the preferred quarry site, therefore it is unknown at this time if mitigation will be required as part of ESA compliance. Potential mitigation could include vegetation management to promote recruitment of native dry forest and could be up to about 7-acres.

Modifications to the natural channel of the Río Guayanilla requires assessment under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899. Features requiring assessment included the diversion structure across the entire channel just downstream of PR-2, dolomitic limestone, steel sheet pile, and other erosion features. The 404(b)(1) detailed assessment is located in Appendix A. The proposed project would have long-term impacts on a portion of the Rio Guayanilla, particularly in terms of connectivity, structure and natural riverine processes. The diversion structure design minimizes the impacts to riverine connectivity for sediment transport and fish passage, and there is no apparent dependency on system parameters being lost for riverine ephemeral community species or components. The alternative includes ecosystem improvements in the natural estuarine communities which provide some level of compensatory mitigation within the watershed. Additional compensatory mitigation through enhancement or creation of riverine habitat in the channel improvement area and stilling basin will be considered, and incorporated as needed, to ensure compliance with 40 C.F.R. § 230.93.

## 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 channels, inlet/outlet

structures, and tide gates will be the responsibility of Orange County, and specifically OCFCD. OMRR&R activities would include periodic inspections, mowing, debris removal and litter control, vermin control, and repair of structures as needed, in addition to supporting emergency efforts during flood events. OCPW 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 channels in the project 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. Permanent easements for channel improvement and flood reduction will need to be acquired along with temporary work area easement. There is one residence associated with this project that will required 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. Final Array Total and Annualized Costs**

| | Estimated Cost ($000) | |
|---|---|---|
| | Alternative 3 | Alternative 6 |
| Investment First Costs | | |
| Construction Cost | 143,852 | 195,433 |
| LERRDs | 2,036 | 2,518 |
| Subtotal First Cost | 145,888 | 197,951 |
| Interest During Construction | 8,409 | 11,411 |
| Total Gross Investment | 154,297 | 209,361 |
| Annual Cost | 5,855 | 7,945 |
| OMRR&R | 39 | 340 |
| Average Annual Cost | 5,894 | 8,285 |
| *Note: Construction costs include contingency of 52%.*<br>*Interest during construction is calculated at 2.875% for a 4 year construction period*<br>*Costs are in FY 2019 Price Levels and annualized over a 50-year period of analysis* | | |

## 7.5 Risk Analysis

### *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 TSP, 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. The "Risk Assessment for Flood Risk Management Studies" (ER 1105-2-101) dated 17 July 2017 clearly defines two types of residual risks to consider when comparing the potential 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 under 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 Tentatively Selected 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 and increase 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 under the potential with project condition. Under the tentatively selected plan, flood risk is significantly reduced for the 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 500-year event, there are still 1,003 structures at risk of partial inundation.

The following tables display the project performance statistics by reach for the without project and with project condition (with-project performance is the same for Alternative #3 and #6).

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 ACE event (100 year recurrence interval) would be contained by the existing levee for reach 3R is just 1 percent. Inversely, that means there is a 99 percent chance that the 0.01 ACE event would exceed the channel capacity (either through breach or overtopping) and inundate the leveed area. The probability that no flooding occurs in the occurrence of a 100-year event is increased to 98 percent when either Alternative #3 or Alternative #6 is implemented.

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% ACE 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% ACE 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% ACE flood event (500 year recurrence interval)

**Table 33: 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 |

[1]Probability 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 34: With-project performance (%)**

| Reach | AEP[1] | Long Term Risk[2] | | | Assurance[3] | | |
|---|---|---|---|---|---|---|---|
| | | 10 year | 30 year | 50 year | 2.00% | 1.00% | 0.20% |
| 1L | 21.31 | 90.93 | 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 | 17.88 | 86.48 | 99.00 | 99.00 | 2.00 | 2.00 | 1.00 |
| 3L | 0.76 | 10.09 | 27.32 | 41.25 | 82.65 | 61.15 | 17.80 |
| 3R | 0.22 | 2.19 | 6.43 | 10.48 | 99.00 | 98.41 | 57.99 |
| 4L | 0.01 | 0.80 | 2.46 | 4.07 | 98.48 | 97.02 | 95.89 |
| 4R | 14.01 | 81.68 | 99.39 | 99.00 | 4.04 | 3.16 | 1.36 |

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 Completion*

The Draft IFR will undergo concurrent public, agency and internal reviews. Public and agency review would be 30 days, 27 August 2019 thru 27 September 2019. Two public meetings are scheduled for September 2019. After completion of the public review period, comments will be considered and incorporated into the integrated report and EA, as appropriate. The Final Integrated Report will be provided to any public agency that provided comments on the Draft Report.

### *7.6.2 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. Signature of an approved Chief's Report is scheduled to occur on 20 August 2020.

### *7.6.3 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.

### *7.6.4 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 Chapter 8.0.

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) of the project is $51,061,000 for the NED Plan including LERRDs, at the 2019 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 $2,036,000.

The NFS will be required to provide 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.

### *7.6.5 Schedule*

**Table 35: Study schedule.**

| Item | Date |
|---|---|
| Feasibility Cost Sharing Agreement Signed | 24 September 2018 |
| Alternatives Milestone Briefing | 18 December 2018 |
| Alternative Milestone Approved | 7 January 2019 |
| TSP Milestone | 18 June 2019 |
| Draft Report Released for Public Review | 27 August 2019 |
| Agency Decision Milestone | 21 November 2019 |
| Senior Leader Briefing | 27 April 2020 |
| Chief of Engineer's Report Signed | 20 August 2020 |
| Finding of No Significant Impact Signed | TBD |

## 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 formal construction documents and a final detailed cost estimate for implementation.

### *7.7.2 Project implementation strategy*

A preliminary best-case construction schedule was developed for alternative three and resulted in an estimate of 4 years of continuous construction, assuming availability of funding.

### *7.7.3 Operation, Maintenance, Repair, Replacement, and Rehabilitation*

Once construction activities are completed, USACE will send a notice of completion to the NFS, and will furnish the NFS with an OMRR&R Manual for the performance of its responsibilities. OMRR&R activities would include security, periodic inspections, vegetation control, debris removal, litter control, repair of the diversion channel, diversion structure, and floodwalls  The sponsor will also be responsible for outreach to communities, residents, and businesses in the leveed area about the project risks and the development of an emergency action/ response plan.

## 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.

The apparent NED Plan has been identified as alternative three. The estimated first cost (2019 price level) of the NED Plan is $145,887,618 with an estimated maximum federal cost of $94,826,951. This would equate to an estimated non-federal cost of $51,060,667 to implement the NED Plan, with an estimated annual OMRR&R cost of $39,000 (2019 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 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;

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.

_____ _____

Date

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

**DRAFT FINDING OF NO SIGNIFICANT IMPACT**

**Rio Guayanilla Flood Risk Management Study – Integrated Feasibility Report & Environmental Assessment**
**Municipality of Guayanilla**
**the 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 draft Integrated Feasibility Report and Environmental Assessment (IFR/EA) dated **27 August 2019**, 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 draft 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:

- **Alternative #1 Non-Structural Measure – Natural Channel Conveyance**
- **Periodic removal of debris and sediment accumulation at bridge crossings and constrictions on the natural channel of the Rio Guayanilla throughout the project life-cycle**
- **Alternative #3 Structural Measure – Diversion Channel South w/ Single Line Protection**
- **An engineered diversion channel approximately 9,000 feet long, bottom width of 100-feet with 2:1 side slopes; consisting of limestone riprap, concrete, sheetpile, gabions and other shoreline stabilizing measures**
- **Excavated diversion channel material of gravel and sand alluvium to be stored for use or permanently disposed of along the levee in upland locations**
- **A levee on the east side of the diversion channel approximately 9,000 feet long, and one small set-back levee at El Faro approximately 2,750 feet long (set back levee is a conservation measure to offset effects from channel improvements and the diversion structure)**
- **Channel improvements consisting of clearing debris and accumulated sediment from the natural channel of the Rio Guayanilla above PR-2 downstream to diversion structure**
- **An earthen, concrete and sheet pile diversion structure to direct all flood waters over the ~2year flood event into the diversion channel; conservation measures for connectivity, flow and habitat included**
- **Use of 7 to 10 acres of an abandoned quarry for riprap and concrete stone sourcing: quarry use resulted through avoidance planning with USFWS; conservation measures for vegetation and the ground nesting Puerto Rican Nightjar were included**
- **Periodic operations and maintenance activities throughout the project's life-cycle, including but not limited to removal of vegetation, removal of debris and sediment, repair damage caused by erosion, additions of limestone, concrete, gabions, and sheetpile**

In addition to a "no action" plan, **three action** alternatives were evaluated. The alternatives included: **Alternative #1 Non-Structural Measure – Natural Channel Conveyance; Alternative #3 Diversion Channel South w/ Single Line Protection; Alternative #6 Staged Greenway Terraces w/ Single Line Protection.**

***SUMMARY OF POTENTIAL EFFECTS:***

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 and conservation measures were incorporated as part of Alternative #3 to render effects to insignificant. These include the following:**

**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 accurately sized and placed culverts to allow a) fish passage, b) maintenance of low to bank full flows (0-2-year flood events), c) gravel and cobble substrate transport and sorting for channel morphology and habitat.**

**Channel Improvements & Wetland Enhancement Opportunities: To mitigate effects to riverine components from the diversion structure and the temporary habitat disturbance from channel improvements during construction, enhancement of estuarine wetlands has been included in the proposed project. To provide a net benefit to estuarine wetlands, a set-back levee would be provided at El Faro to allow freshwater floodwaters to flush excess salinity from the degraded costal marsh between El Faro and Rio Guayanilla. In addition, this set back levee configuration is more conducive to promoting a naturalistic hydrogeomorphic setting for river mouth delta and estuarine wetlands to form or be restored on. Additional compensatory mitigation through**

**enhancement or creation of riverine habitat in the channel improvement area and/or stilling basin will be considered, and incorporated as needed, to mitigate for impacts to riverine components.**

**Rock Sourcing: To avoid impacts to 5 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, areas within the abandoned quarry that had been previously cleared of vegetation and quarried would not impact federal T&E species should the USFWS find that the Puerto Rican Nightjar is not utilizing these cleared areas as nesting habitat.**

Public review of the draft IFR/EA and FONSI was completed on **27 September 2019**. All comments submitted during the public review period were responded to in the Final IFR/EA and FONSI. A 30-day state and agency review of the Final IFR/EA was completed on **27 September 2019**.

***OTHER ENVIRONMENTAL AND CULTURAL COMPLIANCE REQUIREMENTS:***

***ENDANGERED SPECIES ACT***

***INFORMAL CONSULATION:***

Pursuant to section 7 of the Endangered Species Act of 1973, as amended, the U.S. Army Corps of Engineers has been coordinating with the U.S. Fish and Wildlife Service on potential impacts of the recommended plan. There are no federally listed species within the proposed alternative's footprint except for the proposed abandoned quarry site. An initial assessment by USFWS of the abandoned quarry site indicates that the site does not appear to have listed plant species, but there will need to be an additional survey to see if the Puerto Rican nightjar (Caprimulgus noctitherus) is in the area since this species has been known to nest in previously disturbed areas. Potential conservation measures and mitigation for reducing direct physical impacts and habitat disturbance for the Puerto Rican nightjar could include moving birds from the mining zone during construction, preventing invasive species regrowth, and planting conspecific tree and shrub species after mining activities. Several areas of forest were left undisturbed and future efforts will focus on those areas to determine if T&E species exist within these small segments of native forest.

Based on further assessment of the abandoned quarry site on _[date of future assessment]____, USACE and USFWS have determined that the proposed project is not likely to adversely affect the following federally listed species or their designated critical habitat: ***Puerto Rican Nightjar (Antrostomus noctitherus), Puerto Rican Boa (Epicrates inornatus), Tree (Eugenia woodhuryana*)**, **Tree (*Trichilia tricantlta*)**, **Puerto Rican Manjack (*Varronia rupicola*)**. The U.S. Fish and Wildlife Service (FWS) concurred with the Corps' determination on **DATE OF CONCURRENCE LETTER**

***NATIONAL HISTORIC PRESERVATION ACT***

Consultation with the Puerto Rico State Historic Preservation Office (SHPO) pursuant to Section 106 of the NHPA is ongoing and will be finalized prior to submittal of a final EA. 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. If historic properties are identified within the APE as a result of the survey, USACE will consult with SHPO to avoid, minimize, or mitigate adverse effect. A determination of no adverse effect or a Memorandum of Agreement to mitigate adverse effects will be executed prior to submittal of a final EA.

***CLEAN WATER ACT SECTION 404(B)(1) 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 CFR 230). To mitigate effects to riverine components from the diversion structure and the temporary habitat disturbance from channel improvements during construction, enhancement of estuarine wetlands has been included in the proposed project. Additional compensatory mitigation through enhancement or creation of riverine habitat in the channel improvement area and/or stilling basin will be considered, and incorporated as needed, to mitigate for impacts to riverine components. The Clean Water Act Section 404(b)(1) Guidelines evaluation is found in **Appendix A** of the IFR/EA.

***CLEAN WATER ACT SECTION 401 COMPLIANCE:***

***401 WQC PENDING:***

A water quality certification pursuant to section 401 of the Clean Water Act will obtained from the **Commonwealth of Puerto Rico** prior to construction. In a letter dated **TBD**, the **Environmental Quality Board, Commonwealth of Puerto Rico** stated that the recommended plan appears to meet the requirements of the water quality certification, pending confirmation based on information to be 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.

***CZMA CONSISTENCY PENDING:***

A determination of consistency with the **Commonwealth of Puerto Rico** Coastal Zone Management program pursuant to the Coastal Zone Management Act of 1972 will be obtained from the **Department of Natural and Environmental Resources** prior to construction. In a letter dated **TBD** the **Commonwealth of Puerto Rico** 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.

***OTHER SIGNIFICANT ENVIRONMENTAL COMPLIANCE:***

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

**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.

**Coastal Barrier Resources Act of 1982, 16 USC 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 USC 3501.

***FINDING***

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.[2] 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.[3]

_____ _____

Date

**Aaron W. Reisinger**
**Colonel,** Corps of Engineers
District Commander

[2] ~~40 CFR 1505.2(B) requires identification of relevant factors including any essential to national policy which were balanced in the agency decision.~~

[3] 40 CFR 1508.13 stated the FONSI shall include an EA or a summary of it and shall note any other environmental documents related to it. If an assessment is included, the FONSI need not repeat any of the discussion in the assessment but may incorporate by reference.

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