APPENDIX F – CIVIL ENGINEERING

for

RIO GUAYANILLA, GUAYANILLA, PR

2018 SUPPLEMENTAL APPROPRIATIONS

FLOOD RISK MANAGEMENT STUDY

March 2020

US Army Corps of Engineers®
Chicago District

USACE. 2019. Rio Guayanilla, Guayanilla, PR Flood Risk Management Study. Draft Integrated Feasibility Report Environmental Assessment. U.S. Army Corps of Engineers, Chicago District, 231 S. LaSalle Street, Suite 1500, Chicago, Illinois 60604. March 2020.

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1.0 Introduction

The Rio Guayanilla basin is located within the Municipality of Guayanilla on the southwestern coast of Puerto Rico. The Rio Guayanilla originates at a point near the central mountain range and flows in a southerly direction through steep slopes in the upper part of the basin producing fast runoff velocities and allowing minimal infiltration. The total length of the river channel is approximately 13.9 miles. The total drainage area of the Rio Guayanilla basin is approximately 37 square miles.

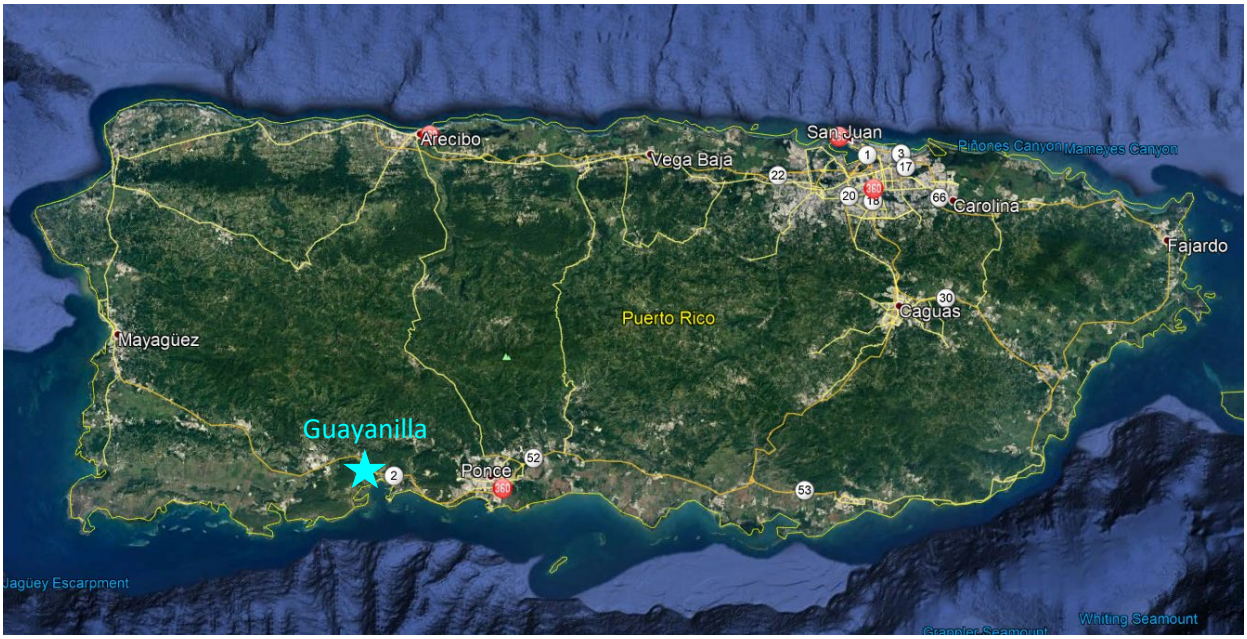

Figure 1. Location of Guayanilla

A Reconnaissance Report was prepared by USACE in 1990 to investigate flooding problems in the Town of Guayanilla and identify measures within the Federal interest. Federal interest was determined but the Non-Federal Sponsor opted out of moving into the Feasibility Phase. The Sponsor constructed a portion of the project recommended in the Reconnaissance Report in 2004. This segment of levee will be referred to as the Phase 1 Levee in this appendix and is located at the coast.

The feasibility team identified six alternatives in the feasibility report, with one alternative as the tentatively selected plan (TSP). The purpose of this appendix is to evaluate the civil and site design considerations, quantities development and related construction considerations for each of the proposed flood risk management alternatives.

2.0 Alternatives

The following paragraphs describe the two alternatives screened for further study. These alternatives are discussed below. The two alternatives share the same features in the northern upstream area at the beginning of the study. The common features then diverge into two distinct alternatives, Alternative 3 – Engineered Channel and Alternative 6 – Greenway Channel.

2.1 Alternatives – Common Features

This appendix discusses the two alternatives that were previously screened for further consideration. Those alternatives not discussed here involve no federal action, non-structural alternatives and other hybrid alternatives discussed in the main report.

Both alternatives, Alternative 3 – Engineered Channel and Alternative 6 – Greenway Channel share the same general features in the upstream northern one-fourth of the study area (approximately Station 00+00 to Station 41+50 as shown on Exhibit 1). Those features are listed and shown on as attachment Exhibits 1 and 2 at the end of this appendix. The following discussion provides a narrative of these features for both the common features and specific features in each alternative. Typical channel details are shown in Exhibit 8 at the end of this appendix.

2.2 Channel Improvements north and south of PR-127

At the upstream point of the study area (approximately Station 00+00 to Station 32+00 as shown on Exhibit 1) channel improvements are proposed. These improvements would involve excavating back material and debris that has sloughed into the river channel and re-defining bank slopes as necessary. The banks would be further stabilized with rip rap to prevent or mitigate further erosion. Figures 2 through 4 below represent existing conditions. Channel improvement cross section are shown as Exhibit 3 at the end of this appendix.

Figure 2. Channel upstream of PR-127 Bridge.

Figure 3. Debris upstream of PR-127 Bridge located downstream of PR-2 Bridge.

Figure 4. Downstream channel of PR-127 Bridge. Downstream embankment on bend was repaired after Hurricane Maria.

2.3 Levees and Floodwall north and south of PR-127

Due to real estate availability and space constraints imposed, a combination of levees and floodwall constructed of steel sheet pile and cap would be constructed in this area (approximately Station 7+00 to Station 32+00 as shown on Exhibit 1). Refer to Appendix K – Structural for further discussion on sheet pile details. The levees will be constructed from compacted karst and armored with riprap on the riversides for added protection. Refer to Appendix H – Geotechnical Engineering for further discussion on conceptual levee design and material selection. Similarly, steel sheet pile will be driven into bedrock in locations where the available real estate narrows and will not accommodate levees due to space constraints. The sheet pile wall elevations be the same as the levee crest and tie in at the transition locations. Cross sections are shown under Exhibits 11 and 12 in this location at the end of this appendix. Potential areas for karst mining materials is also shown as Exhibit 16 at the end of this appendix.

2.4 River widening immediately north and south of PR-127 and bridge expansion on PR-127

Rio Guayanilla will have to be widened approximately 100 feet both upstream and downstream of the bridge on PR-127 (approximately Station 15+00 to Station 19+00 as shown on Exhibit 1). After reviewing several options to lower the 100-year flows below the existing PR-127 bridge deck, widening of the river in this location is shown to be the most cost effective and have the least impacts to the local businesses, traffic and utilities that are located immediately east and west of this bridge crossing.

2.5 River Diversion Structure and Basin

A cast-in-place concrete river diversion structure will be constructed to divert the major storm flow events into the downstream diversion channel (for either alternative). This structure is approximately located at Station 35+00 as shown on Exhibit 1. The structure will allow normal and low flow storm events as well as allow riverine connectivity for sediment transport and fish passage through formed openings to its normal river course. Under high flow events, tail waters will form in the basin area constructed using a rip rap base. These high flows will then divert into the new diversion channel to alleviate overbank flooding in the Rio Guayanilla River as it passes through the population center. Refer to Appendix K – Structural for further discussion on the diversion structure.

2.6 Road Relocation and New Bridge

A segment of the existing road along Calle Vertedero adjacent to the cemetery will have to be relocated where the diversion channel will cross (either alternative). The relocated road will run along the western end of the new channel and tie back in to Cam Boca. So that traffic flow will not be cut off to the town center and new bridge (approximately 350 feet long) will have to be constructed over the diversion channel to maintain vehicular traffic north and south on Cam Boca, and east and west along the abandoned Calle Vertedero. A road and bridge relocation plan and typical road cross sections and details are shown under Exhibits 13 and 14 respectively, at the end of this appendix.

2.7 Alternative 3 – Engineered Channel

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 through banana fields to join up with constructed Phase I project near PR 3336. The overall site plan for Alternative 3 is shown in Exhibit 4 at the end of this appendix. Cross sections for the proposed alignment are shown in Exhibit 6.

The engineered diversion channel is primarily a concrete-lined trapezoidal channel. The channel base is 100-foot wide with 2-to-1 side slopes extending to natural ground. At this level of conceptual design, the concrete is assumed to be 8-10-inches in thickness on all three sides and of typical strength (3,000 psi). The concrete is also assumed to be reinforced with a single mat of coated reinforcing bars. During future detailed design, the concrete sections will be optimized for thickness and reinforcement as well as the need for high-strength concrete for durability, seismic and stagnation pressure loads. No drainage system has been studied at this level of study, however systems will be analyzed during final design to account for hydrostatic pressures. A typical cross section is shown under Exhibit 8 at the end of this appendix. Refer to Appendix K – Structural for further discussion on the engineered channel.

This alternative would have a levee on the east side of the diversion channel. The west side of the channel would remain at grade and allow certain magnitudes of flood to spread wider to the west, flooding non-developed and agricultural lands. The diversion channel side slope of the levee would be lined with riprap to prevent erosion. Upstream of the diversion channel, a combination of levees and floodwalls would be installed on both sides of the river channel. A close up view of this section is shown below in Figure 5.

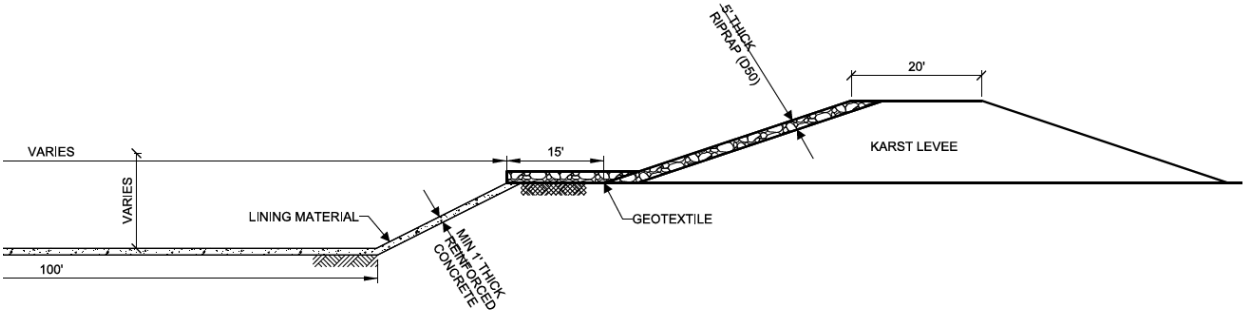

Figure 5. Alternative 3 Cross Section (shown with single line of protection)

2.8 El Faro Levee

A small levee along the east side of the town of El Faro is proposed as part of this alternative; this is basically a "set-back" to allow for ecosystem function to occur. A more detailed discussion of this section of levee can be found in Appendix A - Planning, Coordination & Compliance. A plan view and typical cross sections are shown under Exhibits 17 and 18 respectively, at the end of this appendix.

2.9 Alternative 6 – Greenway Channel

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 Rio Guayanilla, approximately at PR-2. This alternative would have a levee on the eastern side of the terraced greenway. The west side of the channel would remain at grade and allow certain magnitudes of flood to spread wider to the west, flooding non-developed and agricultural lands. It includes rehabilitating Phase I, bridge and conveyance modifications, utility relocation, and minor nature based features, but will be required to focus efforts and costs towards vegetation removal, engineered features, and bank protection. 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 Rio Guayanilla. The diversion structure conceptual design 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, though agriculture fields, where it bends east though banana fields to join up with constructed Phase I project near PR 3336. A new/modified structure would connect the new diversion channel with the in-place Phase I channel. 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 3 to ensure hydraulic forces do not degrade the integrity of the levee and terraces. The terraced greenway footprint for this alternative would be very wide in certain sections, about 780-feet based on current hydrologic and hydraulic modeling. Parts of the channel would remain at grade and allow certain magnitudes of flooding to spread wider to the west, flooding non-developed and agricultural lands.

The diversion channel side slope of the levee would be lined with riprap to prevent erosion. Upstream of the diversion channel, a combination of levees and floodwalls would be installed on both sides of the river channel. Certain terrace reaches may need stone/engineered features as well to prevent erosion at critical hydraulic points. The bottom of the channel would have robust boulder and/or boulder and 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, but will

perform 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 balance the system, making it quite stable, yet dynamic enough for ecosystem communities to develop. The overall site plan for Alternative 6 is shown in Exhibit 5 at the end of this appendix. Cross sections for the proposed alignment are shown in Exhibit 7.

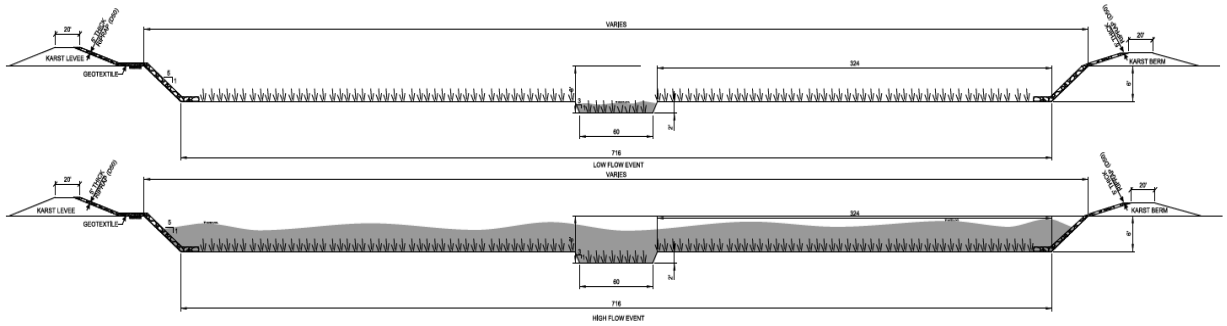

Figure 6. Alternative 3 Cross Section (shown with single line of protection)

3.0 Civil Site Considerations

The following paragraphs discuss the various site design topics taken into consideration for site layout, temporary construction areas, sources of data, utility impacts of the alternatives considered.

3.1 Real Estate

Using existing GIS databases, parcel maps were developed and used to quantify acreages required for the footprint of both alternatives being considered. Where possible, the diversion channel alignments have been examined and revised to minimize the number of real estate parcels impacted while not impacting the hydraulics or functionality of the designs. Both alternatives require substantial excavation for the conveyance channels. It has been determined by geotechnical investigations that these materials are not suitable for use in other parts of the construction project. Therefore, these materials will be stockpiled, hauled and regraded in open field areas near the project site. See Exhibits 9 and 10 for Real Estate acreages required in fee for both alternatives and Exhibits 1 and 2 for locations of stockpiling and regrading these materials (shown as Areas A, B, C and D).

3.2 Staging and Storage

There are three staging and storage areas proposed for the project (see above paragraph). Staging areas are shown on Exhibit1 noted as Areas A, B and C. Area D as shown on Exhibit 2 is an additional area for excavations spoils under Alternative 6 – Greenway Channel, but is not ideal for staging or storage due to its proximity to the channel alternatives. A fourth staging area is proposed at the far northern part of the project for channel improvements and bridge modification at PR-127 to be identified. The staging areas are open generally flat areas. The proposed staging and storage areas will be restored upon construction completion by regrading (see above).

3.3 Access Roads and Haul Routes

For most project measures, temporary haul roads will be built on site as necessary for channel improvements, PR-127 bridge extension / modifications, channel excavation and levee and new bridge

construction activities. These temporary access roads will be determined by the awarded construction contractor(s) based upon their own means and methods and within pre-determined work limits.
The project areas can be accessed from the major and local roads. The existing roads will be used as haul routes where necessary within the project areas. Construction damages to the roads will repaired or replaced upon construction completion.

3.4 Surveying and Mapping

The horizontal coordinates used for this project referenced the NAD 1983 State Plane Puerto Rico Virgin Islands FIPS 5200 feet. The elevations used is referenced to the Puerto Rico Vertical Datum of 2002 (PRVD02) feet. The elevation data used is from Light Detection and Ranging (LIDAR) data provided by USGS from 2015. This data set was created by USGS for High-resolution digital elevation maps generated by airborne and stationary LiDAR. LiDAR provides unique characteristics relative to other remotely sensed data sources by providing three-dimensional feature information that cannot be derived from traditional imaging sensors. This data set is adequate for this feasibility study and actual survey of the site will be performed for the design phase.

3.5 Topographic and Utilities Survey

A task order contract was awarded in April 2019 for a combined topographic & utility survey through the Jacksonville District. Among the various tasks specified in the scope of work were the following: control and topographic survey, bridge and culvert locations, utility survey, existing Phase 1 Levee survey, first floor elevations and select building square footages. The data was received in June 2019 and incorporated into conceptual plan development. Utility survey plans are shown as Exhibit 15 at the end of this appendix.

3.6 Utility Impacts

The alignment of the diversion channel alternatives bisect numerous utilities. These utility lines provide natural gas, sewer, water, oil, and fiber optic services. The majority of the impacted utility lines are located both above and below ground. Temporary relocations will be necessary during construction followed by new permanent overhead poles and lines as well as horizontally directionally drilled lines where feasible. For the PR-127 Bridge extension and new bridge at Gil Vertedero water and other pipelines can be supported by the bridge structures. The major utility lines that cross the proposed channel system are listed in Table 1 below.

Table 1. 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 Munoz Rivera Road From Highway 2 to south of PR127
2" Metal Water line Underground	Along Calle Luis Munoz Rivera Road just north of PR 127
Overhead Communication	Along Calle Luis Munoz Rivera Road just north of PR 127
6" Metal Water line Underground	Down the middle of Calle Luis Munoz Rivera Road just north of PR 127 through the intersection of PR 127
Primary Overhead Electrical/Telephone	Along Calle Luis Munoz Rivera Road From Highway 2 to south of PR127
8" Sanitary Sewer	Calle Luis Munoz Rivera Road just north of PR 127 coming from the east

54" Storm Sewer	Calle Luis Munoz Rivera Road just north of PR 127 coming from the east
Underground Electrical to Light Pole	Calle Luis Munoz Rivera Road just north of PR 127 coming from the east
Overhead Primary Electrical	Calle Luis Munoz 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	
Unknown 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

The following photos depict various overhead utilities within the alignment of the diversion channel alternatives.

Figure 7. Utilities on the intersection of Hwy 127 and Calle Luis Munoz Rivera

Figure 8. Utilities along Calle Vertedero looking west

3.7 Construction and Operational Costs

Full cost estimate information is included in the Appendix G - Cost Engineering. Also refer to the main report for an evaluation of the relative plans costs, construction impacts, and operation and maintenance issues.

3.8 Further Engineering Design

The engineering work completed for this report was at an appropriate level for a concept comparison. Sufficient work was completed to create a base project cost estimated, with assumptions and unknowns documented. Further work to be completed for a complete project design includes, among others, construction methods and concept optimization including VE studies as necessary, design calculations for

all components, HTRW assessment, site-specific survey, additional geotechnical exploration and analysis, and further refinement of the hydraulic models developed.

3.0 Quantity Takeoffs

Quantities for Alternative 3 and Alternative 6 were developed using CAD and surface modeling software. Quantity areas and volumes for specific features have been added to spreadsheets for reference. The below Tables 2 and 3 quantify the major quantities for both alternatives and related features.

Table 2: Quantities for Alternative 3 - Engineered Channel

Description	Unit of Measure	Quantity	Notes
Mobilization	JOB	1	Includes any temp facilities and roads
Demobilization	JOB	1	Remove all temp facilities, site restoration including road damages
Clearing and Grubbing – Channel and Levee	ACRES	36.85	Clearing and grubbing along North Levees, Levee and Berm along the diversion channel, Levee to Tie-into Phase 1 Levee and Levee along El Faro with an additional 15’
Clearing and Grubbing – Karst	ACRES	18.0	Area for karst mining / ripping. Possible previous quarry site.
Grading - Channel Improvement Excavation / Stockpiling	CY	149,730	Excavation north of the Diversion Channel to widen existing channel. Stockpile in Staging / Storage Areas
Grading - Diversion Channel Excavation / Stockpiling	CY	525,269	Excavation to create new channel. Stockpile in Staging / Storage Areas
Channel Lining - Concrete	SF	1,246,000	3,000 psi concrete
Channel Lining – Reinforcement	TONS	3,743	Epoxy-coated bars @ 6.008#/SF
North Levees construction	CY	10,579	Karst material
Diversion Channel Levee and Berm	CY	83,534	Karst material
Phase 1 Tie-In Levee	CY	196,634	Karst material
Utilities Relocate	JOB	1	Includes disconnect & reconnect
Bridge Extension /Modifications – PR-127	JOB	1	Includes new abutments / piers / approach apron
Bridge Construction- Gil Vertedero	JOB	1	As above – only if needed due to design
Diversion Structure 14’D x 162’L x 21H’	CY	735	CIP – includes bypass pumping
Road construction	LF	1,200	Road relocation north of PR-2
Road construction	LF	1,323	Calle Vertedero south of cemetery
Site Restoration	JOB	1	Repair of any damages to existing roads
Riprap Along Levees	CY	109,138	5’ thick along all riverside of levees
Riprap Stilling Basin	CY	27,004	2’ thick at stilling basing at the start of diversion channel

Table 3: Quantities for Alternative 6 Greenway

Description	Unit of Measure	Quantity	Notes
Mobilization	JOB	1	Includes any temp facilities and roads
Demobilization	JOB	1	Remove all temp facilities, site restoration including road damages
Clearing and Grubbing – Channel and Levee	ACRES	36.85	Clearing and grubbing along North Levees, Levee and Berm along the diversion channel, Levee to Tie-into Phase 1 Levee and Levee along El Faro with an additional 15’
Clearing and Grubbing – Karst	ACRES	18.0	Area for karst mining / ripping. Possible previous quarry site.
Grading - Channel Improvement Excavation / Stockpiling	CY	149,730	Excavation north of the Diversion Channel to widen existing channel. Stockpile in Staging / Storage Areas
Grading - Diversion Channel Excavation / Stockpiling	CY	1,611,283	Excavation to create new channel. Stockpile in Staging / Storage Areas
Channel Lining - Concrete	SF	245,000	3,000 psi concrete
Channel Lining – Reinforcement	TONS	736	Epoxy-coated bars @ 6.008#/SF
North Levees construction	CY	10,579	Karst material
Diversion Channel Levee and Berm	CY	171,308	Karst material
Phase 1 Tie-In Levee	CY	196,634	Karst material
Utilities Relocate	JOB	1	Includes disconnect & reconnect
Bridge Extension /Modifications – PR-127	JOB	1	Includes new abutments / piers / approach apron
Bridge Construction- Gil Vertedero	JOB	1	As above – only if needed due to design
Diversion Structure 14’D x 162’L x 21H’	CY	735	CIP – includes bypass pumping
Road construction	LF	1,200	Road relocation north of PR-2
Road construction	LF	1,323	Calle Vertedero south of cemetery
Site Restoration	JOB	1	Repair of any damages to existing roads
Riprap Along Levees	CY	108,836	5’ thick along all riverside of levees
Riprap Greenway Design	CY	59,550	2’ thick riprap along 2nd step of greenway channel
Riprap Basins	CY	80,744	Stilling basin, basin from Greenway to concrete channel, basin from concrete channel to greenway

*Notes:

1. These quantities were used to develop cost estimates for both alternatives. Refer to Appendix G – Cost Engineering for further details.

2. Lump sum (job) units of measure features will have further breakdowns as necessary during final design. Historical or parametric cost estimating will be used for cost estimate development at this level of study for these features. Additionally, these feature also include an applicable cost contingency percentage for this level of study.

4.0 Attachments

The following list of attached exhibits include plan views, cross sections, details and maps for the alternatives under consideration and are included as part of this appendix.

Exhibit Index: