DRAFT
FEASIBILITY REPORT
DELIVERY PACKAGE

Caño Martín Peña Ecosystem Restoration Project

SEPTEMBER 2015

US Army Corps of Engineers®

PROYECTO ENLACE DEL CAÑO MARTÍN PEÑA

U.S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT

CORPORACIÓN DEL PROYECTO
ENLACE DEL CAÑO MARTÍN PEÑA

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The Draft Feasibility Report Delivery Package contains 11 TABS as required by U.S. Army Corps of Engineers Planning Regulation ER 1105-2-100, Appendix G, Amendment #1, dated 30 June 2004.

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- **TAB 2** – Policy and Procedure Issues
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Acronyms and Abbreviations

ac	acres
AAHU	Average Annual Habitat Unit
ACGIH	American Conference on Governmental Industrial Hygienists
ACI	American Concrete Institute
ACM	Articulated concrete mat
ADCP	Acoustic Doppler Current Profilers
adICPR	advanced Interconnected Pond Routing
ADS	Autoridad de Desperdicios Sólidos
ALOHA	Areal Locations of Hazardous Atmospheres
AMC	Antecedent Moisture Condition
ASTM	American Society for Testing Materials
ATSDR	Agency for Toxic Substances and Disease Registry
ATR	Agency Technical Review
B2EHP	Bis (2-ethylhexyl) phthalate
BA	Biological Assessment
BACT	Best Available Control Technology
BDL	Below Detection Limit
BI	Benthic Index
BMP	Best Management Practice
C&D	Construction and demolition debris
°C	degrees Celsius
CAA	Clean Air Act
CAD	Contained Aquatic Disposal
CBIA	Coastal Barrier Improvement Act
CBRA	Coastal Barrier Resources Act
CBRS	Coastal Barrier Resources System
CCMP	Comprehensive Conservation & Management Plan for the San Juan Bay Estuary
CDLUP	Comprehensive Development and Land Use Plan
CDRC	Ciudad Deportiva Roberto Clemente
CE/ICA	Cost Effectiveness/Incremental Cost Analysis
CEM	Conceptual Ecological Model
CEQ	President’s Council on Environmental Quality
CERCLA	Federal Comprehensive Environmental Response, Compensation and Liability Act

CERCLIS	Federal Comprehensive Environmental Response, Compensation and Liability Information System
CFMC	Caribbean Fisheries Management Council
CFR	*Code of Federal Regulations*
CFU	Fecal coliform bacteria units
CH3D-WES	Curvilinear Hydrodynamics in 3 Dimensions, WES version
CHDO	Community Housing Development Organization
CM	Construction Management
cm	centimeters
CMP	Caño Martín Peña
CMP-CLT	Caño Martín Peña Community Land Trust
CMP-ERP	Caño Martín Peña Ecosystem Restoration Project
CMP-MTZ	Caño Martín Peña Maritime Terrestrial Zone
CO	Carbon monoxide
CO_2	Carbon dioxide
COC	Contaminants of Concern
CORRACT	Federal Corrective Actions List
CPI	Consumer Price Index
CRIM	Municipal Tax Revenue Collection Center
CSD	Combined Sewer Discharge
CSO	Combined Sewer Overflow
CSRA	Cost Schedule Risk Analysis
CSS	Combined Sewer System
CVM	Contingent Valuation Method
CWA	Clean Water Act
cy	cubic yards
CZMP	Coastal Zone Management Program
dB	decibel
dB(A)	A-weighted decibel
dbh	diameter at breast height
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DMMP	Dredged Material Management Plan
DNER	Puerto Rico Department of Natural and Environmental Resources
DO	Dissolved oxygen

DSS	Decent, Safe and Sanitary housing
DTPW	Puerto Rico Department of Transportation and Public Works
EA	Environmental Assessment
EC	Engineering Circular
ECC	ENLACE's Community Committee
ECO-PCX	Ecosystem Restoration Planning Center of Expertise
EDR	Environmental Data Resource, Inc.
EFH	Essential Fish Habitat
EGM	USACE Economic Guidance Memorandum
EIS	Environmental Impact Statement
EMF	Electromagnetic field
ENLACE	Corporación del Proyecto ENLACE del Caño Martín Peña
ENLACE Project	Caño Martín Peña ENLACE Project
EO	Executive Order
EPG	Emergency Power Generator
EQ	Environmental Quality Account
ER	USACE Engineering Regulation
ER	Engineering Report
ERAMPT	Ecosystem Restoration Adaptive Management Planning Team
ERDC	USACE's Engineer Research and Development Center
ERL	Effects Range–Low
ERM	Effective Range–Median
ERNS	Federal Emergency Response Notification System
ERP	Ecosystem Restoration Project
ERPG	Emergency Response Planning Guidelines
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
EUA	Ecological Uplift Assessment
°F	degrees Fahrenheit
FDA	Food and Drug Administration
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMC	Fishery Management Council

FMP	Reef Fish Fishery Management Plan
FONSI	Finding of Non-Significant Impact
fps	feet per second
FR	Feasibility Report
FR	*Federal Register*
FRM	Flood Risk Management
FRP	Federal Recreation Plan
ft	feet
ft/s	feet per second
ft/y	feet per year
ft^2	square feet
ft^3	cubic feet
FWCA	Fish and Wildlife Coordination Act
FWPRA	Federal Water Project Recreation Act
FY	Fiscal year
g	grams
G-8	Group of the Eight Communities bordering the Caño Martín Peña
GHG	Greenhouse gas
GIS	Geographic Information System
GPS	Global Positioning System
H	Hybrid
H&H	Hydrology and Hydraulics
H_2S	Hydrogen sulfide
ha	hectare
HAP	Hazardous Air Pollutant
HAPC	Habitat Areas of Particular Concern
HDPE	High-density polyethylene
HEC	Hydraulic Engineering Circular
Hg	Mercury
HHW	Household Hazardous Waste
HIA	Health Impact Assessment
HTRW	Hazardous, Toxic, and Radioactive Waste
HU	Habitat Unit
HW	Household Waste
IA	Initial Assessment
IBC	International Building Code

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Acronyms and Abbreviations

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ACM	Articulated concrete mats
adICPR	advanced Interconnected Pond Routing
ADS	Autoridad de Desperdicios Sólidos
AMC	Antecedent Moisture Condition
ASTM	American Society for Testing Materials
BACT	Best Available Control Technology
BMP	Best Management Practice
C&D	Construction and demolition debris
CAD	Contained Aquatic Disposal
CBIA	Coastal Barrier Improvement Act
CBRA	Coastal Barrier Resources Act
CBRS	Coastal Barrier Resources System
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CDLUP	Comprehensive Development Land Use Plan
CDRC	Ciudad Deportiva Roberto Clemente
CE/ICA	Cost Effectiveness/Incremental Cost Analysis
CEM	Conceptual Ecological Model
CERCLA	Federal Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS	Federal Comprehensive Environmental Response, Compensation and Liability Information System
CFR	Code of Federal Regulations
cm	centimeters
CMP	Caño Martín Peña
CMP-ERP	Caño Martín Peña Ecosystem Restoration Project
cy	cubic yards
CZMP	Coastal Zone Management Program
DMMP	Dredged Material Management Plan
DNER	Puerto Rico Department of Natural and Environmental Resources
DTPW	Puerto Rico Department of Transportation and Public Works
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ENLACE	Corporación del Proyecto ENLACE del Caño Martín Peña

EO	Executive Order
EPA	U.S. Environmental Protection Agency
ER	USACE Engineering Regulations
ERDC	USACE's Engineer Research and Development Center
ERP	Ecosystem Restoration Project
ERPG	Emergency Response Planning Guidelines
°F	degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
fps	feet per second
ft	feet
ft/s	feet per second
ft/y	feet per year
ft^2	square feet
ft^3	cubic feet
FWPRA	Federal Water Project Recreation Act
GIS	Geographic Information System
H_2S	hydrogen sulfide
H	hybrid
H&H	Hydrology and Hydraulics
ha	hectare
HDPE	high-density polyethylene
HEC	Hydraulic Engineering Circular
HTRW	Hazardous, Toxic, and Radioactive Waste
HU	Habitat Unit
IBC	International Building Code
in	inches
in/yr	inches per year
INCICO	Instituto de Ciencias para la Conservación de Puerto Rico
IPCC	Intergovernmental Panel on Climate Change
km^2	square kilometers
kV	kilovolt
LC	Los Corozos
LEERDs	Lands, Easements, Rights-of-Way, Relocations, and Disposal Areas
LI	liquidity index

LL	liquid limit
LLC	Los Corozos Lagoon
LSJ1	Water Quality Station San José Lagoon 1
LSJ2	Water Quality Station San José Lagoon 2
m/s	meters per second
m^3/s	cubic meters per second
MGD	million gallons per day
MHHW	mean higher high water
MHW	mean high water
mi	miles
mi^2	square miles
MLLW	mean lower low water
MLW	mean low water
mm/yr	millimeters per year
mph	miles per hour
MPRSA	Marine Protection, Research, and Sanctuaries Act
MRF	Material Recovery Facility
msl	mean sea level
MTL	Mean Tide Level
NAD 83	North American Datum 1983
NCDC	National Climatic Data Center
NEP	National Estuary Program
NER	National Ecosystem Restoration
NGVD 29	National Geodetic Vertical Datum 1929
NOAA	National Oceanic and Atmospheric Administration
NRC	Natural Research Council
NRCS	Natural Resource Conservation Service
NWI	National Wetland Inventory
ODMDS	San Juan Bay Ocean Dredged Material Disposal Site
P&G	Principles and Guidelines
PDR	Project Design Report
PED	Preconstruction engineering and design
PI	plasticity index
PL	plastic limit
PR	Puerto Rico
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRCCC	Puerto Rico Climate Change Council

PRCZMP	Puerto Rico Coastal Zone Management Program
PREPA	Puerto Rico Electric Power Authority
PREQB	Puerto Rico Environmental Quality Board
PRHTA	Puerto Rico Highway and Transportation Authority
PUD	Permanent Upland Disposal
RCRA	Federal Resource Conservation and Recovery Act
SJ	San José
SJ1	Artificial Pit San José 1
SJ2	Artificial Pit San José 2
SJ3/4/5	Artificial Pit San José 3/4/5
SJB	San Juan Bay
SJBE	San Juan Bay Estuary
SJBEP	San Juan Bay Estuary Program
SJHP	San Juan Harbor Project
SJMA	San Juan Metropolitan Area
SL	shrinkage limit
SLC	sea level change
SLR	Sea Level Rise
SSURGO	Soil Survey Geographic Database
SWMA	Puerto Rico Solid Waste Management Authority
tc	time of concentration
tpy	tons per year
TSP	Tentatively Selected Plan
TSS	Total Suspended Solids
µg/L	micrograms per liter
U.S.	Unites States of America
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
yr	year

Executive Summary

ES.1 Introduction

This document presents the basis of design in support of feasibility studies for the construction of the Caño Martín Peña Ecosystem Restoration Project (CMP-ERP) and incorporates the engineering analysis from other reports conducted for the CMP-ERP.

The CMP-ERP is located in metropolitan San Juan, Puerto Rico and is part of the San Juan Bay Estuary (SJBE), the only tropical estuary included in the U.S. Environmental Protection Agency (EPA) National Estuary Program (NEP). The CMP is an approximately 4-mile-long tidal channel connecting the San Juan Bay with San José Lagoon and Los Corozos Lagoon. The Project Channel is the 2.2-mile eastern reach of the channel between the Luis Muñoz Rivera Avenue Bridge and San José Lagoon. After its dredging by the USACE as part of the Agua Guagua Project, the existing western CMP channel provides access for municipal ferry boats carrying passengers from Old San Juan to the AcuaExpreso ferry terminal.

ES.2 Dredged Material Characteristics

The channel bottom is composed mainly of peat, organic clays, and silts of varying thickness within the proposed dredge footprint. The native sediments are covered by over five decades of accumulated sediment and solid waste (household waste and construction and demolition debris [C&D] materials). It is estimated that the dredged solid waste will make up 10 percent of the total material to be dredged from the Project Channel and the dredged sediments will bulk up to 126 percent of their in situ volume. In addition, chemistry analysis of historic sediment samples collected from within the CMP reveal the presence of elevated levels of contaminants.

ES.3 Hydrological and Hydraulic Conditions

The CMP-ERP lies within the 100-year flood zone which also extends well into the adjacent communities. San José Lagoon receives runoff from two major urbanized watercourses; Quebrada Juan Méndez and Quebrada San Antón. Suárez Canal, located southeast of Luis Muñoz Marín International Airport, connects the San José Lagoon and La Torrecilla Lagoon. Storms lower than 50 years in return interval, with storm surge, produce a maximum difference in water level of 0.23 foot (0.07 meter). The CMP-ERP was modeled to include a "plugged condition" considering construction of a temporary coffer dam near the western bridges to control turbidity during construction. The maximum increase in water surface elevation between Existing and "Plugged" Conditions, with storm surge, is 0.50 foot (0.15 meter) and 2.66 feet (0.81 meter) without storm surge.

The Proposed Condition Model was prepared for a rectangular channel with an initial ten alternatives ranging from 75 feet wide to 200 feet wide. The final array of alternatives included three channel configurations: 75, 100, and 125 feet wide by 10 feet deep. Under storm surge conditions, water surface elevations for the final array of channel alternatives range from 5.9 to 6.3 feet (1.80 to 1.91 meters), varying by only 0.07 foot (0.02 maximum meter) from the existing condition with storm surge. For reference, elevation 5.9 feet (1.80 meters) is the flood elevation in the Zone AE illustrated on the Federal Emergency Management Agency's Flood Insurance Rate Map (FIRM).

Although construction of the Project Channel cannot reduce flooding caused by storm surge or major storm events, it is expected that it would provide positive outlets for localized low level stormwater flows from the community. The hydrologic and hydraulic (H&H) modeling concludes that the CMP-ERP would reduce water surface elevations for storms not subject to surge conditions.

Without storm surge, proposed water surface elevations for the final array of channel alternatives range from 0.00 to 0.50 foot, whereas under existing conditions the range is 0.00 to 2.43 feet. The lowest surface elevations are in the widest, 125-foot-wide channel and the highest in the 75-foot-wide channel with variations between those two ranging from 0.00 to 0.23 foot. Frequent flooding issues documented through community meetings was reportedly due to clogged inlets, clogged sewers, and sanitary sewer overflows. Peak stormwater discharges from the communities into the Project Channel were calculated assuming an improved condition, and recommendations for sizing for culverts are provided.

ES.4 Hydrodynamic Model and Water Quality

The previously developed, USACE approved CH3D-WES hydrodynamic model was reconstructed to study the San Juan Bay estuary. It is noted that, due to the model's required analysis of channels in increments of 3 feet, the channel depths that were modeled were 9 and 15 feet. Results from these efforts, combined with a review of existing literature and the development of a linked hydrodynamic and ecosystem response model, has resulted in the following findings:

- The existing CMP provides only a slight influx of tidal waters to the San José Lagoon.
- Should the CMP be opened up and friction reduced through the removal of material currently clogging the channel, there would be a dramatic increase in tidal amplitude in San José Lagoon.
- The modeled tide range in San José Lagoon increases with increases in the cross-sectional area of a restored CMP, indicating an increased flow into and out of the San José Lagoon.
- Under existing conditions, the average residence time of waters within San José Lagoon is estimated at 16.7 days with a standard deviation of 0.4 day.
- Using modeled channel cross sections of 450, 675, 900, 1,350, and 1,800 square feet, modeled residence times for the San José Lagoon would decrease to 5.0, 3.9, 3.2, 2.7, and 2.4 days, respectively.

- Based on results of a Benthic Index quantification study developed for the San Juan Bay Estuary Program, the ecological health of San José Lagoon ranks considerably below that of La Torrecilla Lagoon and San Juan Bay proper.
- An earlier report on the Benthic Index for San Juan Bay (Bunch et al. 2000) concluded that distance from the Atlantic Ocean, as a surrogate for flushing rates, was a better predictor of Benthic Index scores than water depth alone.
- Substituting residence time estimates for distance from the Atlantic Ocean, Benthic Index scores for shallow water locations throughout the San Juan Bay estuary are statistically significantly and inversely related to residence time.
- Based on residence time estimates generated by the hydrodynamic model, Benthic Index scores for locations throughout San José Lagoon would be expected to more than double with reduced residence times associated with increased flushing of San José Lagoon via a restored CMP.
- The statistically significant increase in Benthic Index scores, when comparing existing conditions to a 450-square-foot cross-sectional area for the CMP, would not be statistically significantly further improved with greater cross sections.
- Peak velocities at smaller cross-sectional areas might prove problematic for scouring within a restored CMP.
- Based on a review of literature of similar tidal restoration efforts, significant improvements to the ecological health of San José Lagoon might be expected to occur within a period of 1 to 3 years, if not less.

ES.5 Initial Array of Channel Alternatives

The initial array of Project Channel alternatives included:

- 75-foot-wide by 10-foot-deep rectangular cross section with steel sheet pile side walls, and a channel bottom that is paved with an articulated concrete mat.
- 100-foot-wide by 10-foot-deep rectangular cross section with steel sheet pile side walls, and an earthen channel bottom.
- 125-foot-wide by 10-foot-deep rectangular cross section with steel sheet pile side walls, and an earthen channel bottom.
- 150-foot-wide by 10-foot-deep rectangular cross section with steel sheet pile side walls, and an earthen channel bottom.
- 125-foot-wide by 15-foot-deep rectangular cross section with steel sheet pile side walls, and an earthen channel bottom.
- 150-foot-wide by 15-foot-deep rectangular cross section with steel sheet pile side walls, and an earthen channel bottom.
- 200-foot-wide by 10-foot-deep rectangular cross section with steel sheet pile side walls, and an earthen channel bottom.

ES.6 Channel Appurtenances

All of the alternatives described above are configured as rectangular channels. An alternative "Hybrid" would provide a 5-foot horizontal to 1-foot vertical earthen slope adjacent to the channel "box" to 1) reduce the quantity and associated costs of the sheet pile, 2) create suitable transitional habitat from open water to forested wetland, and 3) provide variation and interest along the otherwise monotonous parallel lines of the channel bulkheads.

In support of the CMP-ERP's goal of wetland (mangrove) restoration, the channel cross section includes grading both sides of the channel to permit the creation of habitat for mangrove planting. The planting bed would be graded to an elevation at about Mean Lower Low Water (MLLW) extending, in most cases, to the upland side of the Public Domain Limit.

ES.7 Scour Potential

From the hydrodynamic model study, velocities at the channel bottom for each channel alternative are estimated as presented in Table ES-1.

Table ES-1
Channel Velocities

Channel Alternative (feet) Dimensions	Max. Bottom Velocity (feet per second) Within the CMP Project Channel	Max. Bottom Velocity (feet per second) Within the CMP and Adjacent Western Channel
75 x 9	4.22	2.20
100 x 9	4.09	2.80
125 x 9	3.95	3.25
150 x 9	3.85	3.65
125 x 15	3.45	4.34
150 x 15	3.13	4.49
200 x 9	3.13	4.09

Based on the known geotechnical information, the western channel soils are organic silt and clay inter-layered with peat. The materials are very soft, with very low bearing strength to depths of 25 to 30 feet or more beneath the channel. Flow from the Project Channel may create shear stresses exceeding permissible values in the existing western CMP channel with detrimental effects on existing sheet pile walls or other marine structures. Scour could also cause sediments that have accumulated in this existing low flow western CMP channel to enter the water column and be transported either to the San Juan Bay or into the San José Lagoon, causing increased shoaling. On the other hand, the eastern channel bottom soils are hard. As a result of these geotechnical conditions, the recommended maximum channel bottom velocities for the eastern and western

CMP channels are 3.5 to 4.0 feet per second (fps) and 2.0 to 2.5 fps, respectively, with preference for the lower end of the ranges.

For the proposed eastern CMP channel (e.g., Project Channel), calculated velocities are a factor of the cross sectional area and range from 3.13 fps to 4.22 fps. The highest velocity is in the smallest channel configuration, the 75-x-9-foot channel. Analysis of the potential for scour of the channels earthen bottom indicates that the 125-x-15-foot, 150-x-15-foot, and 200-x-9-foot channel sections fall below the minimum threshold of 3.5 fps to 4 fps, while the 75-x-9-foot channel is significantly above the threshold. The 100-x-9-foot channel, at 4.09 fps, is just marginally over the threshold and is considered likely suitable.

Velocities in the existing western CMP channel are a factor of the amount of flow passing from the eastern CMP channel. The larger the cross section area of the eastern channel, the higher the velocity in the receiving existing western channel. Only the 75-x-9-foot channel configuration had a velocity that was within the recommended threshold of 2.0 fps to 2.5 fpsSubsequently, it was determined that channel depths at 10 feet would be preferred to prevent leaving behind debris found to depths of 10 feet. Consequently, velocities in 10-foot-deep channels would be slightly higher than those modeled 9-foot-deep channels.

At the western bridges in the Project Channel, the potential for scour at the piles, columns, and abutments is greater than through the channel. Around these bridges, dredged depths would be shallower than in the main channel. Full bottom and side-wall armoring is recommended.

ES.8 Final Array of Channel Alternatives

As mentioned above, the recommended permissible velocities from the eastern CMP into the existing western channel were in the range of 2.0 to 2.5 fps, with a preference for the lower end. The only channel meeting this criterion is the 75-foot by 10-foot channel section; however, this alternative has an internal channel velocity that will scour its earthen bottom so it must be armored.

Other channel sections that could be utilized are the 100-foot x 10-foot, 125-foot x 15-foot, 150-foot x 15-foot, and 200-foot x 10-foot channel sections if a weir is constructed between the Project Channel and the existing western CMP channel that maintains the flow (Q) at or below the Q for the 75-foot x 10-foot channel section. The weir, if designed as the channel section from the Ponce de León Bridge to the Tren Urbano Guideway and then under the Luis Muñoz Rivera Avenue Bridge, would be a widened channel section of 115 feet with a depth of –6.5 providing the same cross sectional area as a 75-foot x 10-foot section. Channel side walls would be rip rapped and the channel bottom protected with articulated concrete mats comprised of flexible, interlocking machine formed concrete block units interconnected with cables. With this scour protection, its bottom and sides are protected and velocities into the western channel are mitigated. At the same time, the channel invert is elevated, reducing or avoiding potential impacts to existing bridge foundations. Due to the need for the higher channel invert under the bridges, a weir would be needed for any channel configuration, including the 75-foot by 10-foot channel.

After consideration of other screening criteria besides the potential for scour, the final array of alternatives consisted of four alternative plans:

No Action Alternative Plan: Involves no further Federal actions.

Alternative Plan 1: Consists of a 75-foot-wide by 10-foot-deep channel; articulated concrete mats along the entire channel bottom for erosion control; an elongated weir under the Martín Peña, Tren Urbano, and Luis Muñoz Rivera bridges involving a 115-foot-wide by 6.5-foot-deep channel with riprap on side slopes and articulated concrete mats at the channel bottom; dredging approximately 680,000 cubic yards (cy) of mixed materials along 2.2 miles of the eastern CMP; construction of a vertical concrete-capped steel sheet pile with hydraulic connections with the surrounding lands; and, restoration of 20.42 acres of open water and 39.62 acres of wetland.

Alternative Plan 2: Consists of a 100-foot-wide by 10-foot-deep natural bottom channel; an elongated weir under the Martín Peña, Tren Urbano, and Luis Muñoz Rivera bridges involving a 115-foot-wide by 6.5-foot-deep channel with riprap on side slopes and articulated concrete mats at the channel bottom to reduce water velocity and erosion, and to control scour; dredging approximately 762,000 cy of mixed materials along 2.2 miles of the eastern CMP; and construction of a vertical concrete-capped steel sheet pile with hydraulic connections with the surrounding lands; restoration of 25.57 acres of open water and 34.48 acres of wetland.

Alternative Plan 3: Consists of a 125-foot-wide by 10-foot-deep natural bottom channel; an elongated weir under the Martín Peña, Tren Urbano, and Luis Muñoz Rivera bridges involving a 115-foot-wide by 6.5-foot-deep channel with riprap on side slopes and articulated concrete mats at the channel bottom to reduce water velocity and erosion, and to control scour; dredging approximately 872,000 cy of mixed materials along 2.2 miles of the eastern CMP; and construction of a vertical concrete-capped steel sheet pile with hydraulic connections with the surrounding lands; restoration of 30.97 acres of open water and 29.08 acres of wetland.

For Alternative Plans 1, 2, and 3, total construction time would be approximately 27 months, maintenance dredging would be required, and dredged material disposal would be divided between upland landfill for solid waste and contained aquatic disposal in the San José 1 and San José 2 pits for dredged sediments.

ES.9 Dredged Material Management

A total of 10 possible channel configuration alternatives were considered as part of the feasibility study. Based on visual observations and geotechnical investigations, it is assumed that the sediment and solid waste within the Project Channel is proportioned as 90 percent sediment, 10 percent solid waste. Solid waste is documented to occur as far down as −10 feet mean low low water, and its disposal would have to occur in a landfill.

Based on the information regarding available landfills and capacities, solid waste debris from the CMP-ERP would be transported from the Ciudad Deportiva Roberto Clemente (CDRC) staging area to the Humacao landfill site, which is located approximately 32 miles from the CMP-ERP site. A total of 6 acres are included within the project footprint of the CDRC staging area on the southeast shore of San José Lagoon. Of these 6 acres, 5 acres are upland habitat and 1 acre is mangrove fringe. The staging area includes a dock for loading/unloading the dredged material to be transported to the landfill. The five upland acres are within a previously disturbed 35-acre parcel.

The dredged sediments would be encapsulated in geotextiles and placed in San José Lagoon in artificial subaqueous pits (CAD sites). The trash & debris would be separated, collected, transported to the Humacao landfill. Construction of the Project is estimated to take 27 months. Prior to clearing, grubbing, and dredging activities, a sampling and remediation plan would be developed and approved by ENLACE, USACE, USEPA, and PREQB to ensure that hazardous materials are identified, managed, and disposed of according to applicable Federal, state, and local rules and regulations.

The Tentatively Selected Plan (TSP)/National Ecosystem Restoration (NER) Plan is the 100-foot-wide by 10-foot-deep channel configuration, requiring the dredging and disposal of 762,000 cy of mixed sediment and solid waste, of which 76,200 cy is anticipated to be solid waste. It is anticipated that the dredged sediments would bulk up to 126 percent of their in situ volume. Approximately 685,800 cy of in situ sediments would be placed in the CAD pits which would be enlarged to accept the total dredged volume and provide storage for future maintenance dredging. Approximately 37,800 cy of in situ sediments would be used to complete the sheet pile construction and mangrove bed restoration.

For activities related to the installation of the weir in the western end of the Project Channel, an upland staging area near the four western bridges would be used to temporarily stockpile and transfer the collected solid waste excavated during the dredging process. Equipment and materials would be staged on floating barges. After the construction of the weir, and once the dredging from the eastern portion of the Project Channel opened the CMP, the temporary coffer dam would be removed, and the stockpiled solid waste would be placed into shallow-draft barges for transport to the CDRC staging area. At the CDRC staging area, the material would be off-loaded, placed into trucks, and hauled for disposal at the Humacao upland landfill.

ES.10 Recreation

The Federal Recreation Plan would consist of 3 types of recreation access areas on approximately 5 acres along the Project Channel. The 3 types allow for major recreational use in some areas and median use in others. Two types would be adjacent to the proposed Paseo (whose construction is not a part of this federal ecosystem restoration project). This approach allows for large uninterrupted areas of restoration with major recreation areas that have access to the water, and median use areas along the smaller neighborhoods while connecting to the Paseo along the CMP.

Recreational Access Parks: Nine recreational access parks would be dispersed along the CMP-ERP. These would be the larger parks in the community with open access to the CMP. The parks would include picnic tables and benches, signage, safety fencing, and other pedestrian amenities.

Recreational Parks: This recreational area would be smaller in scale than the proposed recreational access park. Six would be provided along the corridor without direct access to the CMP and another six with trail connections to the water. These parks would have amenities similar to the recreation access parks.

Linear Park: A linear park would be provided along the western end of the Project Channel, extending the existing linear park from the western CMP (Parque Lineal Enrique Martí Coll), to the first recreational park in the Parada 27 community along the southern side of the channel. The park would be constructed over the proposed sheet pile bulkhead; however, in the area of the proposed weir, the walkway would be elevated on piles or extended overland.

ES.11 Utility Relocation

Major utilities within the Project Area include a segment of the Rexach Trunk Sewer and a segment of the Borinquen Water Transmission Line. Immediately adjacent but outside of the Project Area are improvements to the San José Trunk Sewer. Also, construction of the CMP-ERP requires demolition of structures and roadways adjacent to the channel and interruption of the existing stormwater systems. Similarly many of the streets within the demolition limits contain underground sanitary sewer collection piping, cable, electrical service and water services that will be impacted and require new terminuses or connections. Of the three major utilities identified, only the demolition of the Rexach Truck Sewer and the Borinquen Water Transmission Line would be a component of the CMP-ERP. The relocation of the San José Trunk Sewer is not a component of the Federal Project.

An existing 115-kV overhead transmission line currently runs from a substation near the Tren Urbano guiderail on the western end of the CMP-ERP, east via Rexach Avenue and then south to the channel and San José Lagoon. It has been relocated along the northern side of the CMP through an effort associated with the Federal Project, and accordingly, its relocation is a component of the CMP-ERP.

1.0 INTRODUCTION

1.1 PURPOSE

This appendix documents the engineering analysis used in support of the feasibility study for the Caño Martín Peña Ecosystem Restoration Project (CMP-ERP), and presents the basis of design for its future preconstruction engineering and design (PED) phase. For the most part, the appendix is based upon other separate reports for each of the studies conducted for the CMP-ERP. Areas covered herein include surveying and mapping, geotechnical investigations, hydraulics and hydrology, and civil design. A full description for civil design and a detailed summary of the separate reports is included herein.

1.2 GENERAL

The Caño Martín Peña (CMP) is a waterway approximately 4 miles long, connecting San Juan Bay and San José Lagoon, in metropolitan San Juan, Puerto Rico. It is part of the San Juan Bay Estuary (SJBE), the only tropical estuary that is included in the U.S. Environmental Protection Agency (EPA) National Estuary Program (NEP). As one of the most important natural habitat systems in the metropolitan area and Puerto Rico, the SJBE is a system of interconnected lagoons and channels including the San Juan Bay, Condado Lagoon, San José Lagoon, Los Corozos Lagoon, Piñones Lagoon, La Torrecilla Lagoon, Caño Martín Peña, and Suárez Canal. The system discharges into the Atlantic Ocean through the San Juan Bay (and Condado Lagoon) and through Boca de Cangrejos. The total drainage area of the CMP is about 4 square miles (2,500 acres).

The SJBE and its associated marine ecosystems are considered the "Study Area," because the proposed CMP-ERP is expected to have direct, indirect, and cumulative beneficial effects on this whole region (Figure 1.2-1). The "Project Area," which mostly lays out the construction footprint, has been defined as the Project Channel, where dredging would take place, and the adjacent delimitation of the public domain lands within the MTZ-CMP where relocations are scheduled to occur. Also included in the Project Area is the 6-acre dredged material staging area within the 35-acre Ciudad Deportiva Roberto Clemente (CDRC) site, the boating routes from the eastern limit of the CMP to the CDRC and the nearby San José Lagoon pits, and the five pits in San José Lagoon (Figure 1.2-2).

The CMP is surrounded by eight communities: Barrió Obrero (Oeste and San Ciprián), Barrio Obrero Marina, Buena Vista Santurce, Cantera, Parada 27, Las Monjas, Buena Vista Hato Rey, and Israel Bitumul (Figure 1.2-3). The population is estimated to be 27,000 inhabitants. Over 335 owner/occupants and renters families still live in the areas directly adjacent to the CMP and within the Public Domain.

Figure 1.2-1. San Juan Bay Estuary Study Area

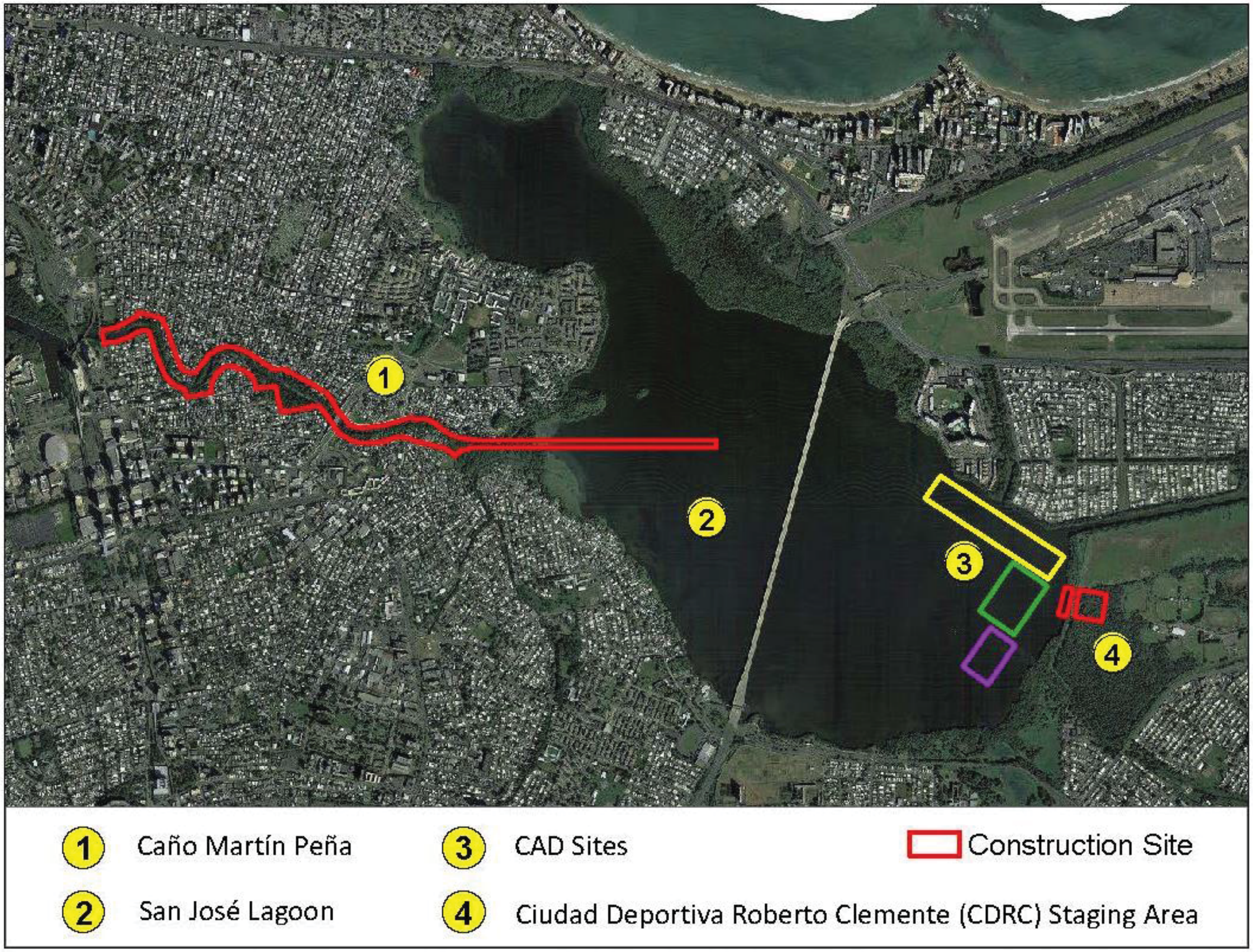

Figure 1.2-2. CMP-ERP Project Area

Figure 1.2-3. Communities Adjacent to the Caño Martín Peña

Historical data observed from the 1936 aerial photography available for the CMP (Figure 1.2-4) shows that the area was characterized as an open water channel allowing tide exchange in the defined channel with banks conformed by mangroves, mainly on the central and eastern side.

Figure 1.2-4. Historic aerial photo showing the conditions of the CMP in 1936

The waterway of the CMP had a historical average width of at least 200 feet and provided tidal exchange between San Juan Bay and San José Lagoon; however, since the 1920s, the channel and its wetlands began to be modified as a result of development pressures from growth in the area. The wetlands adjacent to the San Juan Bay and along CMP were used as a disposal site for the material that was dredged from the San Juan Harbor CMP-ERP affecting or eliminating more than 80 percent of the original mangrove acreage found in this area of the SJBE. In addition, as the result of the decay of the sugar cane industry among other factors, massive migration from rural Puerto Rico to San Juan led to squatter settlements in areas along CMP.

The CMP's historical ability to convey flows has been almost completely blocked as a result of siltation, accumulation of solid waste, and the encroachment of housing and other structures within the Public Domain (Figure 1.2-5). Recent subsurface investigations in the remaining channel and along both banks of the eastern half of CMP found solid waste up to 10 feet below the surface.

As a result of the progressive channel clogging, there is very little tidal exchange between the San José Lagoon and San Juan Bay and very poor water quality, which has resulted in depressed ecological conditions in both the CMP and the San José Lagoon. Poor water quality is exacerbated by the lack of adequate infrastructure, a combined (stormwater and wastewater) sewer system, leaching from on-site septic systems, and many direct discharges of untreated sewage into the CMP. Direct raw sewage discharges, from the encroachment of communities into the channel and from

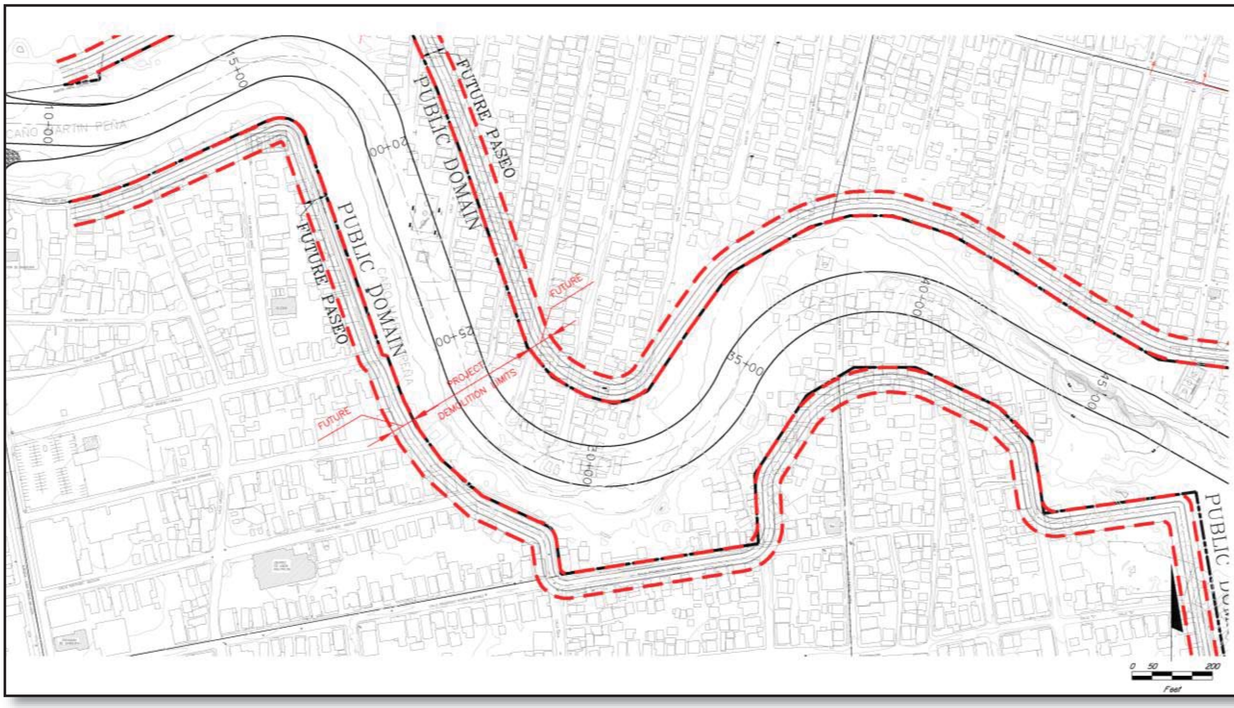

Figure 1.2-5. Demolition Limits

other areas of San Juan, have transformed the CMP into a public health hazard. Encroachment along the eastern half of CMP has increased the intensity and frequency of flooding, affecting nearby communities with a combination of storm and untreated sanitary waters. Wildlife habitat loss has occurred within the system as a result of direct (e.g., construction, dredging, filling) and indirect impacts. Mangrove and other native flora and associated fauna have significantly diminished in the CMP and adjacent areas.

The CMP-ERP is the latest of several prior attempts to bring about an improvement in the quality of life for residents living along the CMP and to restore and/or improve water quality and habitat values in the CMP and San José Lagoon, as well as a key restoration component for the entire SJBE. The relocation and resettlement of residents from areas adjacent to the CMP began in 2002. These initial efforts were carried out with the anticipation that they would be followed by the initiation of the CMP-ERP that was presented to the U.S. Congress in 2002.

The CMP-ERP proposes to dredge the eastern segment of the channel to restore the CMP and areas adjacent to it and increase tidal flushing of the San José Lagoon, in order to achieve environmental restoration, and as ancillary benefits, reduce localized flooding. In addition, the CMP-ERP would allow for the potential of environmentally sound waterway transportation, and promote recreation and tourism, with minimal negative impact on the ecosystem and the adjacent communities. The western segment of the CMP was previously dredged in the mid-1990s as part of the Agua-Guagua Project, and the construction of the CMP-ERP would complete the dredging of the channel and restore the CMP to act as the historical tidal connection between San Juan Bay and San José Lagoon. The western channel provides access for water ferries between the San Juan Bay and the AcuaExpreso intermodal terminal, a distance of about 2 miles. The channel was constructed to provide ferry service between Old San Juan, Cataño, and Hato Rey. It was designed to accommodate ferry vessels with a beam of 30 feet and a length of 85 feet with a static draft of 6 feet. (USACE, Agua-Guagua Project, Dredging Martín Peña Navigation Channel, Final Letter Report, August 1983).

Previous studies suggest that the environmental restoration of the CMP can be achieved by dredging the channel and constructing a vertical steel sheet pile and concrete bulkhead system with a transitional section towards the opening to the San José Lagoon. A major function of the dredging is to provide restoration of tidal exchange between the San José Lagoon and the San Juan Bay. This increased flushing would provide an ecological lift for both the CMP and the majority of the San José Lagoon. Within the CMP, the mangroves are anticipated to increase in density along the banks. Design alternatives were developed to create a balance between the cross-sectional area of the channel, flushing rates, environmental benefits, and CMP-ERP costs, both economic and social. Design alternatives also provide for secondary project components such as recreational features along the north and south banks of the Project Channel, allowing for areas of interactivity between the communities and the CMP (Figure 1.2-6).

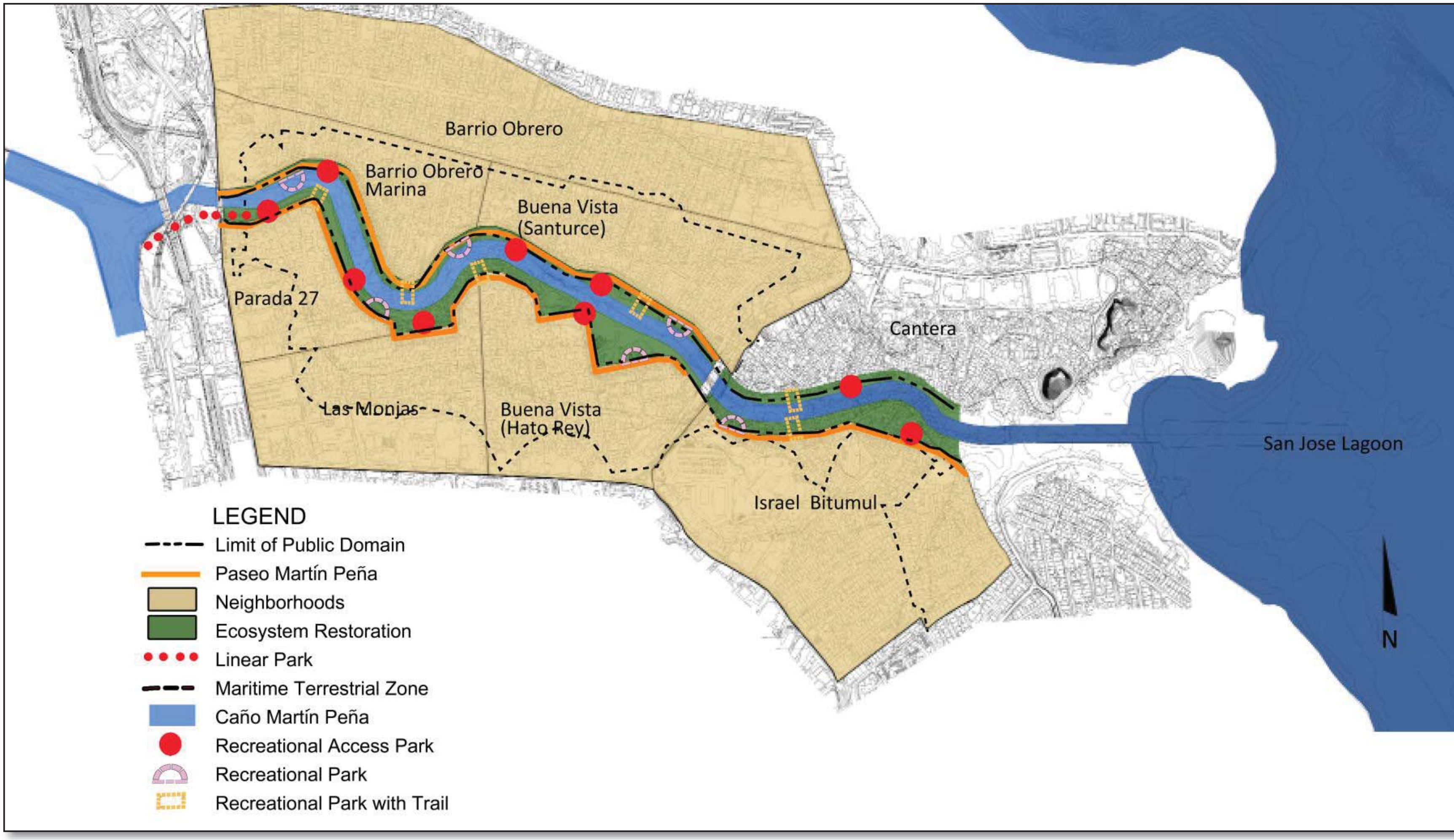

Figure 1.2-6. Proposed Federal Recreation Plan

A future endeavor, outside of the Project Area but adjacent to the CMP limit of Public Domain, is a perimeter road called Paseo del Caño Norte on the north side and Paseo del Caño Sur on the south side. Figure 1.2-7 illustrates a similar solution that is being employed in the adjoining Cantera neighborhood and Figure 1.2-8 provides a cross section of a channel alternative for the CMP-ERP along with the future Paseo.

1.3 PRIOR STUDIES AND REPORTS

This design study builds up upon the previous studies for the feasibility of the CMP-ERP, many of which are identified below. These studies collected sediment and geotechnical data, made construction assessments, and recommended alternatives.

- "Dredging the Caño Martín Peña, Project Design Report (PDR) and Environmental Impact Statement (EIS), Appendix B, Geotechnical Investigations." U.S. Army Corps of Engineers (USACE), Jacksonville District. March 2001.
- "Joint Permit Application, Caño Martín Peña Rehabilitation Project," CMA Architects & Engineers LLP for Puerto Rico DTPW, May 2003.
- "Electrical and Communications Installations Study, ENLACE Caño Martín Peña Project." UNIPRO Architects, Engineers, and Planners and CMA Architects & Engineers, LLP, December 2002.
- "Potable Water and Sanitary Sewer Installations Study, ENLACE Caño Martín Peña Project." UNIPRO Architects, Engineers, and Planners and CMA Architects & Engineers LLP for Puerto Rico HTA. December 2002.
- "Proyecto ENLACE del Caño Martín Peña "CMP" – Estudio de Instalaciones de Alcantarillado Pluvial." UNIPRO Architects, Engineers, and Planners and CMA Architects & Engineers LLP for Puerto Rico HTA. February 2003.
- The State of the Estuary, San Juan Bay Estuary Program, Management Plan, July 2002.
- "Preliminary Site Characterization – Martín Peña Channel, San Juan Puerto Rico," Roy Weston, Inc. August 5, 1997.
- "Caño Martín Peña Waterway Improvements." Moffatt & Nichol Engineers for UNIPRO Architects, Engineers, and Planners, September 2003.
- Enlace Caño Martín Peña, San Juan, Puerto Rico, Preliminary Engineering Report. 2008. ENTECH/CH Caribe.
- Bridges on the Caño Martín Peña San Juan, Puerto Rico: A Reconnaissance Level Conceptual Study and Cost Estimate. Contract Number: DAC17-98-D-0019. December, 1999. HDR Engineering, Inc.
- Plan De Desarrollo Integral Y Usos Del Terreno Del Distrito De Planificación Especial Del Caño Martín Peña, Autoridad de Carreteras y Transportación Departamento de Transportación y Obras Públicas

Figure 1.2-7. Cantera Paseo Norte

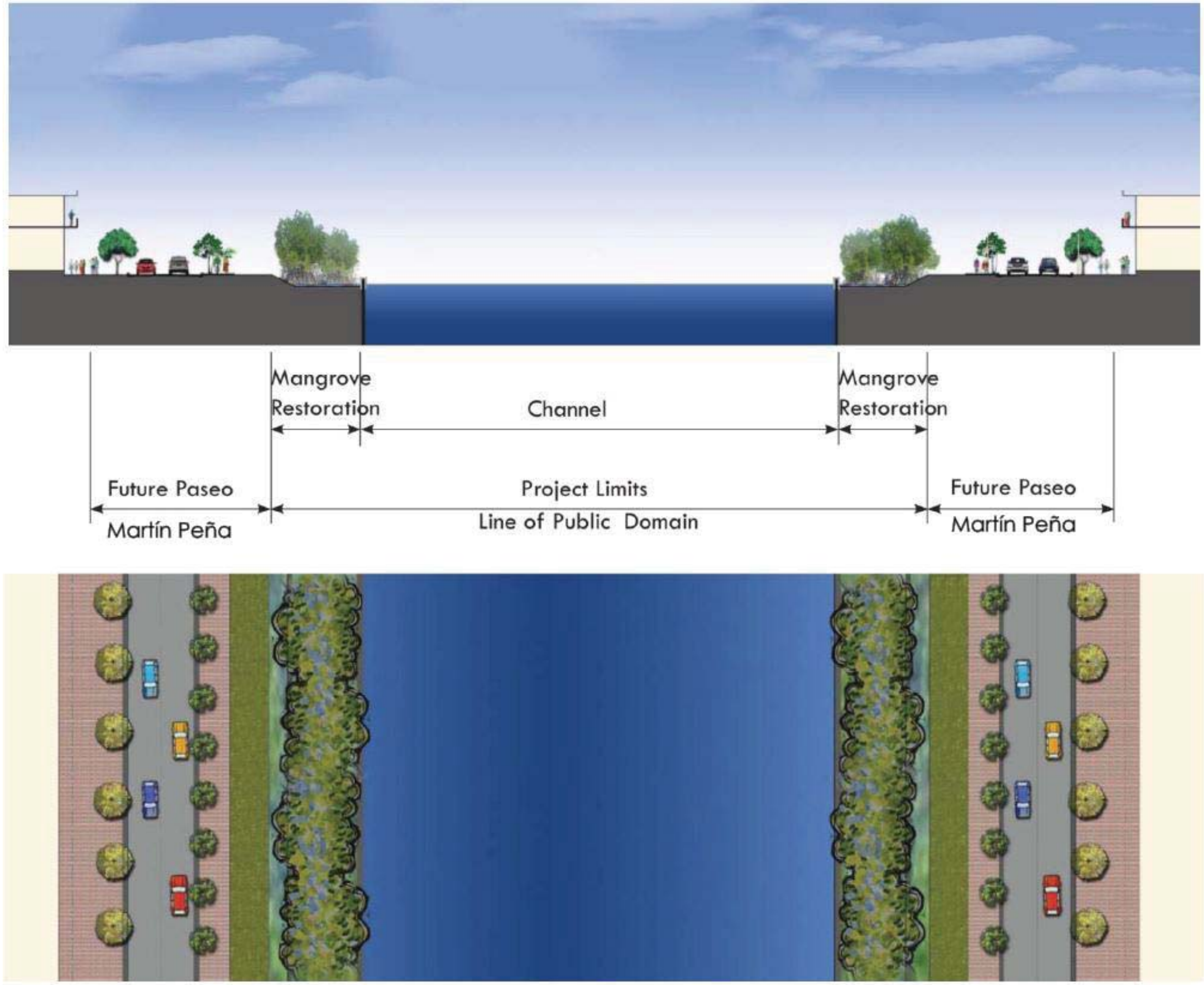

Figure 1.2-8. Typical Channel Plan and Section

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2.0 SURVEYING, MAPPING, AND OTHER GEOSPATIAL DATA REQUIREMENTS

Survey and mapping necessary to support the preparation of the feasibility report and real estate appendix requires topographic and bathymetric mapping within the CMP-ERP's Project Area. Other mapping of importance includes underground and overhead utilities immediately outside the line of Public Domain.

2.1 SURVEYING AND MAPPING UTILIZED

Survey and mapping utilized for the CMP-ERP included the following:

- Photogrammetric Topographic Survey from aerial photos taken 8-23-02 by Certified Photogrammetrist Ramon Figueroa;
- Various GIS collections of data: Drainage basins in the estuary system, Land use from 1977 coverage, Soils, Topography, well locations, Habitat coverages, used in a report "Synoptic Survey of Water Quality and Bottom Sediments, San Juan Bay Estuary System, Puerto Rico, December 1994–July 1995" by Richard Webb and Fernando Gomez-Gomez, U.S. Geological Survey, Water Resources Investigations Report 97-4144;
- Elevated Train construction plans, prepared by Iberica De Estudios E Ingenieria, S.A. Dated June 30, 1998;
- Ponce de León Avenue, Barbosa Avenue, and Luis Muñoz Rivera Avenue Bridge surveys dated December 1996, prepared by R. Lopez de Azua & Associates for the USACE. These plans also include some relevant data on adjacent utilities such as tops and inverts of various SSMH, and Catch Basins;
- Photogrammetric surveys that include the data from the 1996 bridge surveys but also the entire project area and the aerials themselves dated February 1997, prepared by Photo Science, Inc.;
- Core Boring location plans dated October 22, 1999, and prepared by the USACE;
- Hydrographic Bathymetric survey dated May 1996, prepared by R. Lopez de Azua & Assoc. for the USACE;
- Storm sewer and sanitary sewer infrastructure of the San Juan Municipality; the autonomous municipality of San Juan, Planning and Land Management;
- Topographic surveys covering portions of Barrio Obrero Marina, Buena Vista (Santurce), Las Monjas and Buena Vista (Hato Rey) provided by ENLACE;
- Topographic surveys and cross sections of Caño Martín Peña adjacent to Cantera, Parada 27 and Israel Bitumul and western channel entrance, both sides, prepared by PBS&J Caribe, April 2011;
- The Public Domain Limit, provided by ENLACE.

2.2 DATUM

Horizontal controls for the topographic survey and the plans refer to North American Datum 1983 (NAD 83). Horizontal coordinates or other dimensioning are not referenced in the report. Elevations in this report use vertical datum National Geodetic Vertical Datum 1929 (NGVD 29), Mean Sea Level 0.0.

2.3 ADDITIONAL SURVEY AND MAPPING STUDIES NEEDED DURING PRECONSTRUCTION, ENGINEERING AND DESIGN

The following surveys would need to be conducted during PED for the CMP-ERP:

- Determine clearances underneath bridges and utilities to fully document and inform choice of dredge plans, sheet pile driving equipment, and other construction methods so that the likelihood or accidents occurring would be minimized;
- Determine depth of cover over bridge pile caps in vicinity of the proposed project channel to prevent disturbing these existing bridge structures during dredging; and
- Ensure that the final design of the project fully complies with setback requirements from existing structures that will remain in areas adjacent to the project after construction.

3.0 GEOTECHNICAL INVESTIGATIONS AND DESIGN

A series of geotechnical investigations were performed between 1997 and 2011. A summary of the results of these investigations is presented herein. The sediments that characterize the first 40 feet, where sheet pile would be installed, varies greatly, with soft to very soft black organic mud, clays, silts with some lenses of sandy material, hard sandy clay and hard silty clay. The sediments that characterize the first 10 feet are expected to be soft to very soft black organic mud, clays, and silts with some lenses of sandy material. Gravels, cobbles and boulders in the eastern portion of the CMP Project Channel may be encountered. Solid waste (household waste and construction debris) was found in the upper 10 feet. Approximately 10 percent of the sediments in the first 10 feet are estimated to be solid waste. Due to the high contents of organic silts and clays within the sediment profiles, the liquid limit and plasticity index tend to be high. The shear strength values for the channel banks do not represent a concern for the dredging of the channel. Following is a detailed description of the geotechnical investigations.

3.1 FIELD EXPLORATION

The available geotechnical investigations and evaluations conducted by Weston (1997), USACE, (2001), Bailey et al. (2002), Moffatt & Nichol (2003), and GeoEnviroTech (2011) covered the general characteristics of the channel and channel banks, with the cores providing data on the physical and chemical properties of the materials to be dredged. Physical characteristics were also collected on the channel banks where the sheet pile walls and dredged slopes would be constructed.

Core samples were taken from the CMP: thirty four from the channel banks, thirty eight from test pits on the channel bank, two grab samples in the borrow pits, and 1 sample from an unknown location in the San José Lagoon. The results of these core samples are presented in Table 3.1-1. Of the 72 total core samples taken in the CMP, only 11 cores were analyzed for chemical analysis in the Weston (1997) report, while 10 cores were chemically analyzed in the GeoEnviroTech (2011) report. The existing data indicates the presence of contaminated sediments at various locations; however, due to the relatively few samples taken, it is not possible to determine what percentage of the dredged material, if any, would need to be treated as contaminated sediment that could not be disposed of in an aquatic environment (e.g., ocean disposal).

A list of the known geotechnical data and evaluations sources is provided below:

- **GeoEnviroTech, Inc**. **(2011)**. Limited geotechnical investigation undertaken as part of the CMP-ERP study effort. The investigation included assessing the physical and chemical properties of sediments within the CMP, San José Lagoon, and Los Corozos Lagoon.

- **Moffatt & Nichol (2003)**. No geotechnical data was collected as part of the report, but geotechnical evaluations were performed based on geotechnical field investigations conducted by others.
- **Bailey et al. (2002)**. No geotechnical data was collected as part of the report, but geotechnical and chemistry evaluations were performed based on geotechnical field investigations conducted by others.
- **USACE (2001)**. Collected several core borings.
  - **Phase 1**: Eleven core borings were taken from the channel and 5 from the channel banks.
  - **Phase 2**: Seventeen core borings were taken from the channel and 24 were taken from the test pits.
- **Weston (1997)**. Conducted a geotechnical investigation along a portion of the CMP. Ten borings were drilled in the channel and 5 borings drilled on the channel banks. Two composite sediment samples were collected within the Corozos and the San José Lagoons at the identified sites for sediment disposal.
- **Caribbean Soils Testing (1997)**. Atkins staff discovered a historic geotechnical log of a sediment core collected in February 1997 at an undetermined location within the San José Lagoon. This core was collected by the firm Caribbean Soils Testing for a site assessment of the Teodoro Moscoso Toll Road; however, no specific location of the coring station was recorded to allow for estimating the general geotechnical and geological setting at an area within the lagoon.

Table 3.1-1
Field Exploration Samples

Source	No. Cores (Channel)	Depth (feet)	No. Cores (Banks)	Depth (feet)	No. Test Pit (Banks)	Depth (feet)	No. Grabs (Borrow Pits)	Depth (feet)	Lagoons (C)	Depth (feet)
GeoEnviroTech (2011)	10	–12 to –15							6	–30.5 to –39.5
Moffatt & Nichol (2003)										
USACE Bailey (2002)										
USACE (2001) Phase 1	11	–17 to –22.5	5	–50 to –59						
USACE (2001) Phase 2	17	–17 to –22.5			24	–9 to –12				
Weston (1997)	10	–20	5	–60			2	–		
Caribbean Soils(1997)*									1	–75

*Not a source for the CMP

3.2 CORE BORINGS AND LABORATORY TESTING

The physical laboratory testing included geotechnical indexing tests. The indexing test included sieve analysis, Atterberg limits (liquid and plastic limit), standard penetration test, unit dry weight, moisture test, and visual soil classification. Laboratory testing was generally conducted on representative samples and the results of these tests were used to classify the various material layers.

3.2.1 Grain Size Analysis

Grain or particle-size analysis is the measurement of the proportion of the various sizes of primary soil particles as determined usually either by their capacities to pass through sieves of various mesh size or by their rates of settling in water. This geotechnical process assists in the classification of soils which, when known, aids in the understanding of the soils suitability for construction purposes as well as its predictability for soil water movement for dredging projects. The sediments that characterize the first 10 feet of the dredged channel are generally formed of soft to very soft black organic mud, clays, and silts with some lenses of sandy material. The sediments that characterize the first 40 feet on the channel banks show a large range of geotechnical conditions from soft to very soft black organic mud, clays, silts with some lenses of sandy material, consistent with the channel, then become stiff sandy clays and stiff silty clays, sandy gravels and clayey gravels. Gravels, cobbles and boulders may be present near the Cantera area. Other than the potential rocks near the Cantera area, there are no grain size issues to limit hydraulic dredging.

3.2.2 Atterberg Limits

Atterberg limits provide parameter inputs for the engineering planning, design, construction, operational, and management aspects of dredging and dredged material disposal. They are a set of index tests performed on fine grained silt/clay soils or sediments to determine the relative activity of the soils and their relationship to moisture content. The liquid limit (LL), plastic limit (PL) and shrinkage limits (SL) define the relative stages of behavior when the soil moves from the solid to liquid state. These limits are used to estimate strength and settlement characteristics of the materials and the water content boundaries between nonplastic, plastic, and viscous fluid states. The plasticity index (PI) and liquidity index (LI) are used to identify the potential range of plastic state. This test enables the prediction of the clumping capability in mechanical dredging. LL and PI provide an indication of the “clayeyness” of a soil. Materials with a high LL and PI are normally dense fine sediments that are unsuitable for many construction applications due to the “clayeyness.” The Bailey et al. (2002) report analyzed the Atterberg limits for the sediments collected in the previous studies. Due to the high contents of organic silts and clays within the sediment profiles, the LL and PI values in the channel and the banks of the CMP tend to be high.

3.2.3 Shear Strength

Shear strength values (τ) have been considered for the channel slopes. Where the channel slopes would be excavated, long-term drained shear strengths are generally considered to be critical. Under these conditions, pore pressures increase with time as the excavated material is relieved of the overburden pressure. This increase in pore pressure reduces the shear strength of the soil. Shear strength values and associated design parameters for channel slopes were derived from the available data including boring logs and laboratory test data, and test pits. Reduced pore pressure can also increase the potential for scour under high flows.

Shear strength values and associated design parameters for channel walls where established in the USACE (2001) report. The analysis was conducted because of the need for information on the lateral loads due to the fact that the channel banks would be lined with a concrete-capped sheet pile system. This information supported the recommended design methods considering the local anomalies. The shear strength values for the channel bank do not represent a concern for the dredging of the channel.

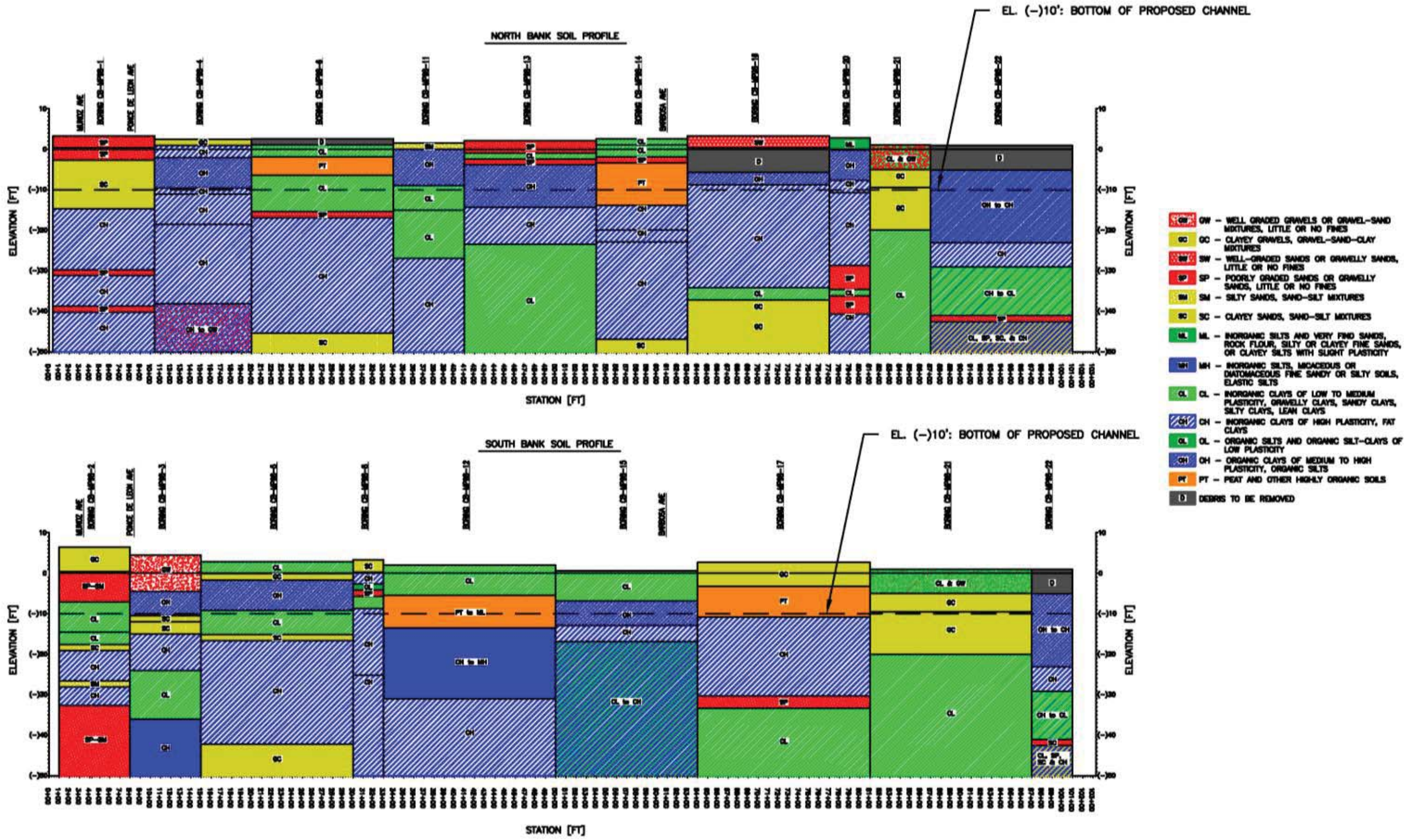
3.3 GEOTECHNICAL DATA INFORMATION

The geotechnical data gathered for the development of the alternative plans for the CMP was focused on the following specific aspects:

- The core boring data in the CMP channel;
- The core borings and test pits data on the CMP channel banks;
- The surficial sediments within the artificial depressions in the San José Lagoon (borrow pits); and
- Core borings within San José and Los Corozos Lagoons.

3.3.1 Geotechnical Data in the CMP Channel

A total of 48 core samples were collected in 1997, 2001, and 2011 within the CMP channel. The sediments that characterize the first 10 feet are formed mainly of soft to very soft black organic mud, clays, and silts with some lenses of sandy material. Several of the channel borings encountered very soft sediments with zero blow counts. The data available shows that the sediments to be dredged in the Project Channel from 0 to –10 feet should not present concerns to dredging activities based on the physical properties. A profile, prepared using the core boring logs, indicates the soil characteristics along the CMP Channel (Figure 3.3-1).



NOTE:
GEOTECH BORINGS CORRESPOND TO: DREDGING OF CANO MARTIN PENA FINAL PROJECT DESIGN REPORT AND ENVIRONMENTAL IMPACT STATEMENT.

Figure 3.3-1. Channel Soil Profile

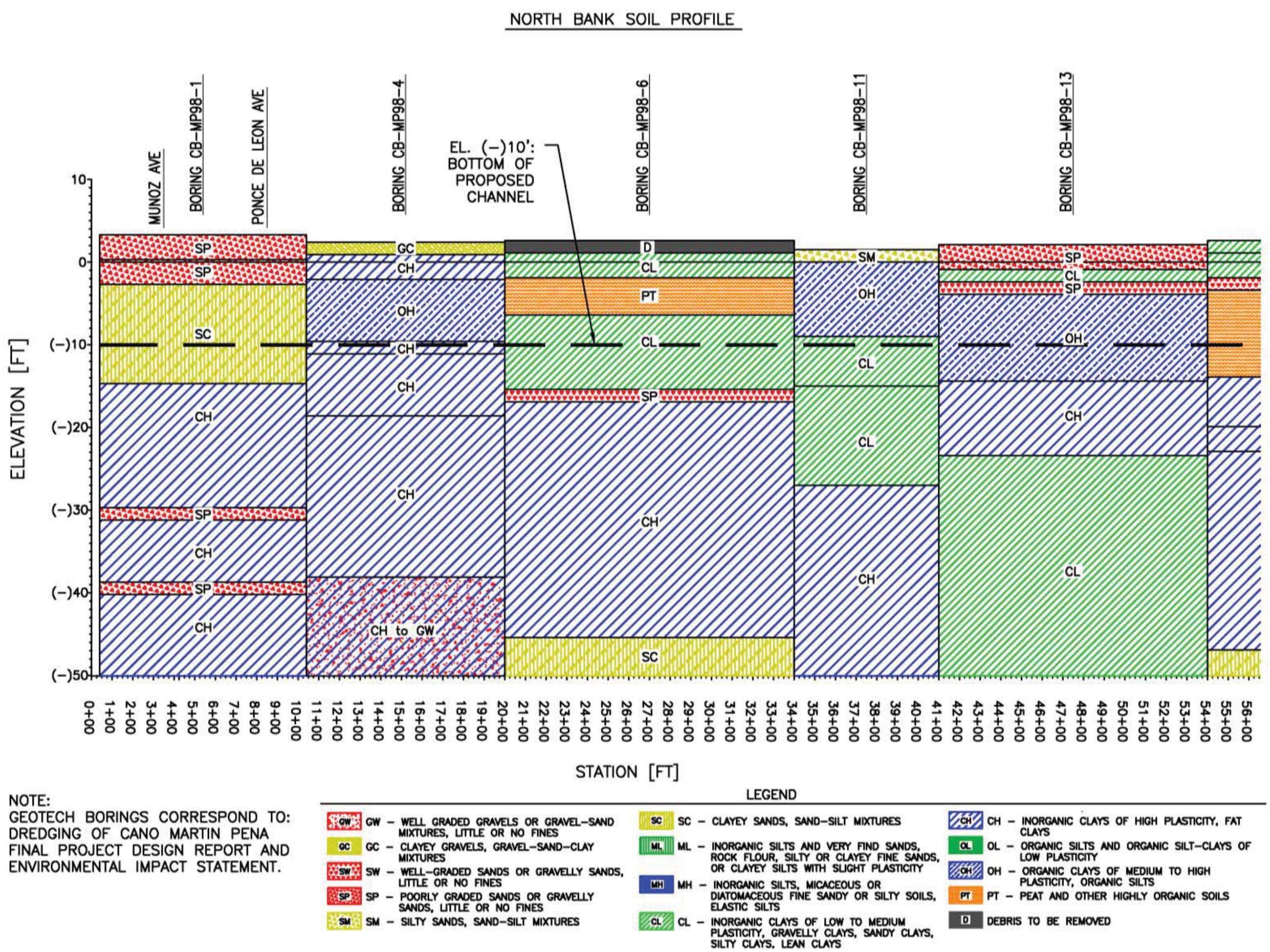


Figure 3.3-1, cont'd

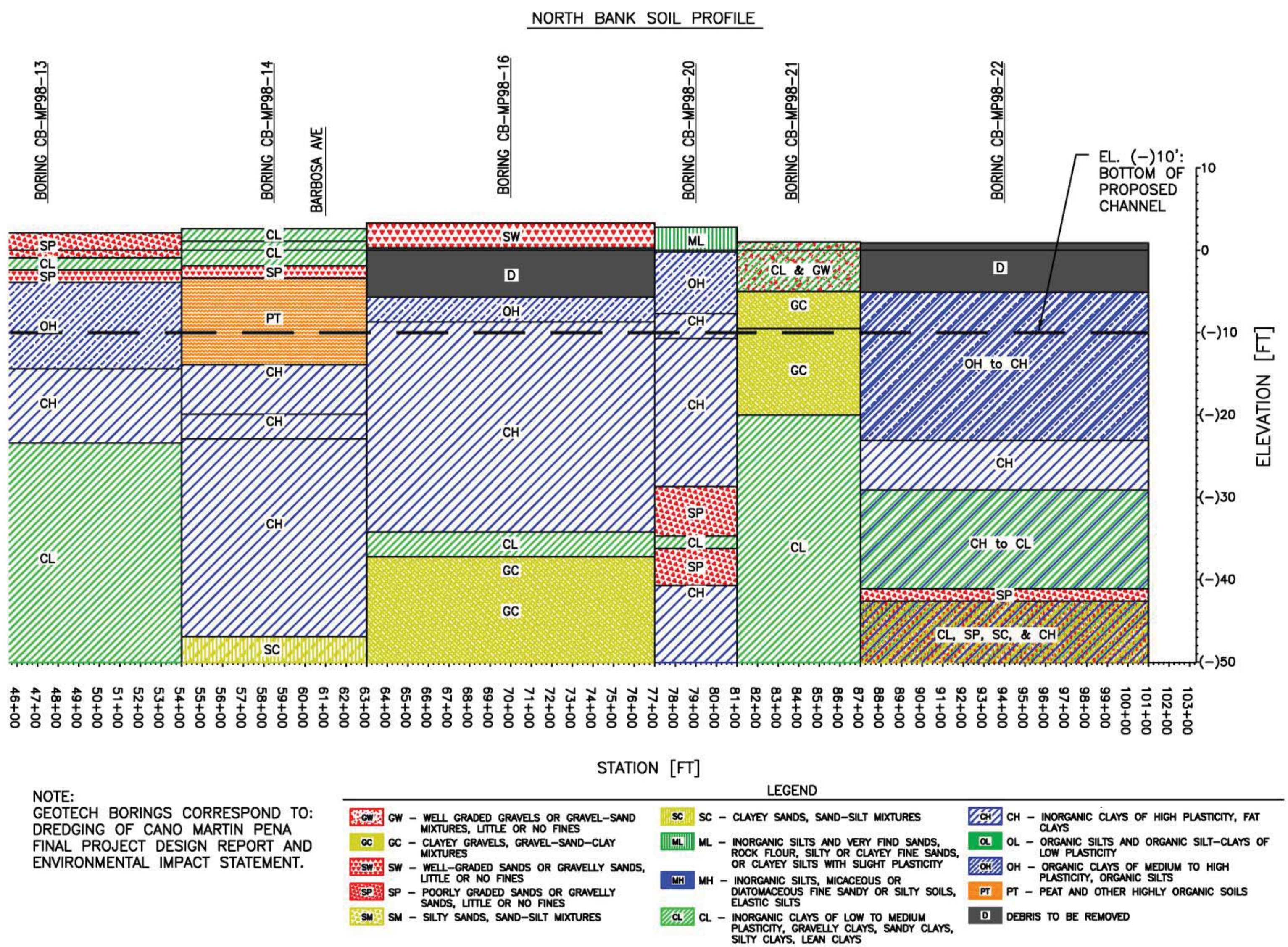


Figure 3.3-1, cont'd

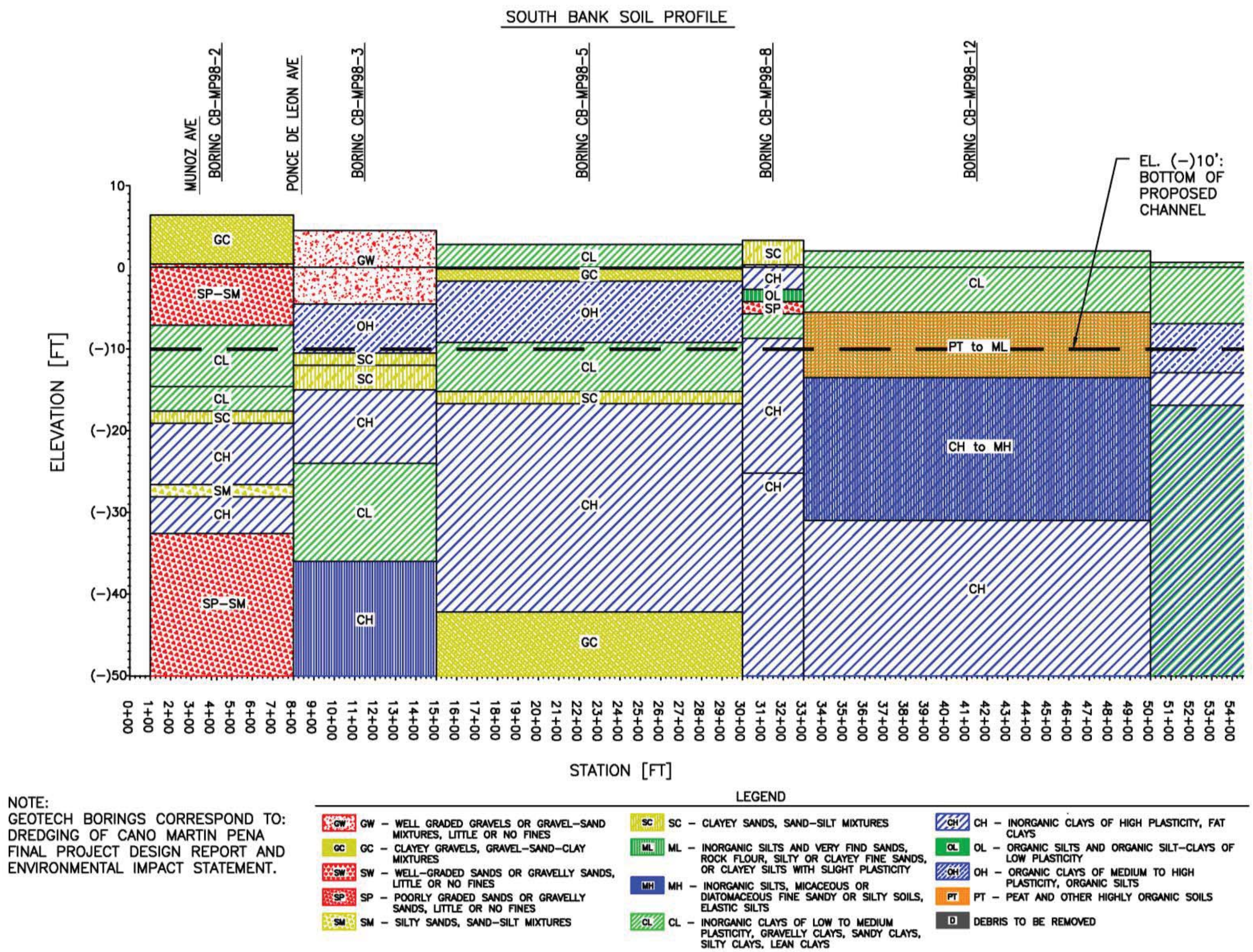


Figure 3.3-1, cont'd

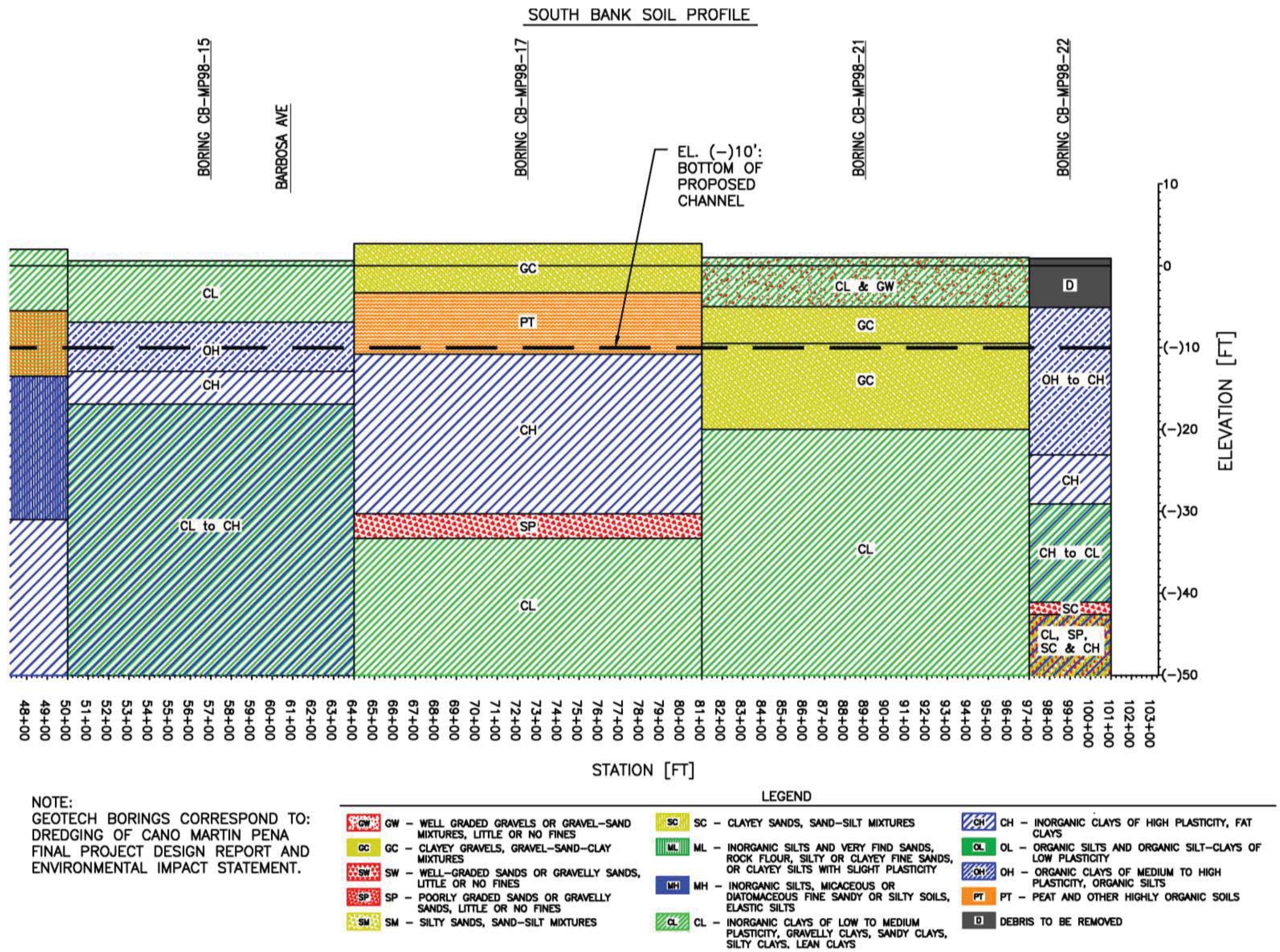


Figure 3.3-1, cont'd

3.3.2 Geotechnical Data in the Channel Banks

A total of 10 cores and 24 test pits were performed on the channel banks. The sediments that characterize the first 40 feet (used as the depth for the installation of the sheet pile, which will serve to stabilize the channel walls) shows a big range of geotechnical conditions: soft to very soft black organic mud, clays, silts with some lenses of sandy material, hard sandy clay and hard silty clay. Some clasts and gravels were also observed on specific areas. The blow counts at the surface reached from 1 up to 42 counts per foot associated with rubble and debris. Important concerns are present in the area near Cantera, where several cores reached the limestone in the channel at depths as shallow as –10.5 feet (USACE, 2001). The presence of gravels, cobbles and boulders in the channel from the limestone in the eastern side of the CMP may be possible (Table 3.3-1).

Table 3.3-1
Depth of Limestone in the Channel Banks

Core	Depth (feet)
CB-MP98-16	–40.5
CB-MP98-17	–36.0
CB-MP98-21	–10.5
CB-MP98-16	–43.5

Source: USACE 2001 Report.

In the Cantera area near core CB-MP98-21, limestone may appear in areas on the surface during the dredging of the channel. Limestone may present not only a concern for the installation of the sheet pile wall, but when dredging the channel as well. The dredge may encounter some small outcrops of the limestone, which may cause a modification in the means and methods of the dredging, including subsequent limestone removal as part of the debris management plan.

3.3.3 Solid Waste in the Cores

The Weston (1997) and USACE (2001) reports show that extensive filling took place in the main channel and the channel banks over the last 80 years. The reports conclude the fill material in the channel and channel banks consist mainly of solid waste (household waste and construction debris). The Bailey et al. (2002) report describes the presence of solid waste and debris content in CMP banks as observed in the test pits. The Weston (1997) report estimated a 5 percent solid waste content in the materials to be dredged. Considering the solid waste in the channel and the material to be dredged in the banks of the channel, which will have to be sloped for the sheet pile installation, a conservative estimate for use in the CMP-ERP is that 10 percent of the sediments are made up of solid waste. It should be noted that none of the previous testing and analysis included tests to determine the percent solid waste to sediment in the cores, which would be used to further refine the estimate of sediment to solid waste in the CMP.

In terms of solid waste, 24 out of 27 test pits showed the presence of household wastes and construction and demolition debris (C&D) materials from the surface to an elevation of –10 feet. In several cores along the channel bank, solid waste is noted to maximum depths averaging –10 feet with a few instances of 1 or 2 feet deeper. Solid waste is an important component of the volumes of material to be dredged and/or remove from the channel and the channel banks (Table 3.3-2).

Table 3.3-2. Maximum Depth of Debris in Test Pits

Core	Depth (feet)	Core	Depth (feet)	Core	Depth (feet)
TP-MP98-01	–2.5	TP-MP98-10	–10	TP-MP98-19	–9
TP-MP98-02	–11	TP-MP98-11	–6	TP-MP98-20	–10
TP-MP98-03	–12	TP-MP98-12	–5	TP-MP98-21	–7
TP-MP98-04	–10	TP-MP98-13	–9	TP-MP98-22	–1.5
TP-MP98-05	–7.5	TP-MP98-14	–11	TP-MP98-24	–10
TP-MP98-06	–10	TP-MP98-15	–12	TP-MP98-29	–11
TP-MP98-07	–3.5	TP-MP98-16	–7	TP-MP98-30	–4
TP-MP98-08	–10	TP-MP98-17	–11	TP-MP98-31	–9
TP-MP98-09	–9	TP-MP98-18	–10	TP-MP98-32	–11

Materials within the Caño Martín Peña include various types of solid waste, debris, and other materials. Such materials will require further testing prior to and/or during project construction, as appropriate, in accordance with an agreed sampling plan. If the testing determines that any materials contain hazardous substances at levels that are not suitable for unregulated disposal, they will be managed in accordance with the applicable laws and regulations of the relevant regulatory agencies.

3.4 CHANNEL AND SAN JOSÉ LAGOON PITS STABILITY

The USACE (2001) report included the geotechnical design for the sheet pile walls and channel dredging. The channel and channel banks would be dredged considering the local conditions. When dredging, it was determined that temporary construction channel bank slopes of 1V:3H (vertical:height) were considered safe from 0 to –5 feet and dredge slopes of 1V:5H in the channel from –5 to –10 feet were considered acceptable. It was determined that the sheet pile could be installed with a vibratory hammer and a diesel, steam or hydraulic pile hammer for sections of sheet pile that may not be able to be driven completely to the required tip elevation. During dredging operations, temporary slope angles would be maintained until the installation of the sheet pile. These actions would have to be managed from the water or from the shores of the channel.

3.5 ADDITIONAL GEOTECHNICAL INVESTIGATIONS NEEDED DURING PRECONSTRUCTION ENGINEERING AND DESIGN

Additional chemistry data and bioaccumulation tests are required to verify the presence, concentrations, and toxicity of contaminants in the Project Channel. Additional geotechnical investigations using test pits or other suitable methods are needed to determine the volume and location of dredged sediments that would be suitable and/or unsuitable for unconfined open-water disposal, as well as to refine the current proportion of sediment to solid waste, 90 percent to 10 percent, respectively.

The use of the San José Lagoon pits is considered as one of several options for the disposal of dredged sediment; however, there is insufficient data to characterize the stability of the pits during or after a disposal operation. Should disposal of dredged sediment in the pits become the recommended aquatic disposal option, this issue should be investigated in more detail to prevent potential landslides, mainly slumps during the disposal.

4.0 HYDRAULICS AND HYDROLOGY

The purpose of this section is to present a review and update to the previous hydraulic and hydrology studies performed by the USACE and ENLACE.

4.1 CLIMATOLOGY

4.1.1 Climate

The climate is tropical marine with warm and sunny days most of the year. The winds blow from the East and moderate temperatures and rainfall. Hurricanes frequently occur between August and October. The relative humidity is high, about 80 percent throughout the year.

4.1.2 Precipitation and Temperature

At the Rio Piedras Agricultural Substation in San Juan the National Climatic Data Center (NCDC) collected temperature and rainfall data from 1981 to 2010 (http://www.srh.noaa.gov/sju/?n=climo_san_juan). Table 4.1-1 provides a summary of the average high and low temperatures for each month and the average rainfall in each month. The average high temperature throughout the year is about 87.6 degrees Fahrenheit (°F) and the average low temperature is about 70.4°F. The average monthly temperatures do not deviate much from the yearly average. The average rainfall in a year at about 71 inches. Figure 4.1-1 provides a graphic of the mean annual precipitation from 1981 to 2010 for all of Puerto Rico (http://www.srh.noaa.gov/sju/?n=mean_annual_precipitation).

Table 4.1-1
Summary of Temperature and Rainfall Data Collected by the NCDC
from 1981 to 2010 at the Rio Piedras Agricultural Substation in San Juan

NCDC 1981–2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average High (F)	84.3	84.7	86.1	86.9	88.3	89.9	89.6	90.3	90.0	89.3	86.7	84.8	87.6
Average Low (F)	66.8	66.5	67.2	68.8	71.5	72.9	73.3	73.6	73.1	72.5	70.6	68.3	70.4
Average Rain (in.)	4.79	3.19	3.52	5.80	7.17	4.54	6.70	6.44	7.39	6.79	8.06	6.39	70.78

4.1.3 Storms and Floods of Record

The study area has experienced numerous floods from hurricanes, tropical storms, and heavy rainfall. A description of significant storms and floods is presented in Figure 4.1-1 and Table 4.1-2 (http://www.srh. noaa.gov/sju/?n=tropical02).

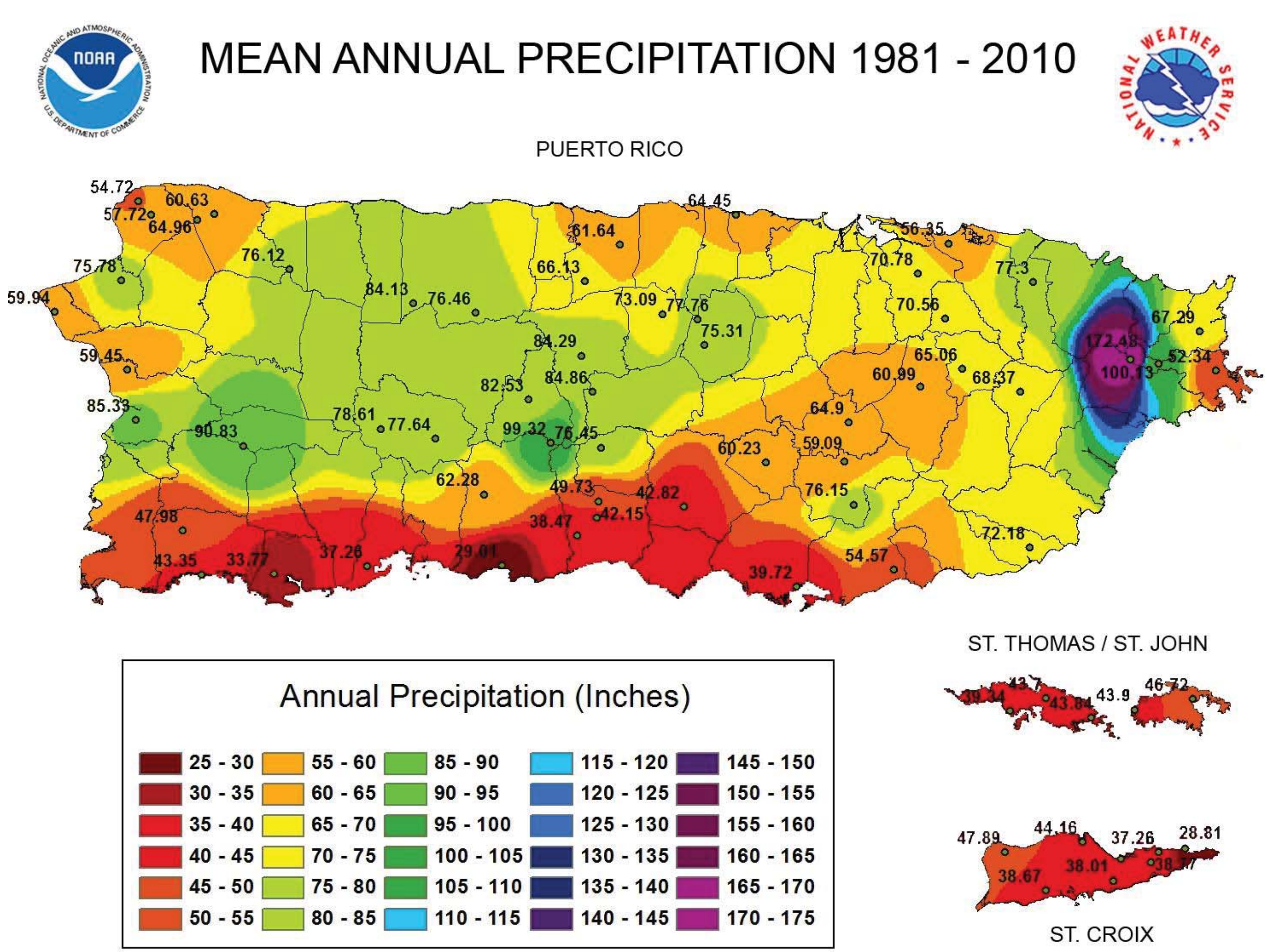


Figure 4.1-1. Mean annual precipitation for Puerto Rico from 1971 to 2000

Table 4.1-2
Storms and Their Effects on Puerto Rico

2009, Sep 04-05	Tropical Storm Erika developed from a wave that originally came off the coast of Africa. Mostly located in the mid- and upper-levels of the atmosphere, the wave never became very organized at the surface to maintain its strength. As a result, Erika was downgraded to a tropical depression and remnant low as it passed south of Puerto Rico and the U.S. Virgin Islands.
2009, August 17	Tropical Storm Ana was the first Cape Verde storm of the 2009 season. It eventually weakened into a depression as it traversed the tropical Atlantic before passing just to the south of Puerto Rico and the U.S. Virgin Islands.
2008, October 14-16	Hurricane Omar passed within 1 degree latitude to the south of Puerto Rico and the U.S. Virgin islands in a southwest to northeast direction.
2007, December 11-12	Subtropical Storm Olga moved westward along the northern coast of Puerto Rico on December 11 and then made landfall along the northern coast of Puerto Rico around 0700 UTC (3 AM AST)
2007, August 17-18	Hurricane Dean passed to the south of Puerto Rico and the U.S. Virgin Islands from east to west.
2004, September 15-16	Tropical Storm Jeanne passed just south of St Croix and then entered southeast Puerto Rico near Maunabo and traveled west then north and west again across Puerto Rico and exited over the northwest tip of the island near Aguadilla.
2001, August 22-23	Tropical Storm Dean formed from a tropical wave over the Virgin Islands on August 22nd and a Hurricane Hunter plane indicated winds near hurricane force later that day. The system encountered an unfavorable environment the next day north of Puerto Rico and weakened to a tropical wave. Winds to tropical storm force were reported in the U.S. Virgin Islands and there was an estimated $2 million in damage due to flooding in Puerto Rico.
2000, August 21-23	Hurricane Debby passed just north of St Thomas and within 1^{o} latitude to the northeast of Puerto Rico in an E-SE to W-NW direction.
1999, November 16-18	Hurricane Lenny passed within 1^{o} latitude to the south of Puerto Rico and the U.S. Virgin Islands in a W to E direction and then eventually turned E-NE over the northern Leeward Islands and into the Atlantic..
1999, October 20-21	Tropical Storm Jose passed within 1^{o} latitude to the northeast of Puerto Rico and the U.S. Virgin Islands in a E-SE to W-NW direction and then turned N-NE once in the Atlantic to the north of our local islands.
1998, September 21-22	Hurricane Georges passed over St Croix in the U.S. Virgin Islands and then entered Puerto Rico near Humacao and traveled through the interior of the island exiting just south of Mayaguez in Cabo Rojo. The hurricane traveled mainly in an E to W direction.

1997, September 5-8	Hurricane Erika passed about 2° latitude northeast of Puerto Rico and the U.S. Virgin Islands in a SE to NW direction.
1996, September 9-10	Hurricane Hortense passed over the southwest corner of Puerto Rico in a SE to NW direction.
1996, July 8-9	Hurricane Bertha passed just northeast of Puerto Rico and the U.S. Virgin Islands in a SE to NW direction.
1995, October 23-24	As Tropical Storm Sebastien passed within 1° latitude southeast of U.S. Virgin Islands it weakened to a tropical depression and then dissipated just SE of Puerto Rico as it moved in a NE to SW direction.
1995, September 15-16	Hurricane Marilyn passed over St. Thomas in the U.S. Virgin Islands in a SE to NW direction.
1995, September 5-6	Hurricane Luis passed just north of U.S. Virgin Islands in a SE to NW direction.
1993, August 16	Tropical Storm Cindy passed almost 2° southwest of Puerto Rico in a SE to NW direction.
1990, October 7	Tropical Storm Klaus passed just northwest of northern U.S. Virgin Islands in a E-SE to W-NW direction.
1989, September 17-18	Hurricane Hugo passed over St Croix…then Vieques and Culebra and the northeast corner of Puerto Rico in a SE to NW direction.
1989, August 3-4	Hurricane Dean passed almost 2° northeast of Puerto Rico in a SE to NW direction.
1988, September 10	Tropical Storm Gilbert turned into Hurricane Gilbert as it passed about 2° latitude south of Puerto Rico in a SE to NW direction.
1987, September 22	Hurricane Emily passed almost 2° latitude southwest of Puerto Rico in a SE to NW direction.
1984, November 6-7	Tropical Storm Klaus passed just between Puerto Rico and the U.S. Virgin Islands in a SW to NE direction.
1981, September 8	Tropical Storm Gert passed just near St. Croix and then over the northeast corner of Puerto Rico in a SE to NW direction.
1981, September 4	Tropical Storm Floyd passed within 1° latitude of northern U.S. Virgin Islands in a SE to NW direction.
1979, September 3-4	Tropical Storm Frederic passed over St. Croix and then traveled right along the southern coast of Puerto Rico in a E to W direction.
1979, August 30	Hurricane David passed about 1° latitude south of Puerto Rico in a E-SE to W direction.

1979, July 17-18	Tropical Storm Claudette passed over northern U.S. Virgin Islands and weakened to a Tropical Depression just as it hit the northeast coast of Puerto Rico. It then traveled right along the northern coastline of Puerto Rico in a E to W direction.
1975, September 15	Tropical Depression developed into Tropical Storm Eloise just as it reached within 1^o north of the northeastern tip of Puerto Rico as it passed in a E to W direction.
1974, August 29-30	Tropical Depression developed into Tropical Storm Carmen as it passed about 1^o south of Puerto Rico in a E to W direction.
1973, September 3-4	Tropical Storm Christine weakened into a tropical depression before passing over the northern U.S. Virgin Islands and just northeast of the NE tip of Puerto Rico. It dissipated shortly afterwards.
1967, September 9-10	Hurricane Beulah passed within 1^o southwest of southwestern corner of Puerto Rico in a SE to NW direction.
1966, September 28	Hurricane Inez passed about 1^o latitude south of Puerto Rico and St. Croix in a E to W direction.
1966, August 26	Hurricane Faith passed about 1^o latitude northeast of the Virgin Islands in a E-SE to W-NW direction.
1965, August 28-29	Tropical Depression turned into Tropical Storm Betsy within 2^o latitude E -NE of U.S. Virgin Islands in a S to N direction. Shortly afterwards it became Hurricane Betsy.
1964, August 22-23	Hurricane Cleo passed within 2^o latitude south of Puerto Rico from a E to W direction.
1963, September 26-27	Hurricane Edith headed due N toward the southwestern tip of Puerto Rico and then turned due W just before making land.
1961, October 2-3	Hurricane Frances passed within 1^o latitude from the southwestern corner of Puerto Rico in a SE to NW direction
1960, September 4-6	Hurricane Donna passed within 1^o latitude from St. Thomas in the U.S. Virgin Islands.
1959, August 18-19	Tropical Storm Edith passed within 1^o latitude south of Puerto Rico and the U.S. Virgin Islands from a E to W direction.
1958, September 13-14	Tropical Storm Gerda passed about 1^o latitude from southwestern corner of Puerto Rico in a ESE to WNW direction
1956, August 11-12	Hurricane Betsy (Santa Clara) crossed Puerto Rico in a SE to NW direction.

1955, September 11-12	Tropical storm Hilda passed within 1° latitude north of St. Thomas in the U.S.V.I. in a ESE to WNW direction reaching hurricane intensity on the 12th.
1955, January 3	Hurricane Alice passed within 1° latitude southeast of St. Croix in the U.S.V.I. in a ENE to WSW direction.
1954, August 30-31	Tropical storm Dolly formed just off the northwestern corner of Puerto Rico and moved off in NNW direction.
1953, September 14	Tropical storm Edna passed within 1° latitude northeast of the Virgin Islands in a SE to NW direction.
1950, August 23	Tropical storm passed over the southwest corner of Puerto Rico in a ESE to WNW direction.
1949, September 2-3	Tropical storm developed between Puerto Rico and the Virgin Islands and moved northwest, reaching hurricane intensity and changing course to northward after passing 20° N latitude on the 3rd day.
1947, October 16-17	Tropical storm passed just northeast of St. Thomas in the U.S.V.I. in a SE to NW direction.
1945, September 12-13	Hurricane passed within 2° latitude north of the Virgin Islands and Puerto Rico in a ESE to WNW direction.
1945, August 3	Tropical storm passed within 1° latitude of the southwestern corner of Puerto Rico in a ESE to WNW direction.
1944, July 12-13	Tropical storm apparently developed just off the northwest corner of Puerto Rico and moved northwestward.
1943, October 14	Hurricane passed between Hispaniola and Puerto Rico in a S to N direction.
1943, August 13-14	Tropical storm passed just northeast of St. Thomas in the U.S.V.I. in a ESE to WNW direction.
1942, November 4	Tropical storm apparently developed just off southeastern Puerto Rico and crossed the northeastern part of the island in a ESE to WNW direction.
1940, August 5	Tropical storm passed just north of St. Thomas in the U.S.V.I. in a ESE to WNW direction.
1939, August 7	Tropical storm apparently developed about 1o latitude northeast of St. Thomas in the U.S.V.I. and moved northwestward.
1938, August 8	Tropical storm passed through Virgin Islands and skirted north coast of Puerto Rico in a E to W direction.

1937, August 24-25	Tropical storm passed within 2º latitude northeast of Virgin Islands in a ESE to WNW direction.
1934, September 18	Tropical storm passed within 2º latitude northeast of Virgin Islands in a SE to NW direction.
1934, August 21-22	Tropical storm passed within 2º latitude south of Puerto Rico in a E to W direction.
1933, September 27-28	Tropical storm passed within 1º latitude south of Puerto Rico in a E to W direction.
1933, July 25-26	Tropical storm passed just northeast of Virgin Islands in a ESE to WNW direction.
1932, September 26-27	Destructive hurricane, known as San Ciprian, passed through Virgin Islands and across Puerto Rico in a E to W direction.
1931, September 10-11	Violent hurricane known as San Nicolas, passed through Virgin Islands and skirted north coast of Puerto Rico in a E to W direction causing destruction along a strip 10 to 12 miles wide.
1931, August 17	Tropical storm crossed Puerto Rico in a SE to NW direction.
1928, September 13	Devastating Hurricane San Felipe II passed through Puerto Rico in a SE to NW direction.
1916, July 12-14	Tropical storm passed through Virgin Islands in a SE to NW direction.
1915, August 10-12	Hurricane skirted south coasts of St. Croix , U.S.V.I. and Puerto Rico in a E to W direction.
1910, September 6-7	Hurricane skirted south coast of Puerto Rico in a E to W direction.
1910, August 24-25	Tropical storm passed off south coast of Puerto Rico in a E to W direction.
1909, November 12-13	Tropical storm passed off northwestern corner of Puerto Rico in a WSW to ENE direction.
1908, September 26-27	Tropical storm passed off south coast of Puerto Rico in a E to W direction.
1908, September 9-10	Hurricane passed off north coast of Puerto Rico in a E to W direction.
1903, July 19-20	Tropical storm crossed Puerto Rico in a ESE to WNW direction.

1901, October 8-10	Tropical storm crossed northeastern corner of Puerto Rico in a SE to NW direction.
1901, September 11-13	Tropical storm skirted north coast of Puerto Rico in a SE to NW direction.
1901, July 6-8	Hurricane crossed southwestern Puerto Rico in a SE to NW direction.
1900, October 24-26	Tropical storm crossed southwestern corner of Puerto Rico in a SE to NW direction.
1900, August 30-September 1	Tropical storm skirted south coast of Puerto Rico in a E to W direction.
1899, August 7-8	Disastrous hurricane known as San Ciriaco, crossed Puerto Rico in a ESE to WNW direction.
1898, September 21-22	Tropical Storm crossed northeastern Puerto Rico in a ESE to WNW direction.
1896, August 31-September 1	Hurricane crossed southwestern corner of Puerto Rico in a SE to NW direction.
1893, August 16-17	Hurricane passed Puerto Rico in a ESE to WNW direction.
1891, August 19-20	Hurricane crossed eastern Puerto Rico in a SE to NW direction.
1889, September 3	A very destructive hurricane in St. Thomas. It passed east of the U.S. Virgin Islands in a SE to NW direction.
1876, September 13	A violent hurricane known as San Felipe I. It struck St. Thomas and skirted the south coast of Puerto Rico.
1867, October 29	The most violent hurricane in many parts of Puerto Rico, known as San Narcisco. Accounts indicate it was a was a storm of small diameter and rapid movement. Also affected St. Thomas in the U.S. Virgin Islands where 1,000 lives were lost.
1852, September	Affected Puerto Rico; exact date unknown.
1851, August 18-19	A violent hurricane, known as Santa Elena,(also known as San Agapito) skirted the south coast and crossed the southwestern corner of Puerto Rico in a ESE to WNW direction.
1846, September 12-13	Passed by northeastern corner of Puerto Rico in a SE to NW direction.

1840, Sep. 16	Severely affected Puerto Rico.
1837, August 2-3	A violent hurricane, known as Los Angeles, struck St. Thomas and skirted the northeastern coast of Puerto Rico in a ESE to WNW direction.
1837, July 31	Severely affected St. Thomas in the U.S. Virgin Islands.
1835, August 13	Crossed Puerto Rico in a ESE to WNW direction.
1830, August 11-12	Severely affected St. Thomas in the U.S. Virgin Islands.
1827, August 28	Affected Virgin Islands severely, especially St. Thomas.
1827, August 18-19	Very destructive hurricane crossed Puerto Rico in a SE to NW direction.
1825, July 26-27	A very violent hurricane, known as Santa Ana, which was very destructive in Puerto Rico.
1819, September 22	Very destructive in Virgin Islands and severe in Puerto Rico.
1818, September 22	Seriously affected Puerto Rico.
1816	A violent hurricane passed over Puerto Rico; exact date unknown.
1814, July 22-23	Affected Puerto Rico.
1813, July 23	Affected Puerto Rico.
1812, July 23, August 21	Seriously affected Puerto Rico.
1807, August 17-19	Severe hurricane from the east lasted 50 hours in Puerto Rico.
1804, September 21	This great hurricane known as San Mateo II, remained in the memory of Puerto Ricans for a very long time.
1788, August 16	Seriously affected Puerto Rico.
1785, September 25	A furious hurricane that passed over Puerto Rico.
1780, October 14	Probably the most devastating hurricane of record up to this date. It is known as "The Great Hurricane." Passed over southwestern corner of Puerto Rico in a SE to NW direction.
1772, August 28	Affected Puerto Rico.
1767, August 7	Plantations destroyed and livestock drowned in Puerto Rico.

1751, August 18	Affected Puerto Rico.
1740, August	Affected Puerto Rico; exact date unknown.
1738, September 12	Affected Puerto Rico.
1615, September 12	The most severe hurricane to affect Puerto Rico in 40 years. (This suggests that other tropical storms may have occurred between 1575 and 1615.)
1575, September 21	Severe Hurricane, known as San Mateo I in Puerto Rico.
1568, August 24	Affected Puerto Rico.
1537, July and August	Three hurricanes within 2 months in Puerto Rico; exact dates unknown. Many slaves and cattle drowned.
1515, July	Exact date unknown. Caused death of many Indians in Puerto Rico.

4.1.4 Tides

4.1.4.1 Tidal Station

The tidal station referenced for the CMP-ERP is the La Puntilla station, number 9755371. It is located across the San Juan Bay at the U.S. Coast Guard Station on La Puntilla, latitude 18° 27.5' N, longitude: 66° 6.9' W, NOAA Chart #25670. Tides have a mean range of 1.10 feet and a diurnal range of 1.58 feet.

Due to the clogging of the CMP, there is presently little to no tidal exchange between San Juan Bay "proper" (located to the west of the western end of the CMP) and San José Lagoon (i.e., Bunch et al. 2000, Cerco et al. 2003, USACE 2004).

4.1.4.2 Tidal Datum

Per NOAA, elevations of tidal datum referred to Mean Lower Low Water (MLLW). Conversions from NOAA to NGVD 29 are presented as well.

	Meters (NOAA)	Feet (NOAA)	Feet (NGVD 29)
Highest Observed Water Level (09/21/1998)	0.849	2.785	2.02
Mean Higher High Water (MHHW)	0.480	1.575	0.80
Mean High Water (MHW)	0.400	1.312	0.54
Mean Sea Level (MSL)	0.234	0.768	0.00
Mean Tide Level (MTL)	0.232	0.761	-0.01
Mean Low Water (MLW)	0.063	0.207	-0.56
Mean Lower Low Water (MLLW)	0.000	0.000	-0.77
Lowest Observed Water Level (12/20/1968)	–0.331	–1.085	-1.86

4.1.5 FEMA Flood Mapping

The entire CMP-ERP lies within flood zone AE (see Figure 4.1-2). FEMA mapping indicates base flood elevations (100-year) along the CMP at 5.9 feet (1.8 meters) MSL. The 100-year floodplain extends up to 1,100 feet south and up to 1,800 feet north from the channel. These base flood levels are influenced by the storm surges at San José Lagoon and San Juan Bay (USDHS, 2009).

Figure 4.1-2. Flood Insurance Rate Map

4.1.6 Site Topography and Water Bodies

The SJBE discharges into the Atlantic Ocean through the San Juan Bay (and Condado Lagoon) and through Boca de Cangrejos.

The CMP connects San Juan Bay and San José Lagoon across a 3.75-mile channel that varies in width from 55 meters west of Ponce de León Avenue to approximately 6 meters, and smaller, along the eastern portion of the channel. San José Lagoon receives runoff from two major urbanized water-courses; Quebrada Juan Méndez and Quebrada San Antón.

Suárez Canal, located southeast of Luis Muñoz Marín International Airport, connects the San José Lagoon and La Torrecilla Lagoon with a 2.3-mile channel that receives runoff from part of the airport and Urbanización Los Angeles. La Torrecilla Lagoon, located east of the airport, discharges into the Atlantic Ocean through Boca de Cangrejos and receives runoff from the urban watershed of Quebrada Blasina (Channel Blasina). La Torrecilla Lagoon actually connects to Piñones Lagoon through Channel Blasina, via Channel Piñones, which is located 850 meters upstream of Blasina's mouth at La Torrecilla Lagoon.

Maximum elevations along the channel's northern watershed are approximately 100 feet MSL, and street slopes are approximately of 4 percent. Elevations along the communities located south of the channel are gentler, with maximum elevations of approximately 33 feet MSL and street slopes averaging 1 percent.

4.2 HYDRAULIC AND HYDROLOGIC STUDIES

The purpose of the hydrologic and hydraulic study is to describe the project's pre and post construction flood potential. The work included a review of existing studies and confirming the drainage area and rainfall data. Since the project includes the potential closure of the channel during construction to control the dispersion of contaminants turbid water, the study compares flooding in a closed versus open channel. Each of the proposed channel sections flood potential, with and without storm surge was evaluated. Lastly, interior drainage flows were calculated to determine stormwater management needs and the required sizing of culverts for stormwater conveyance from the community into the Project Channel.

4.2.1 Prior Hydraulic and Hydrology Studies

Prior studies contributing to the hydrologic and hydraulic analysis for the CMP-ERP included the following:

- *FEMA Mapping*: According to FEMA mapping, the base flood elevation (100-year) along the CMP is 5.9 MSL. The 100-year floodplain extends up to 1,150 feet south and up to 1,899 feet north from the channel.

- *CMA Architects & Engineers LLP, "Hydrologic-Hydraulic Study, Caño Martín Peña Rehabilitation CMP-ERP, Puerto Rico Highway and Transportation Authority Dredging of Caño Martín Peña, San Juan, Puerto Rico," February 2003*. The study determined peak discharges for all watersheds tributary to the SJBE system, and flood levels along CMP for existing conditions and for three channel geometry alternatives.

- *CMA Architects & Engineers LLP and UNIPRO Architects, Engineers and Planners, "Estudio de Instalaciones de Alcantarillado Pluvial" (Study of Stormwater Sewer Installations) for the Puerto Rico Highway and Transportation Authority in February 2003*. The study identifies existing drainage areas and stormwater infrastructure, and documents the extent of the existing flooding issues through meetings with the community.

4.2.2 Scope and Purpose of CMP-ERP Hydrologic and Hydraulic Study

This document presents the hydrologic-hydraulic analysis of the CMP as prepared by Gregory Morris Engineering, P.S.C. The study was undertaken to determine:

1. Drainage area and 2-, 5-, 10-, 25-, 50-, 100-year peak discharges for the watersheds tributary to the San Juan Bay Estuary System using recent rainfall data published by the National Oceanic and Atmospheric Administration (NOAA);
2. The 2-, 5-, 10-, 25-, 50-, 100-year flood levels along the CMP under an Existing and "Plugged" Condition: closing the channel at the Ponce de León Avenue to minimize the dispersion of contaminants while the dredging is under way);
3. The 2-, 5-, 10-, 25-, 50-, 100-year flood levels along CMP under Proposed Widths of 75-, 100- and 125-foot Conditions, with and without storm surge;
4. Interior drainage for 10- and 25-year events, and hydraulic design parameters for structures required to convey interior drainage into the restored CMP; and
5. Runoff volumes directly entering the CMP, and sizing of detention areas intended for stormwater quality enhancement.

4.2.3 San Juan Bay Estuary Hydrologic Analysis

4.2.3.1 Study Approach and Methodology

The hydrologic analysis was performed using the USACE-approved Interconnected Channel and Pond Routing Model (adICPR) unsteady flow hydrologic-hydraulic modeling system (Streamline Technologies v3.0, Winter Park, Florida). Hydrographs were calculated by the Natural Resources Conservation Service's (NRCS) Unit Hydrograph (UH) methodology with a peaking factor of 484. The analysis was performed for the 2-, 5-, 10-, 25-, 50- and 100-year events.

4.2.3.2 Watershed Delimitation

Watersheds were delimited using USGS topographic mapping and verified through field visit. The watershed tributary to the San Juan Bay Estuary System was divided into a total of ten sub-basins: six for the area that drains into CMP east of Ponce de León Avenue, and four for the system's remaining major drainage areas, as seen in Figure 4.2-1 and 4.2-2, respectively.

The watershed tributary to Piñones Lagoon consists mainly of the area east of the lagoon, which corresponds to the western portion of the Río Grande de Loíza floodplain. The area that drains into La Torrecilla Lagoon corresponds mainly to Quebrada Blasina and the eastern portion of the airport. The watershed tributary to San José Lagoon covers areas of San Juan and Carolina. The area that drains into CMP west of Ponce de León Avenue consists mainly of Hato Rey.

The area draining into CMP, east of Ponce de León Avenue, consists of Barrio Obrero, Barrio Obrero Marina, Buena Vista Santurce, Cantera, Parada 27, Las Monjas, Buena Vista Hato Rey, and Israel y Bitumul. The existing storm sewer drainage systems in most of these communities are combined with the sanitary sewer (Figure 4.2-3). Figure 4.2-4 illustrates the physical location of the adICPR nodes.

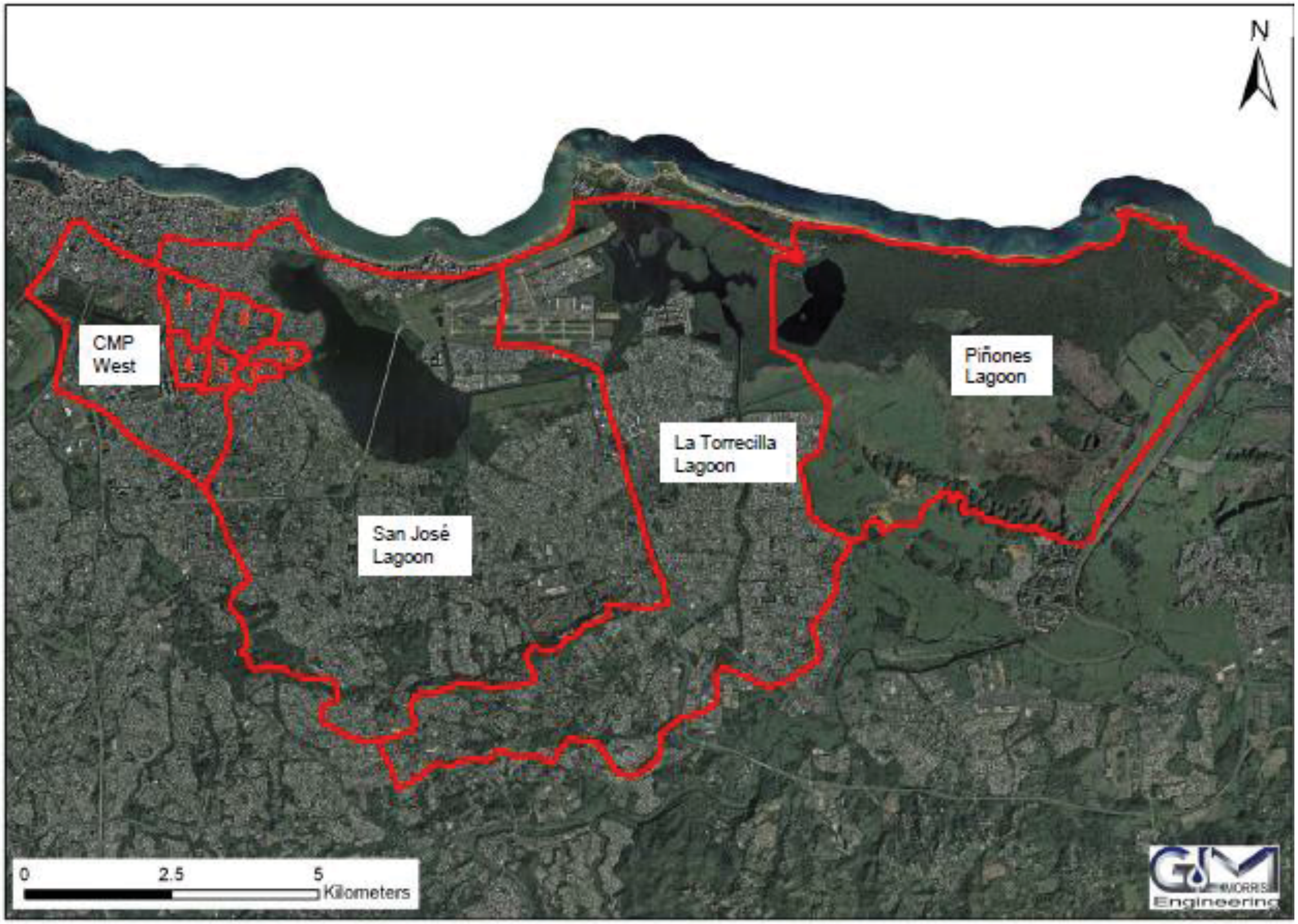


Figure 4.2-1. Major San Juan Bay Estuary System Watershed Limits

Figure 4.2-2. Watershed Limits for areas draining into CMP east of Ponce de León Avenue

Figure 4.2-3. Existing Storm Sewers North of CMP

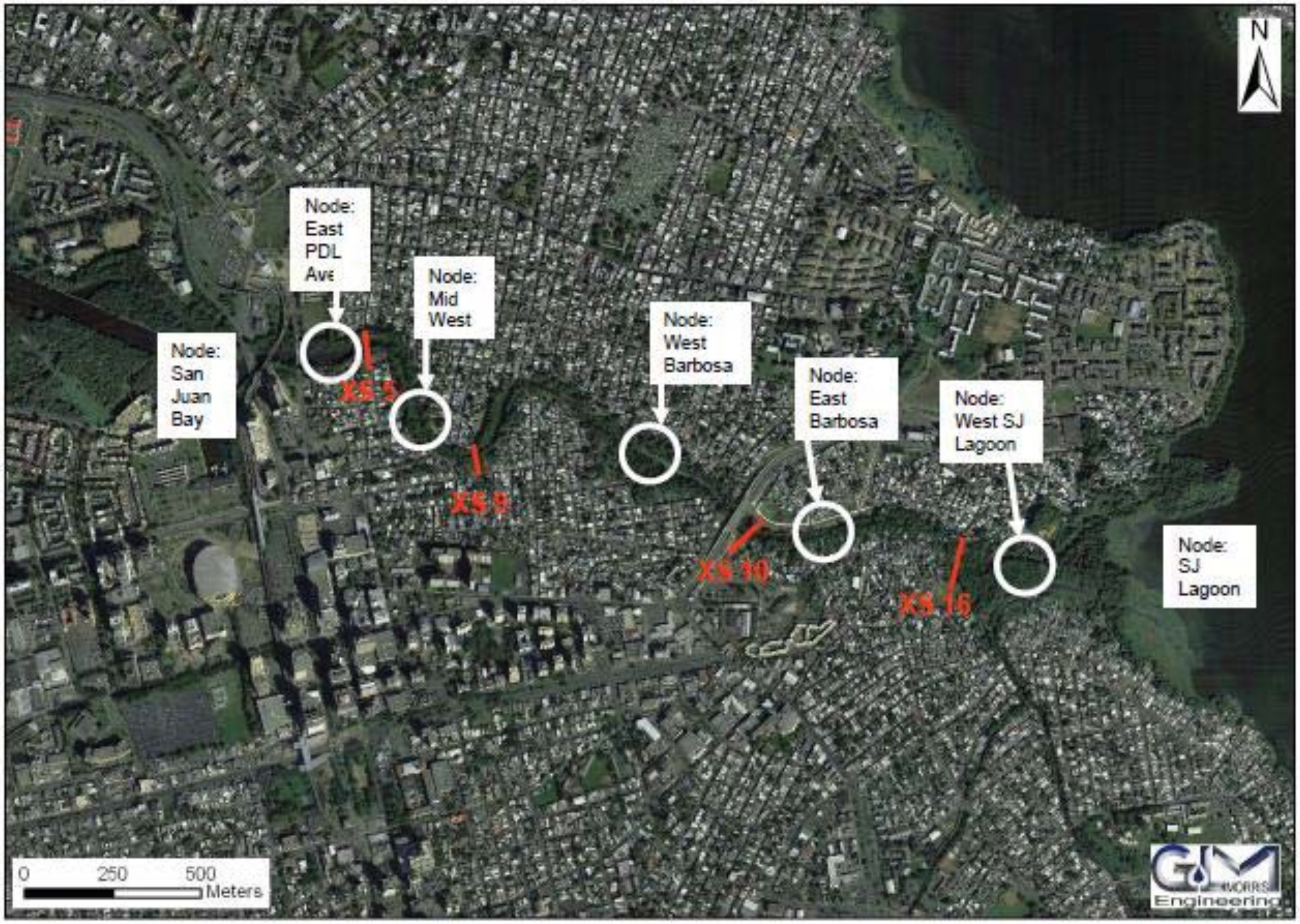


Figure 4.2-4. Physical Location of the adICPR Nodes

4.2.3.3 Time of Concentration

The time of concentration (tc) is the time required for a drop of water falling on the most distant point of the watershed to influence discharge at the watershed exit. The time of concentration was calculated using Soil Conservation method (TR-55). For sheet flow calculation the following equation was used:

$$t_c \quad \frac{0.007 * (n * L)^{0.8}}{P_2^{0.5} * S^{0.4}}$$

where:

t_c = time of concentration (hours)
n = Manning's roughness coefficient
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (4.01 in)
S = slope of hydraulic grade line (land slope, ft/ft)

For shallow concentrated flow calculation the following equation was used:

$$t_c \quad \frac{L}{60 \times V}$$

where:

t_c = time of concentration (minutes)
L = flow length (ft)
V = average velocity of flow (ft/s)

For channel flow, Manning's equation was used to calculate velocity:

$$V \quad \frac{1.49 * R^{2/3} * S^{1/2}}{n}$$

where:

V = channel velocity (ft/s)
R = channel hydraulic radius (ft)
S = channel slope
n = Manning's roughness coefficient

The travel time along the channel was calculated with the following equation:

$$t_c \quad \frac{L}{60 * V}$$

where:

t_c = time of concentration (minutes)
L = channel length (ft)
V = average velocity of flow (ft/s)

4.2.3.4 Soil Types and Curve Number

Curve Number represents the runoff potential within a watershed and is estimated based on soil type (hydrologic soil group), land use and Antecedent Moisture Condition (AMC). In this study an AMC-II was used. The watershed tributary to the San Juan Bay Estuary System is almost fully urbanized, except for the area that drains into Piñones Lagoon. A Curve Number of 98 was used for urbanized areas, and a Weighted Curve Number was calculated for watershed "Piñones Lagoon." Soil types within the watersheds were obtained from Soil Survey Geographic Database (SSURGO), which contains the most detailed level of soil mapping performed by the Natural Resources Conservation Service (NRCS).

Table 4.2-1 and 4.2-2 show the hydrologic parameters for the major watersheds tributary to the San Juan Bay Estuary System, and for the watersheds that drain into CMP east of Ponce de León Avenue, respectively.

Table 4.2-1
Hydrologic Parameters of San Juan Bay Estuary System Watersheds

Watershed	Area (km^2)	Time of Concentration (min)	CN
Piñones Lagoon	31.8	401.6	89
La Torrecilla Lagoon	36.3	213.7	98
San José Lagoon	45.0	148.3	98
CMP West	7.3	54.7	98

Table 4.2-2
Hydrologic Parameters of Watersheds that drain into CMP east of Ponce de León Avenue

Watershed	Area (km^2)	Time of Concentration (min)	CN
CMP 1	0.91	27.0	98
CMP 2	0.83	15.8	98
CMP 3	0.33	10.0	98
CMP 4	0.46	45.1	98
CMP 5	0.38	62.8	98
CMP 6	0.24	13.3	98

4.2.3.5 Rainfall Depths

Hyetographs were constructed for the drainage areas using the 100-year rainfall depths as reported in NOAA Atlas 14 published October 26, 2006. This publication updates and replaces similar data contained in Technical Paper-42 (1961).

Table 4.2-3 presents 100-year rainfall duration and depths used to construct the dimensionless hyetograph. Table 4.2-4 shows the 24-hour rainfall depths for the 2-, 5-, 25-, and 50-year events.

Table 4.2-3
100-year Rainfall Durations and Depths; NOAA Atlas

Duration (hrs)	Rainfall Depth	
	inches	centimeters
0.5	1.96	4.98
1	2.91	7.39
2	4.08	10.36
3	4.71	11.96
6	6.60	16.76
12	9.01	22.89
24	11.43	29.03

Table 4.2-4
24-hour, 2-, 5-, 25-, 50-year Rainfall Depths; NOAA Atlas

Return Interval (years)	Rainfall Depth	
	inches	centimeters
2	4.01	10.19
5	5.83	14.81
10	7.11	18.06
25	8.79	22.33
50	10.10	25.65

4.2.3.6 Results of Hydrologic Analysis

Table 4.2-5 shows the peak discharge for the major watersheds tributary to the SJBE system. Table 4.2-6 shows the peak discharge for the watersheds that drain into CMP east of Ponce de León Avenue.

Table 4.2-5
Peak Discharges of Major San Juan Bay Estuary System Watersheds

Watershed	Peak Discharge (m^3/s)					
	2-year	5-year	10-year	25-year	50-year	100-year
Piñones Lagoon	62	99	125	159	185	212
La Torrecilla	127	186	227	281	323	365
San José Lagoon	193	283	345	427	491	556
CMP West	54	80	97	120	138	156

Table 4.2-6
Peak Discharges of CMP Watersheds east of Ponce de León Avenue

Watershed	Peak Discharge (m^3/s)					
	2-year	5-year	10-year	25-year	50-year	100-year
CMP 1	9.7	14.2	17.3	21.4	24.6	27.8
CMP 2	10.9	16.0	19.5	24.1	27.7	31.4
CMP 3	4.9	7.2	8.7	10.8	12.4	14.1
CMP 4	3.8	5.5	6.7	8.3	9.6	10.8
CMP 5	2.6	3.8	4.7	5.8	6.7	7.6
CMP 6	3.3	4.9	6.0	7.4	8.5	9.6

4.2.3.7 Comparison to Previous Study

Table 4.2-7 compares peak discharges with previous hydrology (CMA, 2003), which used TP-42 rainfall data and a Type-II rainfall distribution. Our analysis uses a local rainfall distribution based on NOAA Atlas-14 rainfall depths.

Variations between the two studies correspond mainly to differences in time of concentration and rainfall data and rainfall distribution. The GME (2011) study utilized the most current data. Hydrology performed with up-to-date rainfall data provided a more accurate result than hydrology performed with outdated rainfall data.

Table 4.2-7
Comparison to Previous Hydrology

Watershed	Storm Event	CMA (2003)	GME (2011)
Piñones Lagoon	2-year	19	62
	5-year	24	99
	10-year	28	125
	25-year	33	159
	50-year	37	185
	100-year	42	212
La Torrecilla	2-year	155	127
	5-year	187	186
	10-year	219	227
	25-year	251	281
	50-year	282	323
	100-year	314	365
San José Lagoon	2-year	257	193
	5-year	309	283
	10-year	362	345
	25-year	399	428
	50-year	466	491
	100-year	518	556
CMP East and West*	2-year	150	89
	5-year	180	131
	10-year	211	160
	25-year	241	198
	50-year	271	228
	100-year	301	258

*Compares CMA's watershed "CMP East and West" with the sum of basins "CMP West" and basins "CMP 1 through 6."

4.2.4 Hydraulic Analysis of Caño Martín Peña

4.2.4.1 Study Approach and Methodology

The hydraulic analysis of the CMP was performed using the USACE-approved Interconnected Channel and Pond Routing Model (adICPR) unsteady flow hydrologic-hydraulic modeling system (Streamline Technologies v3.0, Winter Park, Florida). The adICPR model dynamically routes stormwater through open channels, closed conduits and detention ponds. The program's solution algorithm allows it to simulate a variety of complex conveyance systems. Each node in adICPR represents a control volume. Change in storage for each node is calculated based on the difference between inflows and outflows at each time step during the simulation period. The change in storage is used to determine elevations at each node at the end of each time step. Flow through each link is calculated from the known elevations at each end of the link and the hydraulic properties of the link.

The analysis was performed to determine the effects on flood levels of closing the CMP channel at the Ponce de León Avenue bridge to minimize the dispersion of contaminants (closing of area towards the western half of the channel while the dredging is under way) for the existing channel geometry. The hydraulic model covers a total reach of approximately 11,500 feet, from the Ponce de León Avenue to San José Lagoon, and it was prepared for the 2-, 5-, 10-, 25-, 50-, and 100-year events.

4.2.4.2 Models Prepared for the Hydraulic Analysis

The CMP was modeled as "closed" at the eastern face of the Ponce de León Avenue bridge. This condition basically forces runoff that enters CMP to flow east towards San José Lagoon. Model node locations were selected to best represent the hydraulic characteristics of the study reach. Figure 4.2-7 shows the physical location of the adICPR model nodes on recent aerial photography. Node "San Juan Bay" represents the portion of CMP, west of Ponce de León Avenue, which is directly influenced by the water level at San Juan Bay. Node "SJ Lagoon" represents the water level at the San José Lagoon.

The following models were prepared for the analysis of CMP:

1. **Existing Conditions without Storm Surge**. Models current hydraulic conditions along CMP, without storm surge at either San Juan Bay or San José Lagoon.
2. **"Plugged" Conditions without Storm Surge**. This model shuts off flow across the Ponce de León Avenue bridge, and it was run without storm surge at San José Lagoon. A water surface elevation of 0 foot MSL was used at San José Lagoon.
3. **Existing Conditions with Storm Surge**. This model simulates current hydraulic conditions in CMP, with a storm surge elevation of 5.9 feet MSL at San José Lagoon as published by FEMA in its FEMA FIRM panel 370J.
4. **"Plugged" Conditions with Storm Surge**. This model shuts off flow across the Ponce de León Avenue Bridge, and it was run with a storm surge elevation of 5.9 feet MSL at San José Lagoon as published by FEMA in its FEMA FIRM panel 370J.

4.2.4.3 Hydraulic Modeling Coefficients (Manning's n-value)

Manning's n-values were estimated based on field observations, recent photography, and checked with reference to Barnes (1967) and Chow (1959). The n-values were selected based on channel form, bed material and vegetation. Table 4.2-8 shows the coefficients used in hydraulic modeling.

Table 4.2-8
Hydraulic Coefficients Used in Modeling

Parameter	Value
MANNING'S N-VALUE	
Main Channel	0.04
Overbanks	0.08
COEFFICIENT OF EXPANSION	
Gradual Transition	0.1
Abrupt Transition	0.3
COEFFICIENT OF CONTRACTION	
Gradual Transition	0.3
Abrupt Transition	0.5

4.2.4.4 Results of CMP Hydraulic Analysis

Tables 4.2-9 through 4.2-14 compare water surface elevations at CMP under Existing and Plugged Conditions, with and without storm surge, for the 2-, 5-, 10-, 25-, 50- and 100-year events, respectively. Water levels along the CMP are directly influenced by the storm surge at San Juan Bay and San José Lagoon, for all of the analyzed return intervals.

Storms lower than 25-years in return interval, with storm surge, were virtually the same for the existing and plugged condition with a maximum difference in water level of 0.07 meter less for the plugged condition. Storms with return periods of 25 years or greater with storm surge experienced a maximum increase of 0.5 foot (0.15 meter). The plugged condition had slightly higher surface elevations, in some of the scenarios, by 0.03 to 0.36 foot (0.01 to 0.11 meter).

Table 4.2-9
2-year Water Surface Elevations at CMP

ICPR Node	Water Surface Elevation (m-MSL)					
	without storm surge			with storm surge		
	Existing Condition	Plugged Conditions	Diff	Existing Condition	Plugged Conditions	Diff
East PDL Ave	0.30	0.52	0.22	1.93	1.86	-0.07
Mid West	0.30	0.52	0.22	1.92	1.86	-0.06
West Barbosa	0.40	0.50	0.10	1.84	1.84	0.00
East Barbosa	0.50	0.43	-0.07	1.82	1.82	0.00
West SJ Lagoon	0.40	0.50	0.10	1.81	1.81	0.00
SJ Lagoon	0.00	0.00	0.00	1.80	1.80	0.00

Table 4.2-10
5-year Water Surface Elevations at CMP

ICPR Node	Water Surface Elevation (m-MSL)					
	without storm surge			with storm surge		
	Existing Condition	Plugged Conditions	Diff	Existing Condition	Plugged Conditions	Diff
East PDL Ave	0.30	0.72	0.42	1.93	1.91	-0.02
Mid West	0.30	0.72	0.42	1.92	1.90	-0.02
West Barbosa	0.43	0.59	0.16	1.85	1.86	0.01
East Barbosa	0.50	0.53	0.03	1.83	1.84	0.01
West SJ Lagoon	0.50	0.50	0.00	1.82	1.82	0.00
SJ Lagoon	0.00	0.00	0.00	1.80	1.80	0.00

Table 4.2-11
10-year Water Surface Elevations at CMP

ICPR Node	Water Surface Elevation (m-MSL)					
	without storm surge			with storm surge		
	Existing Condition	Plugged Conditions	Diff	Existing Condition	Plugged Conditions	Diff
East PDL Ave	0.30	0.85	0.55	1.93	1.94	0.01
Mid West	0.31	0.85	0.54	1.92	1.94	0.02
West Barbosa	0.51	0.69	0.18	1.86	1.88	0.02
East Barbosa	0.50	0.62	0.12	1.84	1.85	0.01
West SJ Lagoon	0.50	0.50	0.00	1.82	1.82	0.00
SJ Lagoon	0.00	0.00	0.00	1.80	1.80	0.00

Table 4.2-12
25-year Water Surface Elevations at CMP

ICPR Node	Water Surface Elevation (m-MSL)					
	without storm surge			with storm surge		
	Existing Condition	Plugged Conditions	Diff	Existing Condition	Plugged Conditions	Diff
East PDL Ave	0.30	1.00	0.70	1.93	1.99	0.06
Mid West	0.39	1.00	0.61	1.92	1.99	0.07
West Barbosa	0.60	0.82	0.22	1.88	1.91	0.03
East Barbosa	0.54	0.73	0.19	1.85	1.88	0.03
West SJ Lagoon	0.50	0.50	0.00	1.83	1.83	0.00
SJ Lagoon	0.00	0.00	0.00	1.80	1.80	0.00

Table 4.2-13
50-year Water Surface Elevations at CMP

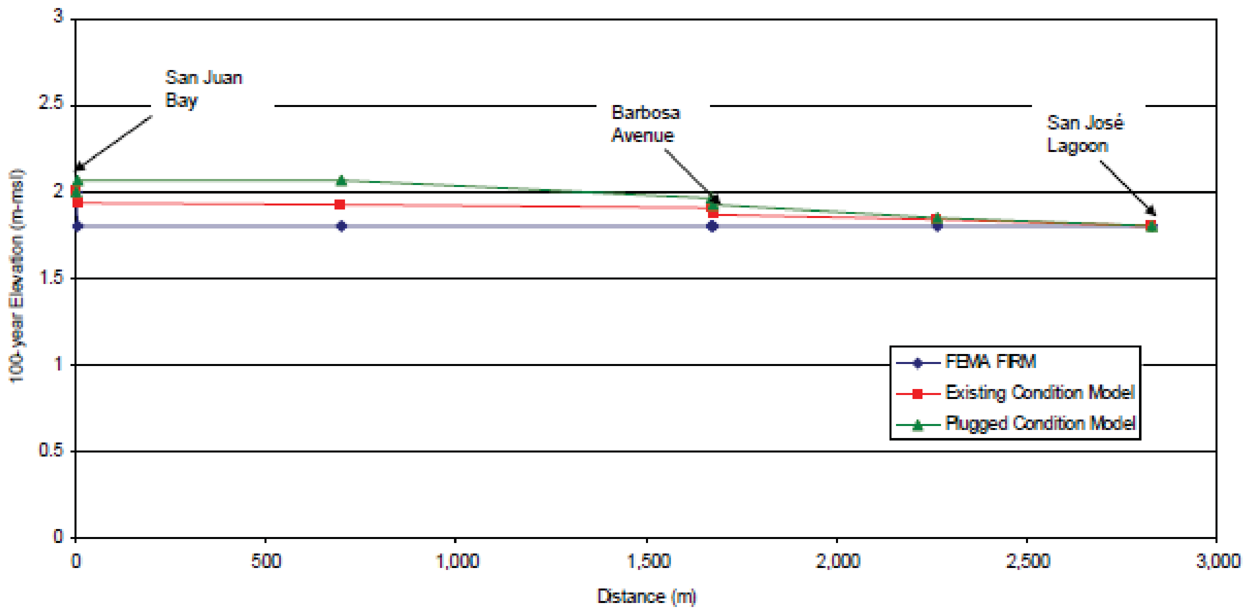
ICPR Node	Water Surface Elevation (m-MSL)					
	without storm surge			with storm surge		
	Existing Condition	Plugged Conditions	Diff	Existing Condition	Plugged Conditions	Diff
East PDL Ave	0.34	1.10	0.76	1.93	2.03	0.10
Mid West	0.45	1.10	0.65	1.92	2.03	0.11
West Barbosa	0.67	0.90	0.23	1.89	1.94	0.05
East Barbosa	0.61	0.81	0.20	1.86	1.90	0.04
West SJ Lagoon	0.50	0.51	0.01	1.83	1.94	0.11
SJ Lagoon	0.00	0.00	0.00	1.80	1.80	0.00

Table 4.2-14
100-year Water Surface Elevations at CMP

ICPR Node	Water Surface Elevation (m-MSL)					
	without storm surge			with storm surge		
	Existing Condition	Plugged Conditions	Diff	Existing Condition	Plugged Conditions	Diff
East PDL Ave	0.39	1.20	0.81	1.93	2.07	0.14
Mid West	0.51	1.20	0.69	1.92	2.07	0.15
West Barbosa	0.74	0.98	0.24	1.91	1.96	0.05
East Barbosa	0.67	0.89	0.22	1.87	1.92	0.05
West SJ Lagoon	0.50	0.58	0.08	1.84	1.85	0.01
SJ Lagoon	0.00	0.00	0.00	1.80	1.80	0.00

Figure 4.2-5 compares the Existing Condition (with storm surge) 100-year water surface profile with FEMA base flood elevations. The Existing Condition Model provides flood levels similar to those reported in FEMA's FIRM, which also represents flooding conditions with storm surge. The maximum increase in water surface elevation between Existing and "Plugged" Conditions, with storm surge, is 0.5 foot (0.15 meter). This increase occurs approximately 2,300 feet east of Ponce de León.

Figure 4.2-5. Comparison of FEMA, Existing and Plugged Condition Model (with storm surge) 100-year water surface profile



Storm events without storm surge are the ones most affected by the blocking of flow at Ponce de León Avenue, particularly in areas closer to the bridge. For the 100-year event without storm surge, water surface increases under "Plugged" Conditions at the eastern face of Ponce de León a maximum of 0.81 meter.

4.2.5 Results of Proposed Condition Model

The proposed condition is the three project channel alternatives, the 10-x-75, 10-x-100, and the 10-x-125-foot channels. Tables 4.2-15 through 4.2-20 show the Proposed Condition water surface elevations, with and without storm surge. Storm surge elevations controls water levels along CMP under proposed conditions, for all return interval rainfall events. The maximum difference in water levels between the three proposed channel alternatives is 0.07 foot (0.02 meter), with or without storm surge. During rainfall events without storm surge, the decrease in water levels is due to the reestablishment of the direct connection between water levels at CMP and water levels at San Juan Bay and San José Lagoon, which will allow standing water levels at CMP to be lower at the beginning of the storm event.

Table 4.2-15
2-year Water Surface Elevations (m-MSL) for Proposed Widths of 75, 100, and 125 Feet

	Without storm surge				With storm surge			
ICPR Node	**Existing**	**75 ft**	**100 ft**	**125 ft**	**Existing**	**75 ft**	**100 ft**	**125 ft**
East PDL Ave	0.30	0.02	0.02	0.02	1.93	1.91	1.90	1.89
Mid West	0.30	0.03	0.02	0.02	1.92	1.90	1.88	1.88
West Barbosa	0.40	0.03	0.02	0.02	1.84	1.86	1.86	1.86
East Barbosa	0.50	0.02	0.01	0.01	1.82	1.84	1.83	1.83
West SJ Lagoon	0.50	0.02	0.01	0.01	1.81	1.82	1.81	1.81
SJ Lagoon	0.00	0.00	0.00	0.00	1.80	1.80	1.80	1.80

Table 4.2-16
5-year Water Surface Elevations (m-MSL) for Proposed Widths of 75, 100, and 125 Feet

	Without storm surge				With storm surge			
ICPR Node	**Existing**	**75 ft**	**100 ft**	**125 ft**	**Existing**	**75 ft**	**100 ft**	**125 ft**
East PDL Ave	0.30	0.03	0.03	0.03	1.93	1.91	1.90	1.89
Mid West	0.30	0.05	0.04	0.03	1.92	1.90	1.88	1.88
West Barbosa	0.43	0.05	0.04	0.03	1.85	1.86	1.86	1.86
East Barbosa	0.50	0.04	0.02	0.02	1.83	1.84	1.83	1.83
West SJ Lagoon	0.50	0.03	0.02	0.01	1.82	1.82	1.81	1.81
SJ Lagoon	0.00	0.00	0.00	0.00	1.80	1.80	1.80	1.80

Table 4.2-17
10-year Water Surface Elevations (m-MSL) for Proposed Widths of 75, 100, and 125 Feet

	Without storm surge				With storm surge			
ICPR Node	**Existing**	**75 ft**	**100 ft**	**125 ft**	**Existing**	**75 ft**	**100 ft**	**125 ft**
East PDL Ave	0.30	0.04	0.04	0.04	1.93	1.91	1.90	1.89
Mid West	0.31	0.07	0.05	0.04	1.92	1.90	1.88	1.88
West Barbosa	0.51	0.07	0.05	0.04	1.86	1.86	1.86	1.86
East Barbosa	0.50	0.06	0.03	0.02	1.84	1.84	1.83	1.83
West SJ Lagoon	0.50	0.04	0.02	0.02	1.82	1.82	1.81	1.81
SJ Lagoon	0.00	0.00	0.00	0.00	1.80	1.80	1.80	1.80

Table 4.2-18
25-year Water Surface Elevations (m-MSL) for Proposed Widths of 75, 100, and 125 Feet

	Without storm surge				With storm surge			
ICPR Node	**Existing**	**75 ft**	**100 ft**	**125 ft**	**Existing**	**75 ft**	**100 ft**	**125 ft**
East PDL Ave	0.30	0.05	0.05	0.05	1.93	1.91	1.90	1.89
Mid West	0.39	0.10	0.07	0.06	1.92	1.90	1.88	1.88
West Barbosa	0.60	0.10	0.07	0.06	1.88	1.86	1.86	1.86
East Barbosa	0.54	0.08	0.05	0.03	1.85	1.84	1.83	1.83
West SJ Lagoon	0.50	0.06	0.04	0.02	1.83	1.82	1.81	1.81
SJ Lagoon	0.00	0.00	0.00	0.00	1.80	1.80	1.80	1.80

Table 4.2-19
50-year Water Surface Elevations (m-MSL) for Proposed Widths of 75, 100, and 125 Feet

	Without storm surge				With storm surge			
ICPR Node	**Existing**	**75 ft**	**100 ft**	**125 ft**	**Existing**	**75 ft**	**100 ft**	**125 ft**
East PDL Ave	0.34	0.06	0.06	0.06	1.93	1.91	1.90	1.89
Mid West	0.45	0.12	0.09	0.07	1.92	1.90	1.88	1.88
West Barbosa	0.67	0.12	0.09	0.07	1.89	1.86	1.86	1.86
East Barbosa	0.61	0.10	0.06	0.04	1.86	1.84	1.83	1.83
West SJ Lagoon	0.50	0.08	0.05	0.03	1.83	1.82	1.82	1.81
SJ Lagoon	0.00	0.00	0.00	0.00	1.80	1.80	1.80	1.80

Table 4.2-20
100-year Water Surface Elevations (m-MSL) for Proposed Widths of 75, 100, and 125 Feet

	Without storm surge				With storm surge			
ICPR Node	**Existing**	**75 ft**	**100 ft**	**125 ft**	**Existing**	**75 ft**	**100 ft**	**125 ft**
East PDL Ave	0.39	0.07	0.07	0.06	1.93	1.91	1.90	1.89
Mid West	0.51	0.14	0.10	0.08	1.92	1.90	1.88	1.88
West Barbosa	0.74	0.15	0.10	0.08	1.92	1.86	1.86	1.86
East Barbosa	0.67	0.12	0.07	0.05	1.87	1.84	1.83	1.83
West SJ Lagoon	0.50	0.09	0.06	0.04	1.84	1.83	1.82	1.81
SJ Lagoon	0.00	0.00	0.00	0.00	1.80	1.80	1.80	1.80

4.2.6 Interior Drainage Analysis

4.2.6.1 Study Approach and Methodology

The purpose of this analysis is to identify the impacts caused by the proposed restoration on the existing storm sewer and provide hydraulic design recommendations.

The Puerto Rico Planning Board's "*Normas de Diseño de Alcantarillado Pluvial, 1975*" requires that minor storm sewer systems for residential areas less than 150 acres be designed for the 10-year event, and that the system's slopes shall not produce flow velocities lower than 2 ft/s and higher than 40 ft/s. The existing storm sewer system was designed more than 35 years ago, and most likely does not comply with current regulations and requirements. In addition, the storm sewer's hydraulic capacity has been compromised by an unknown amount of sanitary sewage that enters the combined system. The current hydraulic capacity of the combined system was not determined in this study.

As part of ENLACE's implementation of the district's integrated development plan, sanitary and storm sewers will be separated into independent systems. Even though this analysis does not include the design of the proposed storm and sewer systems, it does provide hydraulic design recommendations for the conveyance structure required immediately upstream of CMP to convey street runoff under the proposed boardwalk and into the CMP.

Culvert analysis was performed using the Federal Highway Administration's (FHWA) HY-8 (v 7.2) program. Culverts capacity was determined for free-outfall conditions and a minimum 3 percent slope.

4.2.6.2 Current Flooding Issues

Existing flooding issues have been documented in the past through meeting with the community organized by the Puerto Rico Highway and Transportation Authority (PRHTA) in 2003. The following is a summary of current flooding issues.

Residents of Barrio Obrero have indicated that frequent flooding occurs at the storm sewer inlets located along Avenida Rexach. These inlets are easily clogged by garbage carried by runoff from streets north of the avenue, even during small rainfall events. Residents have also indicated that overflow of the sanitary sewer system occurs along Calle 15, Calle 11, Calle 5, Calle Lippit and Avenida Rexach. Major flooding issues were reported by residents along Calle San Ciprian and Calle Dolores. Residents of Marina indicate that some areas lack sanitary sewers, and that the storm sewer is clogged. They also indicate that the low lying areas adjacent to the CMP are most affected during storm events. Buena Vista Santurce drains into the CMP via pumping from the Barrio Obrero Pump Station.

Las Monjas residents have indicated that the storm sewer system is currently clogged and poorly maintained. The storm sewer outlets at the CMP are clogged by growing vegetation. In Buena Vista Hato Rey residents state that overflow of sanitary sewer occurs at Calle C and Calle 3.

There are areas in the vicinity of the CMP-ERP with existing ground elevations too low to drain into the proposed channel. These are areas with elevations near mean low water and are likely to be wetlands now and if outside of the proposed channel improvements and their drainage is not currently collected at pump stations, will continue to be wetlands after construction. The draining of these areas is not part of the CMP-ERP. Construction of the Project Channel would not impede the flow of runoff from the community, and the proposed channel would affect more positive flow of stormwater away from the area.

4.2.6.3 Impact on Existing Storm Sewer Infrastructure

The existing drainage system north of the channel is shown in Figure 4.2-9. The area west of Calle William drains into the CMP by gravity (areas identified as “Barrio Obrero Oeste” and “Buena Vista Santurce Oeste”), while the area east of Calle William is pumped into CMP by the Barrio Obrero Pump Station (area identified as “Buena Vista Santurce Este”). The hydraulic analysis was performed only for the area that drains into the CMP by gravity.

Figure 4.2-6 shows the portion of existing storm sewer that would be impacted with the restoration of the CMP.

4.2.6.4 Interior Drainage Areas

The analyzed drainage areas were selected based on topography, as seen in figures 4.2-7 and 4.2-8, to determine the runoff which drains superficially along the streets that run perpendicular to CMP. Existing storm inlets along Borinquen Avenue, Avenue A, and Rexach Avenue are frequently clogged with sediment and solid waste, and runoff that fails to enter these inlets continues south along the streets until it reaches the CMP. Peak discharges were determined for the 10- and 25-year events. Peak discharges were determined with the Rational Method, which is based on the following equation:

$$Q \quad C * I * A$$

where:

Q = peak discharge (ft^3/s)
C = runoff coefficient
I = rainfall intensity (in/hr)
A = drainage area (acres)

Figure 4.2-6. Portion of Existing Storm Sewer Affected by CMP Restoration

Figure 4.2-7. Drainage Areas North of CMP used in interior drainage analysis

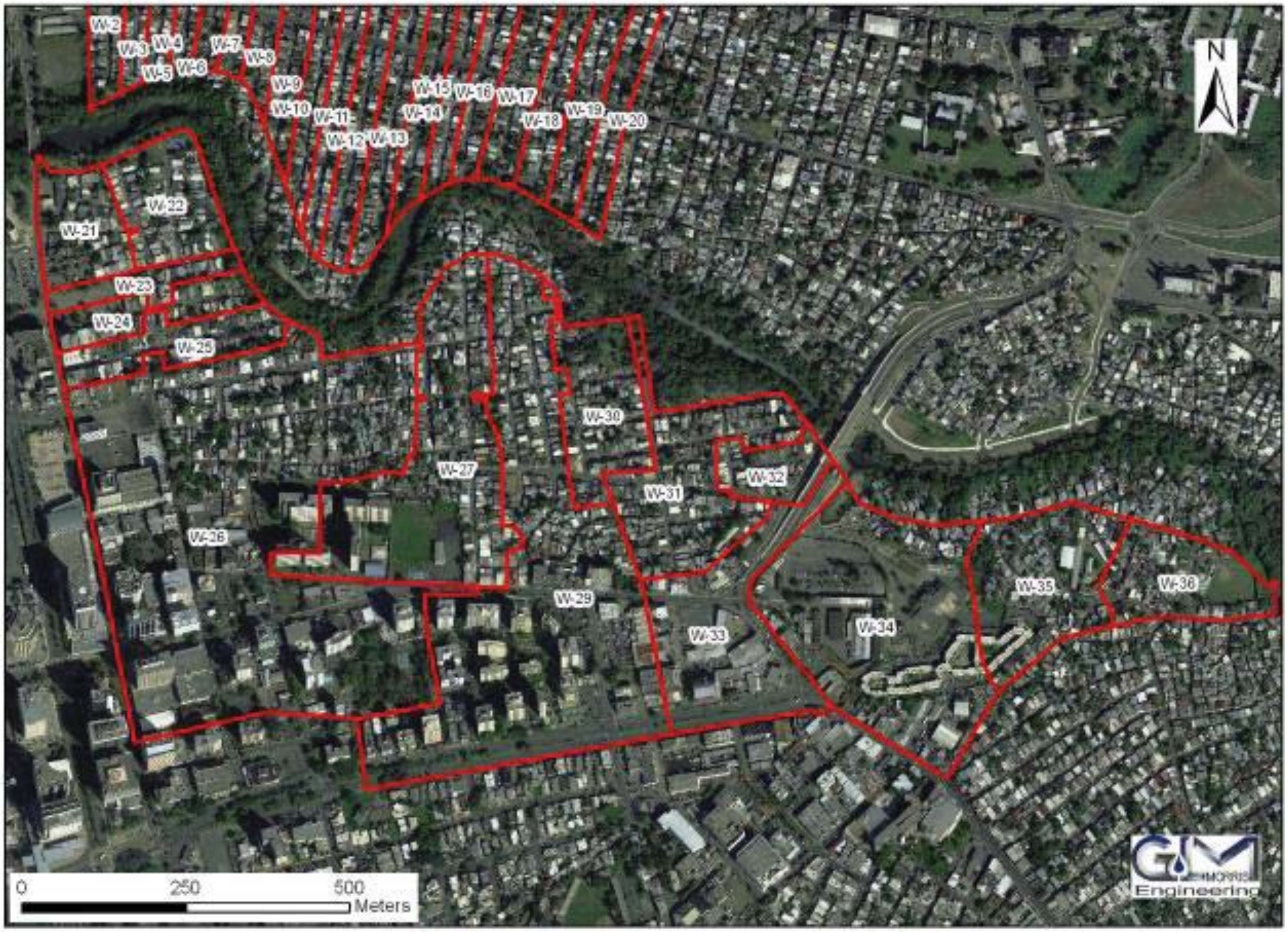


Figure 4.2-8. Drainage Areas south of CMP used in interior drainage analysis

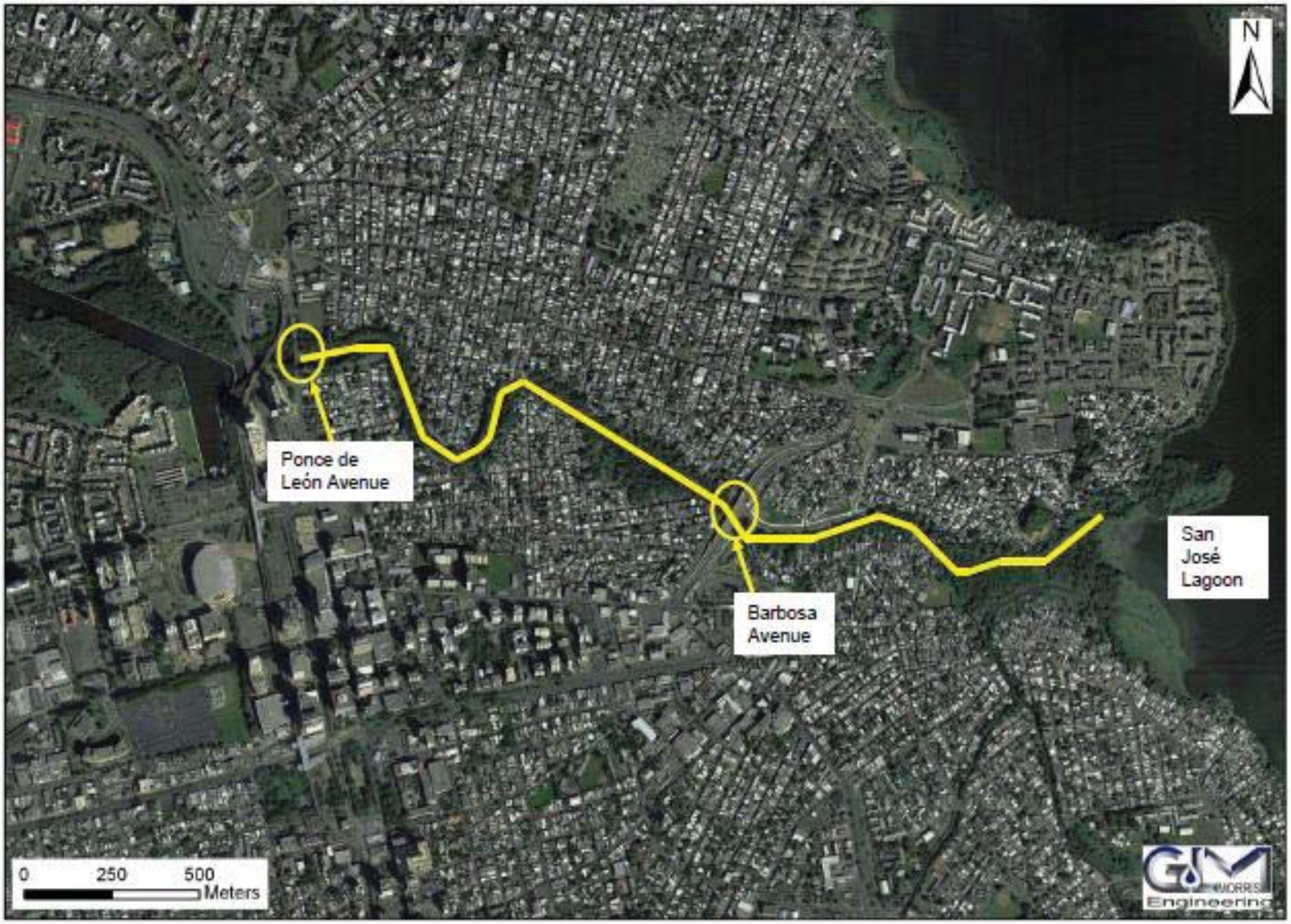


Figure 4.2-9. Study Reach Location

Use of the Rational Method is valid for drainage areas smaller than 150 acres. The value of rainfall intensity was obtained from "Precipitation-Frequency Atlas of United States, NOAA Atlas 14" (see Appendix A). The runoff coefficient parameter for all basins (0.65) was obtained from "*Normas de Diseño para Sistemas de Alcantarillado Pluvial.*" Table 4.2-21 shows the results of the interior drainage hydrology.

Table 4.2-21
Results of Interior Drainage Hydrology

Sub-Basin	Area (acres)	TC (min)	I_{10} (in/hr)	I_{25} (in/hr)	Q_{10} (m^3/s)	Q_{25} (m^3/s)
2	11.54	15.7	4.02	4.45	0.85	0.95
3	9.03	13.6	4.26	4.72	0.71	0.78
4	4.67	11.3	4.60	5.09	0.40	0.44
5	8.35	11.9	4.50	4.99	0.69	0.77
6	9.00	10.2	4.80	5.31	0.79	0.88
7	4.49	8.8	5.10	5.64	0.42	0.47
8	18.79	14.2	4.19	4.64	1.45	1.60
9	10.53	14.2	4.19	4.64	0.81	0.90
10	9.96	16.7	3.92	4.34	0.72	0.80
11	17.01	19.6	3.67	4.06	1.15	1.27
12	7.27	19.8	3.65	4.04	0.49	0.54
13	7.61	17.1	3.88	4.30	0.54	0.60
14	10.15	16.3	3.96	4.38	0.74	0.82
15	8.60	16.0	3.99	4.41	0.63	0.70
16	15.69	16.9	3.90	4.32	1.13	1.25
17	11.37	16.5	3.94	4.36	0.82	0.91
18	4.70	8.1	5.27	5.84	0.46	0.51
19	18.85	13.7	4.25	4.71	1.47	1.63
20	5.40	10.4	4.76	5.27	0.47	0.52
21	5.50	7.2	5.53	6.13	0.56	0.62
22	6.63	11.4	4.58	5.07	0.56	0.62
23	2.78	14.8	4.12	4.56	0.21	0.23
24	4.16	12.5	4.41	4.89	0.34	0.37
25	5.31	14.7	4.13	4.57	0.40	0.45
27	21.14	25.7	3.28	3.63	1.28	1.41
29	39.48	49.5	2.51	2.78	1.82	2.02
30	7.87	13.6	4.26	4.72	0.62	0.68
31	12.16	17.8	3.81	4.23	0.85	0.95
32	3.48	11.5	4.57	5.06	0.29	0.32
33	13.68	25.4	3.30	3.65	0.83	0.92
34	24.94	23.7	3.39	3.76	1.56	1.73
35	11.20	12.0	4.49	4.97	0.93	1.02
36	7.15	4.7	6.59	7.30	0.87	0.96

4.2.6.5 Culvert Analysis

Hydraulic capacity for concrete culverts of various diameters was determined, as seen in Table 4.2-22. Headwater depth was limited to the pipes crown elevation.

Table 4.2-22
Results of Proposed Culvert Analysis

Parameter	Pipe Diameter			
	18-inch	24-inch	30-inch	36-inch
Quantity of Barrels	1	1	1	1
Geometry	circular	circular	circular	circular
Minimum Slope	0.03	0.03	0.03	0.03
Headwater Depth (m)	0.50	0.61	1.26	1.42
Velocity (m/s)	2.80	3.05	3.34	3.52
Capacity (m^3/s)	0.20	0.37	0.64	1.02

4.2.7 Stormwater Quality Enhancement

4.2.7.1 Study Approach and Methodology

The quality of runoff water can be enhanced by trapping and holding the "first flush" of runoff volume for approximately 24 hours to allow for the sedimentation of solids and surface-attached contaminants. This "first flush," which contains the most concentration of contaminants, has commonly been associated with the first inch of rainfall. The first half-inch refers to the runoff resulting from the first inch of rainfall. For stormwater quality enhancement purposes, a 24-hour, 0.5-inch rainfall event was also analyzed for the watersheds that drain into the CMP between the Ponce de León and Barbosa Avenues (see Figure 4.2-9).

Early studies in Florida determined that the first flush generally carries 90 percent of the pollution from a storm (Novotny 1995). The quantity of runoff and the concentration of contaminants from the first one inch of rainfall depend upon the surface of the area rained on as well as the intensity of the rain. Contaminants from porous surfaces such as asphalt may take longer to float out of the pores and into the water stream whereas contaminants from smooth surfaces such as concrete are taken up more quickly. Partially paved (pervious) surfaces will permit some rainfall to filter into the ground below the surface. Higher rainfall intensities result in greater runoff. One inch of rainfall falling over one hour produces more runoff than one inch falling over 24-hours. So for purposes of establishing a standard, the treatment of the first half-inch of runoff from a 24-hour rainfall event was adopted as a water quality volume sizing criterion throughout most of the United States including Puerto Rico.

4.2.7.2 24-hour, 0.5-inch Rainfall Event

Runoff hydrographs were computed for the 24-hour, 0.5-inch rainfall event to determine volume associated with the first flush of runoff. Table 4.2-23 presents peak discharge and runoff volume generated by the 24-hour, 0.5-inch rainfall event, as well as the minimum storage volume and surface area required for stormwater quality enhancement.

Table 4.2-23
Results of 24-hour, 0.5-inch Rainfall Event

Watershed	Peak Discharge (m^3/s)	Runoff Volume (m^3)	Area for 1-m Pond depth (m^2)	Area for 1.5-m Pond depth (m^2)
CMP 1	0.91	7,338	7,338	4,892
CMP 2	1.04	6,690	6,690	4,460
CMP 3	0.47	2,661	2,661	1,774
CMP 4	0.36	3,712	3,712	2,475
CMP 5	0.25	3,068	3,068	2,045
CMP 6	0.32	1,935	1,935	1,290

4.2.8 Additional Hydraulic and Hydrologic Investigations Needed During Preconstruction Engineering and Design

Additional hydraulic and hydrologic (H&H) modeling and/or analyses are needed to assist with the completion on PED. They include:

- Link tidal amplitude and flood surface elevations linearly from the western to the eastern ends of the channel to prepare a map that shows flood plain limits for various storm return periods. Based upon the topographic data, it is known that certain portions of the adjoining community are below base flood elevations. The preparation of a map that links tidal amplitude/flood elevations would provide a higher level of detail for determining where temporary flood protection of the adjoining community would be needed at the micro level while the project channel is under construction.
- Update the existing H&H to determine allowable top of weir elevations for the installation of temporary cofferdams that will not cause the inundation of structures within the Project limits. The top of the temporary coffer dam at the western bridges must have a weir or spillway to control the maximum pool elevation of the water staging behind it. That elevation must be determined in conjunction with the top elevation of the temporary flood protection dams. This analysis would be a refinement of the work performed during the feasibility study.
- Ensure infrastructure improvements that are not being accomplished as part of the Federal project are compatible with the CMP-ERP. Ongoing planning efforts by ENLACE as part of the Comprehensive Development Land Use Plan (CDLUP) would establish

proposed elevations for the adjoining infrastructure are compatible. This effort must be carefully coordinated with the design of the Project Channel. This comparative analysis cannot be conducted without detailed engineering of these adjoining areas. For example, the improvements to the 115-kV Power Line that crosses the CMP must contain a height that is sufficient to avoid posing a hazard to construction/dredge equipment used during the construction activities associated with the CMP-ERP.

- Eastern CMP flows to and from the West via the existing western channel, then into the Rio Puerto Nuevo and finally the San Juan Bay. The Rio Puerto Nuevo's drainage basin covers an area of approximately 24.2 square miles. A recent project to mitigate flooding in the Rio Puerto Nuevo's basin included the construction of enlarged, paved, high velocity channels. Concerns have been expressed over whether these improvements might have detrimental effects on the CMP-ERP. It is understood that the Corps modeled 10 scenarios resulting in hydrologic and water quality changes as part of the Hydrodynamic and Water Quality Model Study conducted for the SJBE Program in 2000. At least one of the scenarios, with a similar configuration as the Tentatively Selected Plan for CMP-ERP, did not point to problems or issues such as backflow into the Lagoon, or significant increases in flood levels to those communities fringing the Eastern CMP. The model showed that levels in the San José Lagoon increased due to tidal influence. It is recommended that this and other modeling conducted as part of the Puerto Nuevo Flood Control project be further reviewed to determine whether the simulations accounted for the Eastern CMP's proposed configuration, whether there are any problems or issues such as backflow into the San José Lagoon, or a significant increase in flood levels resulting from the Puerto Nuevo Flood Control Project that would affect those communities fringing the Eastern CMP once it is dredged. Dependent upon the results of the review, further modeling may be warranted.

Related to the CMP-ERP, but independent of it as a project component or additional study, it is recommended that the non-Federal sponsor, ENLACE, coordinate with the relevant Commonwealth of Puerto Rico agencies for additional studies that are needed as the basis for design of proposed infrastructure associated with the restoration of CMP. The improvement of existing storm and sanitary systems, mainly through the elimination of a combined system and the proper disposal of effluent, requires a series of additional analyses.

4.2.9 Summary and Conclusions

1. The CMP, an important part of the SJBE system, has suffered uncontrolled urban development over the past 40 years that has encroached upon both sides of the channel, reducing its hydraulic capacity and water quality.
2. Figure 4.1-1 shows a portion of the FEMA FIRM panel 370J dated November 18, 2009, where the CMP has been located. According to FEMA mapping, the 100-year flood elevation along the CMP is 5.9 feet MSL. The 100-year floodplain extends up to 1,150 feet south and up to 1,800 feet north from the channel. These base flood levels are influenced by the storm surges at San José Lagoon and San Juan Bay.
3. The hydrologic analysis was performed based on the NRCS's UH methodology and recent rainfall data published in NOAA Atlas-14. The analysis was performed for the 2-, 5-, 10-, 25-,

50- and 100-year events. Results of the hydrologic analysis are presented in tables 4.2-5 and 4.2-6.

4. The hydraulic analysis of CMP was performed to determine the effects on flood levels of closing the CMP channel at the Ponce de León Avenue to minimize the dispersion of contaminants (closing of area towards the western half of the channel while the dredging is under way) for the existing channel geometry under the 2-, 5-, 10-, 25-, 50-, and 100-year events. Results of the CMP hydraulic analysis are presented in tables 4.2-9 through 4.2-14.
5. The interior drainage analysis was performed to identify the impacts on the existing storm sewer caused by the proposed restoration and provide hydraulic design recommendations. Culvert analysis was performed using the FHWA HY-8 program. Culverts capacity was determined for free-outfall conditions and a minimum 3 percent slope.
6. The quality of runoff water can be enhanced by trapping and holding the “first flush” of runoff volume for approximately 24 hours to allow for the sedimentation of solids and surface-attached contaminants. This “first flush,” which contains the most concentration of contaminants, has commonly been associated with the first inch of rainfall. For stormwater quality enhancement purposes, a 24-hour, 0.5-inch rainfall event was also analyzed for the watersheds that drain into CMP between the Ponce de León and Barbosa Avenues.

4.3 HYDRODYNAMIC MODEL STUDY

The CH3D-WES hydrodynamic model, developed by Corps’ Engineering Research and Development Center (ERDC) in 1990 and approved for use by the USACE Headquarters, was used in this study to determine the circulation parameters for assessing ecological uplift potential for various tidal restoration alternatives. This model was chosen because it was used in conjunction with a water quality model, also developed by the ERDC (Bunch et al. 2000), for a previous study of the SJBE and, in particular, the proposed dredging of the CMP. ERDC performed a data collection effort in 1995, completed hydrodynamic modeling in 1997 using CH3D-WES, and produced a final report of the hydrodynamic and water quality modeling in 2000.

4.3.1 Study Purpose

The purpose of the hydrodynamic modeling was to assess changes in the hydrodynamic flows through the CMP due to increasing the area of the proposed channel. Results from the efforts to use this existing modeling resulted in the following findings:

- The modeling effort led by Atkins was able to successfully replicate the processes and output of the CH3D-WES hydrodynamic model previously developed and used by ERDC.
- Based on results of these current model runs, and as has been previously reported, the CMP, in its frequent condition, provides only a small influx of tidal waters to the San José Lagoon.
- Should the CMP be significantly enlarged through the removal of material currently clogging the channel, there would be a dramatic increase in tidal amplitude in San José Lagoon.

- The modeled tidal range in San José Lagoon will increase as the cross-sectional area of a restored CMP increases. There is a direct correlation with tidal amplitude and increased flow into and out of the San José Lagoon.
- Under existing conditions, the average residence time of waters within San José Lagoon is estimated at 16.7 days with a standard deviation of 0.4 day. Estimated residence times ranged between 16.0 and 17.3 days. Exchange between the coastal ocean and San José Lagoon is almost entirely through the Suárez Canal.
- Using modeled channel cross sections of 450, 675, 900, 1,350, and 1,800 square feet, modeled residence times for the San José Lagoon would decrease to 5.0, 3.9, 3.2, 2.7, and 2.4 days, respectively. These changes are due entirely to the increased flows through the CMP.

The results of the hydrodynamic modeling were linked to an ecosystem response model (the Benthic Index) allowing for the use of these combined tools to conduct an Ecosystem Restoration Benefit Analysis Evaluation for the CMP-ERP (Appendix A – NER Benefits Evaluation).

4.3.2 Model Selection

The CH3D-WES model is a three dimensional curvilinear finite difference model developed by Johnson et al. (1991). The model is described in greater detail in the ERDC report (Bunch et al. 2000). The scope of services requested by ENLACE was to use the model developed in the original EIS performed by the USACE and to extend the use of this model for the conditions outlined in the revised EIS analysis. By using this existing hydrodynamic model, efforts to develop a new model grid and calibrate and verify the model were avoided. The model was tested against results described in the earlier modeling effort by ERDC and was found to represent the data consistent with the documentation stated in the earlier report.

4.3.3 Grid Development, Boundary Conditions, and Input Data

This modeling effort used the same grid and boundary conditions as found in Bunch et al. (2000). The numerical grid (Figure 4.3-1) contains 2,690 planform cells with a maximum of 30 vertical layers. Each layer is 3 feet (0.91 meter) thick except for the top layer which varies with the tide. With much of the system being very shallow, many of the planform cells are represented by one layer. Thus, the computations involve a mixture of 3D as well as vertically averaged computations (Bunch et al. 2000). Figure 4.3-1 provides a sketch of the model grid overlaid with a regional map.

The analysis was performed with the goal of removing the majority of the solid waste from the channel's cross section. The targeted channel bottom to accomplish this was 10 feet. The CH3D-WES model must be run in fixed, 3-foot-thick layers and does not permit variance of the layer thickness. Therefore, a model run with three layers (9 feet) was the closest to reach this goal. A four layer model (12 feet) would overreach the goal and contribute more dredging cost to the project. Consequently, the three layer (9 feet) model was chosen. To book end the analysis, a single layer (3 feet) and five layer (15 feet) models were run. Additional modeling at 6 feet and 12 feet was deemed too close to add significant value to the analysis.

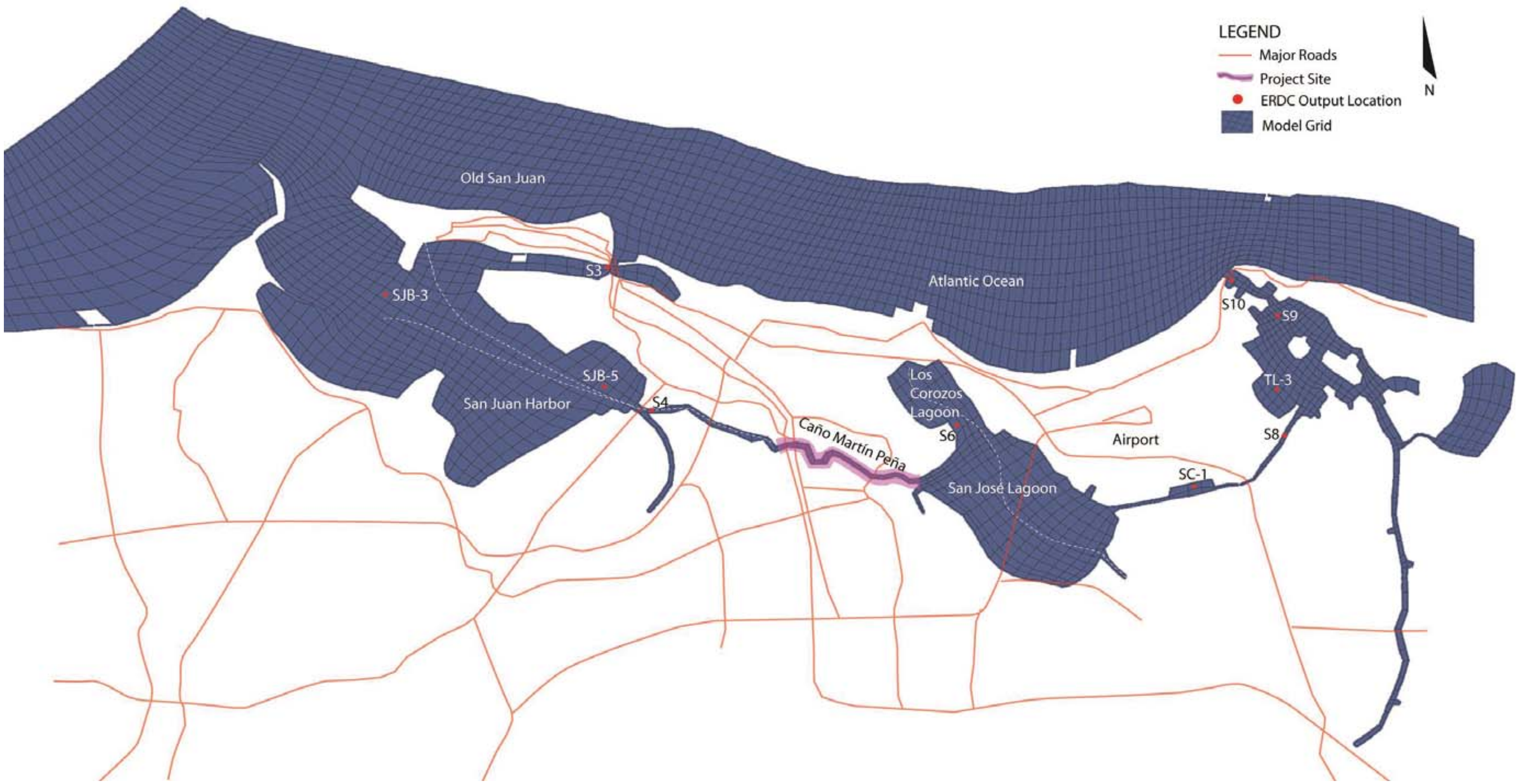


Figure 4.3-1. CH3D-WES Numerical Grid

4.3.4 Model Calibration and Verification

Calibration was performed for the original model and is detailed in Bunch et al. (2000). The model was again tested as part of this study and found to adequately represent tidal variation consistent with published data.

4.3.5 Model Results

Modeling results show that the CMP provides only a very small influx of tidally driven flow waters to the San José Lagoon. This is due to the heavily vegetative and shallow depth of the channel. Should the CMP be opened up by dredging a deeper channel, there would be a dramatic increase in tidal amplitude in San José Lagoon. The modeled tide range in San José Lagoon increases with an increase in the cross-sectional area of a restored CMP. This is an indication of increased flow from the CMP into and out of the San José Lagoon. This increased flow only slightly reduces flow from the Suárez Canal. Figure 4.3-2 provides a graph of the modeled tidal range in San José Lagoon for the existing channel and various proposed channel configurations. Table 4.3-1 provides a listing of the modeled tidal range for a channel depth of 9 feet and widths ranging from 50 to 200 feet.

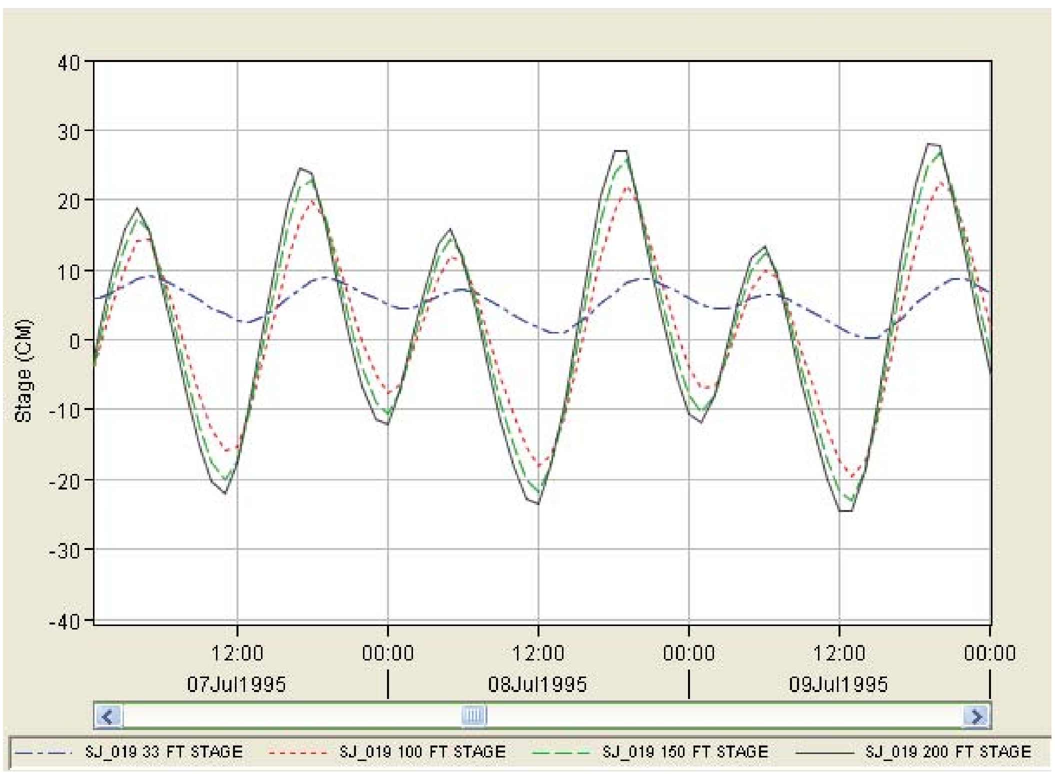


Figure 4.3-2
Tide signal modeling results in San José Lagoon
Time shown is 3 days; existing conditions shown as blue dot-dash line;
a 100-foot by 9-foot channel shown as a red dotted line; a 150- by 9-foot channel shown as a green dash line. A 200-foot by 9-foot channel shown as a black solid line.

Table 4.3-1
Tide Range in San José Lagoon on a spring tide as a function of channel width
(with 9-foot channel depth).

	Existing Condition	Dredged Channel Widths (ft) (depth = 9 ft)						
		50	75	100	125	150	175	200
Tide Range (cm)	9.97	32.83	41.6	48.93	53.39	56.42	59.69	62.59

Under existing conditions, the average residence time of waters within San José Lagoon is estimated at 16.9 days with a standard deviation of 0.4 day. This calculation was derived by calculating the time frame it would take to modify the salinity between the ocean and a fresh San José Lagoon by 90 percent. Almost all of the new water entering San José Lagoon is through the Suárez Canal. This technique used the conservative properties of salt water and is not necessarily useful for non-conservative constituents.

Taking the 16.9 days as a base line a set of simple calculation were run with the model to assess the additional flows that would move into and out of the San José Lagoon after the CMP was dredged. This volume was calculated over numerous tidal cycles to derive the time it takes the volume of the San José Lagoon to be replaced. This is due to tidal flows from the CMP, sometimes called a tidal prism calculation and is a rough approximation of residence time.

Using modeled channel cross sections ranging from 675 to 2,250 square feet, approximated residence times for the San José Lagoon would decrease from approximately 16.9 days to less than 5 days. Channel depths chosen for the model ranged from 3 feet to 15 feet, taken in 2-cell thicknesses or 6-feet. Thicknesses less than 6-feet were eliminated because differences were not expected to be significant between them. See Table 4.3-2 for a table of the residence time results for various channel configurations.

Table 4.3-2
Channel configurations, channel cross-sectional area (square feet), residence time estimates for San José Lagoon (days), and maximum bottom velocities (feet per second) for eastern and western portions of Caño Martín Peña for various alternatives

Channel Configuration (depth by width)	3 x 33*	9 x 75	9 x 100	9 x 125	15 x 75	9 x 150	15 x 100	9 x 175	9 x 200	15 x 125	15 x 150
Area (ft^2)	99	675	900	1,125	1,125	1,350	1,500	1,575	1,800	1,875	2,250
Hydraulic Conveyance	184.2	2,530.4	3,487.2	4,450.0	5,467.6	5,416.1	7,659.3	6,384.0	7,353.3	9,880.5	12,118.7
Residence Time (days)	16.90	3.86	3.23	2.87	2.61	2.66	2.37	2.49	2.38	2.25	2.19
Max. Bot. V-CMP-East (fps)	1.25	4.22	4.09	3.95	4.54	3.85	3.92	3.52	3.13	3.45	3.13
Max. Bot. V-CMP-West (fps)	0.74	2.20	2.80	3.25	3.50	3.65	4.06	3.89	4.09	4.34	4.49

*Modeled configuration for existing conditions.

Examination of Table 4.3-2 shows that there are particular channel configurations that are problematic due to high bottom velocities capable of scouring unconsolidated sediments. Unconsolidated sediments are generally referred to as sand, silt, and organic material that is not cemented together. The upper strata, to depths of 8 feet or deeper, are known to be comprised of previously disturbed fill, comprised of a mix of natural sediments, organics and debris. The 9-foot channel depths in Table 4.3-2 are based on the 3-foot model increments. The proposed channel depth is 10 feet to remove the additional debris. The 10-foot-deep section would slightly reduce the velocity of the flow and modify the characteristics in Table 4.3-2 by slightly increasing area and hydraulic conveyance while slightly reducing residence time and bottom velocities. The comparisons between the 9- and 10-foot channels are not different enough to warrant special model runs.

The channel configurations that result in the two lowest peak channel bottom velocities in the eastern end of the CMP are the 9 feet deep by 200 feet wide and 15 feet deep by 150 feet wide (both at 3.13 feet per second [fps]) channels. The channel configurations that result in the two lowest peak channel bottom velocities of the western end of the Caño Martín Peña are those where the channel would be 9 feet deep by 75 feet wide and 9 feet deep by 100 feet wide (2.20 and 2.80 fps, respectively).

Choosing a channel configuration that balances construction costs with concerns over scouring involves developing a balance between volumes of dredged material and the expected rate of scouring at the eastern and western portions of the CMP; however, in terms of water quality improvement, there does not appear to be a compelling basis for increasing the cross-sectional area much beyond a minimal amount needed for constructability. Further channel section enlargements provide only modest increases in the flushing rate for the San José Lagoon.

Refer to the Hydrodynamic Model Study annex for more-detailed documentation and graphical/ tabulated presentation of CH3D modeling results.

4.3.6 Tidal Amplitude

Regarding the potential for impacts caused by the increase of tidal amplitude within the CMP and indirectly the Lagoon, the following is offered. Table 4.3-3, the 100-foot-wide channel (preferred alternative) compares pre and post construction San José Lagoon spring tide ranges on the channel. Spring tides occur once monthly and represent the highest and lowest tides of the month.

Prior to construction, the Lagoon has a tide range of 0.33 foot (9.97 cm). After construction of the 100-foot-wide channel, the tide range increases to 1.61 feet (48.93 cm) or 1.28 feet greater than preconstruction. This equates to a 0.64-foot increase in average water levels (monthly) after construction.

Table 4.3-3
Pre/Post-Construction Tide Range

	Tide Range (feet) (R)	High Tide (feet) (1/2 R)
Pre-Construction	0.33	0.16
Post-Construction 100-foot channel	1.61	0.80
Difference	1.28	0.64

Tidal amplitude within the CMP and the San José Lagoon would increase as a result of construction of the channel. The Lagoon's tide range is expected to increase 1.28 feet after construction, which would equate to a 0.64-foot increase in average monthly water levels. The water surface rise may affect extremely low-lying structures around the SJL. In addition, storm sewers from the airport, at the north of the Suárez Canal, outfall into the SJL. The airport has been present for decades and presumably operating prior to the filling of the CMP. The airport is higher than its outfalls and thus may be able to build up a hydraulic head in its conduit to offset these monthly events.

The proposed Project Channel, along with its sheet pile walls and adjoining mangrove beds, are intended to form the floodway to contain the frequent storm events. Flood control measures, such as the construction of suitable protective structures between the channel waters and the adjoining low areas, will be incorporated to mitigate water backflow effect. Other alternatives may include the installation of a temporary sheet pile wall with local select backfill to buttress the structure (such as with Barrio Obrero Marina). These temporary flood protection solutions would remain in place until the proposed sheet pile channel wall and upland embankment of the mangrove bed are installed. Proper construction (e.g., elevation) of the Paseo and related structures would provide additional, ancillary community flood protection.

Additional hydraulic and hydrologic (H&H) modeling and analyses are needed to confirm the potential for induced flooding as a result of the implementation of the CMP-ERP. This additional technical investigation would be completed before the conclusion of PED.

4.3.7 Channel Velocities and Scour

CMP velocities have been reviewed for their potential capability of scouring sediments, both in the proposed channel of the CMP-ERP, the eastern channel, CMP-ERP and the Western CMP, or western channel. The western channel was previously dredged under the Agua Guagua (AcuaExpreso) CMP-ERP by the USACE in the mid-1990s. Bottom channel velocities within the eastern CMP-ERP channel are a factor of cross sectional areas, with the smallest cross sections producing the highest velocity. At the CMP-ERP eastern channel's outfall into the western channel, bottom velocities are a factor of the volume of flow from the east with higher flows producing higher bottom velocities in the Western channel. Hence, the larger the cross sectional area of the eastern Project Channel, the higher the scour potential in the receiving channel.

The Hydrodynamic Model Study evaluated a total of 10 proposed channel configurations (Table 4.3-2). Due to the poor results for residence time and bottom velocities, the 15-x-75-foot, 15-x-100-foot, and 15-x-75-foot channels were eliminated. Velocities at the channel bottom for each of the remaining channel alternatives estimated are presented in Table 4.3-4.

Table 4.3-4
Channel Velocities

Channel Alternative (feet) Dimensions	Max. Bottom Velocity (fps) Within the CMP Project Channel	Max. Bottom Velocity (fps) Within the CMP and Adjacent Western Channel
75 x 9	4.22	2.20
100 x 9	4.09	2.80
125 x 9	3.95	3.25
150 x 9	3.85	3.65
125 x 15	3.45	4.34
150 x 15	3.13	4.49
200 x 9	3.13	4.09

The recommended maximum channel bottom velocities for the eastern and western channels are 3.5 to 4.0 fps and 2.0 to 2.5 fps, respectively, with preference for the lower end of the ranges. For the eastern channel of the CMP-ERP, calculated channel bottom velocities range from 3.13 fps to 4.22 fps (see Table 5.2-1). All of the proposed channel cross sections except the 75-x-9-foot channel, fall sufficiently below the maximums to permit their use with earthen bottoms. The 75-x-9-foot channel would require a paved bottom. For flows entering the existing western channel, velocities ranged from 2.20 to 4.09 fps, with only the 75-x-9-foot channel falling within the allowable maximum velocities. Modeling of a channel configuration between 9 and 15 feet deep (12 feet deep) was considered but not performed because its maximum bottom velocities adjacent to the Western Channel would exceed the maximum permissible velocities.

Therefore, all of the channel alternatives in Table 4.3-4, except the 75-x-9-foot channel, could be constructed within the eastern CMP without a paved bottom. Only the 75-x-9-foot channel (or equivalent cross sectional area) with a paved bottom could be constructed at the entrance to the western CMP.

Channel dimensions shown above are driven by the model's 3-foot-deep cell increment. Due to the model's required analysis of channels in increments of 3 feet, the channel depths that were modeled were 9 feet and 15 feet. Subsequently, it was determined that channel depths of 10 feet would be preferred to prevent leaving behind debris anticipated to be found to depths of 10 feet. The bottom velocities modeled for the 9-foot channels are expected to be similar to those for 10-foot channels. Channel velocity is a function of cross sectional area. The 10 x 100 channel has a cross sectional area nearly midway (0.44) between the 9 x 100 and the 9 x 125. By interpolation, the 10 x 100 channel has bottom velocities of 4.03 (east) and 3.00 (west). As previously stated, the recommended maximum channel bottom velocities are 3.5 to 4.0 fps (east) and 2.0 to 2.5 fps (west). Therefore, the 10 x 100 is expected to provide slighter more suitable velocities for the Project Channel (east). Mitigation of high velocities (west) is discussed in Section 4.3.8. The colonization of channel walls by invertebrate communities would not impede or affect velocities. Invertebrate communities typically occupy any hard structure in the area.

Table 4.3-5
Comparison of Intermediate Channel Velocities

Channel Dimensions (feet)	Cross Sectional Area (square feet)	Bottom Velocities (feet per second)	Method of Determination
9 x 100	900	4.09 (east) 2.80 (west)	CH3D-WES
10 x 100	1,000	4.03 (east) 3.00 (west)	Interpolation
9 x 125	1,125	3.95 (east) 3.25 (west)	CH3D-WES

4.3.7.1 Potential for Scour in the Project Channel

An evaluation was performed to estimate the potential for scouring of the proposed channel. The soils information contained in Appendix B of the CMP-ERP Design Report and Environmental Impact Statement for dredging of the CMP (USACE 2001) was used for this evaluation. Due to the irregular placement of sediments, solid waste dumped over the decades, considerable variations are found in their characteristics. To illustrate this, the soil borings were used to construct general soil profiles of the northern and southern banks of the proposed channel's corridor (see Figure 3.3-1).

Although variations exist, the soils are predominantly hard silts and clays at a depth of 10 to 15 feet below the existing bottom, near the proposed channel bottom. For cohesive soils such as these, the permissible shear stress depends on cohesive strength and soil density. Cohesive strength is associated with plasticity index (PI) and soil density is a function of void ratio (e). The soils information (USACE 2001) contained the Plasticity Index for several soil samples in or adjacent to the channel at the approximate depth of the proposed channel bottom. The PI values ranged from 14 to 37 at borings CBMP98-1 and CBMPUC-L2, respectively. Only two borings had a PI <20. The void ratio was not determined in the soils investigation.

The potential for scouring was determined using the procedures of Federal Highway Administration's (FHWA) Hydraulic Engineering Circular (HEC)-15, Third Edition, 2005 "Design of Roadside Channels with Flexible Linings." Within this circular, an equation is provided for calculating the permissible shear stress based on plasticity index and void ratio. This was of marginal use because the void ration is unknown and PI varies. Table 2.3 of HEC-15 provides permissible shear stresses for bare cohesive soils assuming a void ration of 0.5. This is a reasonable assumption compared to a typical value for stiff clay (e = 0.6) suggested by Das 1990 in "Principles of Geotechnical Engineering." Table 2.3 indicates that the permissible shear stress for cohesive soils with PI >20 varies from 0.072 lb/ft^2 for silty sands to 0.094 lb/ft^2 for clayey sands to 0.14 lb/ft^2 for inorganic clays. Given the preliminary nature of this evaluation and the variation in the soils, the permissible shear stress was assumed to be limited to the range of 0.072 to 0.094 lb/ft^2. Assuming a proposed channel configuration of 100 feet wide and 10 feet deep, the velocities at which the shear stresses would exceed permissible values were determined to be in the range of 3.5 to 4 fps. This method ignores the effects at bends which have higher velocities at the outside of the bend.

Investigations conducted by Suelos Inc. (2011) found some somewhat higher values in some cases. Looking at the values from the geotech liquid and plastic limit tests performed by Suelos, Inc., the following are the high and low values for the major soil layers near the surface (Table 4.3-6).

This analysis of the potential for scour of the channels earthen bottom indicates that the 125-foot x 15-foot, 150-foot x 15-foot, and 200-foot x 10-foot channel sections fall below minimum thresholds. The 100-foot x 10-foot channel, at 4.09 fps is just marginally over the threshold and likely suitable as well.

Table 4.3-6
Soil Values (Suelos, Inc., 2011)

Boring Name	Material Description	USCS Designation	Depth (ft)	LL	PL	PI
CB-MPUC-C1	Silt	MH	6.5–8	92	52	40
CB-MPUC-C2	Clayey Silt	MH	7–8.5	105	53	52
CB-MPUC-C3	Sandy Clay	CL	9–10.5	50	26	24
CB-MPUC-C5	Organic Silt	OH	7.5–9	88	48	40
CB-MPUC-C7	Clay	CL	7.5–9	44	24	20
CB-MPUC-C7	Clay	CH	9–10.5	56	27	29
CB-MPUC-C8	Organic Silt	OH	5.5–7	95	49	46
CB-MPUC-C10	Organic Silt	OH	4.5–6	101	66	35
CB-MPUC-C10R	Silt	MH	4.5–6	103	55	48

4.3.7.2 Effects of Scour on Existing Bridges

At the bridges, the potential for scour at the piles, columns, and abutments is greater than through the channel. The depth and configuration of the piles and columns is unknown. Dredged depths will be shallower than in the main channel. At this stage, full bottom and side-wall armoring is recommended to protect against potential harmful scour.

4.3.8 Effects of Scour on Western Channel

4.3.8.1 Description of Western CMP Channel Design

The following discussion about the soils and channel design of the Agua Guagua Project has been taken from the project's design report (USACE, Agua-Guagua Project, Dredging Martín Peña Navigation Channel, Final Letter Report, August 1983).

Soils encountered during the soils surveys were almost entirely organic silt and clay interlayered with peat. Minor amounts of silty sand were present near the western end of the alignment. The materials were very soft, with very low bearing strength to depths of 25 to 30 feet or more beneath the channel centerline. Mangrove protection from ferry vessel wakes was proposed in the form of bulkheads and revetted dikes. It was anticipated that ongoing maintenance dredging would be required to control shoaling caused by sediments carried in from the Bay as well as the CMP.

The channel width had a design width of 100 feet for one-way traffic with periodic turnouts and a width of 180 feet for two-way traffic. Bulkheads would be precast concrete king piles with precast concrete panels. Pile penetration would be 10 to 15 feet into the stiff clay material underlying the peat and silt materials. Pile spacing would be 8.0 feet. Top of piles would be elevation plus 1.5 feet MSL with a pile cap to elevation plus 3.0 feet MSL. The bulkhead system is not designed to withstand a substantial load on the landward side. The bulkhead system was designed to withstand a maximum boat wake of 3.0 feet when the channel tide elevation is 0.0 foot MSL. Construction of the bulkhead system would require excavation of the navigation channel to provide access for barges to install piles and panels. The bulkhead system would be installed 10.0 feet beyond the channel bottom in order to facilitate future maintenance of the navigation channel and not damage the system.

The retaining bulkhead system considered is either a wall constructed of precast concrete king piles with precast concrete panels or precast concrete sheet piling. King pile and sheet pile penetration would be 12 feet into the stiff clay material underlying the peat and silt materials. King pile spacing would vary from 4.0 to 6.0 feet, depending on top elevation of underlying clay material. Top of piles would be elevation plus 1.5 feet MSL with a pile cap to elevation plus 3.0 feet MSL. The concrete panels would extend from elevation plus 3.0 feet MSL to elevation minus 15.0 feet MSL, except at locations where it is necessary to allow tidal flow into the mangroves. The top panel would be left out at these locations. The bulkhead system is designed to withstand loading on the landward side. Construction of the bulkhead system would require excavation of a minimum 100-foot channel to provide access for barges to install the piles and panels. The bulkhead system would be installed 10.0 feet beyond the channel bottom in order to facilitate future maintenance of the navigation channel and not damage the system.

The revetted dike system would be placed along the channel except where it is required to allow tidal flow into the existing mangroves. The above bulkhead system would be used at these locations to permit flow of water. Top of the dike would be elevation plus 4.0 feet MSL. The top elevation is based on 1-foot vessel wake, high water of about 1.5 feet above MSL and wave run-up of 1.0 foot. The toe of the revetment would be placed 10 feet beyond the channel bottom to facilitate future maintenance dredging. The side slopes would be 1 vertical on 3 horizontal above 0.0 foot MSL and 1 vertical on 4 horizontal below 0.0 foot MSL. Excavation of the peat and silt to elevation minus 10.0 feet MSL across the base of the dike would be required prior to construction of the dike. Subsidence of about 6 feet can be expected. The revetment would consist of 9 inches of filter bedding stone and 20 inches of riprap stone above 0.0 foot MSL and 12 inches of filter bedding stone and 30 inches of riprap stone below 0.0 foot MSL. Bedding stone gradation will be of 3-inch maximum size with no greater than 10 percent passing a No. 100 sieve. Riprap stone gradation would be W50 of 160 pounds with maximum of 350 pounds.

4.3.8.2 Potential for Scour in the Western CMP

Based upon the bathymetric survey and the hydrodynamic model, flow from the completed CMP-ERP may create shear stresses exceeding permissible values in the existing channel west of the Project Channel. It is not known whether scour caused by increased flows from construction of the CMP-ERP would have detrimental effects on existing sheet pile walls or other marine structures in the Western Channel. Scour could also cause sediments that have accumulated in this existing dead end channel to enter the water column and be transported either to the San Juan Bay or into the San José Lagoon, causing increased shoaling in those locations.

Given these conditions, it is recommended that permissible velocities from the CMP-ERP into the receiving existing western channel be in the range of 2.0 to 2.5 fps and preferably closer to 2.0. The only channel meeting these criteria is the 75-foot by 10-foot channel section.

Critical channel velocities are both those flowing along the channel's bottom and the average velocity for the channel. As stated, the only channel alternative with a channel velocity unlikely to scour the existing Western CMP is the 75-x-10-foot channel but its bottom velocity is great enough to scour its earthen bottom; therefore an articulated concrete mat bottom is proposed. Although all of the other alternatives have bottom channel velocities below the scour limit and would not require channel bottom paving, their higher channel velocities would scour the existing Western CMP. Therefore, it is recommended that if a channel alternative other than the 75-x-10-foot be chosen, that segment of the channel near the confluence into the existing Western CMP be constructed as a weir, utilizing the 75-x-10-foot cross section or equivalent area with a paved bottom. The 75-x-10-foot configuration may be varied as long as the same cross sectional area (750 square feet) is met.

4.3.9 Benthic Index

Using residence times as calculated, a benthic indexing calculation was performed. Its purpose was to characterize water quality changes as a result of hydrodynamic modifications within the CMP and the San José Lagoon. The basis for this analysis was a review of the benthic community within major portions of the San Juan Bay estuary.

The results of the analysis found that the ecological health presently found in the San José Lagoon's ranked well below that of La Torrecilla Lagoon and San Juan Bay proper. Utilizing a 75-foot-wide by 9-foot-deep channel would nearly double the Lagoon's benthic index scores for the San José Lagoon. Further channel widening continues to reduce residence time and increase the benthic index. The largest changes occur with a minimal opening and gains created by further widening are only marginal. Refer to Figure 4.3-3 for these results. Results for all of the channel configurations are in Table 6.3-1.

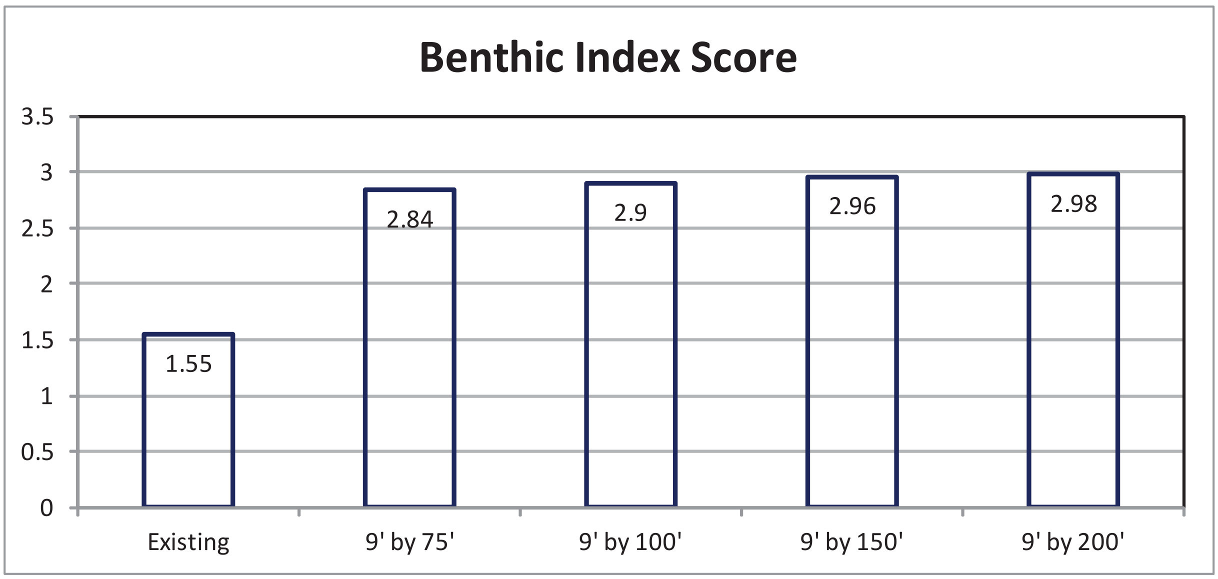


Figure 4.3-3
Comparison of Benthic Index Scores – 9-Foot-Depth Channel Alternatives

Because a 75-foot-wide by 10-foot-deep channel was the only dimension that resulted in a bottom velocity that was low enough to prevent unacceptable scour in the western CMP, every larger channel dimension that was modeled (e.g., 100-, 125-, 150-, and 200-foot widths) must include a design component to reduce water flow at the western end of the Project Channel consistent with the model output for the 75-x-10-foot channel if they were to be retained as viable, feasible dimensions. The inclusion of a weir (115-foot-wide by 6.5-foot-deep), described in Section 5.2.5, would enable the larger channels to replicate the cross-sectional area of the smaller 75-x-10-foot channel, and, in turn, maintain the same flow characteristics. With such a weir in place, the potential for unacceptable scour in the western CMP would be resolved while accommodating wider channel widths in the rest of the Project Channel.

With respect to benefits derived from the various channel alternatives, modeling concludes that there is a significant benefit to the San José Lagoon (based on the benthic index score) once the CMP channel is widened to 75 feet due to tidal amplitude, or volume of water flowing into and out of the lagoon. Increasing channel widths to 100 and 125 feet would progressively result in additional, albeit marginal, benefit as a result of the increased water flows and reduced water residence times. Although the western and eastern segments of the Project Channel have different cross-sectional areas and bottom elevations for the 100- and 125-foot alternatives with the weir, water flow through a tidal system such as the CMP is, and would continue to be, restricted by the smallest cross-sectional area. Accordingly, once the weir is included in the larger channel configurations, there is no further benefit to residence time in San José Lagoon with channel widths wider than 75 feet, and thus no additional NER benefits.

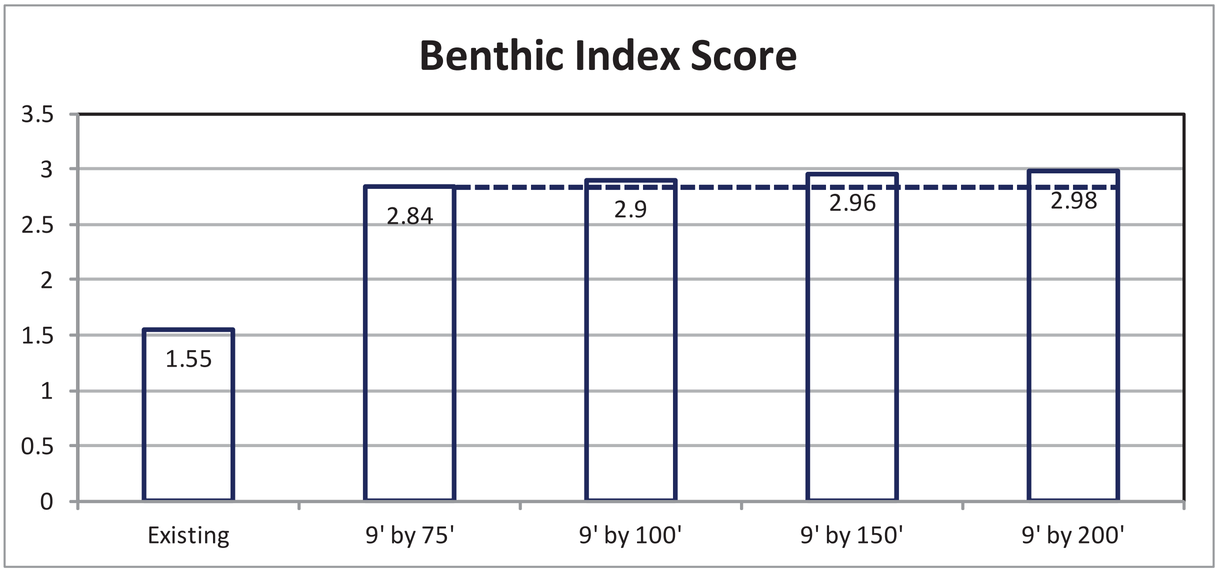


Figure 4.3-4
Influence of the 9-x-75-foot Weir on Benthic Index Scores – San José Lagoon

4.3.10 Additional Hydraulic, Hydrologic, and Hydrodynamic Studies Needed During Preliminary Engineering and Design

Additional technical investigations and studies are required for the CMP-ERP during PED. These investigations include hydraulic, hydrologic, and/or hydrodynamic modeling and/or analyses to:

- Link tidal amplitude and flood surface elevations linearly from the western to the eastern ends of the channel to prepare a map that shows flood plain limits for various storm return periods. Based upon the topographic data, it is known that certain portions of the adjoining community are below base flood elevations. The preparation of a map that links tidal amplitude/flood elevations would provide a higher level of detail for determining where temporary flood protection of the adjoining community would be needed at the micro level while the project channel is under construction;
- Update the existing analysis to determine allowable top of weir elevations for the installation of temporary cofferdams that will not cause the inundation of structures within

the Project limits. The top of the temporary coffer dam at the western bridges must have a weir or spillway to control the maximum pool elevation of the water staging behind it. That elevation must be determined in conjunction with the top elevation of the temporary flood protection dams. This analysis would be a refinement of the work performed during the feasibility study; and,

- Ensure infrastructure improvements that are not being accomplished as part of the Federal project are compatible with the CMP-ERP. Ongoing planning efforts by ENLACE as part of the CDLUP would establish proposed elevations for the adjoining infrastructure are compatible. This effort must be carefully coordinated with the design of the Project Channel. This comparative analysis cannot be conducted without detailed engineering of these adjoining areas. For example, the improvements to the 115-kV Power Line that crosses the CMP must contain a height that is sufficient to avoid posing a hazard to construction/dredge equipment used during the construction activities associated with the CMP-ERP.
- The soil investigation indicates that the silt clay material near the proposed channel bottom is predominantly hard and stiff, so there will be a time dependency for scouring. Extremely hard material can be very resistant to scour. Given that the peak tide velocities will only occur for several hours a day, this could be factored in to the design if the scour rate can be predicted. During the design phase, consideration should be given to more detailed sampling of the soil to determine the scour rate. The FDOT has a procedure for predicting the scour rate of this type material.
- Related geotechnical studies to:
  - Determine the depth of bury over the pile caps supporting the Ponce de León and Luis Muñoz Rivera Avenue bridge foundations. It is also recommended that a detailed structural conditions analysis be conducted for these two bridges and the existing Linear Park pedestrian bridge. Since as-built plans of the bridges were unavailable, the feasibility study was conducted without accurate information of the bridge pile cap elevations. Dredging under the bridges may not exceed the original construction depths. Otherwise, the bridge structures would become exposed and possibly require fortification. The additional studies would determine as-built pile cap elevations by performing non-destructive excavations (test pits and borings) to expose the bridge pile caps. Should it be determined that the preliminary plan for the channel under the bridges would expose bridge foundations, the proposed channel would be reconfigured around these structures and scour protection provided for their protection. It is anticipated that reconfiguration may widen the channel and adjust the channel invert in a manner that would maintain the cross sectional area required for the weir to function. As with any project, the construction documents, to be prepared later, should include language requiring the contractor to provide temporary protection for bridges and other structures against destabilization due to storm events. This protection would be initiated when dredging begins around the structures.
  - Confirm sedimentation rates associated with the Juan Méndez, as the estimates used during the feasibility study are believed to be conservative. It is expected that a new investigation would identify a lower sedimentation rate because the 2003 study effort (Moffat and Nichol 2003) was conducted during the construction of 2 large

developments along the Juan Méndez, and it is believed that the resulting sedimentation rates were elevated as a result of these activities. Moreover, the 2003 study effort did not account for mitigating factors such as improved tidal flow through the CMP, which may serve to disperse the sediments into lower energy environments. If a lower sedimentation rate is confirmed, the operation and maintenance costs of the CMP-ERP would be reduced, perhaps significantly reduced.

- Perform bridge scour and analysis in accordance with the following documents:
  - Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance-Third Edition
  - Publication No. FHWA-NHI-09-111 HEC-23, September 2009
  - FHWA Technical Advisory T 5140.23, Evaluating Scour at Bridges
  - NCHRP WEB only Document 107, Risk-Based Management Guidelines for Scour at Bridges with Unknown Foundations

5.0 CIVIL DESIGN

The purpose of this section is to present the results of the preparation of project design which have been taken to a functional level of design to enable the development of cost estimates of sufficient detail to support feasibility level planning, USACE technical and policy review, and decision making for CMP-ERP authorization. Included are channel dredging, sheet pile wall, dredged material management, recreation, and ancillary site features.

The Project Channel is a proposed rectangular shaped channel with steel sheet pile walls for most of its length. Numerous alternatives to its width and depth are examined as part of the alternatives analysis. Additionally, the Project Channel requires several changes to its geometric configuration as it traverses the length of the CMP. At its terminus with the San José Lagoon, an extended channel would be dredged east into the San José Lagoon (over a distance of approximately 4,300 feet) as a hydraulic transition from the CMP. This extended channel would transition from the depth of the Project Channel to the 6-foot depth of San José Lagoon. The extended channel would maintain the Project Channel's width but replace its steel sheet pile walls with earthen slopes (5 horizontal to 1 vertical slope). At the Barbosa Bridge crossing, the Project Channel transitions to wider channel configurations. From just west of the Ponce de León Avenue Bridge to the channel terminus west of the Luis Muñoz Rivera Avenue Bridge, the Project Channel is configured as a weir to control flow with a cross section of 115 feet wide by 6.5 feet deep. Paving of the Project Channel bottom is necessary under the Barbosa Bridge and the weir. One of the channel alternatives (10-foot x 75-foot) requires channel bottom paving for its entire length. The geometric configuration of the alternatives examined for the main channel, measured by width and depth in feet, were 75 x 10, 100 x 10, 125 x 10, 150 x 10, 125 x 15, and 150 x 15.

Velocity in the channel alternatives, the main channel and both ends was reviewed for potential for scour of the earthen bottom. The smaller channel cross sections produce the higher velocities. Bottom channel velocities at the western end of the Project Channel were determined to be problematic with the potential that scour could affect the existing western channel. It was determined that the only channel alternative that sufficiently reduced bottom velocities was the 75-x-10-foot channel. With the exception of the 75-x-10-foot channel, velocities were low enough to permit the use of earthen bottoms. The 75-x-10-foot channel would require a paved bottom. If a 75-x-10-foot channel or one with an equivalent cross sectional area with a paved bottom were constructed at the western end of the Project Channel for the protection of the existing western channel, other sections could be utilized for the remainder of the channel to the East.

Materials examined for potential protection of the channel bottom against scour were riprap, geotextiles, poured-in-place concrete and articulated concrete mats. Riprap is expected to be readily available and is the preferred alternative for protection of the channel sidewalls under the western bridges. It was dismissed from consideration as a channel bottom as its resistance to flow would require increasing the cross sectional area of the channel. Geotextiles, engineering fabrics, for placement over the bottom, were not considered due to channel velocities and wear and tear. Poured-in-place concrete required complicated construction and high costs and was therefore dismissed from further consideration. Articulated concrete mats, interlocking concrete block units, is the preferred alternative for channel bottom paving and possible use on the sidewalls due to their light weight, relative ease of installation and resistance to high velocities.

Adjacent to the channel, mangroves would be planted as part of the restoration effort. This would require grading a planting bed at about MLLW elevation extending, in most cases, to the upland side of the line of Public Domain. Windows would be cut in the sheet pile walls to permit tidal flows to sustain the plantings.

The use of vertical sheet pile walls versus a nonstructural sloped channel edge was evaluated. For the most part, it was determined that the vertical walls of a rectangular shaped channel require fewer earthworks than a channel with earthen slopes. Earthwork was determined to be the more costly than sheet pile wall installations. The side slopes require a widened channel footprint, consuming lands that would otherwise be suitable for mangrove restoration or public uses. Solid waste remaining in the earthen channel side slopes might work loose and become a nuisance to the area. Lastly, the well-defined edge of the sheet pile walls provides a deterrent to the dumping of solid wastes.

The channel bulkhead was designed with consideration of the mechanical properties of the soil, seismic influence on soils, corrosion, durability, serviceability, constructability for access, overhead clearance, side bank clearance, worker health and safety. The bulkhead was designed with storm drain/tidal cut-outs and a concrete wall cap. The wall was designed for dredge depths of 10 and 15 feet with embedment depths to 30 and 40 feet, based upon the soil characteristics.

Following is a detailed description of the civil design features of the CMP.

5.1 CHANNEL ALTERNATIVES

5.1.1 General

This section provides a description of the alternatives considered for the channel including the geometric configuration, shoreline, and channel bottom treatment for each channel alternative. The channel alternatives vary by width, depth, shoreline, and channel bottom treatment, and each one has the same channel alignment, which generally follows the existing CMP channel from the San José Lagoon on its eastern end to its connection with the existing, navigable portion of the CMP channel on its western end. Because the San José Lagoon is shallower than the proposed channels, each alternative utilizes a trapezoidal channel section with a vertical transition over approximately 4,300 feet along the channel centerline from approximately elevation –6.0 feet in the lagoon to the invert of the proposed channel alternative. The proposed channel also transitions to wider and shallower channel configurations at the Barbosa Avenue Bridge and from the Ponce de León

Avenue Bridge to the channel terminus west of the Luis Muñoz Rivera Avenue Bridge. Cross sections at each of the bridges are presented at the end of this section as figures 5.1-8 through 5.1-24. A description of the Project Channel configurations and alternatives follows.

5.1.2 San José Lagoon Entrance Channel

The San José Lagoon entrance channel, also referred to as the "extended channel," is a trapezoidal shaped channel with 5 to 1 side slopes that extends ~4,300 feet into San José Lagoon. Its bottom width would be the same as the main Project Channel alternatives. Its depth varies from its terminus in the lagoon at elevation –6.0 sloping down to the invert elevation of the proposed channel.

5.1.3 Barbosa Avenue Bridge Channel

The channel section under the Barbosa Avenue Bridge widens to the full available cross section under the bridge, transitioning back to the main channel over a distance ratio of 1 (width) to 5 (length).

5.1.4 Western Bridges Channel (Weir)

To prevent an erosive velocity at the Project Channel's outfall into the existing, navigable western CMP Channel, the 75-foot x 10-foot alternative cross sectional area (75 feet x 10 feet = 750 square feet) needs to be provided. Given the higher existing channel inverts under the western bridges, and in order to reduce conflicts with the bridge foundations, a channel with a depth of 6.5 feet was selected. To meet the same 750 square feet cross sectional area, the channel width must be 115 feet (115 feet x 6.5 feet = 747.5 square feet). Fitting this channel under the Ponce de León Bridge, the Tren Urbano Guideway, and the Luis Muñoz Rivera Avenue Bridge would create a raised channel downstream from the Project Channel, hence referenced as the "weir" (figures 5.1-1 and 5.1-2,). Utilizing this channel geometry under the western bridges constitutes the provision of a weir for all channel alternatives, including the 75-x-10-foot channel.

The weir would include rip rapped side slopes and a channel bottom paved with articulated concrete mat to mitigate scour level velocities into the western channel.

5.1.5 Project Channel

All of the channel alternatives presented below follow the same centerline and have the same length for the Project Channel. They all are rectangular channels except where they pass under bridges where the channel shallows and widens to the span of the abutments. They all have similar sheet pile wall support. With the exception of the 75-foot-wide channel, they all have earthen bottoms.

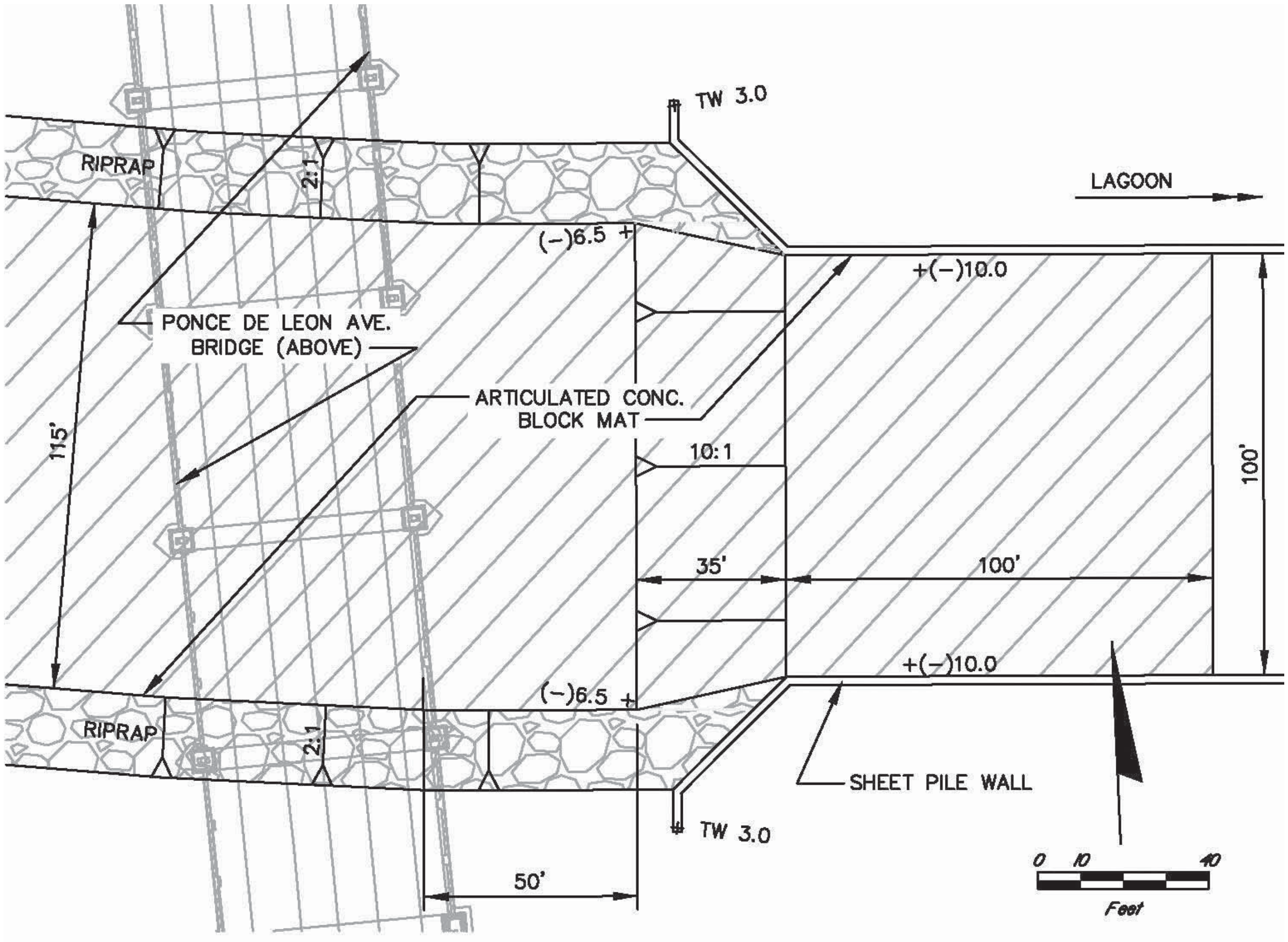


Figure 5.1-1. Weir, Plan View

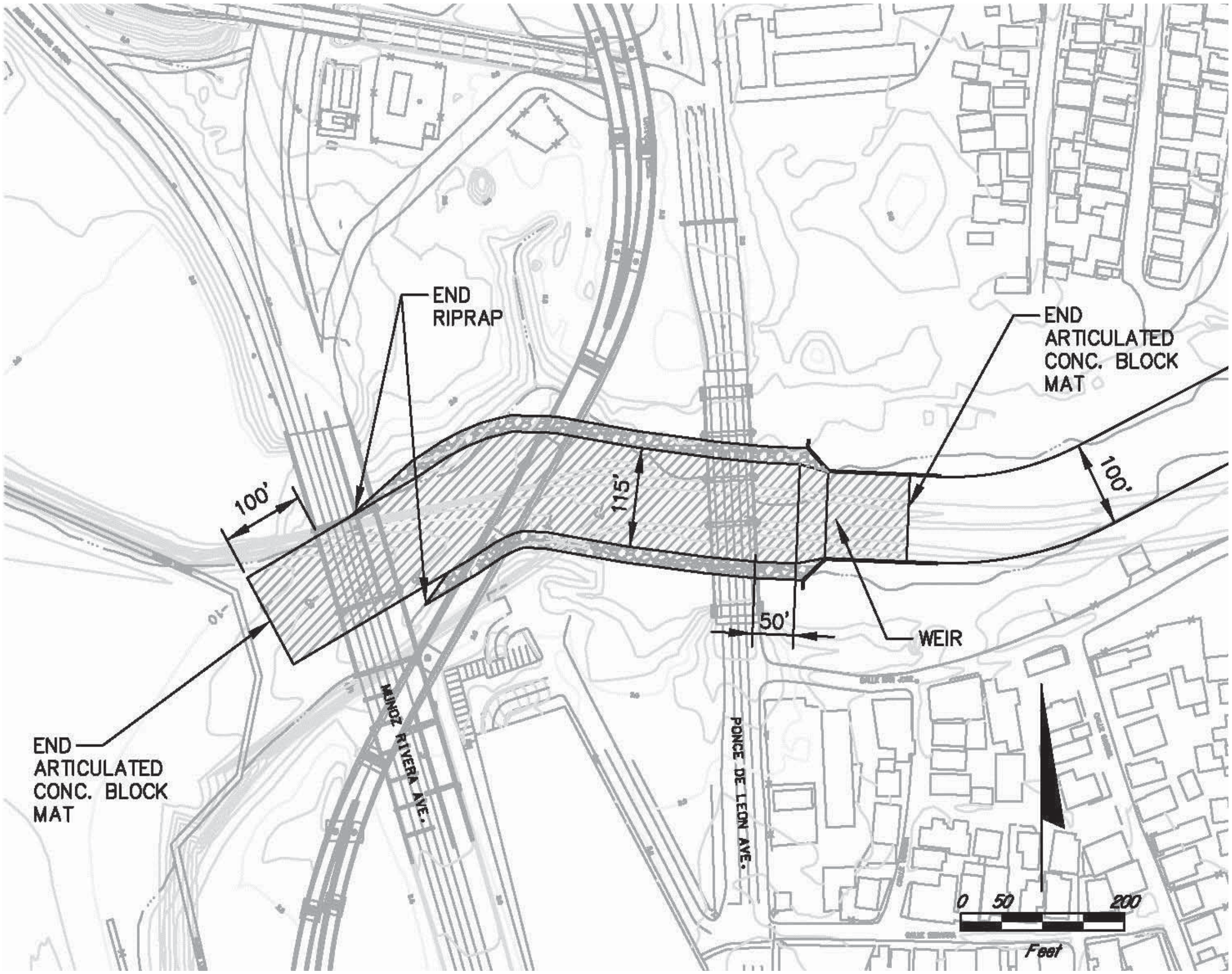


Figure 5.1-2. Weir, Overall Plan

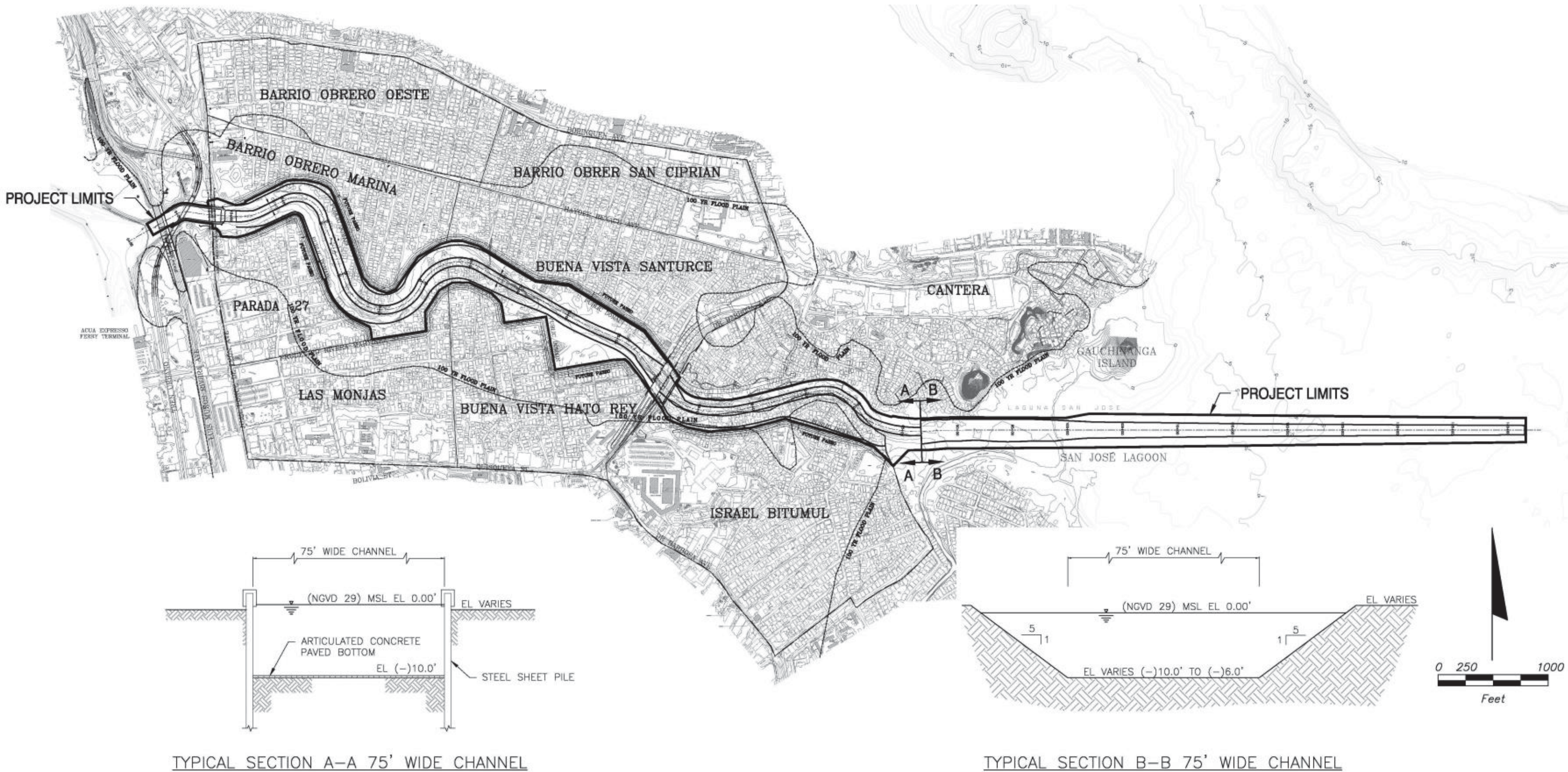


Figure 5.1-3. 75-foot Channel

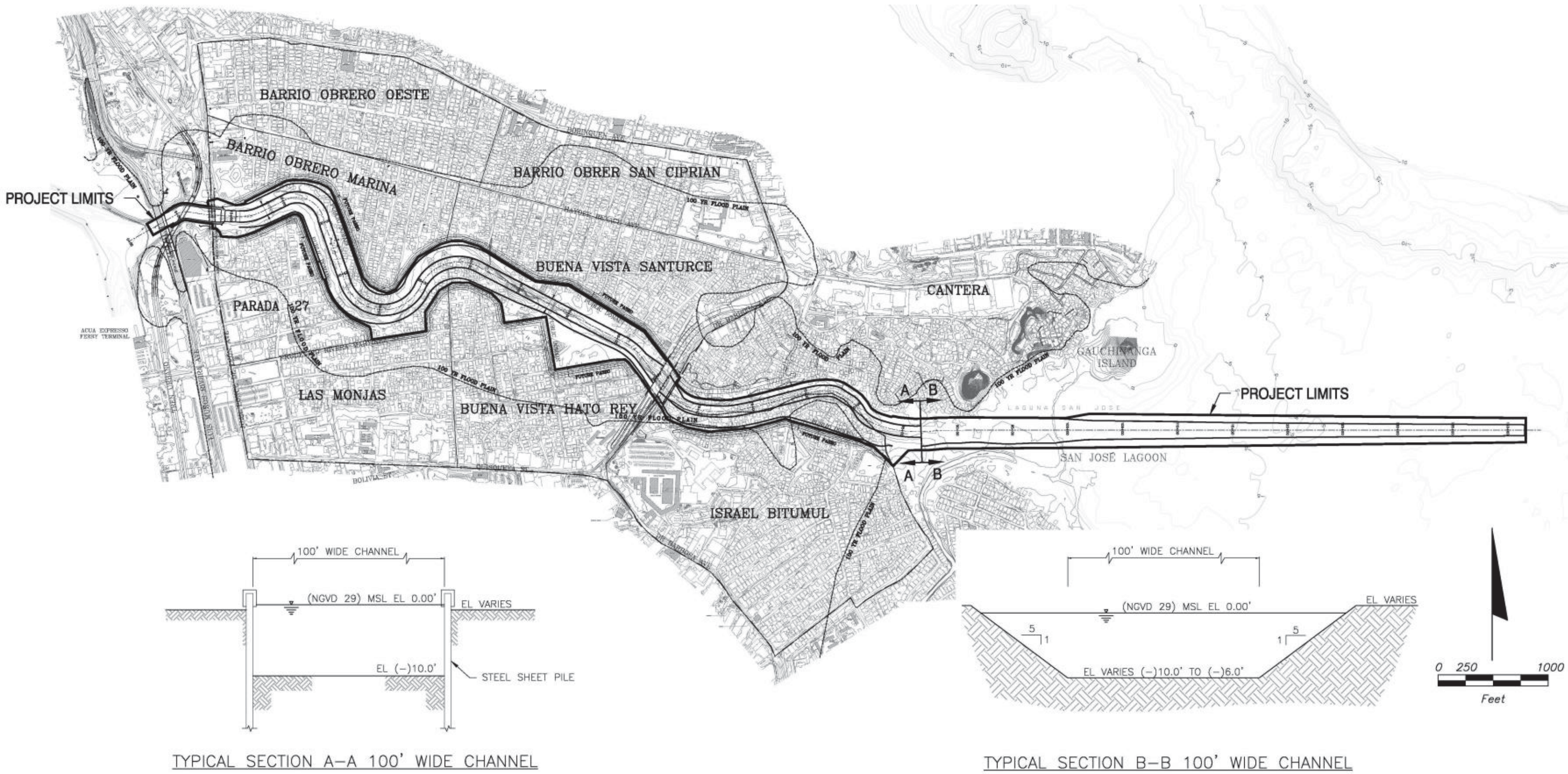


Figure 5.1-4. 100-foot Channel

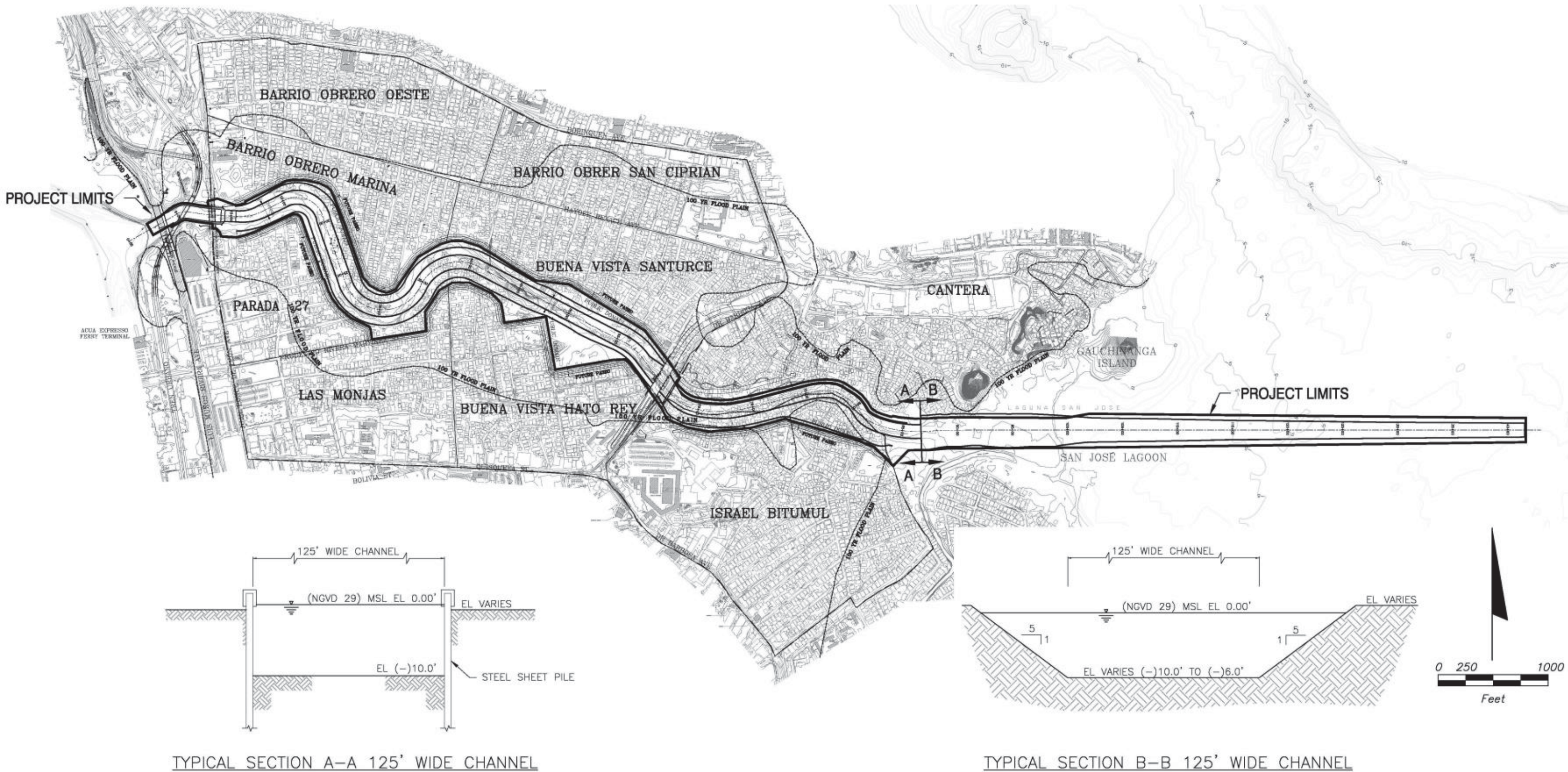


Figure 5.1-5. 125-foot Channel

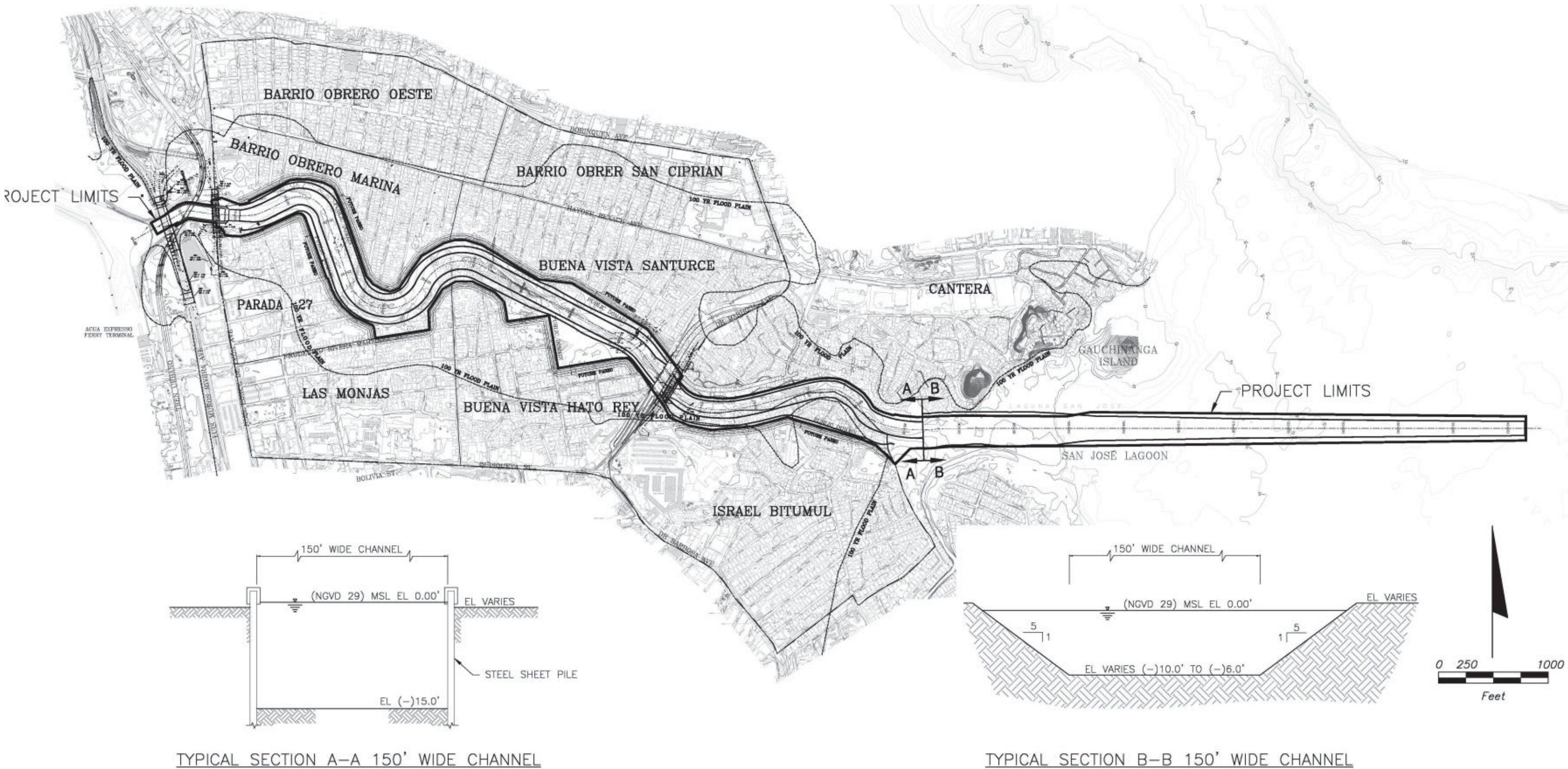


Figure 5.1-6. 150-foot Channel

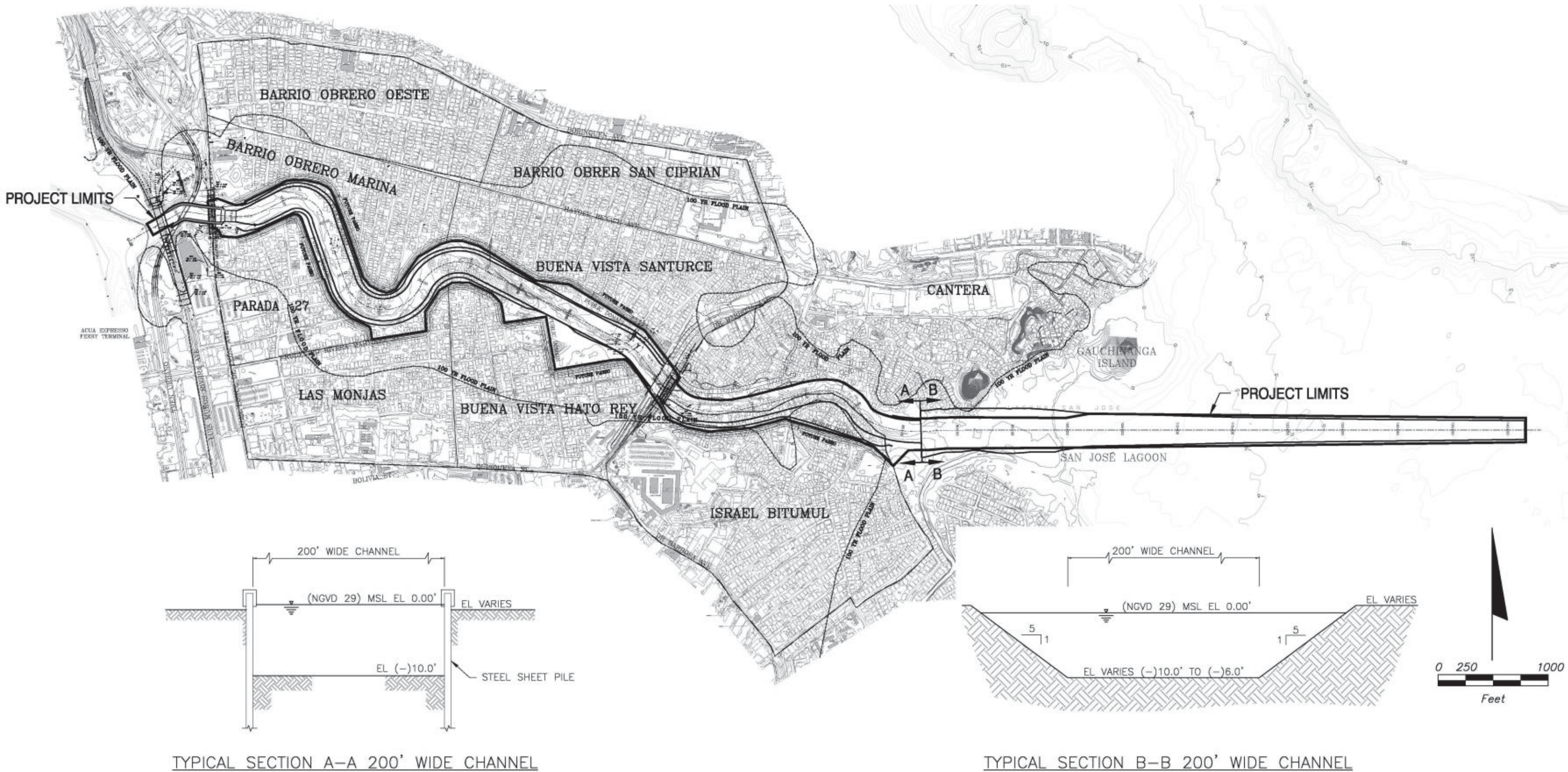


Figure 5.1-7. 200-foot Channel

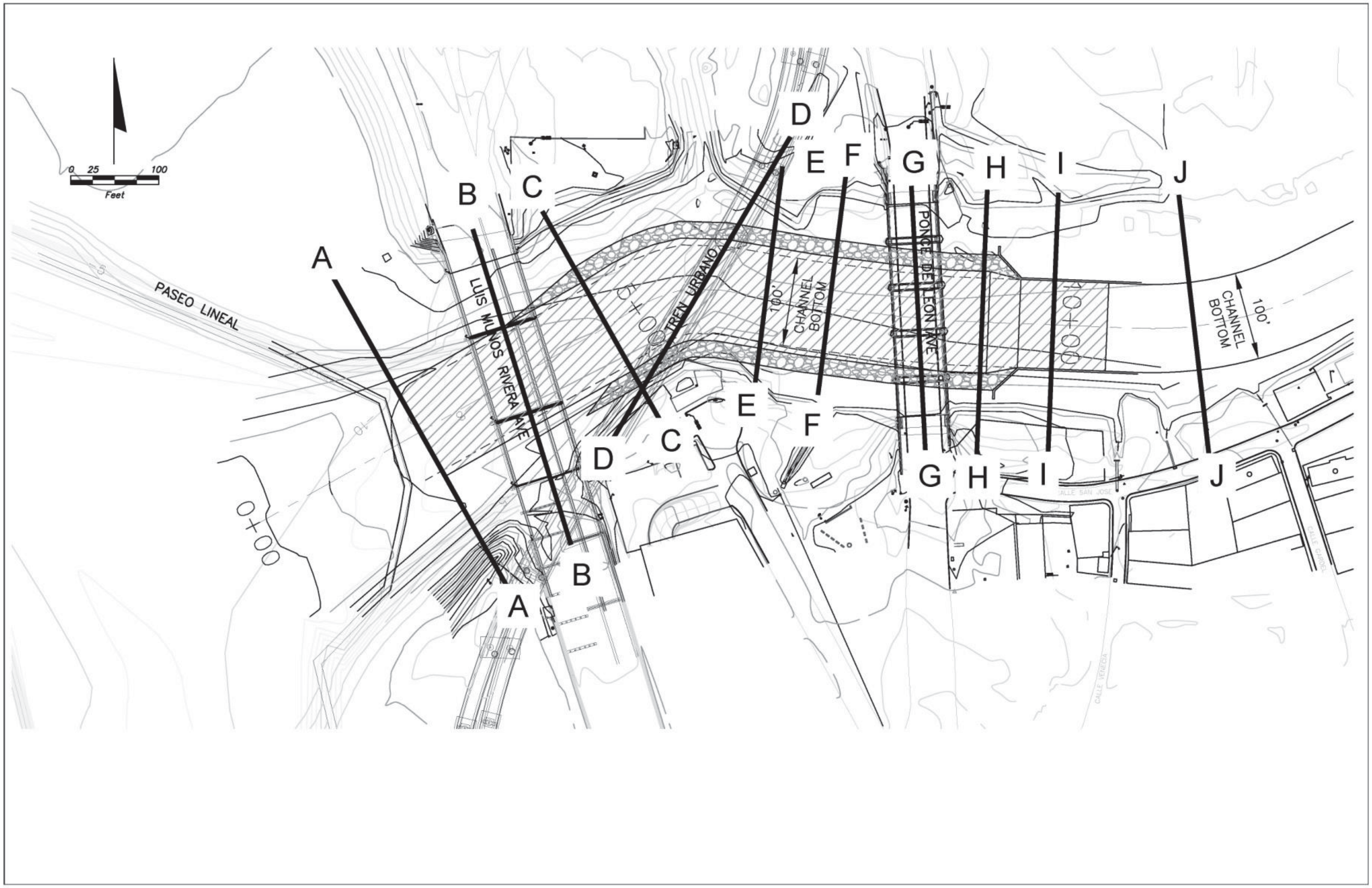


Figure 5.1-8. Cross Sections Plan Locations – Western Bridges

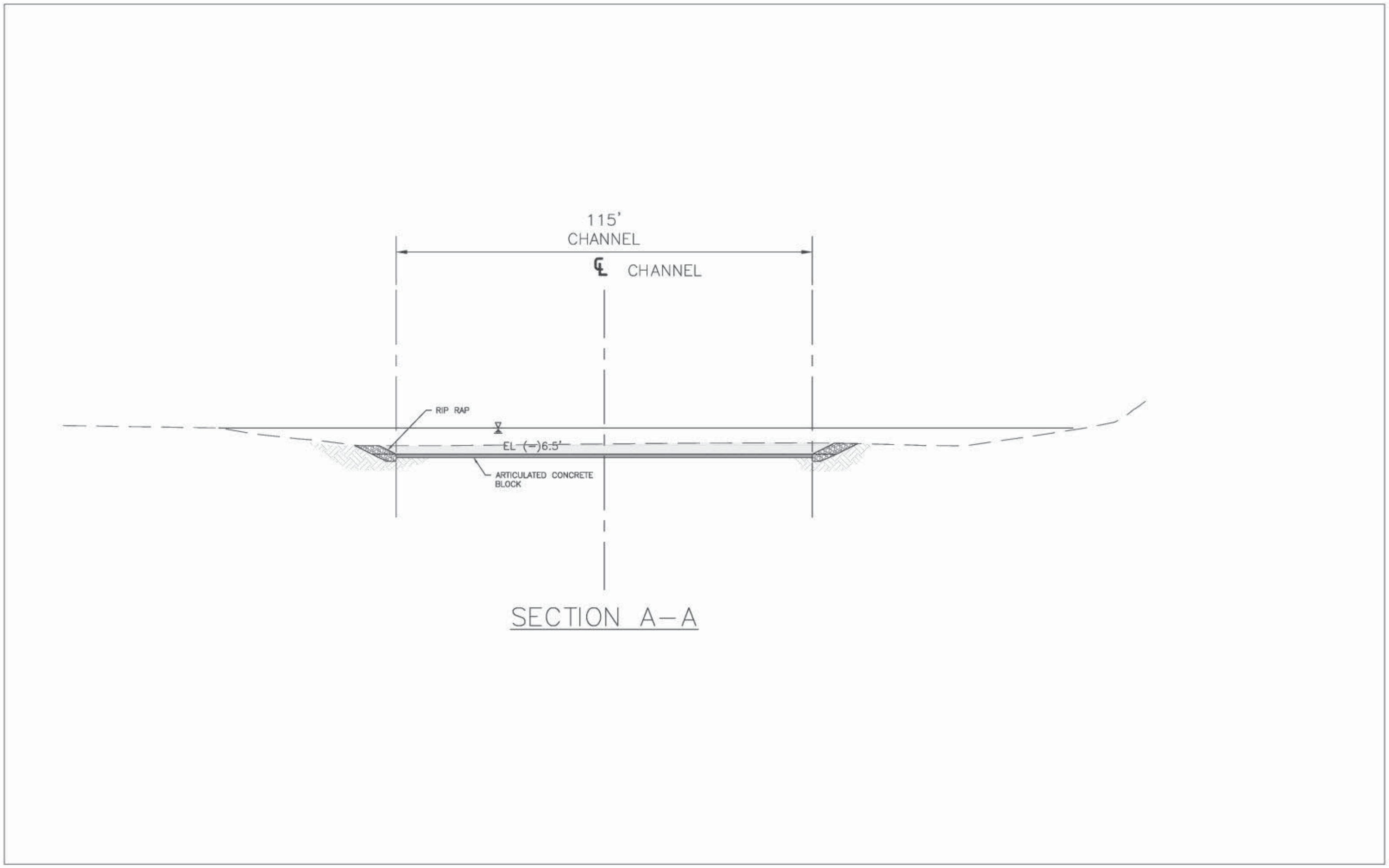


Figure 5.1-9. Cross Section A-A, Luis Muñoz Rivera Avenue Bridge

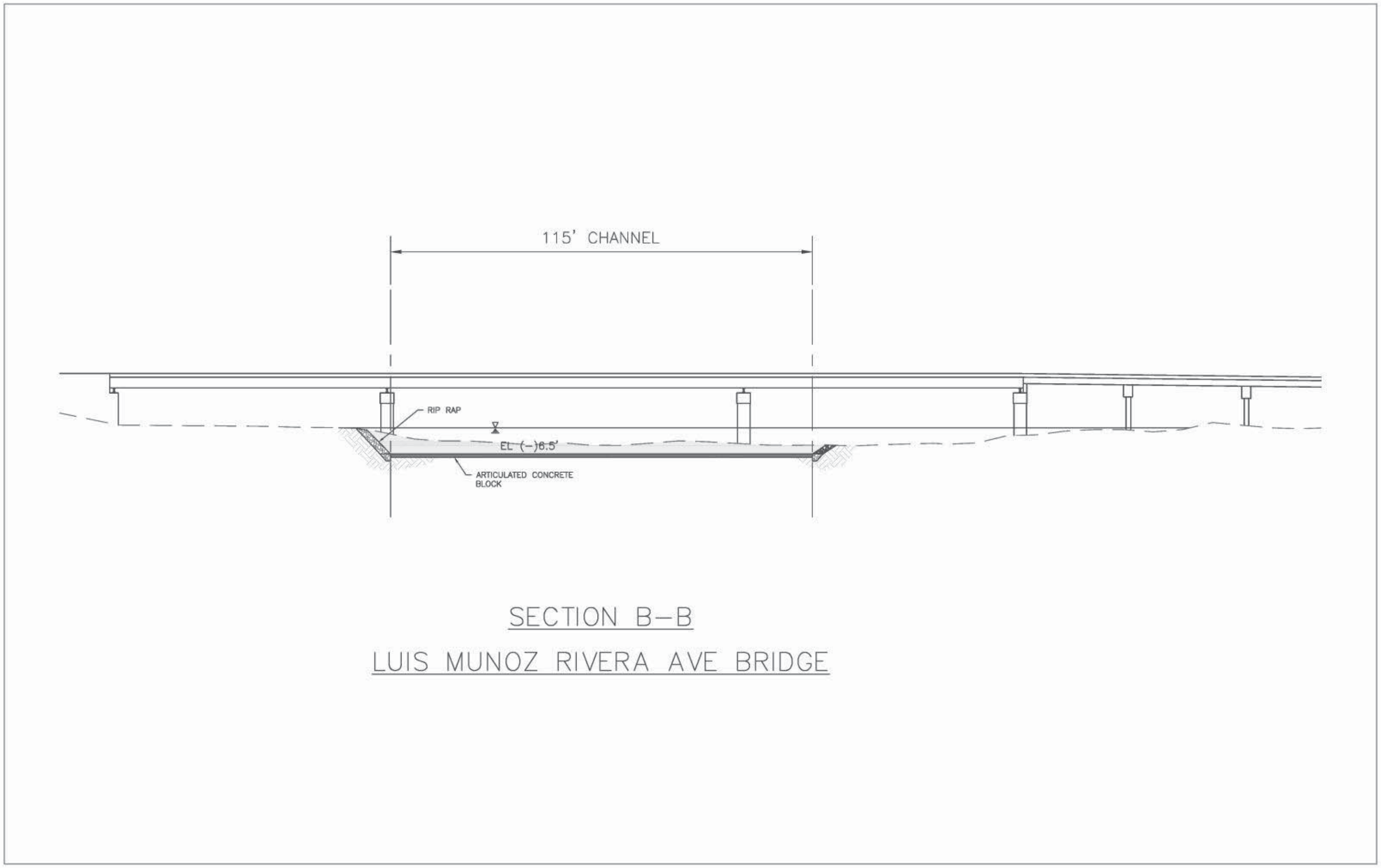


Figure 5.1-10. Cross Section B-B, Luis Muñoz Rivera Avenue Bridge

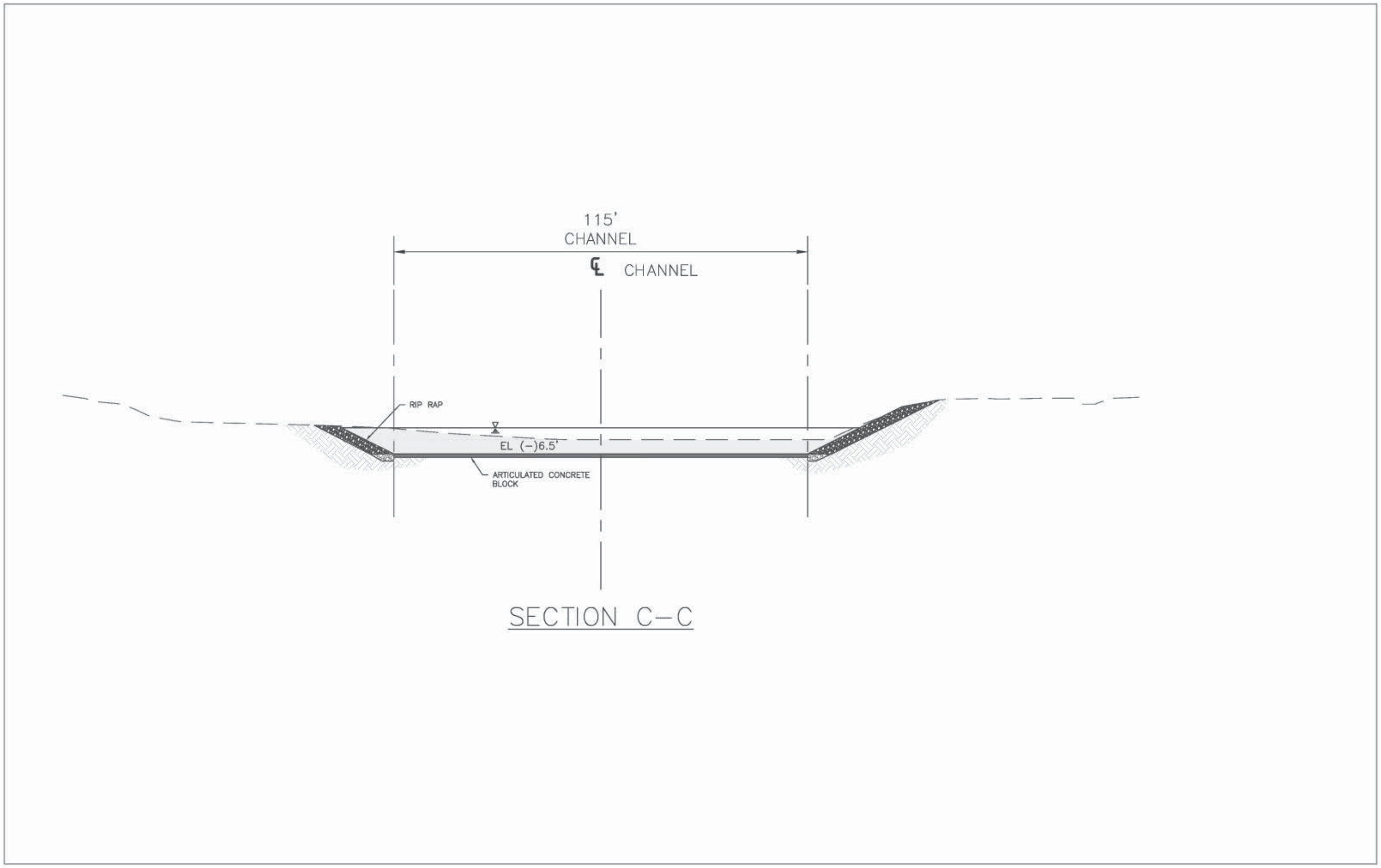


Figure 5.1-11. Cross Section C-C, Luis Muñoz Rivera Avenue Bridge

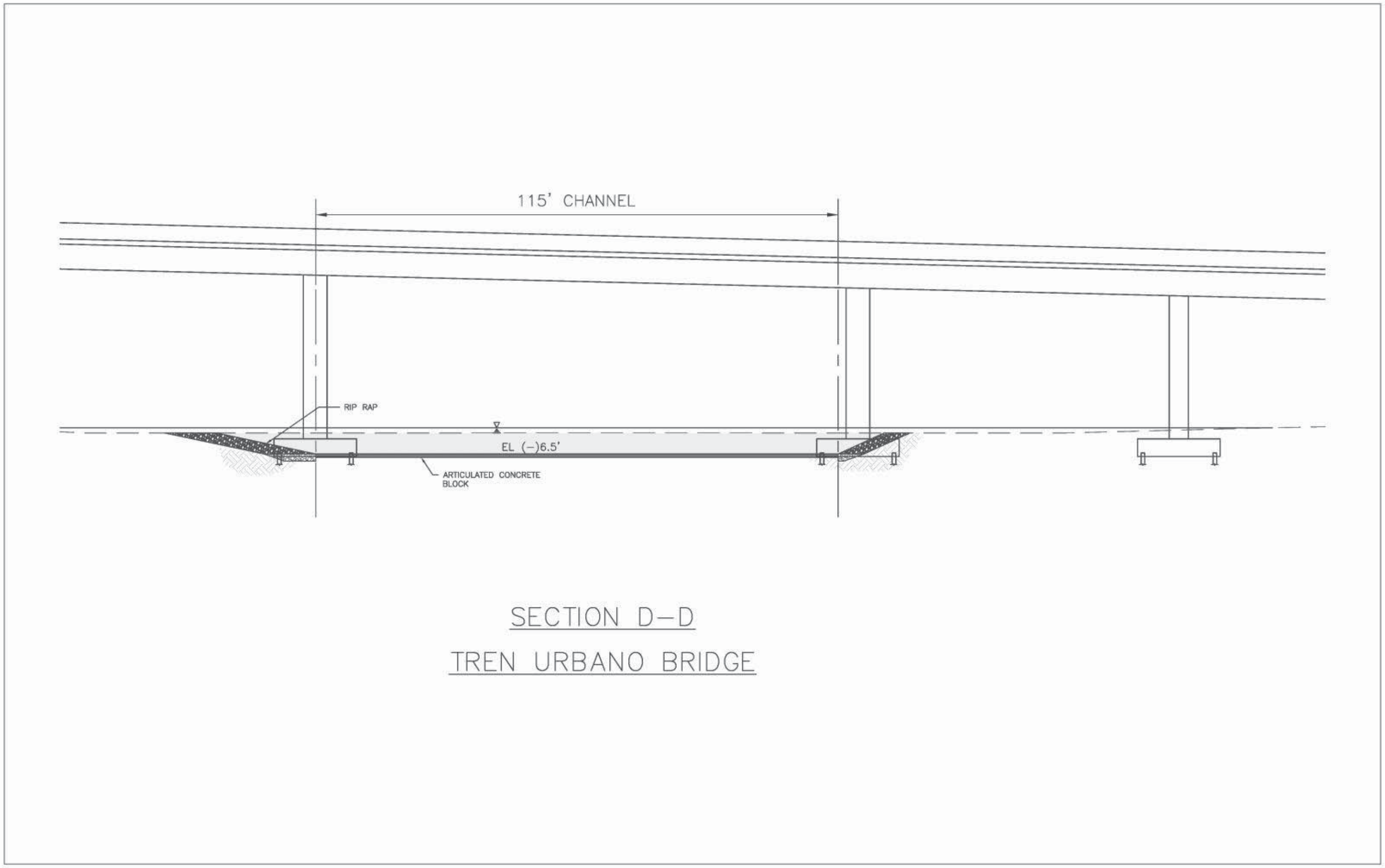


Figure 5.1-12. Cross Section D-D, Tren Urbano Bridge

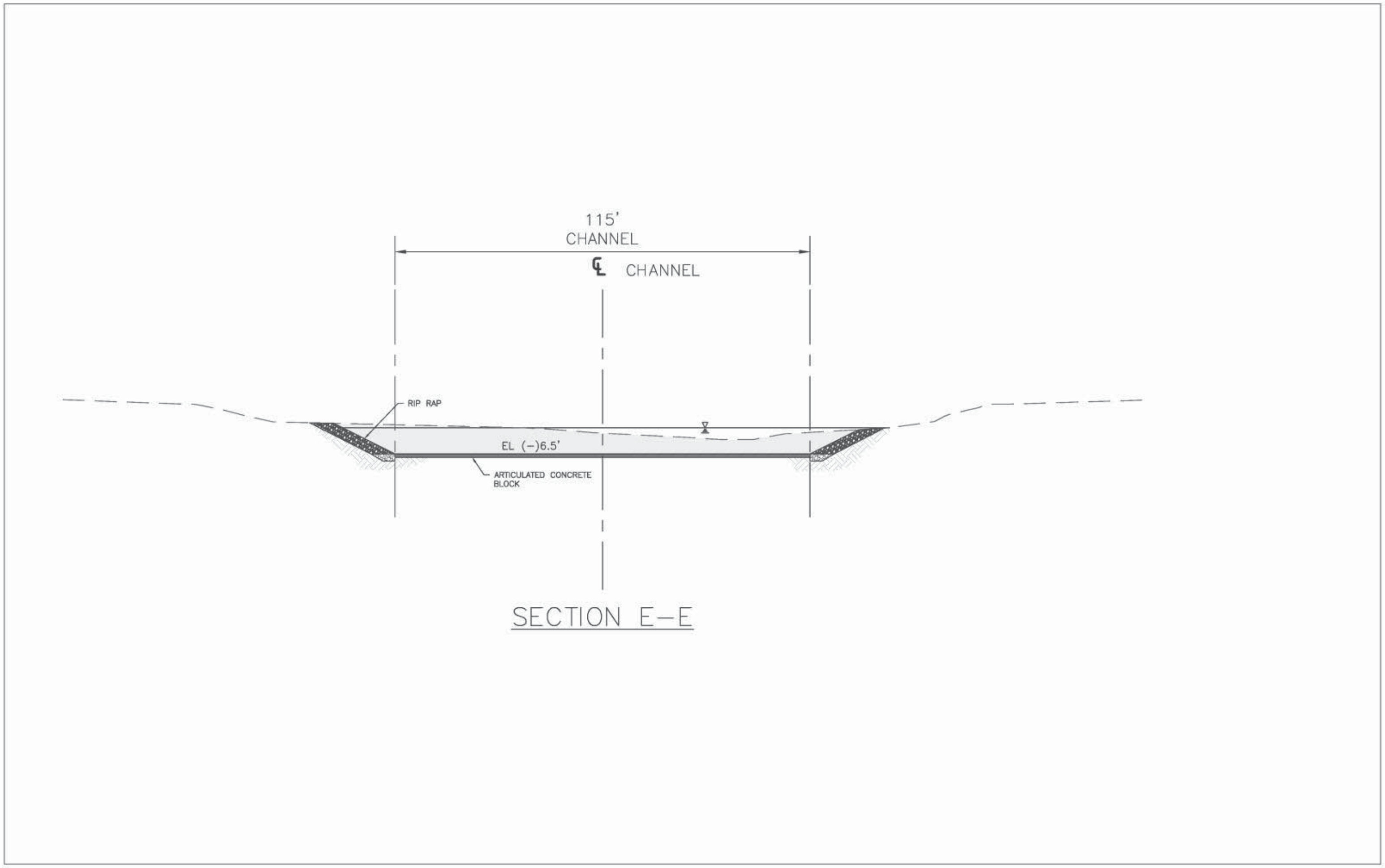


Figure 5.1-13. Cross Section E-E, Tren Urbano Bridge

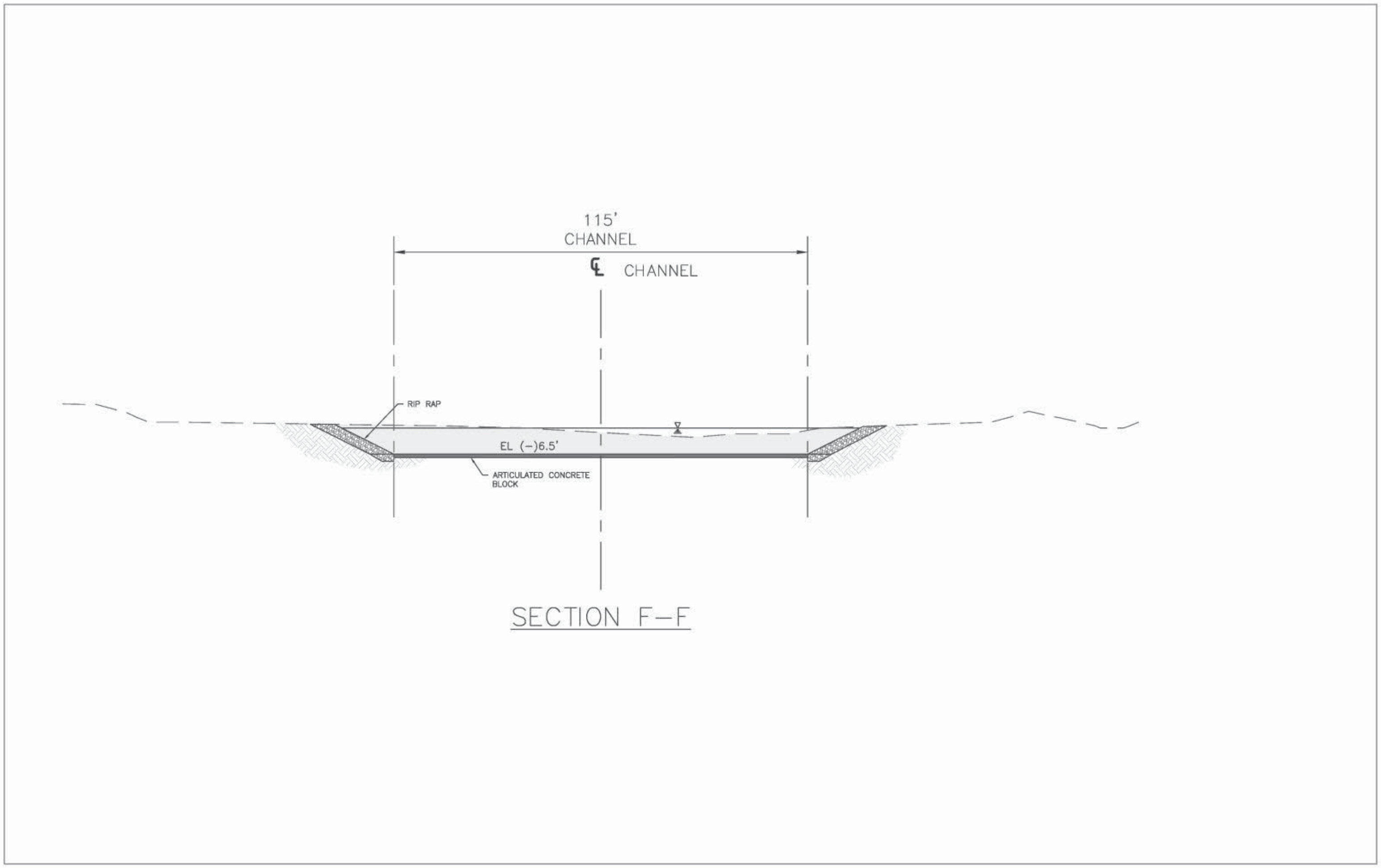


Figure 5.1-14. Cross Section F-F, Ponce de León Avenue Bridge

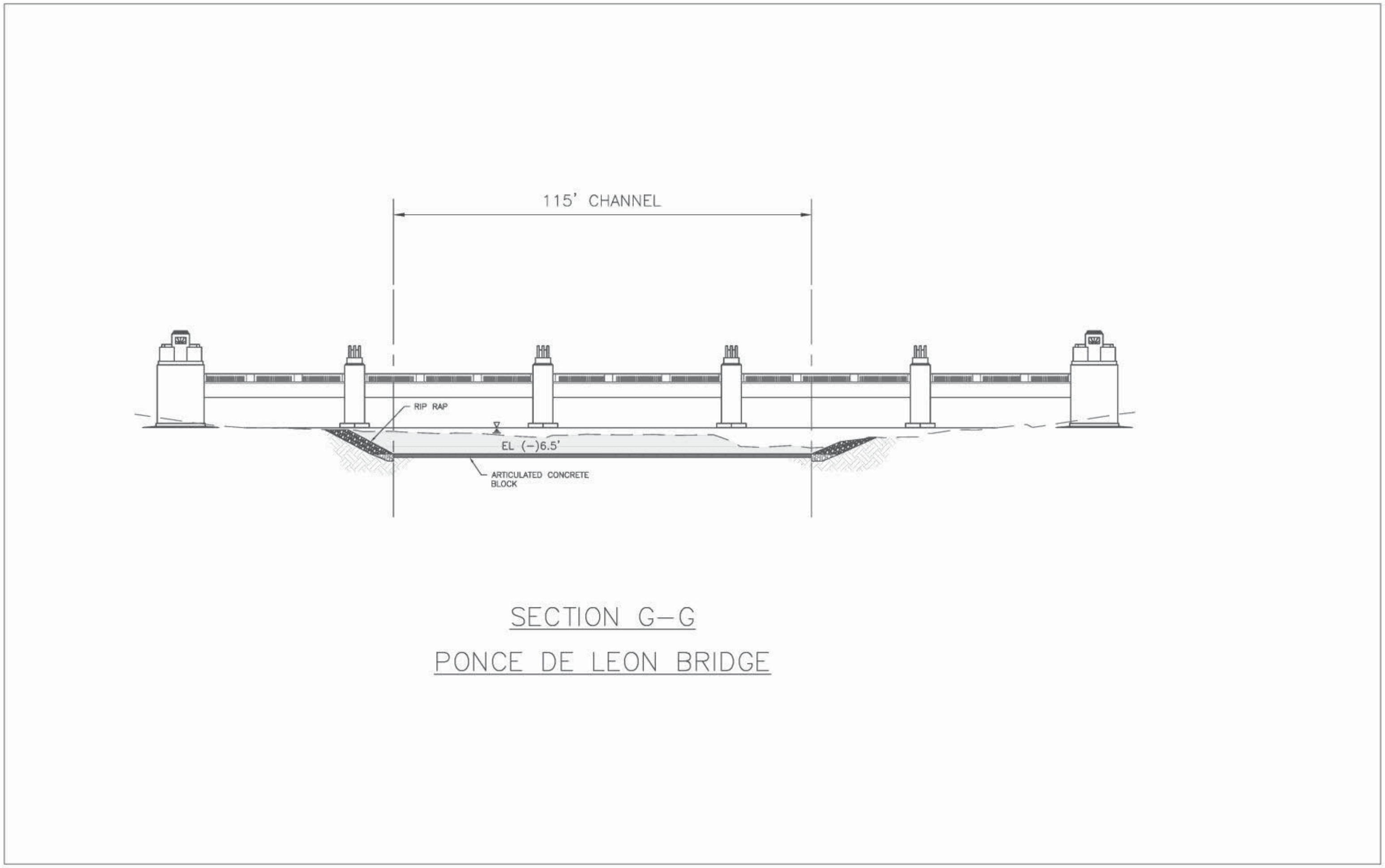


Figure 5.1-15. Cross Section G-G, Ponce de León Avenue Bridge

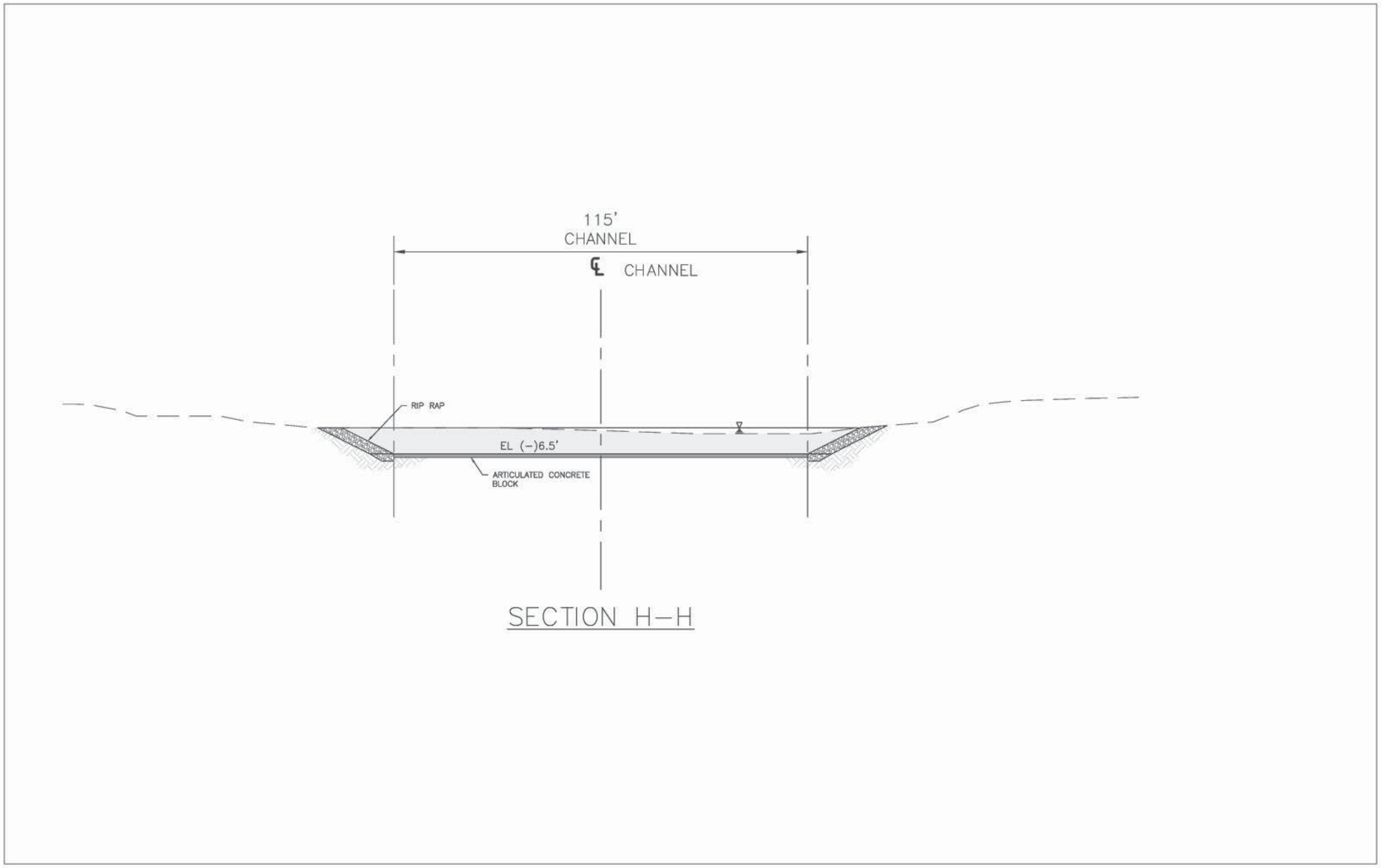


Figure 5.1-16. Cross Section H-H, Ponce de León Avenue Bridge

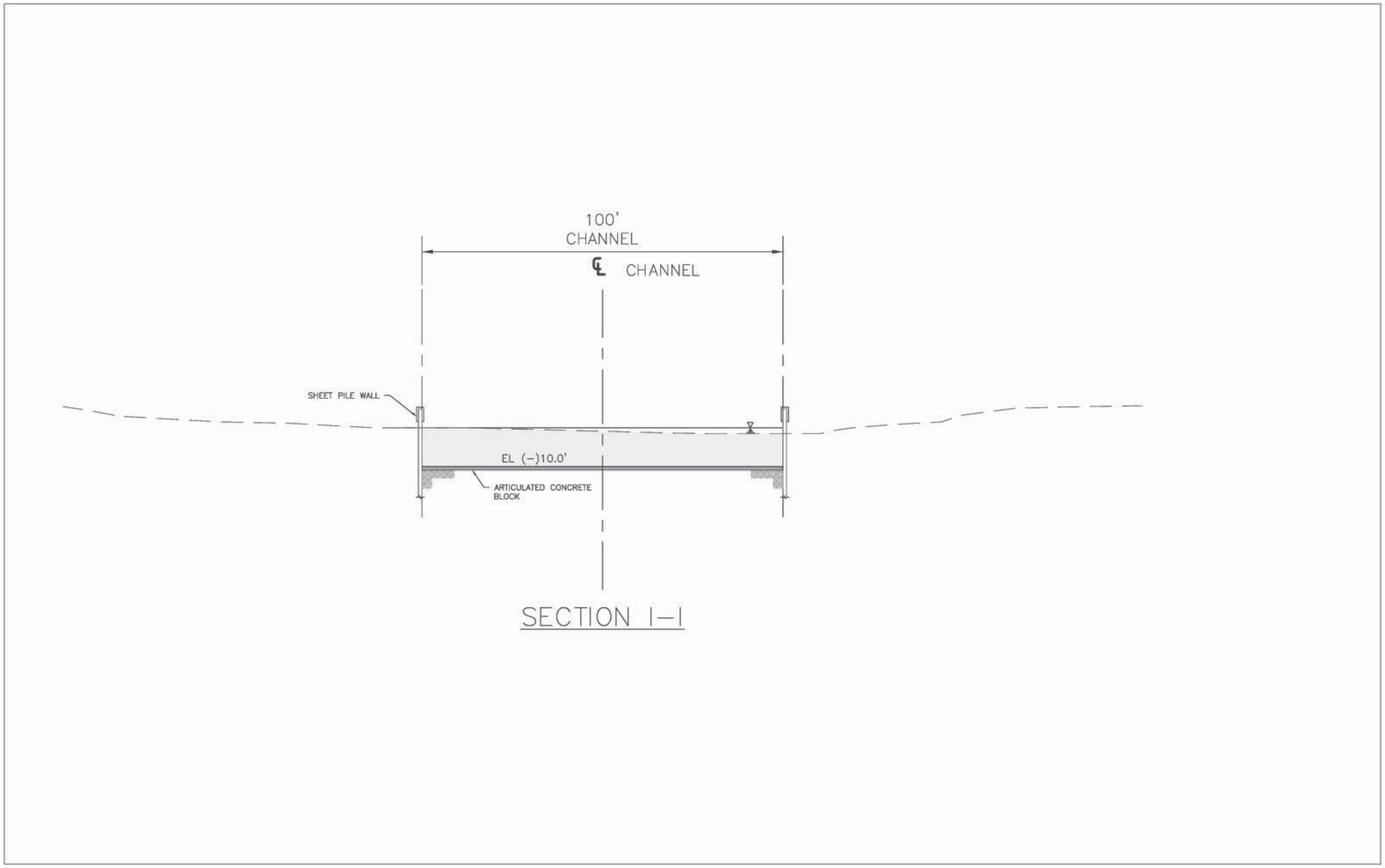


Figure 5.1-17. Cross Section I-I, Weir at Ponce de León Avenue Bridge

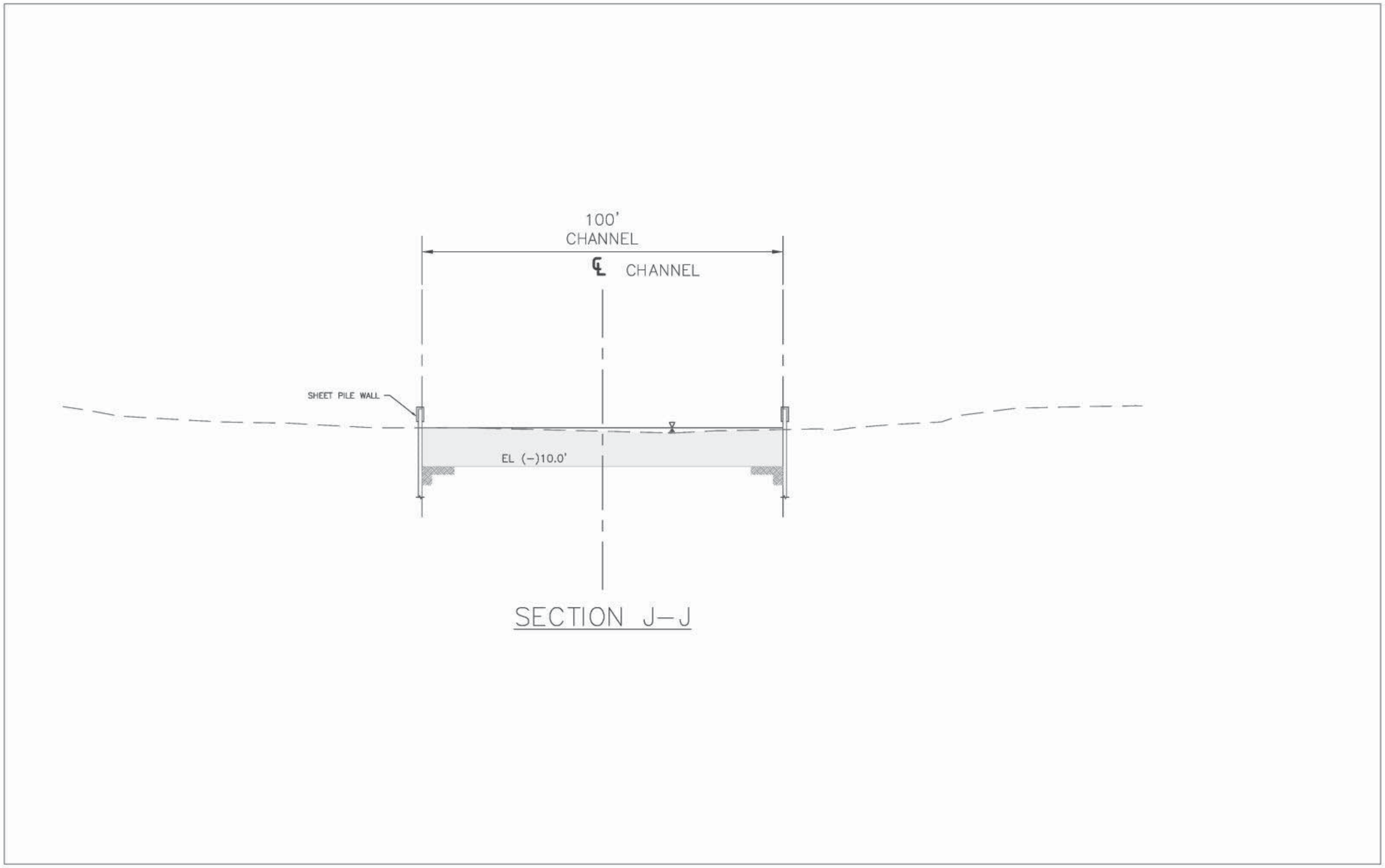


Figure 5.1-18. Cross Section J-J, Typical Channel above Ponce de León Avenue Bridge

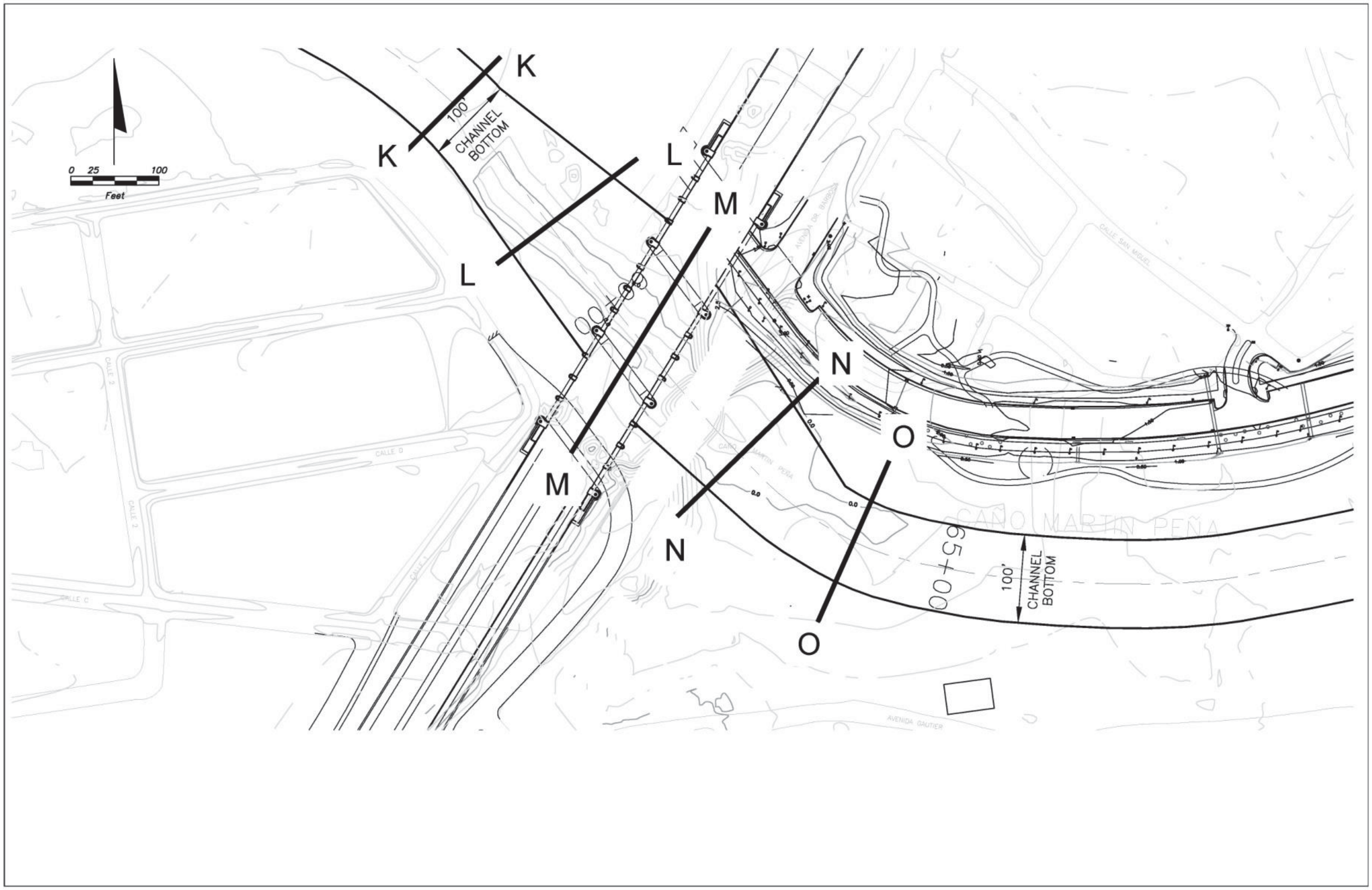


Figure 5.1-19. Cross Section Plan Locations, Dr. Barbosa Avenue Bridge

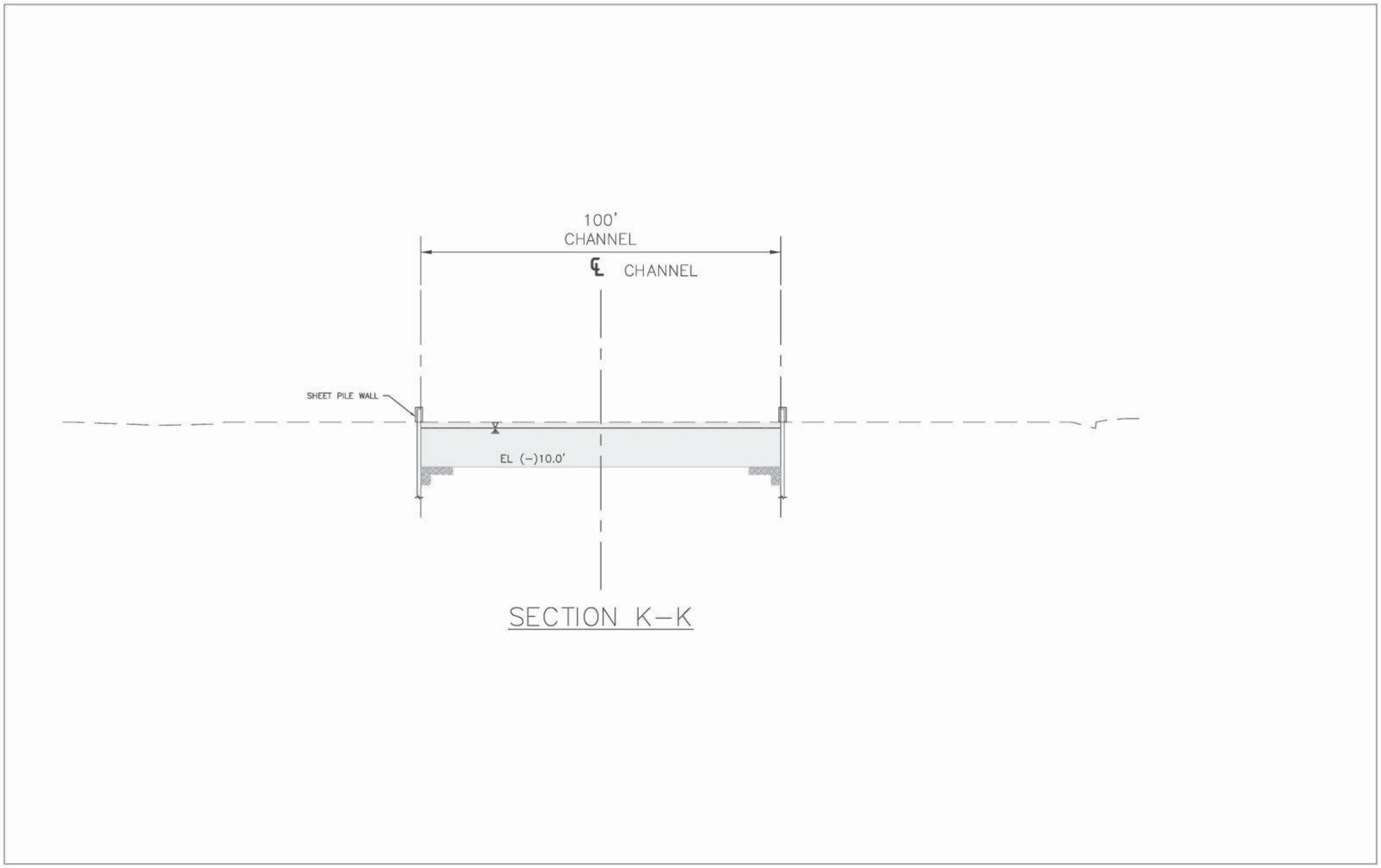


Figure 5.1-20. Cross Section K-K, Typical Channel Below Dr. Barbosa Avenue Bridge

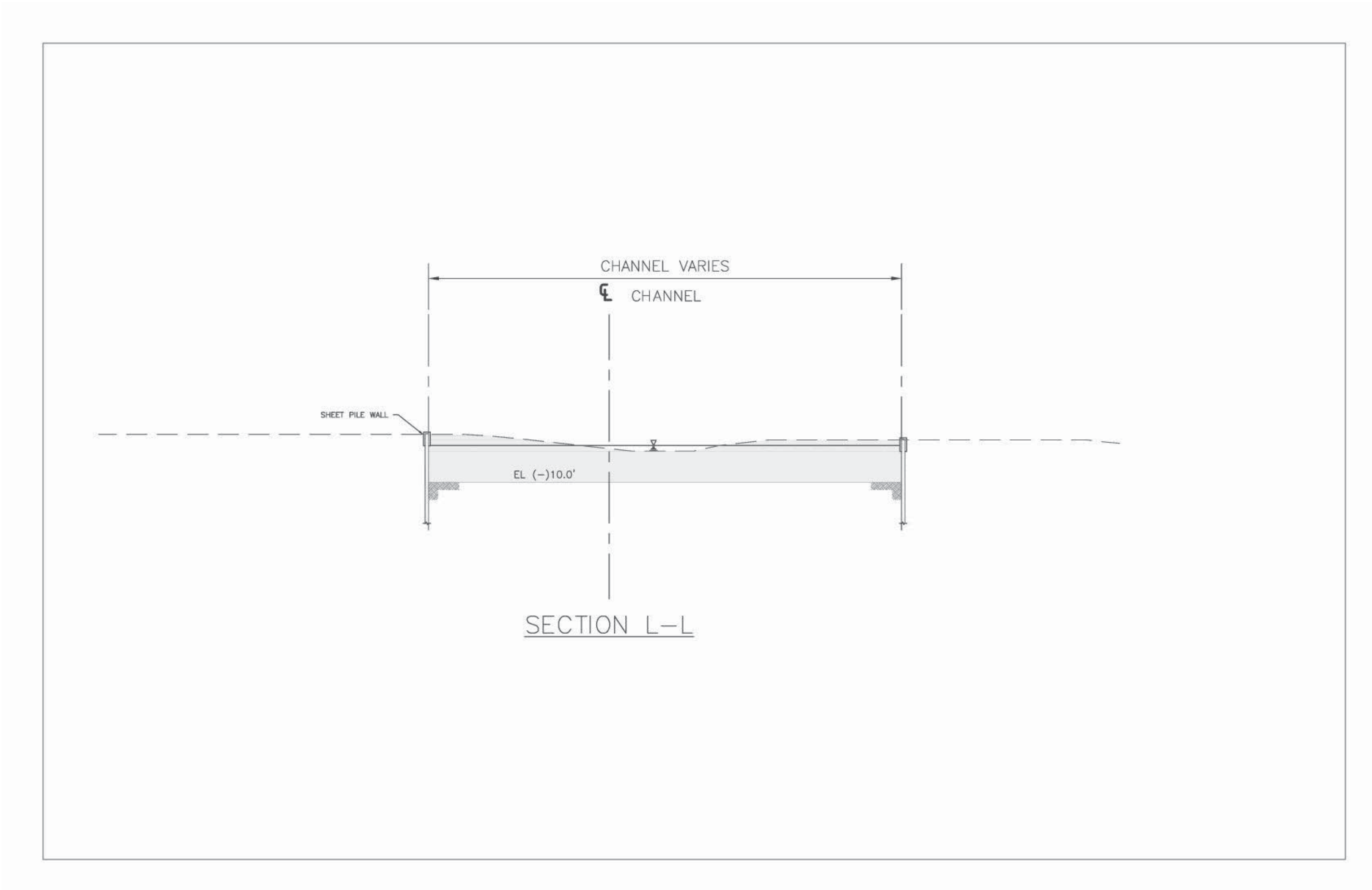


Figure 5.1-21. Cross Section L-L, Dr. Barbosa Avenue Bridge

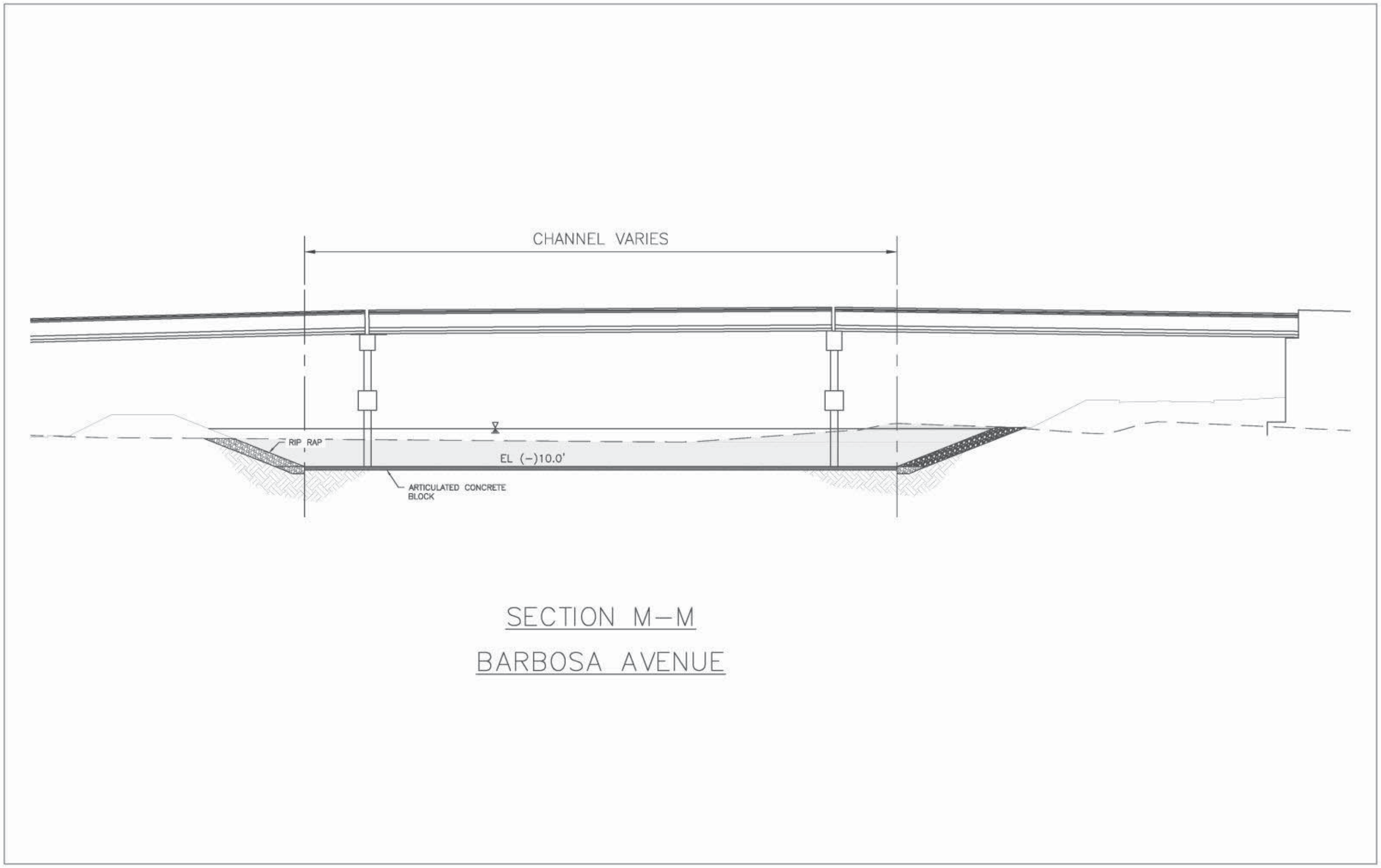


Figure 5.1-22. Cross Section M-M, Dr. Barbosa Avenue Bridge

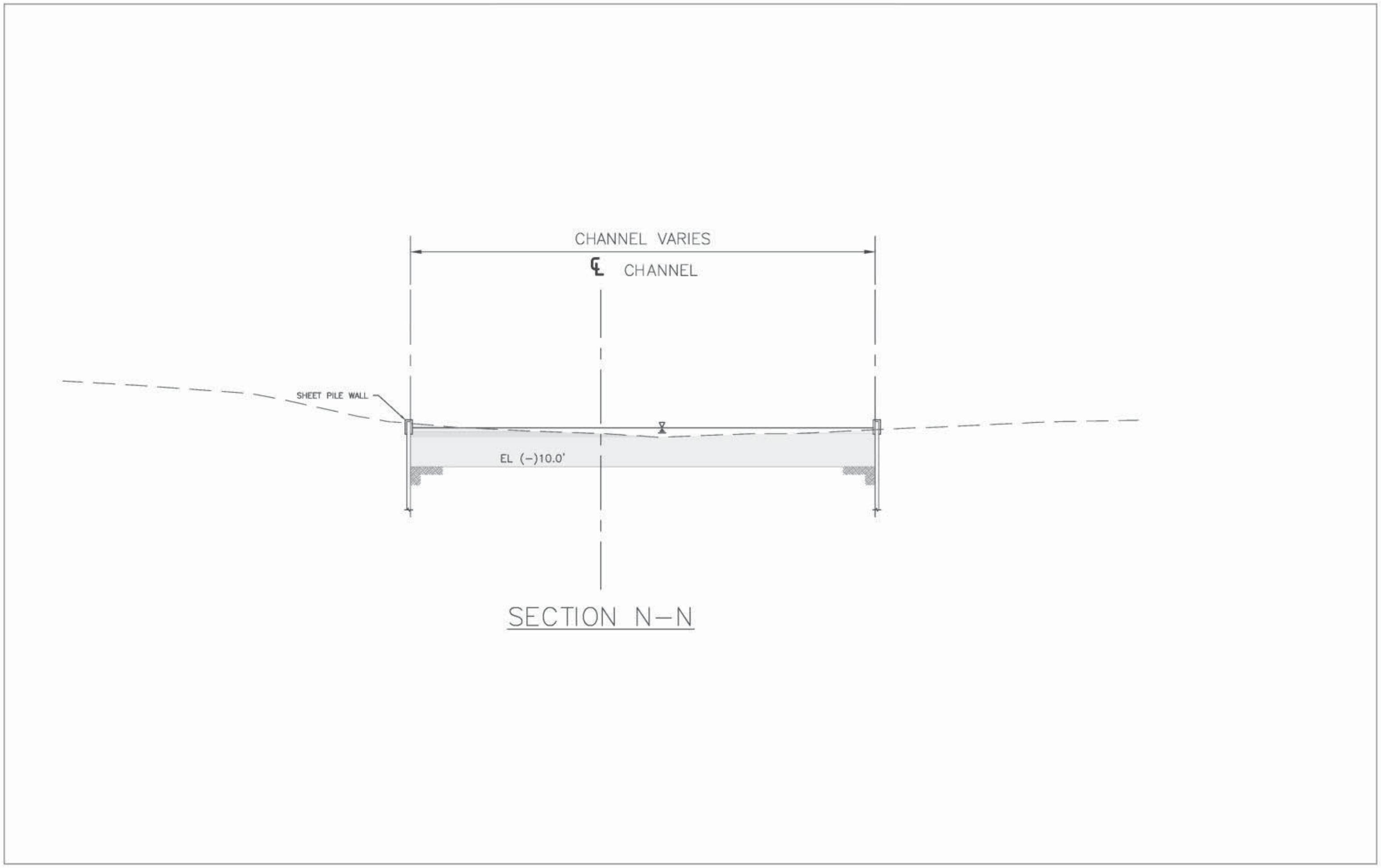


Figure 5.1-23. Cross Section N-N, Dr. Barbosa Avenue Bridge

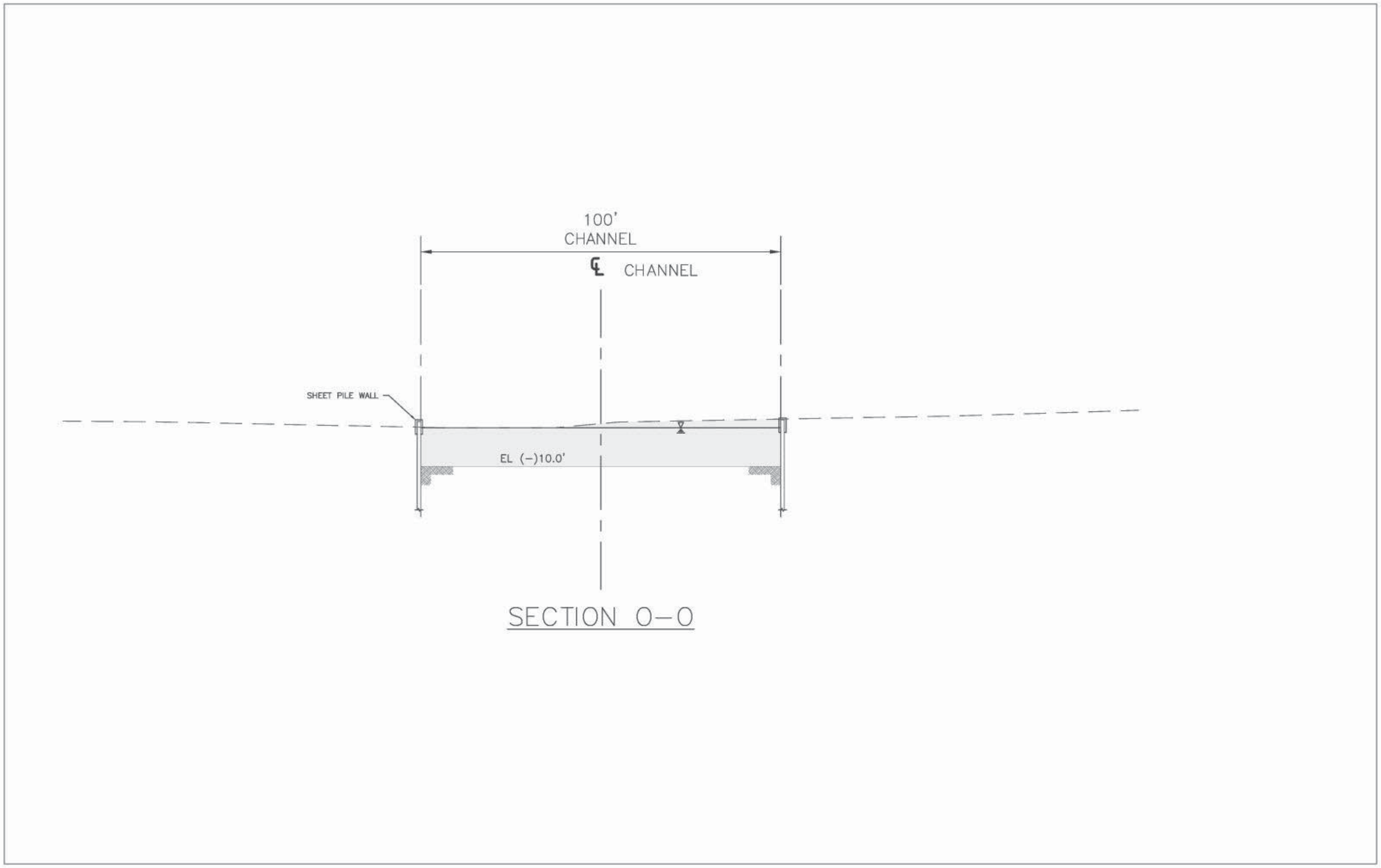


Figure 5.1-24. Cross Section O-O, Dr. Barbosa Avenue Bridge

5.1.6 Design considerations for Channel Selection

5.1.6.1 Channel Dimension Bracketing Analysis

Several considerations were identified that limited channel widths to distances between 75 feet and 200 feet, and channel depths to 10 feet. These factors included: geotechnical, hydrodynamics, scour potential, dredging volumes, mangrove restoration, recreation, navigation, and constructability.

5.1.6.1.1 Width

When considering channel widths, hydrodynamics, scour potential, mangrove restoration, recreation, navigation, and constructability were primary factors.

Greater than 200 feet wide – Mangrove restoration is an essential element of the project. The project is being conducted with the confines of the public domain and the area available for restoration is extremely limited. There has been substantial public participation in the project and there is a strong desire to maintain the overall aesthetics of the CMP, which includes wetland areas that were historically present along the canal. Channel designs with smaller widths would allow for more mangrove restoration potential than those designs with greater widths, especially considering the need for a minimum of approximately 32 feet of mangrove fringe on each side of the CMP (Fisher and Fischenich, 2000). Additionally, enlarging the CMP to widths greater than 200 feet could create a much wider CMP than has historically existed, and would essentially create an artificial waterway that would not meet the definition of restoration.

Recreation is an important secondary element of the project and is essential to maintain recreational opportunities in the highly urbanized area. Channel designs with smaller widths provide more area for recreational elements than those designs with greater widths. Continued navigational access is essential for public acceptance of the proposed project, and elimination of recreation in the area would be viewed as a secondary project impact. As a result of these factors, channel widths greater than 200 feet were not considered for the proposed project.

Less than 75 feet wide – A restored CMP would provide opportunities for recreational and some commercial navigation, primarily small vessels, travelling between San Juan Bay and San José Lagoon. The waterway should be wide enough for safe two-way passage of vessels while also accommodating the mooring of vessels along possible bulkheads and marginal wharves. Channel footprints at least 75-feet wide would be the minimum necessary to ensure safe navigation through any restored CMP channel.

Constructability is also of concern in determining channel design as two barges would be required to work side-by-side during the operation. These barges would need enough room for maneuverability to pass one another, and wider channel footprints would allow more space for these construction vessels to operate.

As 75 feet was determined to produce unacceptable scouring, channel widths were bracketed at this limit and only alternatives at 75 feet or wider were included. Navigational safety and constructability were also considered factors in maintaining alternative widths at 75 feet or wider.

Another factor in restricting channel widths to those 75 feet or greater is the ability of the area to mimic natural conditions. The CMP was historically 200–400 feet wide, and much smaller dimensions would not reflect prior conditions. During public coordination, members of the community expressed an opinion for the CMP to be restored nearest to historical conditions as possible, making dimensions at least 75 feet wide more acceptable.

Conclusion – As a result of these factors, channel widths greater than 200 feet were eliminated from consideration due to loss of restoration potential and recreational impacts. Widths less than 75 feet were eliminated due to navigational safety, scour potential, constructability, and ability to mimic historic conditions.

5.1.6.1.2 Depth

Geotechnical issues and secondary impacts were primary considerations for channel depths.

Less than 10 feet deep – In regards to geotechnical considerations, the CMP and channel banks contain solid waste from the surface to –10 feet. Thus, channel depths less than 10 feet could leave behind waste in the proposed channel's side slopes and bottom, which could work loose over time and be released into the estuary.

Greater than 10 feet deep – There are portions of the CMP channel, notably near the eastern end adjacent to the San José Lagoon, where limestone can be found at depths of -10.5 feet. In these areas, it is likely that substantial rock removal through blasting and disposal would have to be considered for parts of the channel. As this project site is within a highly-urban setting, substantial amounts of blasting would likely violate the constraint of avoiding secondary impacts within the communities adjacent to the CMP. While historic depths within the CMP are unknown, it is believed that depths were not greater than 10 feet based on the presence of limestone rock at –10.5 feet in depth and in light of the fact that solid waste can be found as deep as –10 feet. Increasing depths to 10–15 feet would cause irreversible change to the CMP by the removal of rock, further altering the tributary and creating a much deeper CMP that does not mimic the natural conditions that previously existed.

Conclusion – Water depths were scaled at 10 feet. Depths less than 10 feet would likely leave solid waste to be carried downstream and into other aquatic habitat. Depths greater than 10 feet would likely require blasting, violating a primary project constraint. Also, depths greater than 10 feet would not reflect the natural, historical depths of the CMP.

5.1.6.2 Initial Array of Alternatives

After the bracketing analysis, five combinations of widths and depths were chosen for an Initial Array: 75 x 10 feet, 100 x 10 feet, 125 x 10 feet, 150 x 10 feet, and 200 x 10 feet. The mangrove planting bed measure and all four non-structural measures were combined with each width and depth combination. Erosion control features were also added to each alternative, as appropriate. All measures contain riprap and a weir, and the 75-x-10-foot alternative contains ACM through the Project Channel due to the higher bottom velocities it would create in the Project Channel. Lastly, in order to incorporate the two different disposal options, the number of alternatives was doubled into Series 1-5, and Series 1B-5B. Series 1-5 contains the San José Lagoon pits disposal option, while Series 1B-5B contains the permanent upland disposal option.

5.1.6.2.1 No Action Alternative

Federal planning guidelines require the evaluation of the "No Action" alternative plan. Taking no additional Federal actions would result in the future without-project condition (Section 3) occurring over the planning horizon. The No Action Alternative plan provides a basis for comparing the project effects of alternative plans to conditions that can reasonably be expected to occur without constructing the project. As part of the No Action Alternative, ENLACE would undertake other elements of the CDLUP, but would not continue with the demolition of existing structures within the Public Domain Limit of the CMP Project Area, and the associated relocation of families.

5.1.6.2.2 Alternative Plan 1 – 75-Foot Channel Width, 10-Foot Depth

Alternative Plan 1 includes the following measures: 1) 75-foot-wide, 10-foot-deep rectangular channel with concrete-capped steel sheet pile walls (with variations in channel width and depth at the 4 bridges in the western portion of the Project Channel, the Barbosa Bridge, and terminus of the CMP with the San José Lagoon); 2) trapezoidal channel with 5:1 earthen side slopes exiting from the CMP and extending approximately 4,300 feet into San José Lagoon, 3) disposal of dredged material in the San José Lagoon pits; 4) a weir in the western end of the Project Channel with articulated concrete mat bottom and riprap protection for the bridges, 5) ACM paving throughout the Project Channel, 6) mangrove planting along the channel margins; and 7) non-structural measures.

5.1.6.2.3 Alternative Plan 2 – 100-Foot Channel Width, 10-Foot Depth

Alternative Plan 2 includes the following measures: 1) 100-foot-wide, 10-foot-deep rectangular channel with an earthen bottom and concrete-capped steel sheet pile walls (with variations in channel width and depth at the 4 bridges in the western portion of the Project Channel, the Barbosa Bridge, and terminus of the CMP with the San José Lagoon); 2) trapezoidal channel with 5:1 earthen side slopes exiting from the CMP and extending approximately 4,300 feet into San José Lagoon; 3) disposal of dredged material in the San José Lagoon pits; 4) erosion control weir in the western end of the Project Area with associated riprap for bridges and ACM for the channel bottom; 5) mangrove planting along the channel margins; and 6) non-structural measures.

5.1.6.2.4 Alternative Plan 3 – 125-Foot Channel Width, 10-Foot Depth

Alternative Plan 3 includes the following measures: 1) 125-foot-wide, 10-foot-deep rectangular channel with an earthen bottom and concrete-capped steel sheet pile walls (with variations in channel width and depth at the 4 bridges in the western portion of the Project Channel, the Barbosa Bridge, and terminus of the CMP with the San José Lagoon); 2) trapezoidal channel with 5:1 earthen side slopes exiting from the CMP and extending approximately 4,300 feet into San José Lagoon; 3) disposal of dredged material in the San José Lagoon pits; 4) erosion control weir in the western end of the Project Area with associated riprap for bridges and ACM for the channel bottom; 5) mangrove planting along the channel margins; and 6) non-structural measures.

5.1.6.2.5 Alternative Plan 4 – 150-Foot Channel Width, 10-Foot Depth

Alternative Plan 5 includes the following measures: 1) 150-foot-wide, 10-foot-deep rectangular channel with an earthen bottom and concrete-capped steel sheet pile walls (with variations in channel width and depth at the 4 bridges in the western portion of the Project Channel, the Barbosa Bridge, and terminus of the CMP with the San José Lagoon); 2) trapezoidal channel with 5:1 earthen side slopes exiting from the CMP and extending approximately 4,300 feet into San José Lagoon; 3) disposal of dredged material in the San José Lagoon pits; 4) erosion control weir in the western end of the Project Area with associated riprap for bridges and ACM for the channel bottom; 5) mangrove planting along the channel margins; and 6) non-structural measures.

5.1.6.2.6 Alternative Plan 5 – 200-Foot Channel Width, 10-Foot Depth

Alternative Plan 7 includes the following measures: 1) 200-foot-wide, 10-foot-deep rectangular channel with an earthen bottom and concrete-capped steel sheet pile walls (with variations in channel width and depth at the 4 bridges in the western portion of the Project Channel, the Barbosa Bridge, and terminus of the CMP with the San José Lagoon); 2) trapezoidal channel with 5:1 earthen side slopes exiting from the CMP and extending approximately 4,300 feet into San José Lagoon; 3) disposal of dredged material in the San José Lagoon pits; 4) erosion control weir in the western end of the Project Area with associated riprap for bridges and ACM for the channel bottom; 5) mangrove planting along the channel margins; and 6) non-structural measures.

5.1.6.3 B-Series Alternatives

The B-Series of alternatives is identical to the five above, except that disposal of dredged material would occur within a permanent upland disposal site within 10 miles of the project site instead of the San José Lagoon pits.

5.1.7 Screening of Initial Array

5.1.7.1 Screening of Permanent Upland Disposal Alternatives (B-series)

In order to determine an appropriate Final Array, a screening analysis was conducted to determine whether one of the disposal methodologies was preferable for reasons other than cost. A comparison of the Principles and Guidelines (P&G) Criteria indicated that the Permanent Upland Disposal alternatives (1B–5B) were less acceptable than San José Lagoon pits alternatives (1–5). The permanent upland disposal alternatives would result in significant amounts of heavy truck use through the San Juan area and secondary roads and neighborhoods to reach the upland disposal site(s). The impacts to infrastructure as well as associated noise, air quality, and community impacts would be significant and controversial.

Public input, particularly from recreational and commercial fisherman within the San José Lagoon area, has also indicated that there are concerns with lagoon disposal; however, the temporary loss of access to the San José Lagoon pits for recreational and commercial fisherman is considered more acceptable than sustained trucking impacts to a broad group of residents and businesses along the hauling routes to the permanent upland disposal site(s). As a result, it was determined that San José Lagoon was more acceptable than permanent upland disposal. There are no significant differences between San José Lagoon and permanent upland disposal in regards to meeting the objectives and constraints, the P&G four accounts (see Section 5.4.2 for more information), or any other factors that could be considered. Therefore, alternatives 1B, 2B, 3B, 4B, and 5B were screened as these plans, based on the P&G Criteria of acceptability, would not have been selected as a Tentatively Selected Plan (TSP).

5.1.7.2 Screening of Larger Channel Alternatives

Benefits for the CMP-ERP are directly related to water flow, which controls differences in residence time and tidal range. With respect to benefits derived from the various channel alternatives, there is a significant benefit to the San José Lagoon (based on the benthic index score) once the CMP channel is widened to 75 feet due to tidal amplitude, or volume of water flowing into and out of the lagoon. Increasing channel widths to 100, 125, 150, and 200 feet would progressively result in additional, albeit marginal, benefits as a result of the increased water flows and reduced water residence times (Table 5.1-1). The model could only run in increments of 3 feet, hence the differences between descriptions of model runs as they relate to alternatives (9 feet) versus tables that identify alternatives being considered in the feasibility report (10 feet). Velocities in 10-foot-deep channels would be slightly higher than the modeled 9-foot-deep channels.

Table 5.1-1. Channel Configuration Comparisons

	Channel Configuration (depth by width)						
	3 by 33*	9 by 75	9 by 100	9 by 125	9 by 150	9 by 175	9 by 200
Area (ft^2)	99	675	900	1,125	1,350	1,575	1,800
Hydraulic Conveyance	184.2	2,530.4	3,487.2	4,450.0	5,416.1	6,384.0	7,353.3
Residence Time (days)	16.90	3.86	3.23	2.87	2.66	2.49	2.38
Benthic Index Score	1.33	2.84	2.90	----	2.96	----	2.98
Max. Bot. V-CMP-East (ft/s)	1.25	4.22	**4.09	**3.95	3.85	3.52	3.13
Max. Bot. V-CMP-West(ft/s)	0.74	**2.20	2.80	3.25	3.65	3.89	4.09
Tide Range (feet)	0.33	1.36	1.61	1.75	1.85	1.96	2.05

If these benefits were used for project justification, it is likely that Alternative 5, at 200 x 10 feet, would be selected as a cost-effective plan and best buy; however, once a weir is included in channel alternatives, water flow is restricted for all alternatives in the Initial Array to the level identified for the 75-x-10-foot channel. This results from the fact that water flow in the CMP is tidal and peaks every 12 hours before reversing direction. As a result, large accumulations of flow or head beyond the channel restriction or weir do not occur. This is different than flow in a riverine system not influenced by tides, as water flow would normally be traveling in one direction and the restricting channel would raise the head upstream from a channel constriction, thereby raising water flow. As a result, the flow and thus benefits resulting from larger alternatives with a weir is essentially identical to the flow and benefits identified for the 75-x-10-foot alternative, and larger, costlier alternatives would not be cost effective as they would produce the same benefits as smaller, cheaper alternatives.

Additionally, alternatives with smaller channel configurations would not require as many difficult Real Estate actions as larger alternatives. Once the project footprint becomes larger than that presented for Alternative 3 (125-x10-foot channel), additional acquisitions and relocations become necessary, and the ability to meet the recommended minimum for mangrove fringe (~32 feet) is not feasible. As a result of the larger channel alternative screening analysis, Alternatives 4 and 5 were eliminated from consideration. None of these alternatives would be cost effective if a Cost Effectiveness/Incremental Cost Analysis was conducted, and they would be difficult to implement due to public acceptability and feasibility related to mangrove restoration minimums. Alternatives 1, 2, and 3 were retained to carry forward into a Final Array.

5.1.7.3 Further Bracketing of Alternatives

As there would only be three alternatives within the Final Array (excluding the No-Action), concerns were raised that additional alternatives could have been established to provide an even more comprehensive comparison. In regards to possible alternatives with channel dimensions between 100 and 125-feet wide, these alternatives would have the same benefits due to the weir restrictions, and cost would increase as channel width increases. As a result, nothing would be gained by adding another plan, as the 125-x-10-foot alternative successfully brackets a high end cost alternative that would not have better performance.

Alternative 2, with channel dimensions of 125 x 10 feet, is considered to be the largest channel configuration that would not cause detrimental within-channel scouring. Although numerous alternatives could have been formulated with channel dimension sizes between Alternatives 1 and 2, all of these plans would have required concrete matting to prevent erosion in the Project Channel, would cost more than Alternative 2, and would produce the same benefits as Alternative 2. No new information would be gained from including these additional plans in the analysis.

5.1.8 Final Array of Alternative Plans

The Final Array of Alternative Plans consisted of the No-Action Plan and Alternatives 1, 2, and 3. The following sections provide a more-thorough description of each alternative plan, and are followed by plan evaluation, comparison, and selection.

5.1.8.1 No Action Alternative Plan

No further Federal actions will be implemented under the No Action Alternative.

5.1.8.2 Alternative Plan 1 – 75-Foot Channel Width, 10-Foot Depth

Total construction time for Alternative Plan 1 is approximately 27 months, including mobilization, site preparation, construction, and demobilization.

Alternative Plan 1 consists of dredging approximately 2.2 miles of the eastern end of the CMP to a width of 75 feet and a depth of 10 feet, with slight variations in channel width and depth at the four bridges in the western portion of the Project Channel, the Barbosa Bridge, and terminus of the Project Channel with the San José Lagoon. The walls of the Project Channel would be constructed with vertical concrete-capped steel sheet piles with hydrologic connections to the surrounding lands. The sill depth of the window would be set at mean lower low water so that tidal exchanges are facilitated to the mangrove beds.

At the terminus of the Project Channel with the San José Lagoon, an extended channel would be dredged east into the San José Lagoon (over a distance of approximately 4,300 feet) as a hydraulic transition from the CMP. This extended channel would transition from the 10-foot-deep Project Channel to the 6-foot-deep areas of San José Lagoon. The extended channel would maintain the Project Channel's 100-foot width but replace its steel sheet pile walls with a trapezoidal configuration with 5-foot to 1-foot earthen side slopes.

A barge-mounted mechanical clamshell dredge would be used to widen and deepen the CMP, and would place dredged material into dump scows. Of the 680,000 cy of mixed materials, screens would separate solid waste debris (estimated at 68,000 cy) from sediments. It is estimated that the dredged debris would make up 10 percent of the total material to be dredged from the CMP, and the dredged sediments would bulk up to 126 percent of their in situ volume. Solid waste debris would be transported by shallow-draft barge to a staging area for subsequent landfill disposal. A majority of the sediments would be transported by barge for aquatic disposal, while some sediment would be used to complete the sheet pile construction and mangrove bed restoration.

A weir would be constructed at the western end of the project area to protect the structural integrity of the existing four bridges in the western portion of the Project Channel. The dimensions of the weir (115 x 6.5 feet) would replicate the cross sectional area of the rest of the channel configuration (75 x 10 feet), which would prevent scour around bridges, bulkheads, and other marine structures west of the project area by providing a transition area to reduce unacceptable bottom velocities between the project area and the adjacent channels. The weir would be constructed with an articulated concrete bottom.

5.2 SCOUR PROTECTION

5.2.1 General

In order to avoid potential impacts to the existing bridge structures, caused by the installation of sheet pile and dredging, it is proposed that within the areas of bridge crossings, the channels be dredged to a shallow depth with a trapezoidal cross section. Potentially higher velocities would be mitigated with the placement of scour protection in the bottom and sides of the bridge channels. This section discusses various means of stabilizing and protecting the channel.

5.2.2 Scour Protection Alternatives

5.2.2.1 Riprap

Riprap is a commonly utilized form of channel protection comprised of stone or broken concrete in a range of sizes, placed randomly in several layers. The sizes of the aggregate are selected for their weight to resist movement caused by water flow with lesser sized stones to lock the aggregate into a homogenous blanket. Due to the irregular surface of riprap, a higher coefficient of friction results, potentially requiring enlargement of the channel cross section to compensate. Costs for this application are usually based upon product availability and transportation costs from the quarry and difficulty with installation.

Based upon the subsurface investigations, it is unlikely that sufficient site dredged limestone would be encountered to supply the riprap. Riprap would likely be acquired locally and is expected to be available in sufficient quantity.

This is the preferred alternative for channel sidewalls under the western bridges because it can be easily placed and shaped around existing structures.

5.2.2.2 Geotextiles

Geotextiles are manufactured fabrics placed over a prepared bed of soil or aggregate. These fabrics are designed to allow water to pass through while retaining the soil particles below. The fabrics are typically made of polypropylene or polyester and manufactured by heat bonding, needle perforating or weaving. Benefits of using geotextiles are their ability to prevent the loss of soil particles from the channel section and their light weight for shipping and installation. Geotextile channel protection is not usually considered as a long term solution, particularly with potentially higher channel velocities and wear and tear.

5.2.2.3 Poured-in-place Concrete

Poured-in-place concrete involves constructing concrete slabs on a prepared base. The channel bottom must be dewatered, unsuitable soils removed and replace with compacted granular material. Forms are constructed and concrete poured. Joints between the slabs must be designed to prevent differential settlement which could cause high velocity flow to undermine the slabs, causing catastrophic failure. Costs for this system are based upon a relatively high quantity of materials (concrete, steel reinforcing bars or mesh), difficulty with dewatering and base course preparation.

5.2.2.4 Articulated Concrete Mats

Articulated concrete mats are a hard armor form of erosion protection comprised of flexible, interlocking machine formed concrete block units. The blocks are uniform in shape and weight and interconnected with revetment cables. The cables are made of polyester, galvanized steel or stainless steel, their selection based upon desired longevity. In the case of the CMP-ERP, stainless steel cable would be preferred. The grid like porosity of the mats provides the benefit of being relatively light weight and provides the high tractive force resistance of a rigid lining. Installation is fast and low cost. This is the preferred alternative for the channel bottom and an acceptable alternative for channel sidewalls under the western bridges.

5.3 CHANNEL APPURTENANCES

All of the Project Channel alternatives are configured as rectangular channels. Grading modifications adjacent to the channel “box” are proposed to: 1) reduce the quantity and associated costs of the sheet pile and 2) create suitable habitat for a forested wetland. The sheet pile reduction would be accomplished using a hybrid version of the rectangular channel and the habitat creation adds further earthwork outside of the sheet pile walls. Both are described in further detail below.

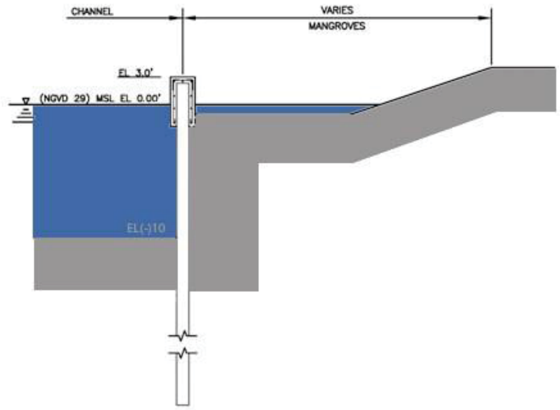
5.3.1 Channel Hybrid Alternative

The single most costly item associated with the channel construction is the sheet pile wall. In an effort to reduce the length of sheet pile, the rectangular channel section is modified in certain locations to delete the vertical sheet pile wall, replacing it with 5-foot horizontal to 1-foot vertical earthen slopes. This cross section adds 50 to 75 feet to the channel's width so its application is limited to the widest portions of the corridor (Public Domain). Its use should also consider appropriate storm water and soil stabilization controls to limit channel siltation caused by silt-laden runoff from upland watersheds (Figure 5.3-1).

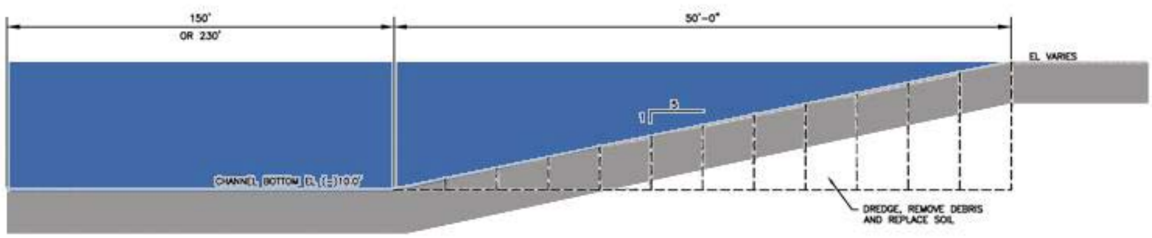
The goal of the hybrid plan is the formation of a more naturalized shoreline where the sloped banks occur. Where the standard channel meets the sloped bank section, the sheet pile wall would angle into and be buried in the bank. Any eddying or shoaling that occurs should have no effect on the sheet pile due to its depth and the resulting shoreline would take on a more natural edge.

5.3.2 Mangrove Planting Bed

In support of the CMP-ERP's goal of wetland (mangrove) restoration, the channel cross section includes grading both the sides of the channel to permit the creation of habitat for mangrove planting. The planting bed would be graded to an elevation at or about Mean Lower Low Water extending, in most cases, to the upland side of the line of Public Domain. The mangrove beds would be constructed along all portions of the lands adjoining the Project Channel except under bridges and at designated recreation areas. Along the eastern end of the Project Channel, the extended channel, mangrove beds would be constructed where existing grades adjoining the channel are at or above mean lower low water. Grading will be performed utilizing the dredge equipment as well as land-based earthmoving equipment. See Section 5.7, Site Work for Mangrove Restoration, for further detail (Figure 5.3-2).



TYPICAL SECTION – SHEET PILE WALL



TYPICAL SECTION – 5:1 SLOPE

Figure 5.3-1. Channel Edge Alternatives

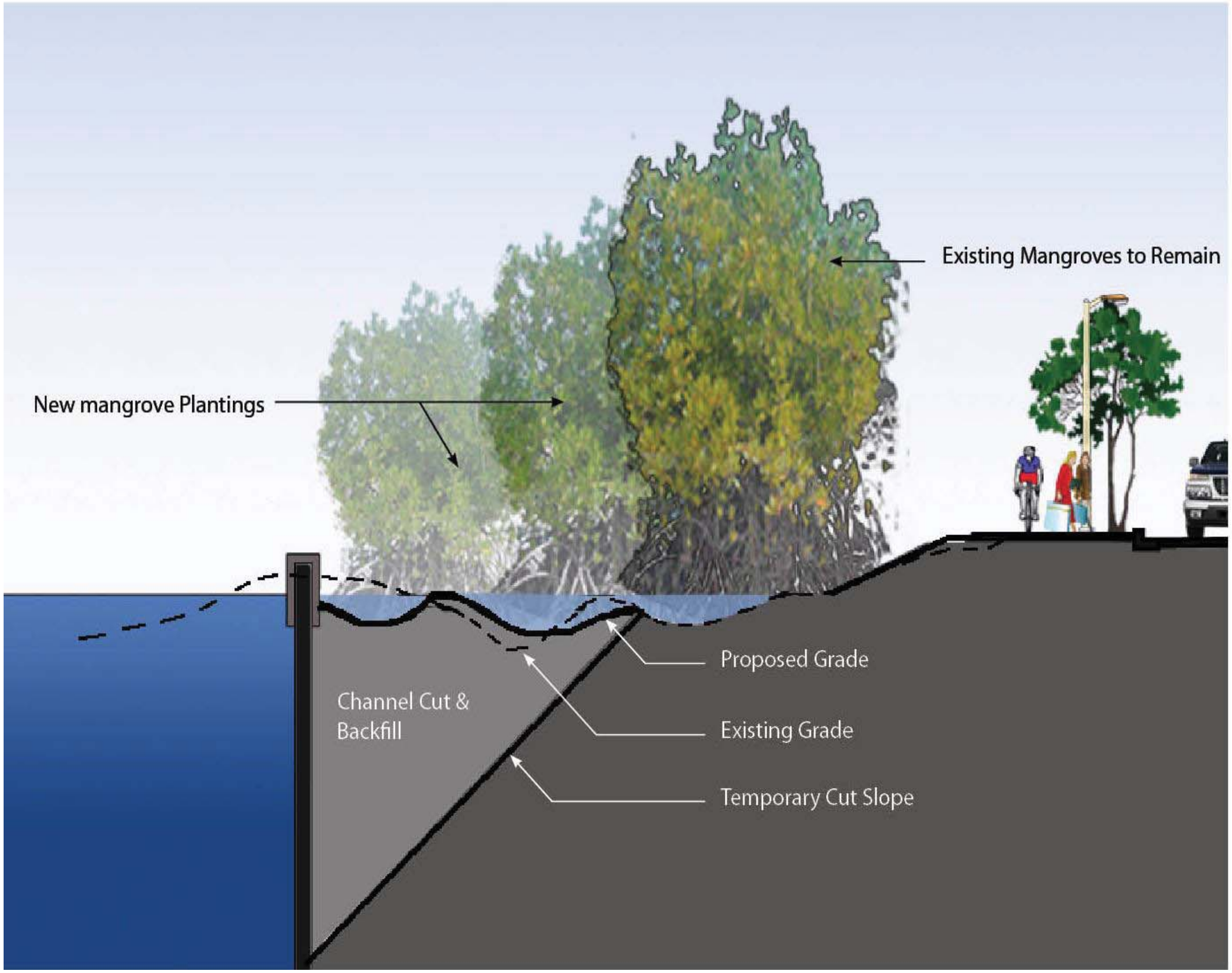


Figure 5.3-2. Mangrove Restoration

5.3.3 Slope versus Bulkhead Comparisons

Two types of channel cross sections were considered for the Project Channel, rectangular cross-section and a hybrid design. A rectangular channel would utilize sheet piles with concrete caps along the entire length to prevent erosion. The hybrid channel employs sheet pile in areas that would be subject to erosive conditions and 5-foot to 1-foot earthen slopes in other areas. Based on initial calculations, the hybrid design would add 50 to 75 feet to the channel width and would only be feasible within the widest portions of the area.

Based on construction of the USACE's Rio Puerto Nuevo Flood Control Project, the construction of a sloped bank in the Project Channel is not likely feasible. Sloped banks were constructed as part of the Margarita Channel and were later replaced with sheet pile walls after consistent sloughing of fluvial sediment was causing poor project performance. The CMP project is located within a similar part of San Juan within the SJBE, and sloughing of material would also be anticipated within the Project Channel. A 5-foot to 1-foot sloped bank would also reduce the area available for mangrove restoration. For these reasons, the rectangular cross-section channel dredged design was retained and the hybrid design was eliminated for use in the Project Channel. Steel sheet pile was the selected structural treatment for the vertical edge, chosen over concrete sheeting due to its ease of handling and ability to be installed without the need for tie-backs. Although gabions are used for construction of vertical edges, they were not chosen due to their difficulty of construction underwater and their susceptibility to damage or wear.

5.4 CHANNEL BULKHEAD

The Channel Bulkhead section has been prepared to address the design of a bulkhead for shoreline stabilization along the CMP. It identifies existing conditions affecting the design, engineering parameters, and methodology and alternative materials considered.

The report addresses design alternatives that will facilitate water exchange between the channel, storm sewers, mangrove areas behind the sheet piling, and effects of boat wakes on the restored and protected mangroves.

5.4.1 Summary of Structural Background Conditions

5.4.1.1 Channel Location

The channel bulkhead will be aligned along the sides of a dredged and restored waterway. The area has encroachment from development on top of irregular fill and debris. The structural design of these bulkheads will allow for the support and protection of the soils and mangroves behind the wall while allowing for water exchange and movement along the walls (see figures 5.4-1 through 5.4-10).

The issues and conditions that control the design are the loads applied to the bulkheads, the strength of the soils to resist the loads, the design life of the materials, constructability of the systems, and durability of the finished system.

These structural considerations can be summarized as:

- Geotechnical data: Mechanical properties of the soil.
- Seismic influence on soils: Liquefaction.
- Corrosion: Deterioration of steel reinforcement in concrete and of steel sheet piles.
- Durability: Damage to the bulkhead from maintenance dredge operations, debris in the channel and possibly marine operators.
- Serviceability of bulkhead: Reasonable movement/flexibility of the bulkhead, Maintenance considerations.
- Constructability of systems: Access, overhead clearance, side bank clearance, worker health and safety.

5.4.1.2 Geotechnical Data and Mechanical Properties of Soils

The geotechnical data for this project were derived from borings taken along the channel as well as from test pits dug to verify the presence and character of debris along the anticipated alignment of the bulkhead. Data collected by Weston (1997), USACE (2001), Bailey et al. (2002), and Moffatt & Nichol (2003) covered the general characteristics of the channel and channel banks and the cores showed the physical and chemical properties of the materials to be dredged.

The soils that will be encountered are generally characterized as weak and poor. The soils properties were given for three states of the soils: unconsolidated undrained, consolidated undrained, consolidated drained. For the feasibility design, the values of Q (unconsolidated undrained) and 80 percent R (80 percent consolidated undrained) were used for comparative purposes with 80 percent R considered to be the most appropriate values with respect to seismic concerns.

Eighty percent of the R strength was selected for the seismic analysis as per Makdisi and Seed, 1977. These investigators reported that in order for significant strains to develop in a cohesive material, the cyclic stress level has to surpass the cyclic yield strength. The cyclic yield strength is typically in the range of 80 percent to 95 percent of the clay's static undrained strength. Therefore, eighty percent of the R strength for a seismic analysis is at the conservative end of the range suggested by Makdisi and Seed (Weston 1997).

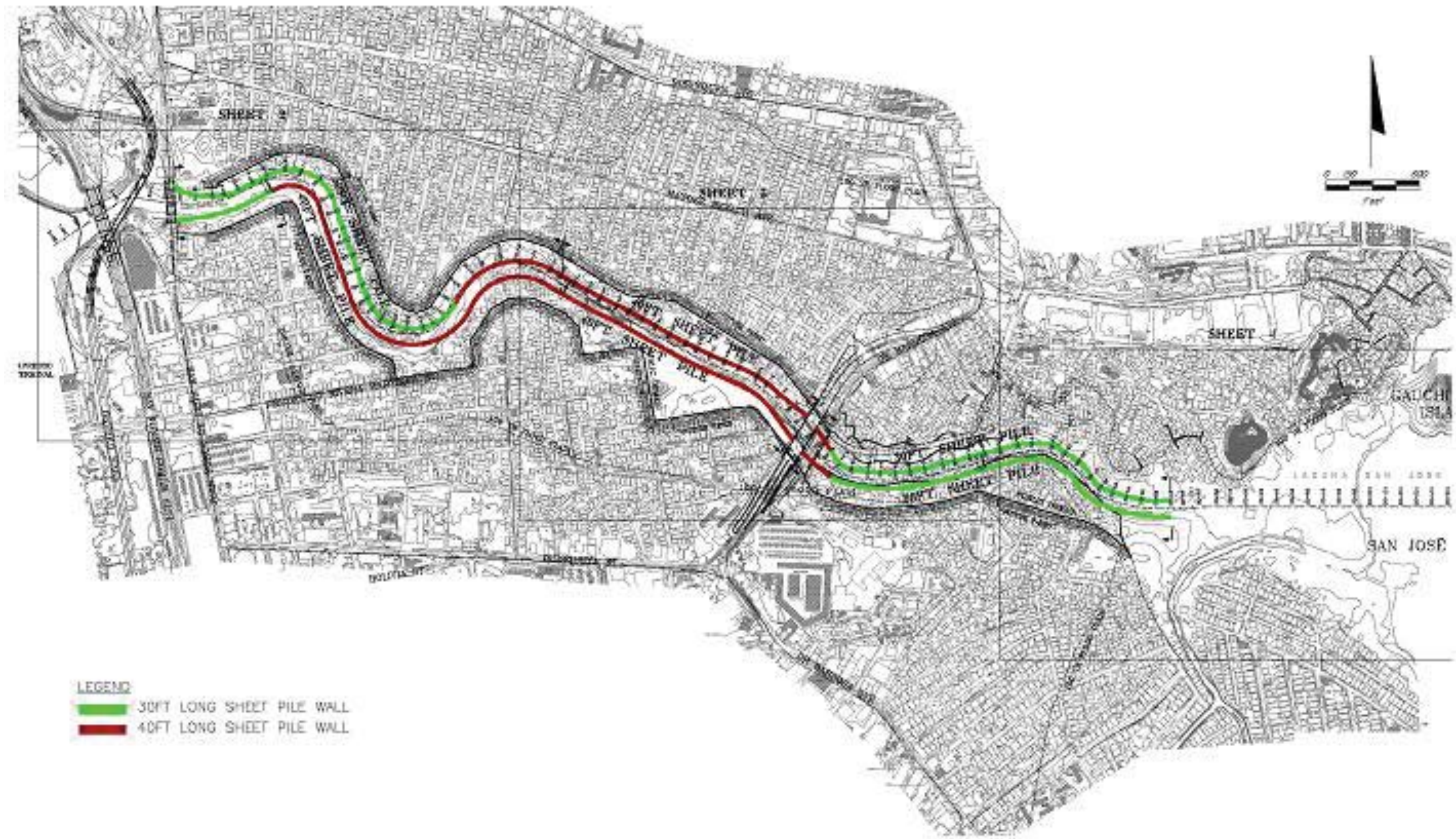


Figure 5.4-1. Sheet Pile Wall Layout, 10-foot-deep Channel

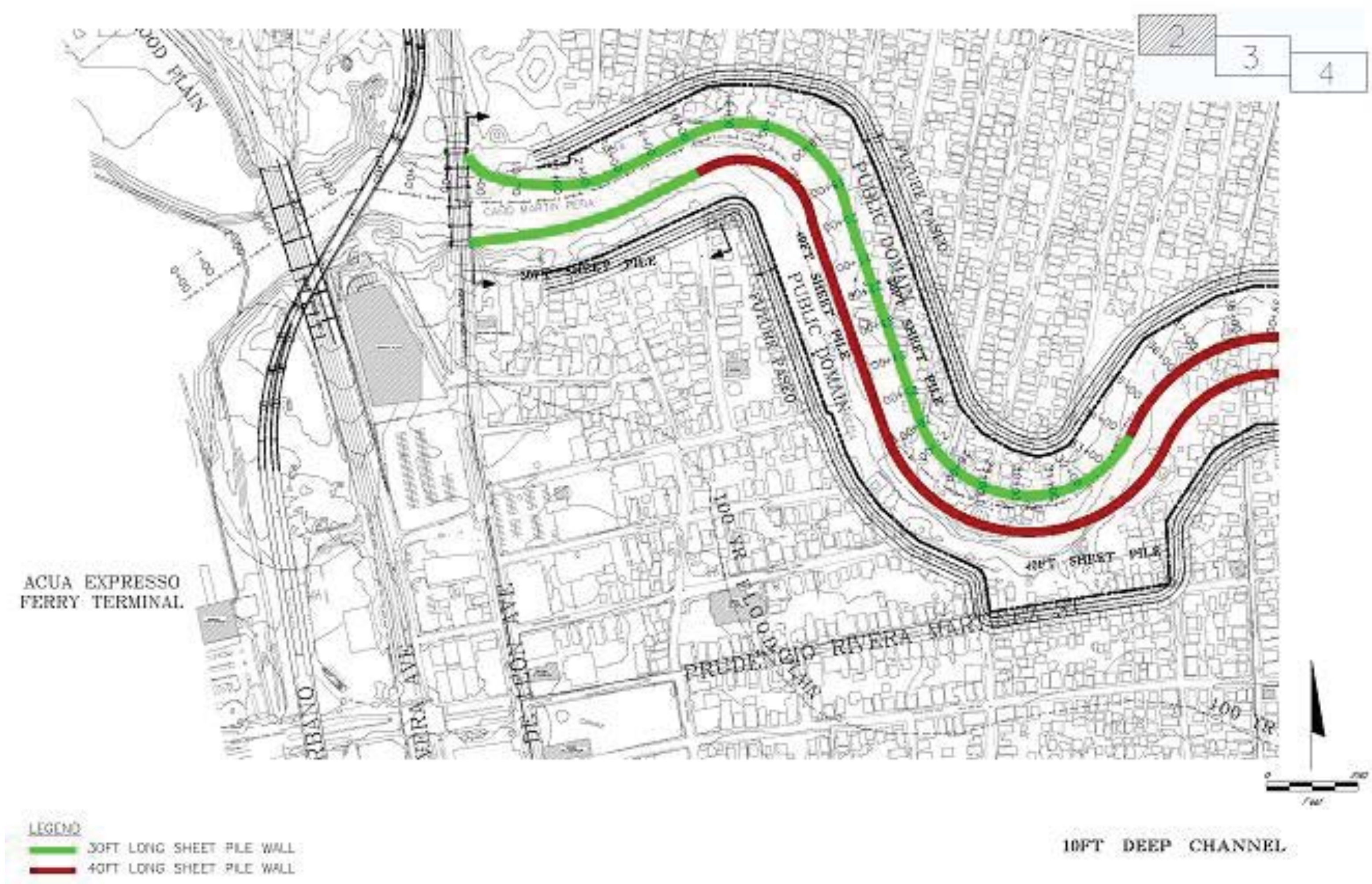


Figure 5.4-2. Sheet Pile Wall Layout, 10-foot-deep Channel

Figure 5.4-3. Sheet Pile Wall Layout, 10-foot-deep Channel

Figure 5.4-4. Sheet Pile Wall Layout, 10-foot-deep Channel

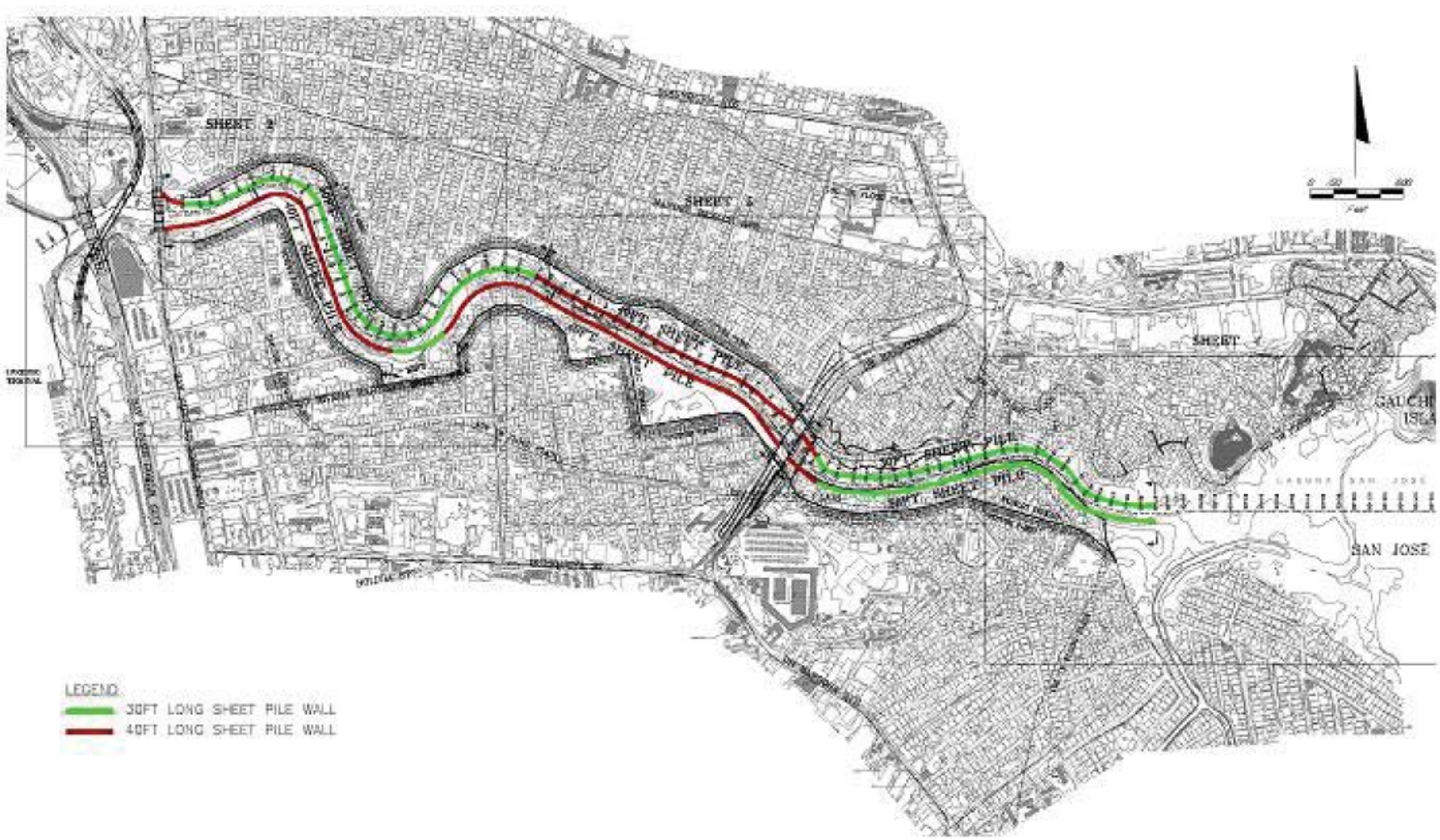


Figure 5.4-5. Sheet Pile Wall Layout, 15-foot-deep Channel

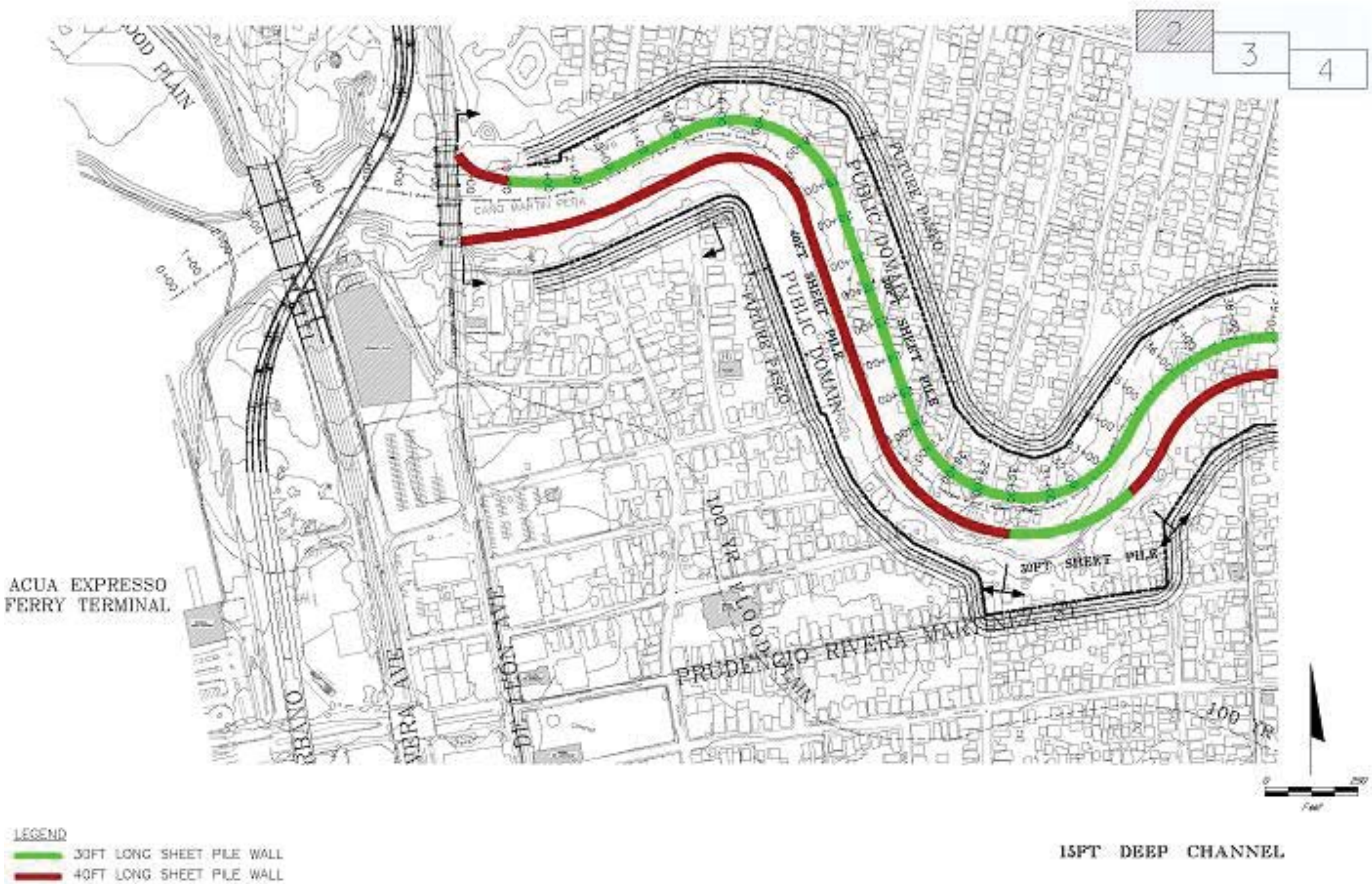


Figure 5.4-6. Sheet Pile Wall Layout, 15-foot-deep Channel

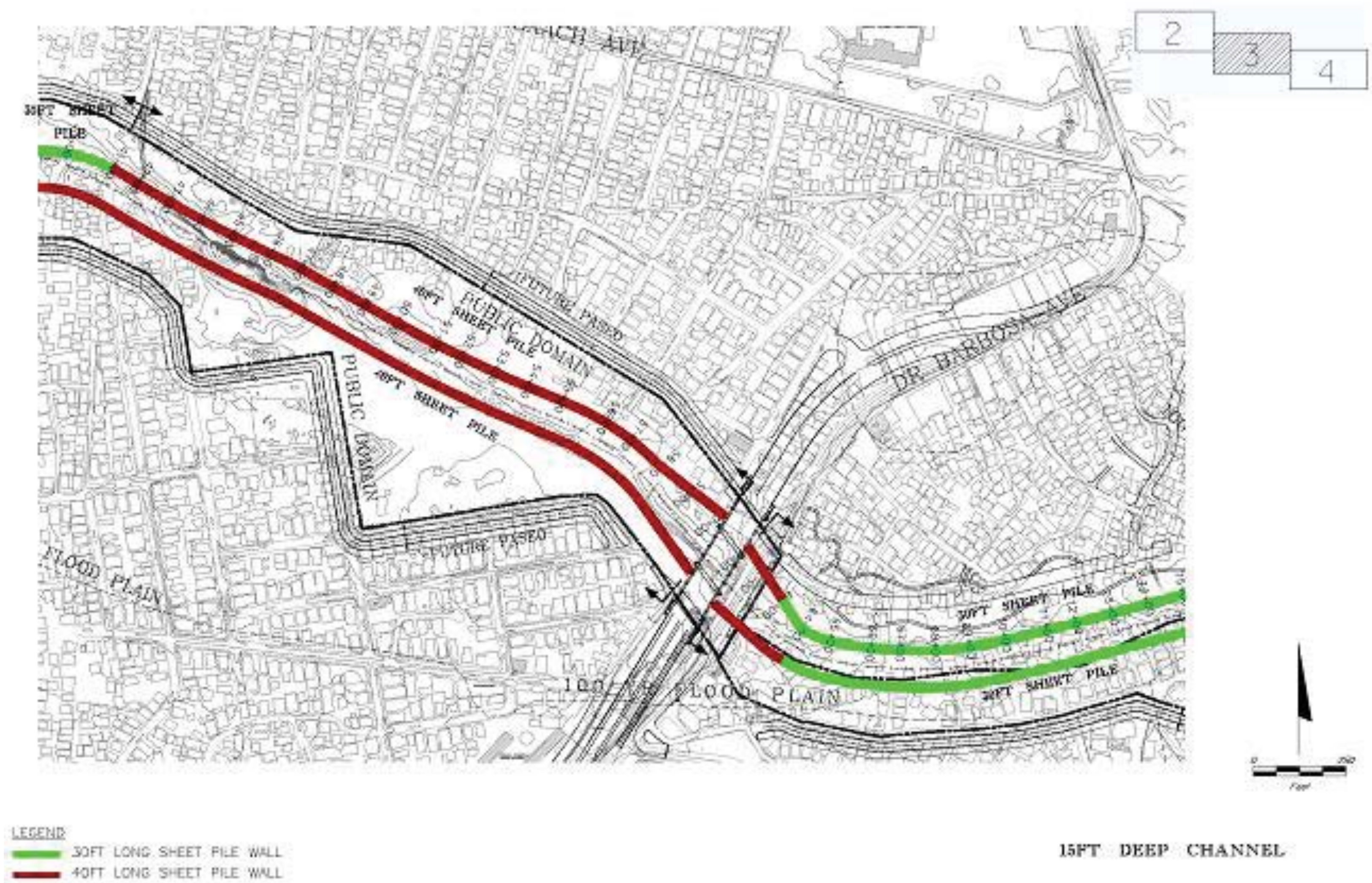


Figure 5.4-7. Sheet Pile Wall Layout, 15-foot-deep Channel

Figure 5.4-8. Sheet Pile Wall Layout, 15-foot-deep Channel

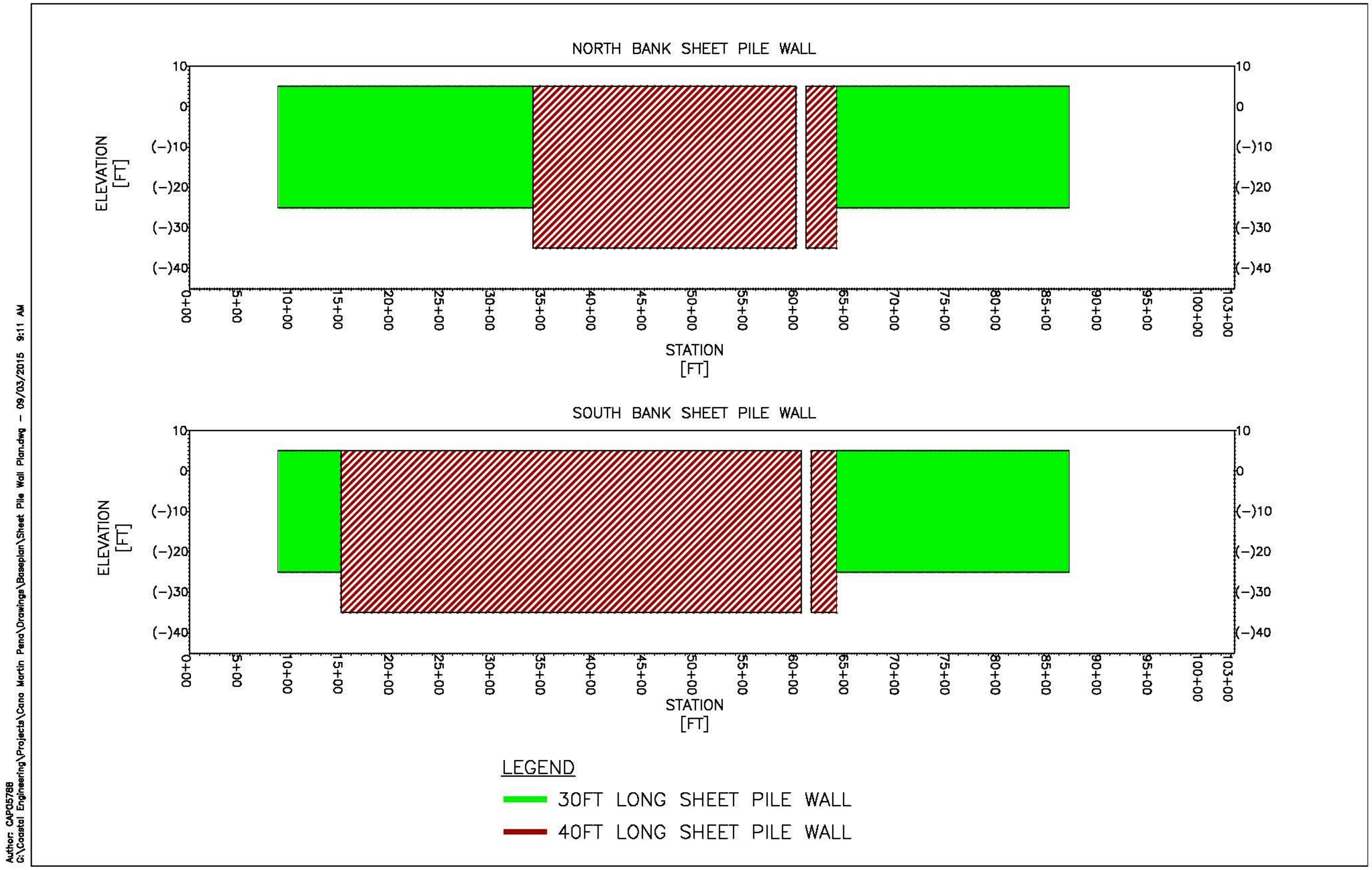


Figure 5.4-9. Sheet Pile Wall Elevation, 10-foot-deep Channel

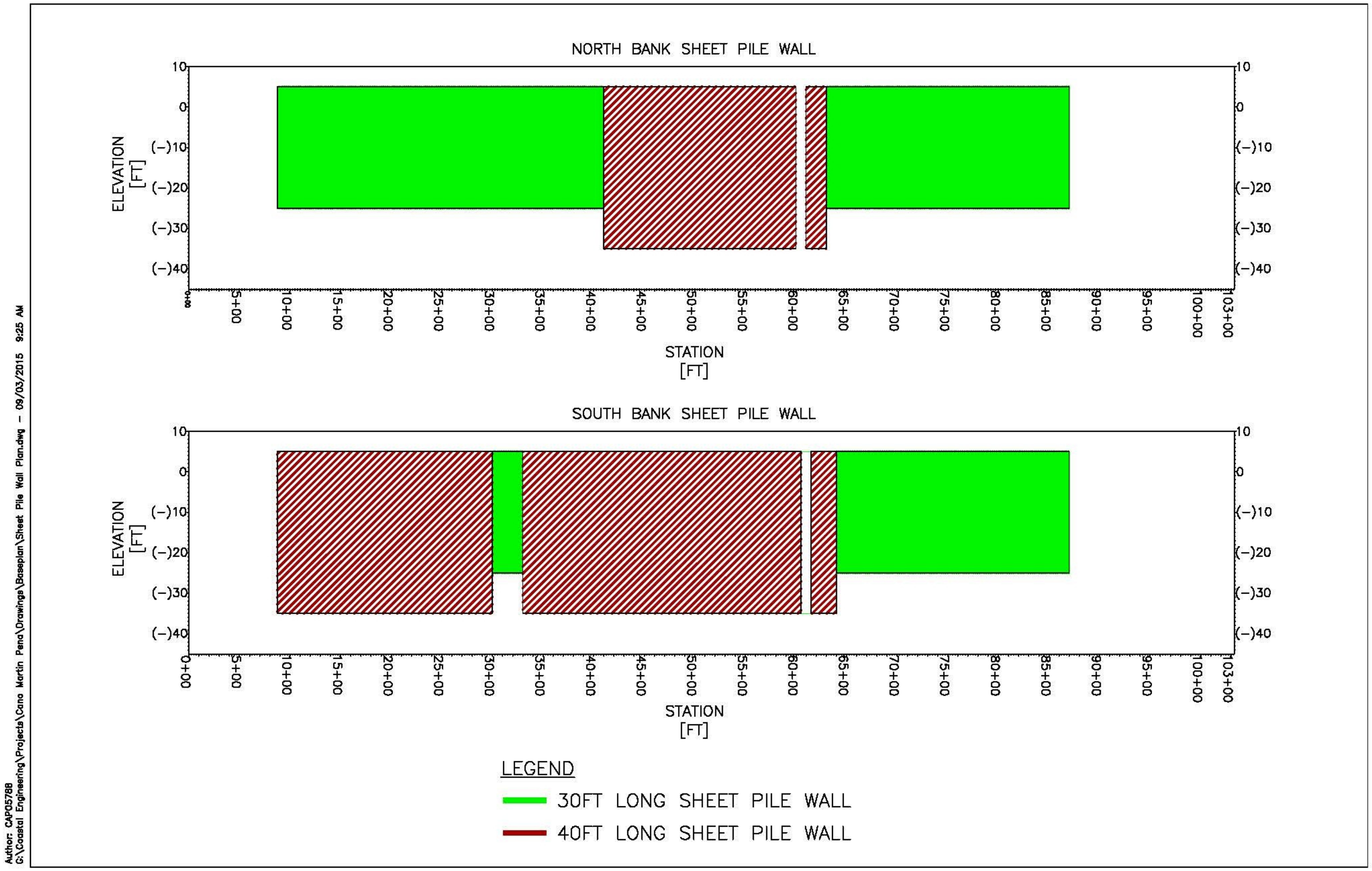


Figure 5.4-10. Sheet Pile Wall Elevation, 15-foot-deep Channel

5.4.1.3 Seismic Effects on Soils

An item that had to be addressed in the design of the bulkheads and which restrains the relatively poor soils along the channel, is liquefaction of the soils behind and supporting the bulkhead. There is a high likelihood for liquefaction in this area. The report by Bachhuber et al. (2008) illuminates the areas and the potential for soil problems.

5.4.1.4 Corrosion and Coatings

Prior studies have identified chlorides and sulfates in sufficient concentrations the raise concerns over the deterioration of the concrete or steel materials. The use of a steel bulkhead merits the use of corrosion resistant materials and protective measures. The use of marine grade steels [ASTM A690] used in conjunction with USACE approved coating system is appropriate.

5.4.1.5 Durability and Debris Damage to Bulkhead

The use of a steel bulkhead has advantages with respect to ability to withstand harsh conditions and hard use from maintenance dredge operations as well as the ability to be repaired in the event of catastrophic damages. The mechanical properties of steel allow for a durable in place product that has the ability to be serviced in place if needed.

5.4.1.6 Serviceability of Bulkhead

The bulkhead runs along the sides of the channel alignment with few permanent structures immediately adjacent to the cap. By allowing the bulkhead to move, a more efficient design can be used. The limit states for the bulkhead design are allowed to be a maximum stress limit and a more relaxed movement limit of 0.5 foot versus a more restrictive lateral movement of H/180 or H/240 (0.11 to 0.22 foot). The basis of the traditional lateral deflection limits has its origins in the need to protect adjacent structures. In the case of the CMP channel, no such structures exist or are proposed. Thus by allowing more movement the design can make better use of the materials strength limits.

5.4.1.7 Constructability of Bulkhead Systems

The ability to install the bulkhead in an efficient manner is an important feature of making the CMP-ERP affordable. The design will need to take into account the factors of access, egress, overhead clearance, safety, and ease of construction. The simpler the construction process, the more likely the contractor will be able to maintain schedule and budget. Less ground disturbance will be a benefit to construction speed, the environmental aspects of the CMP-ERP and the nearby residents as well. Therefore a cantilevered design will allow for the least ground disturbance of all the methods commonly available. The cantilevered installation method also minimizes dangerous, complicated or invasive construction features such as dead-men, walers, and tie-backs used in tied bulkhead construction.

5.4.2 Key Bulkhead Design Issues

The key design features associated with the bulkhead are the storm drain/tidal cut-outs, the wall cap, the dredge effects and constructability. A brief synopsis of the various systems as they relate to these issues is presented below.

5.4.2.1 Wall Features: Tidal flow Cut-out, Ability to Withstand Seismic Forces

- Steel sheet pile: not very porous thus pass through areas and periodic “cut-down” areas to be used for pass through of water for flushing and equilibrium, fair seismic performance although interlocks can “unzip” in strong ground shaking events. Periodic cut-downs will minimize impacts to mangroves caused by boat wakes.
- Concrete King Pile: similar to steel sheet piles as far as porosity, does not have favorable seismic performance due to weak interlocks that can easily open up.
- Concrete Sheet Pile: similar to steel sheet piles as far as porosity, does not have favorable seismic performance due to weak interlocks that can easily open up.
- Gabion: porous and easy flow of water through gabion baskets, flexible system, favorable seismic performance, environmentally friendly.

5.4.2.2 Cap Options: Concrete Cap, Steel Cap, No Cap

- Steel Sheet Pile: easily accommodated conditions with or without a cap. Cap can be concrete, steel, or no cap.
- Concrete King Pile: a cap is preferred with this system to tie elements together. Cap should be concrete, easily formed due to panel profile.
- Concrete Sheet Pile: a cap is preferred with this system to tie elements together. Cap should be concrete, easily formed due to panel profile.
- Gabion: no cap used.

5.4.2.3 Influence of Differing Dredge Methods – Clamshell Bucket, Backhoe, Hydraulic, Hydraulic with Cutterhead

- Steel Sheet Pile: resistant to impact damage during dredge and maintenance.
- Concrete King Pile: somewhat resistant to impact damage during dredge and maintenance.
- Concrete Sheet Pile: somewhat resistant to impact damage during dredge and maintenance.
- Gabion: more fragile than sheet pile bulkheads during dredge and maintenance operations.

5.4.2.4 Constructability

- Steel Sheet Piles: most rapid installing system, can be installed in harsh environmental conditions, can be cut off or spliced in field.
- Concrete King Piles: Rapid installation in a variety of soil conditions may need additional piles for bracing.
- Concrete Sheet Piles: Rapid installation in a variety of soil conditions may need additional piles for bracing.
- Gabions: Very labor intensive, not suited to installation in saltwater environments subject to mechanical wear, solutions for gabions are available to create dry environment for basket fill installation, large ground disturbance area.

5.4.2.5 Special Provisions or Conditions

- Safety Egress for accidental incursions into water – Ladders or landings along sides.
- Debris such as appliances may interfere with pile installation, steel sheet more likely to penetrate challenging strata/debris.
- Low overhead clearance at bridges interferes with the ability to drive piles.

5.4.3 Bulkhead Design Parameters

The design limits for the bulkhead will be a combination of global stability, strength limits, and deflection (serviceability) limits. Reasonable levels of limiting stresses have been used as well as reasonable deflection limits. The use of a larger deflection limit (6 inches) at the bulkhead top allows for a more practical and efficient design that uses more of the sheet piles strength capacity.

5.4.3.1 Design Process

The results from analysis of the bulkhead wall using CWALSHT and SPW911 allowed for a comparison to the design recommendations from previous design. Careful consideration should be taken when questioning previous work products since there is a substantial amount of judgment and expertise that was used in deriving the original designs. Mindful and prudent approaches should be used to make recommendations that are in conflict with the original designs.

Our finding showed general agreement with the prior bulkhead assessment. As such the following tables, 5.4-1, 5.4-2, and 5.4-3, show the original design of the bulkhead system as compared to the more recent preliminary calculations of steel bulkheads.

5.4.3.2 Design Analysis

In most cases a common sheet pile section PZ22 works well as long as the dredge depth is limited to 10 feet. As the depth increases to 15 feet the need for introduction of heaver sections such as the PZ27 are required (see tables 5.4-1 through 5.4-3).

Thus as the design parameters dictate the depth required, the same type of wall is available but the member size will need to be adjusted.

5.4.3.3 Channel Options

The limiting factor for the bulkhead design has only to do with the height of the wall or conversely the depth of dredge. Thus only two design states are required to be examined: 10-foot or 15-foot dredge depths. The various channel configurations are either 10 feet deep or 15 feet deep, actually only presenting two bulkhead depths.

5.4.3.4 Applicable Codes

- International Building Code (IBC)
- USACE and UFC Manuals and Guidelines
- American Concrete Institute (ACI) 318
- Local codes

5.4.4 Bulkhead Alternatives

There are several alternatives to shoreline stabilization along the alignment of this project. The reasonable options are a traditional bulkhead in either concrete or steel, a cantilevered bulkhead wall in either concrete or steel, gabions, or rip-rap armoring. Variations of the traditional and cantilevered systems can use alternating piles of deeper penetration and have common references and King-pile systems and combi-wall systems. These are available in either concrete or steel.

A summary of the system benefits and disadvantages follows.

Table Description	Boring Location	Stationing	Length of Segment [FT]	For Channel Depth (-)10 ft Pile Type	For Channel Depth (-)10 ft Pile Length [FT]	*For Channel Depth (-)15 ft Pile Type	*For Channel Depth (-)15 ft Pile Length [FT]
Table 1	CB-MP-98-1	STA 0+40 to 10+00 North Bank	960	PZ22	30	PZ27	40
Table 2*	CB-MP-98-4	STA 10+00 to 20+00 North Bank	1,000	PZ22	30	PZ22	30
Table 3*	CB-MP-98-6	STA 20+00 to 34+00 North Bank	1,400	PZ22	30	PZ22	30
Table 4*	CB-MP-98-11	STA 34+00 to 41+00 North Bank	700	PZ22	40	PZ22	30
Table 5	CB-MP-98-13	STA 41+00 to 54+00 North Bank	1,300	PZ22	40	PZ27	40
Table 6	CB-MP-98-14	STA 54+00 to 63+00 North Bank	900	PZ22	40	PZ27	40
Table 7*	CB-MP-98-16	STA 63+00 to 77+00 North Bank	1,400	PZ22	30	PZ22	30
Table 8*	CB-MP-98-20	STA 77+00 to 81+00 North Bank	400	PZ22	30	PZ22	30
Table 9*	CB-MP-98-21	STA 81+00 to 87+00 North Bank	600	PZ27	30	PZ22	30
Table 11*	CB-MP-98-2	STA 1+00 to 8+00 South Bank	700	PZ22	30	PZ22	40
Table 12	CB-MP-98-3	STA 8+00 to 15+00 South Bank	700	PZ22	30	PZ27	40
Table 13*	CB-MP-98-5	STA 15+00 to 30+00 South Bank	1,500	PZ22	40	PZ22	40
Table 14*	CB-MP-98-8	STA 30+00 to 33+00 South Bank	300	PZ22	40	PZ22	30
Table 15	CB-MP-98-12	STA 33+00 to 50+00 South Bank	1,700	PZ22	40	PZ27	40
Table 16	CB-MP-98-15	STA 50+00 to 64+00 South Bank	1,400	PZ22	40	PZ27	40
Table 17	CB-MP-98-17	STA 64+00 to 81+00 South Bank	1,700	PZ22	30	PZ22	30
Table 18*	CB-MP-98-21	STA 81+00 to 87+00 South Bank	600	PZ22	25	PZ22	30

* For Channel Depth (-)15ft, an additional 3ft of scour was considered

Description	Channel Depth Condition	Total Length of Driven Sheet Pile [LF]	Area of Wall [SF]	Total Weight of Sheet Pile [tons]
PZ22	(-)10ft	16,660	577,800	6,529
PZ27	(-)10ft	600	18,000	249
PZ22	(-)15ft	10,300	331,000	3,740
PZ27	(-)15ft	6,960	278,400	3,856

Table 5.4-1, Bulkhead Wall Heights vs Dredge Depth

For Channel Bottom = (-)10ft

For PZ-27, I = 187.5 in^4/LF

Boring Description	Boring Name	Boring Location	Pile Tip El [ft]	Moment [lb*ft/ft]	Bending Moment	Stress Ratio	Unit Deflection [lb-in^3]	Deflection [in]	Pile Length [ft]	Pile Length Used
			Sheet Pile Wall Design Results For PZ-27 Sheet Pile Wall — CWALSHT							
Table 1	CB-MP-98-1	STA 0+40 to 10+00 North Bank	-21.00	15674	64506.5	0.24	3.789E+09	0.66	24	30
Table 2*	CB-MP-98-4	STA 10+00 to 20+00 North Bank	-32.00	10987	64506.5	0.17	2.191E+09	0.38	35	40
Table 3*	CB-MP-98-6	STA 20+00 to 34+00 North Bank	-17.00	7995	64506.5	0.12	1.350E+09	0.24	20	20
Table 4*	CB-MP-98-11	STA 34+00 to 41+00 North Bank	-19.00	7754	64506.5	0.12	1.646E+09	0.29	22	30
Table 5	CB-MP-98-13	STA 41+00 to 54+00 North Bank	-32.00	37555	64506.5	0.58	2.199E+10	3.86	35	40
Table 6	CB-MP-98-14	STA 54+00 to 63+00 North Bank	-29.00	38259	64506.5	0.59	1.694E+10	2.97	32	40
Table 7*	CB-MP-98-16	STA 63+00 to 77+00 North Bank	-16.00	7145	64506.5	0.11	1.066E+09	0.19	19	20
Table 8*	CB-MP-98-20	STA 77+00 to 81+00 North Bank	-15.00	6807	64506.5	0.11	8.317E+08	0.15	18	20
Table 9*	CB-MP-98-21	STA 81+00 to 87+00 North Bank	-15.00	4853	64506.5	0.08	6.314E+08	0.11	18	20
Table 10	CB-MP-98-22	STA 87+00 to 101+00 North Bank	-36.00	51452	64506.5	0.80	3.499E+10	6.14	39	40
Table 11*	CB-MP-98-2	STA 1+00 to 8+00 South Bank	-18.00	10736	64506.5	0.17	1.955E+09	0.34	21	20
Table 12	CB-MP-98-3	STA 8+00 to 15+00 South Bank	-29.00	33995	64506.5	0.53	1.479E+10	2.60	32	40
Table 13*	CB-MP-98-5	STA 15+00 to 30+00 South Bank	-18.00	10512	64506.5	0.16	1.968E+09	0.35	21	20
Table 14*	CB-MP-98-8	STA 30+00 to 33+00 South Bank	-15.00	6684	64506.5	0.10	8.815E+08	0.15	18	20
Table 15	CB-MP-98-12	STA 33+00 to 50+00 South Bank	-25.00	22229	64506.5	0.34	7.117E+09	1.25	28	30
Table 16	CB-MP-98-15	STA 50+00 to 64+00 South Bank	-25.00	26704	64506.5	0.41	8.022E+09	1.41	28	30
Table 17	CB-MP-98-17	STA 64+00 to 81+00 South Bank	-17.00	11133	64506.5	0.17	1.690E+09	0.30	20	20
Table 18*	CB-MP-98-21	STA 81+00 to 87+00 South Bank	-14.00	4490	64506.5	0.07	5.473E+08	0.10	17	20

* 6" thick granular layer added as top layer on left and right side in CWALSHT runs to allow program to design sheet wall pile tip

For PZ-22, I = 84.7 in^4/LF

Boring Description	Boring Name	Boring Location	Pile Tip El [ft]	Moment [lb*ft/ft]	Bending Moment	Stress Ratio	Unit Deflection [lb-in^3]	Deflection [in]	Pile Length [ft]	Pile Length Used
			Sheet Pile Wall Design Results For PZ-22 Sheet Pile Wall — CWALSHT							
Table 1	CB-MP-98-1	STA 0+40 to 10+00 North Bank	-21.15	15674	38287	0.41	3.789E+09	1.47	24	30
Table 2*	CB-MP-98-4	STA 10+00 to 20+00 North Bank	-18.70	10987	38287	0.29	2.191E+09	0.85	22	40
Table 3*	CB-MP-98-6	STA 20+00 to 34+00 North Bank	-16.92	7995	38287	0.21	1.350E+09	0.52	20	20
Table 4*	CB-MP-98-11	STA 34+00 to 41+00 North Bank	-18.70	7754	38287	0.20	1.646E+09	0.64	22	30
Table 5	CB-MP-98-13	STA 41+00 to 54+00 North Bank	-32.19	37555	38287	0.98	2.199E+10	8.54	35	40
Table 6	CB-MP-98-14	STA 54+00 to 63+00 North Bank	-29.07	38259	38287	1.00	1.694E+10	6.58	32	40
Table 7*	CB-MP-98-16	STA 63+00 to 77+00 North Bank	-16.23	7145	38287	0.19	1.066E+09	0.41	19	20
Table 8*	CB-MP-98-20	STA 77+00 to 81+00 North Bank	-14.61	6807	38287	0.18	8.317E+08	0.32	18	20
Table 9*	CB-MP-98-21	STA 81+00 to 87+00 North Bank	-14.69	4853	38287	0.13	6.314E+08	0.25	18	20
Table 10	CB-MP-98-22	STA 87+00 to 101+00 North Bank	-36.39	51452	38287	1.34	3.499E+10	13.59	39	40
Table 11*	CB-MP-98-2	STA 1+00 to 8+00 South Bank	-18.09	10736	38287	0.28	1.955E+09	0.76	21	30
Table 12	CB-MP-98-3	STA 8+00 to 15+00 South Bank	-29.08	33995	38287	0.89	1.479E+10	5.74	32	40
Table 13*	CB-MP-98-5	STA 15+00 to 30+00 South Bank	-17.91	10512	38287	0.27	1.968E+09	0.76	21	30
Table 14*	CB-MP-98-8	STA 30+00 to 33+00 South Bank	-15.18	6684	38287	0.17	8.815E+08	0.34	18	20
Table 15	CB-MP-98-12	STA 33+00 to 50+00 South Bank	-24.80	22229	38287	0.58	7.117E+09	2.76	28	30
Table 16	CB-MP-98-15	STA 50+00 to 64+00 South Bank	-24.68	26704	38287	0.70	8.022E+09	3.12	28	30
Table 17	CB-MP-98-17	STA 64+00 to 81+00 South Bank	-16.81	11133	38287	0.29	1.690E+09	0.66	20	20
Table 18*	CB-MP-98-21	STA 81+00 to 87+00 South Bank	-14.17	4490	38287	0.12	5.473E+08	0.21	17	20

* 6" thick granular layer added as top layer on left and right side in CWALSHT runs to allow program to design sheet wall pile tip

Table 5.4-2, Bulkhead Wall Heights vs Dredge Depth of 10 Feet

For Channel Bottom = (-)15ft

For PZ-27, I = 187.5 in^4/LF

Boring Description	Boring Name	Boring Location	Sheet Pile Wall Design Results For PZ-27 Sheet Pile Wall								Pile Length Used
			CWALSHT								
			Pile Tip El [ft]	Moment [lb*ft/ft]	Max Allowable Bending Moment [lb*ft/ft]	Stress Ratio	Unit Deflection [lb-in^3]	Deflection [in]	Stress Ratio	Pile Length [ft]	
Table 1	CB-MP-98-1	STA 0+40 to 10+00 North Bank	-24.35	24,727	64506.5	0.38	7.56E+09	1.33	0.65	27	40
Table 2*	CB-MP-98-4	STA 10+00 to 20+00 North Bank	-34.68	21,174	64506.5	0.33	7.16E+09	1.26	0.55	38	40
Table 3*	CB-MP-98-6	STA 20+00 to 34+00 North Bank	-24.32	19,078	64506.5	0.30	6.10E+09	1.07	0.50	27	30
Table 4*	CB-MP-98-11	STA 34+00 to 41+00 North Bank	-23.00	14,685	64506.5	0.23	4.19E+09	0.74	0.38	26	30
Table 5	CB-MP-98-13	STA 41+00 to 54+00 North Bank	-35.30	52,713	64506.5	0.82	3.49E+10	6.13	1.38	38	40
Table 6	CB-MP-98-14	STA 54+00 to 63+00 North Bank	-31.05	50,096	64506.5	0.78	2.44E+10	4.28	1.31	34	40
Table 7*	CB-MP-98-16	STA 63+00 to 77+00 North Bank	-23.39	15,459	64506.5	0.24	4.62E+09	0.81	0.40	26	30
Table 8*	CB-MP-98-20	STA 77+00 to 81+00 North Bank	-21.29	14,613	64506.5	0.23	3.60E+09	0.63	0.38	24	30
Table 9*	CB-MP-98-21	STA 81+00 to 87+00 North Bank	-21.29	10,245	64506.5	0.16	2.59E+09	0.45	0.27	24	30
Table 10	CB-MP-98-22	STA 87+00 to 101+00 North Bank	-39.14	72,132	64506.5	1.12	5.53E+10	9.71	1.88		
Table 11*	CB-MP-98-2	STA 1+00 to 8+00 South Bank	-27.03	22,586	64506.5	0.35	9.58E+09	1.68	0.59	30	30
Table 12	CB-MP-98-3	STA 8+00 to 15+00 South Bank	-32.79	52,833	64506.5	0.82	2.78E+10	4.88	1.38	36	40
Table 13*	CB-MP-98-5	STA 15+00 to 30+00 South Bank	-24.81	23,289	64506.5	0.36	7.72E+09	1.35	0.61	28	30
Table 14*	CB-MP-98-8	STA 30+00 to 33+00 South Bank	-21.93	14,147	64506.5	0.22	3.71E+09	0.65	0.37	25	30
Table 15	CB-MP-98-12	STA 33+00 to 50+00 South Bank	-28.48	31,076	64506.5	0.48	1.32E+10	2.31	0.81	31	40
Table 16	CB-MP-98-15	STA 50+00 to 64+00 South Bank	-26.19	33,397	64506.5	0.52	1.11E+10	1.95	0.87	29	30
Table 17	CB-MP-98-17	STA 64+00 to 81+00 South Bank	-23.16	23,267	64506.5	0.36	6.54E+09	1.15	0.61	26	30
Table 18*	CB-MP-98-21	STA 81+00 to 87+00 South Bank	-20.79	9,704	64506.5	0.15	2.35E+09	0.41	0.25	24	30

For PZ-22, I = 84.7 in^4/LF

Boring Description	Boring Name	Boring Location	Sheet Pile Wall Design Results For PZ-22 Sheet Pile Wall								Pile Length Used
			CWALSHT								
			Pile Tip El [ft]	Max Bending Moment [lb*ft/ft]	Max Allowable Bending Moment [lb*ft/ft]	Stress Ratio	Unit Deflection [lb-in^3]	Deflection [in]	Stress Ratio	Pile Length [ft]	
Table 1	CB-MP-98-1	STA 0+40 to 10+00 North Bank	-24.35	24,727	38287	0.65	7.56E+09	2.94	0.65	27	40
Table 2*	CB-MP-98-4	STA 10+00 to 20+00 North Bank	-34.68	21,174	38287	0.55	7.16E+09	2.78	0.55	38	40
Table 3*	CB-MP-98-6	STA 20+00 to 34+00 North Bank	-24.32	19,078	38287	0.50	6.10E+09	2.37	0.50	27	30
Table 4*	CB-MP-98-11	STA 34+00 to 41+00 North Bank	-23.00	14,685	38287	0.38	4.19E+09	1.63	0.38	26	30
Table 5	CB-MP-98-13	STA 41+00 to 54+00 North Bank	-35.30	52,713	38287	1.38	3.49E+10	13.56	1.38	38	40
Table 6	CB-MP-98-14	STA 54+00 to 63+00 North Bank	-31.05	50,096	38287	1.31	2.44E+10	9.48	1.31	34	40
Table 7*	CB-MP-98-16	STA 63+00 to 77+00 North Bank	-23.39	15,459	38287	0.40	4.62E+09	1.79	0.40	26	30
Table 8*	CB-MP-98-20	STA 77+00 to 81+00 North Bank	-21.29	14,613	38287	0.38	3.60E+09	1.40	0.38	24	30
Table 9*	CB-MP-98-21	STA 81+00 to 87+00 North Bank	-21.29	10,245	38287	0.27	2.59E+09	1.00	0.27	24	30
Table 10	CB-MP-98-22	STA 87+00 to 101+00 North Bank	-39.14	72,132	38287	1.88	5.53E+10	21.49	1.88		
Table 11*	CB-MP-98-2	STA 1+00 to 8+00 South Bank	-27.03	22,586	38287	0.59	9.58E+09	3.72	0.59	30	30
Table 12	CB-MP-98-3	STA 8+00 to 15+00 South Bank	-32.79	52,833	38287	1.38	2.78E+10	10.81	1.38	36	40
Table 13*	CB-MP-98-5	STA 15+00 to 30+00 South Bank	-24.81	23,289	38287	0.61	7.72E+09	3.00	0.61	28	30
Table 14*	CB-MP-98-8	STA 30+00 to 33+00 South Bank	-21.93	14,147	38287	0.37	3.71E+09	1.44	0.37	25	30
Table 15	CB-MP-98-12	STA 33+00 to 50+00 South Bank	-28.48	31,076	38287	0.81	1.32E+10	5.12	0.81	31	40
Table 16	CB-MP-98-15	STA 50+00 to 64+00 South Bank	-26.19	33,397	38287	0.87	1.11E+10	4.31	0.87	29	30
Table 17	CB-MP-98-17	STA 64+00 to 81+00 South Bank	-23.16	23,267	38287	0.61	6.54E+09	2.54	0.61	26	30
Table 18*	CB-MP-98-21	STA 81+00 to 87+00 South Bank	-20.79	9,704	38287	0.25	2.35E+09	0.91	0.25	24	30

* 6" thick granular layer added as top layer on left and right side in CWALSHT runs to allow program to design sheet wall pile tip

Table 5.4-3, Bulkhead Wall Heights vs Dredge Depth of 15 Feet

5.4.4.1 Steel Sheet Piles

Pros – Can be designed as a cantilevered wall with no tie-backs, many sizes and strengths available, rapid installation, easy handling, good choice for hard driving conditions, can be repaired or spliced easily in the field, corrosion resistant marine grade steels available, easy to field trim, easy to attach other elements to the sheet via welding.

Cons – Corrosion potential, possibility of "unzipping" under seismic loads.

5.4.4.2 Steel King Pile/Sheet Piles

Pros – Can be economical in areas with stiff or strong subsoils, can create very deep and strong bulkhead system, good for use in very deep dredges.

Cons – Extra heavy sections can make a more-complicated installation economy may not be realized in certain soils such as low strength soils, may not be economical in shallow dredge cuts.

5.4.4.3 Concrete Sheet Piles

Pros – Economical, concrete additives available to reduce corrosion and chloride saturation effects, durable, resists many environmental factors.

Cons – Can be difficult to handle and drive well. Not suited to some soils requiring hard driving, can be broken, maintenance/repair can be difficult, easily unzips under seismic loads.

5.4.4.4 Concrete King Piles

Pros – Economical.

Cons – May not be suited to hard driving conditions, may require batter pile arrangement in soft soils, can be difficult to repair/maintain, easily unzips under seismic loads.

5.4.4.5 Gabions-Stainless Steel, Plastic

Pros – Environmentally friendly, permeability helpful in reducing hydraulic loads, void size promotes growth along surface, benched sides allow for a safer wall that can allow refuge and exit, flexibility can be helpful in seismic conditions, flexibility can be helpful under deformation and distress from vessel impact, reduced wave reflection from surface, very long life of product if stainless steel twisted wire baskets are used.

Cons – Expensive, difficult to install in some environments, very labor intensive, very long construction duration, difficult to fill underwater, May require working in a dry hole, requires a foundation layer to support system, susceptible to vandalism (baskets can be "mined" for the stone), plastic gabions are more susceptible than stainless steel to damage and vandalism.

5.4.5 Preferred Bulkhead Alternative

An evaluation of edge treatments determined that the preferred channel edge would be vertical versus sloped due to reduced dredged volumes, reduced exposure of buried solid waste, maximized upland corridor between the channel edge and the CMP-ERP limit and maximized area for mangrove restoration. Steel sheet pile was the selected structural treatment for the vertical edge, chosen over concrete sheeting due to its ease of handling and ability to be installed without the need for tie-backs. Although gabions are used for construction of vertical edges, they were not chosen due to their difficulty of construction underwater and their susceptibility to damage or wear. The preferred bulkhead is a steel sheet pile cantilevered wall with no tie-backs. Windows measuring 72 inches by 15 inches with an invert elevation of 0.0 foot at 30-foot centers would be provided for back drainage. A concrete cap was selected over a steel cap as the concrete cap would add more rigidity to the wall and present a more user-friendly surface (see Figure 5.4-12).

5.5 SITING STRUCTURES WITHIN FLOOD ZONES

The Puerto Rico Planning Board, Special Flood Hazards Areas Regulation, Planning Regulation No. 13 (*Reglamento de Planificación Número 13*) promulgates certain conditions for construction within flood hazard areas. The CMP-ERP site falls within a flood hazard zone with a base elevation established. The entire CMP-ERP lies within flood zone AE with a base flood elevation of 5.9 feet (1.8 meters) and an undetermined floodway.

Regulation No. 13 requires that infrastructure be flood proofed, residential structures have their lowest floor 1 foot (0.3 meter) above base flood elevation and non-residential structures to have their lowest floor at or above the base flood elevation. Additionally, public utility connections must be above the base flood elevation. Increases in base flood elevation caused by proposed construction may not exceed 0.5 foot (0.15 meter).

It is of interest that existing grades in the area of the future peripheral roads are much lower than the base flood elevation of 5.9 feet (1.8 meters), normally in the range of 2.5 to 3.5 feet (0.75 to 1.07 meters). Regulation No. 13 does not specifically address the need for roadways to be constructed to a specific elevation for flood hazard mitigation. Raising the roadway to 5.9 feet or higher may create a dike along the channel, requiring additional upland disturbances and infrastructure improvements. Additional structures may have to be removed, causing further relocation of residents. The purpose and value of building residential and non-residential structures and supporting utilities above flood elevations is understood; however, roadways may not need to meet the same criteria. If a raised roadway is not necessary for traffic egress during flood events, it may be inappropriate to construct the peripheral road to a high elevation. However, if properly constructed, every foot of additional height on the roadway provides further flood protection for the community.

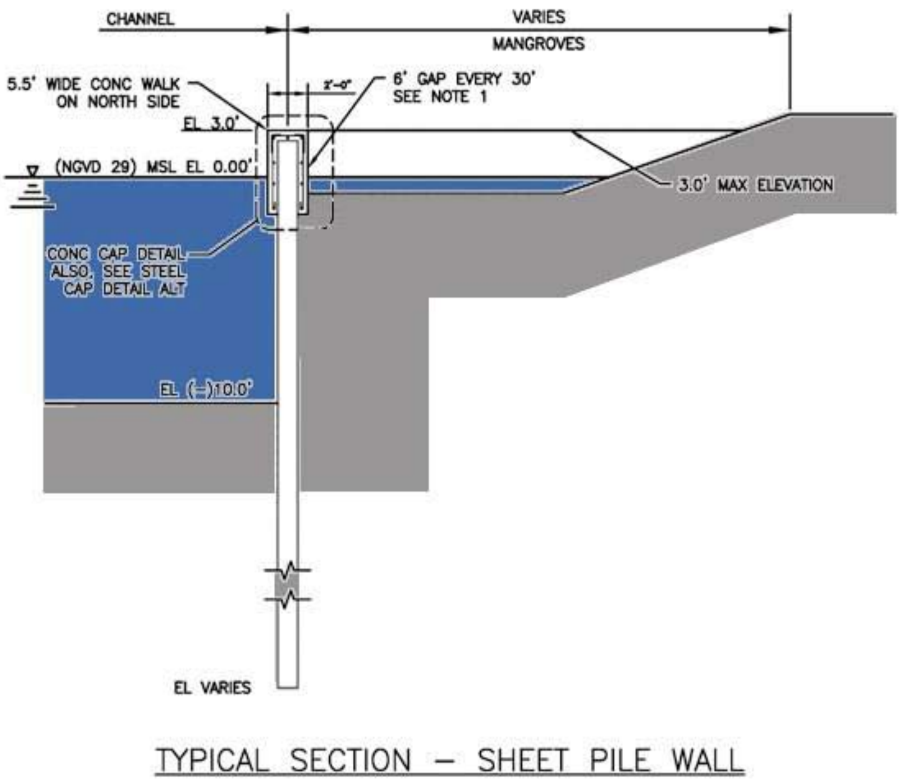
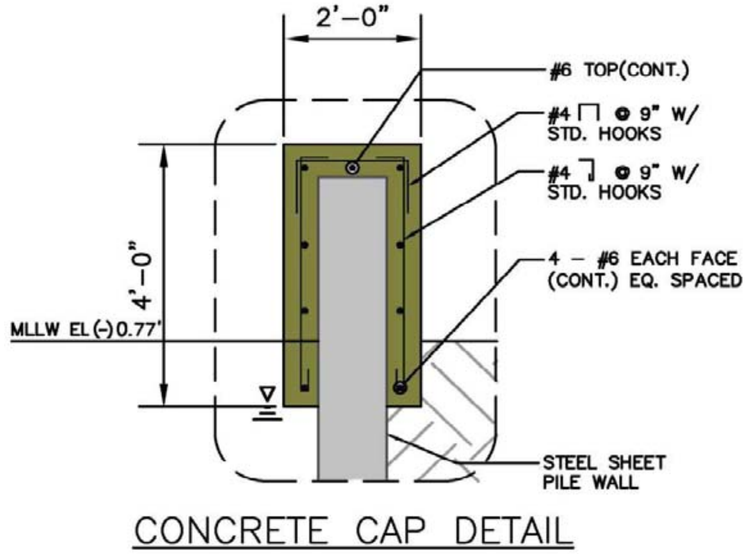


Figure 5.4-11. Channel Wall – Steel Sheet Pile



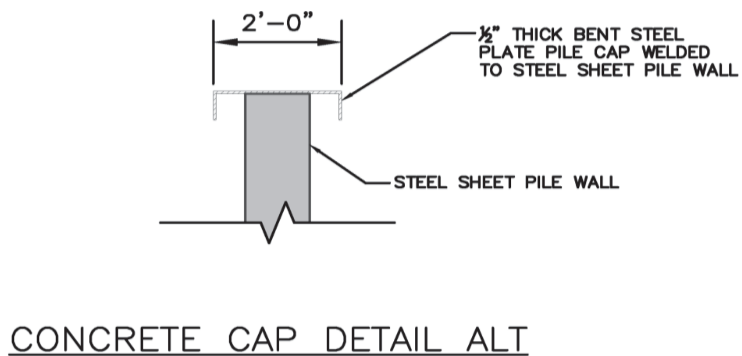


Figure 5.4-12. Channel Wall – Concrete or Steel

5.6 EFFECTS OF CHANNEL ALTERNATIVES ON PROPOSED LAND USE

The majority of the proposed channel lies within the boundaries of a fixed corridor of land known as the Public Domain. Land uses proposed for occupancy of the Public Domain are the channel, mangrove (wetland) restoration, and upland, including community recreation. Consequently, the more land committed to the channel footprint, the less remains for other uses. Upland areas remain relatively stable in the range of 7 to 8 acres for each of the channel alternatives. This is due to the fact that most of the upland falls within the widened segments of the corridor (figures 5.6-1 through 5.6-6).

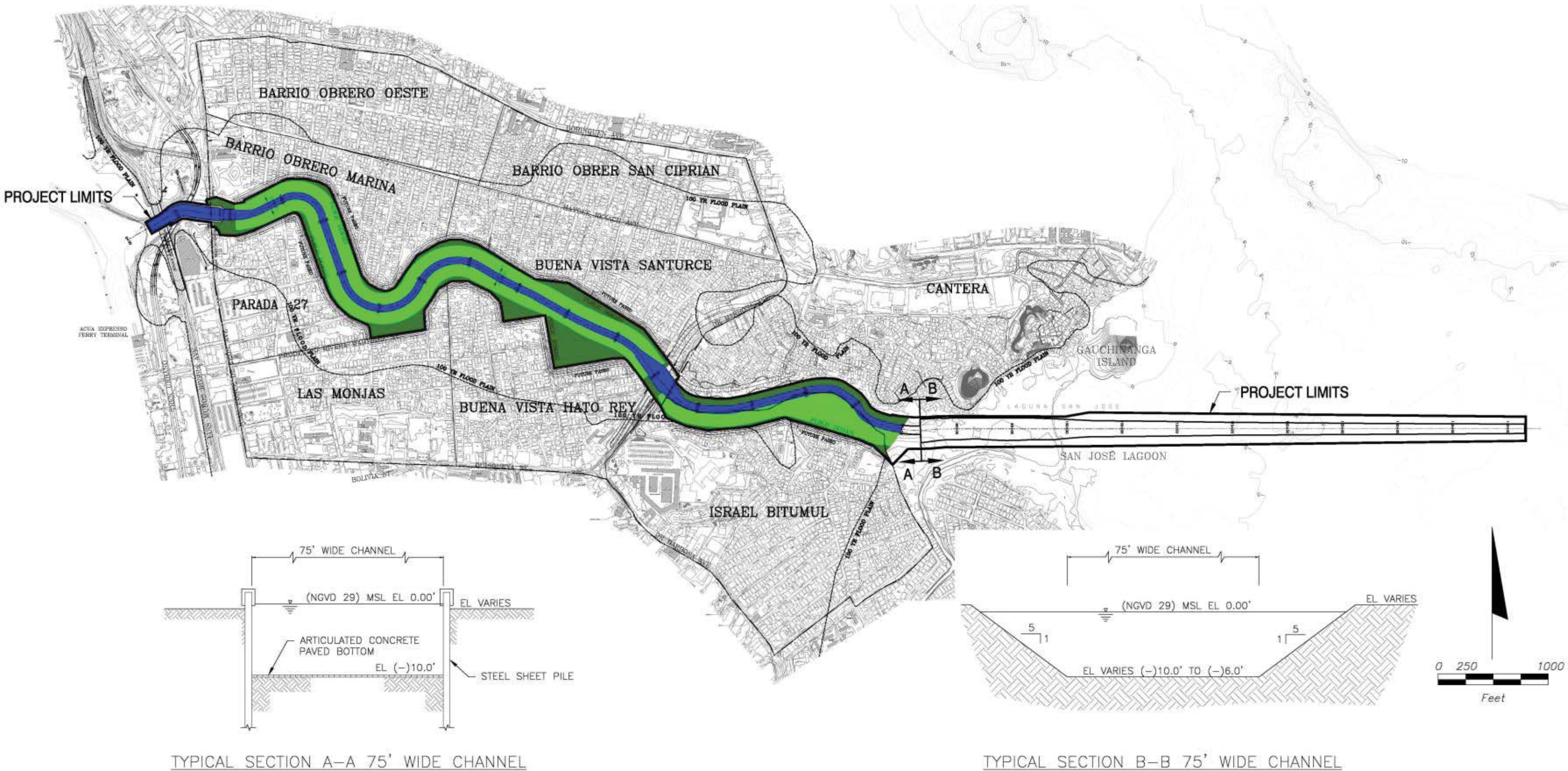


Figure 5.6-1. 75-foot Channel

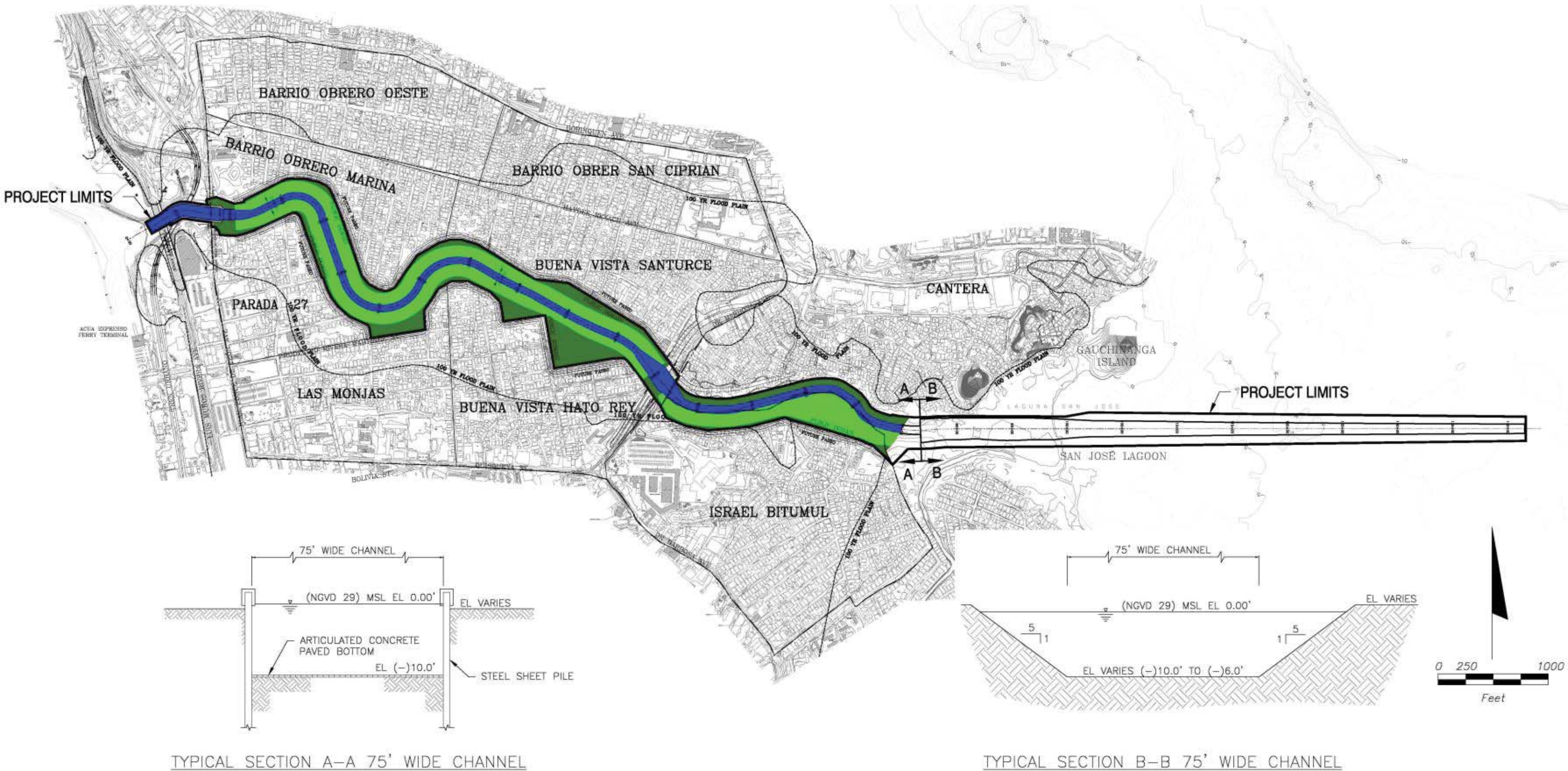


Figure 5.6-2. 100-foot Channel

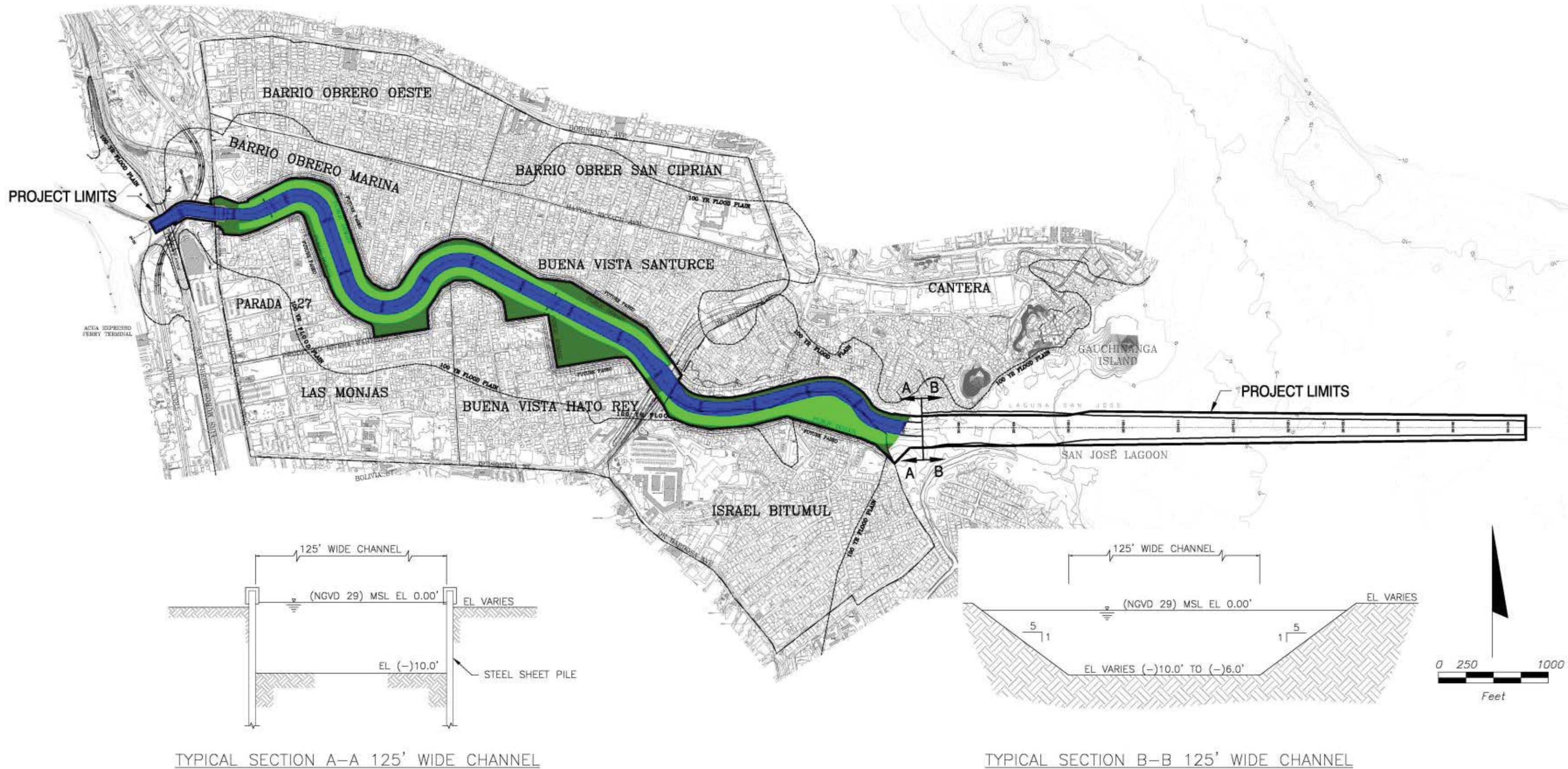


Figure 5.6-3. 125-foot Channel

Figure 5.6-4. 150-foot Channel

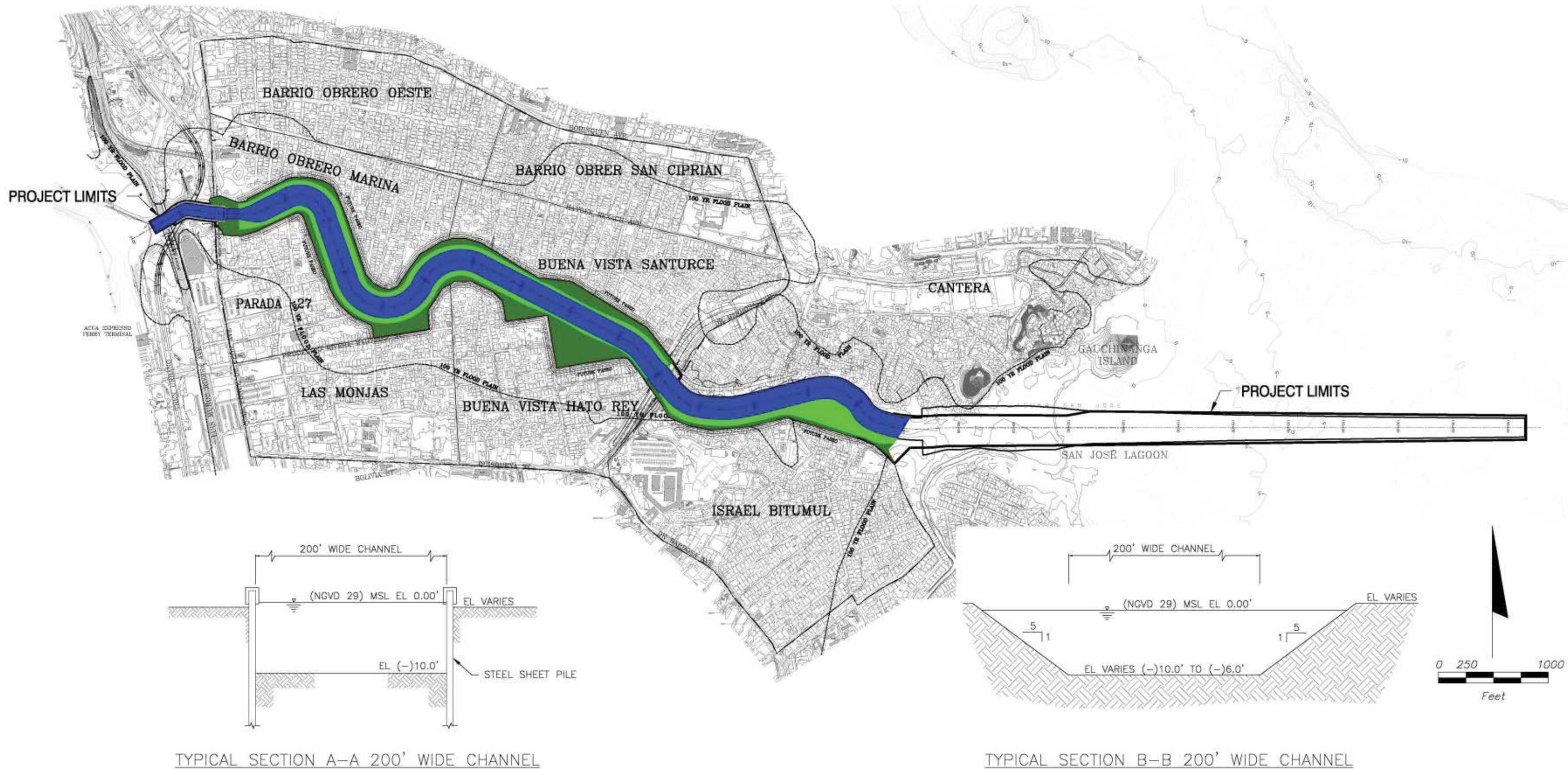


Figure 5.6-5. 200-foot Channel

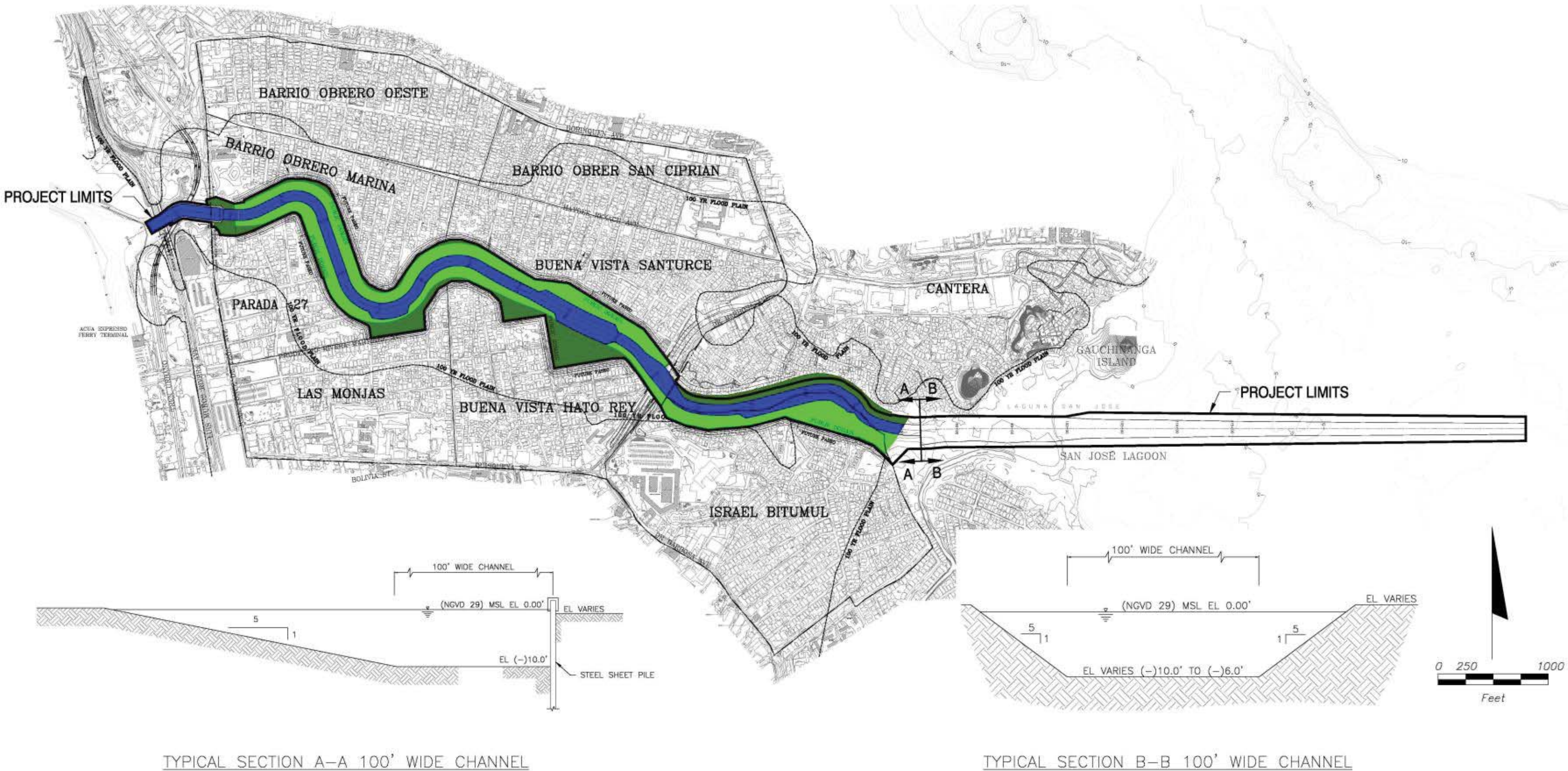


Figure 5.6-6. Hybrid Channel

5.7 DREDGED MATERIAL MANAGEMENT PLAN

The Dredged Material Management Plan (DMMP) for the CMP-ERP has been prepared to analyze alternatives for dredging, transport, and disposal of materials proposed to be dredged from the CMP. Several dredging methodologies, along with dredged material disposal alternatives, were evaluated to identify a preferred plan for the dredging and disposal of the dredged material. Prior to clearing, grubbing, and dredging activities, a sampling and remediation plan would be developed and approved by ENLACE, USACE, USEPA, and PREQB to ensure that any materials that contain hazardous substances at levels that are not suitable for unregulated disposal will be managed in accordance with the applicable laws and regulations of the relevant regulatory agencies.

Various methodologies and disposal alternatives were considered. Dredged volumes for the channel alternatives ranged from 638,000 cubic yards (cy) for the 75-x-10-foot channel to 1,286,668 cy for the 150-x-15-foot hybrid channel. Considerations for the type of dredges were shallow water, low bridge clearances, and the characteristics of the material to be dredged. A small clamshell mechanical dredge was chosen as the best alternative to excavate the sediments.

Dredging would start at the channel's confluence with the San José Lagoon so that the debris may be barged to the CDRC staging site. Concurrently, dredging under the western bridges would begin. Dredging systems would have to be barge mounted, floating on the Lagoon or the newly dredged waters of the Project Channel. Dredging would involve mechanically excavating the sediments, dumping them onto a rigid screen within a hopper to filter out the debris, allowing the sediments to fall through the screen and into the hopper. The screened debris would be removed and placed in a barge for upland disposal. Solid waste collected at the western bridges would be placed along the shore for later collection when the eastern channel dredging reaches the western bridges. Solid waste would air dry during transport to the upland landfill.

The preferred disposal alternative for sediments to be dredged between the existing bottom depth and –10 feet is to reconfigure the SJ1 and SJ2 CAD sites to increase the disposal capacity; encapsulate the dredged sediments in geotextile containers; dispose of the geoencapsulated dredged sediments within the reconfigured SJ1 and SJ2 CAD sites and; cap the material with 2 feet of clean sediments. The source for the sand cap is assumed to be a nearby quarry; however, the use of crushed, recycled glass could also be considered.

Construction under the western bridges, due to their low clearances and shallow depths, will require the use of scaled down equipment, with dredging starting from the west. At the eastern end of the Project Channel, should rock outcrops be encountered, it may be possible to avoid the rock with slight adjustments to the channel's configuration.

The barged debris would be transported across the San José Lagoon to the staging area and then trucked on to the landfill. The dredging operation may involve two excavators, one to sift and pick out large debris in the area being dredged and a second to excavate sediments for dumping onto the screen. The debris picker may also be used to move debris from the screen into the staging area scow.

The collected solid waste would be transferred to the docking area at the CDRC and then transported by truck to the Humacao landfill. Where feasible, recyclable material would be separated from trash and debris at the staging/processing sites, and transported to an appropriate material recovery facility.

Turbidity controls would be employed at the site of the dredging, the hopper loading, sediment screening and the loading/unloading/dewatering areas. Turbidity controls may take the form of turbidity barriers, booms and other devices. Allowable turbidity limits would be monitored at each end of the Project Channel and at the pipeline discharge point.

5.7.1 Dredged Material Characteristics

The channel bottom is composed mainly of peat, organic clays, silts of varying thickness within the proposed dredge footprint. The native sediments are covered by over five decades of accumulated sludge, solid waste. For the CMP-ERP, dredged material is defined as a collective mix of sediments or soils ("dredged sediments") and solid waste ("dredged debris"). It is estimated that the dredged debris will make up 10 percent of the total material to be dredged. In addition, chemistry analysis of historic sediment samples collected from within the CMP-ERP reveal the presence of elevated levels of contaminants.

The CMP-ERP site is located in the central northern coastal plain of Puerto Rico. This specific region consists of middle Tertiary limestone in sporadic outcrops, mostly forming prominent hills, locally referred to as "mogotes." On top of the limestone lies the upper Tertiary and Quaternary coastal, lagoon, fluvial and eolian sediments, mainly from the late Pleistocene and Holocene, which cover older deposits (Pease and Monroe 1977).

The coastal plain of the San Juan Metropolitan Area shows a surficial geology dominated by lagoonal and estuary environments, covered by fluvial and eolian deposits that have dictated the geomorphologic evolution of the area. The estuary areas are characterized by low-lying flat land that has evolved to its present conditions by erosion, deposition, compaction, and subsidence, all of which are still active.

The local geology is characterized by a middle Tertiary Aymamon limestone formation (Tay), composed of a light pale, very porous fossileferous, massive-to-thick limestone beds. The Aymamon limestone at the proposed contained aquatic disposal (CAD) site has been mined forming the pits and is considered an important source for land fill and construction materials. The adjacent hills to the CMP are called the "Cantera" ("quarry"), and portions of this limestone appear as the calcareous clastic material found within the geotechnical cores taken at the CMP-ERP site. Although the maximum exposed thickness for the Ayamon formation is mentioned by Pease and Monroe (1977) to be 33 feet (10 meters), there are other older limestone formations below this unit, which control the structure of the regional area.

Overlying the limestone are late Tertiary, Pleistocene and Holocene deposits. The Late Tertiary deposits consist of older alluvial units (Qtt) composed of weathered clay, silt and sandy sediments that include fragments of the Mucarabones sand and the relicts of the San Sebastian Formation from Oligocene age. The thickness of this formation appears to be greater than 100 meters. Fragments from the older alluvial deposits can also be observed in the geotechnical data collected at the CMP-ERP site. The Pleistocene deposits correspond to the alluvial fan deposits. The alluvial fan deposits (Qf) include reworked rocks and sediments from older formations formed of weathered clay, silt and sandy sediments. They consist of mottled red and light gray deposits and are the sediments forming the banks of the CMP and some of the submerged areas in the San José Lagoon. The Holocene deposits consist of silica sands, swamp deposits and alluvium. The silica sands (Qss) consist of very pure and clean quartz sand derived from the weathering of previous formations. The thickness of these sands varies from 3.3 to 13.1 feet (1 to 4 meters) and borders the lagoon area on the north site. These silica sands have been an important source of quartz for the glass and construction industry and if identified in the area, may play an important role in the clean sandy sediments needed for the cap recommended for the CAD sites in the lagoon.

Finally, swamp deposits and alluvium are the most recent deposits in the area. Swamp deposits (Qs) consist mostly of sandy muck, clayey sand, and peats in areas with very organic sediments associated with low energy estuary environments and mangrove areas. These deposits have been intensively filled artificially within the CMP-ERP area. The alluvium deposits (Qa) are made up of recent fluvial sands, clays and sandy clays. Thickness of this formation a few miles west of CMP was reported to be 20 meters.

For the dredging phase of the CMP, the geology suggest that the sediments along the channel consist of unconsolidated sands and clays from the Qf and potentially gravels and cobbles at top of the Qtt, which should be more consolidated. Silica sands (Qss), swamp (Qs) and alluvium (Qa) appear to be the most unconsolidated deposits in the area. These deposits may also be sources of sand for the cap if needed at the submerged pits since they tend to be of poorly graded and contain loose sand.

5.7.2 CMP Configuration Alternatives

As shown in Table 5.7-1, a total of 12 possible channel configuration alternatives were evaluated for dredging volumes. The channel configuration alternatives include stabilizing the sides of the channel with sheet pile or cutting back the sides to a stable 5:1 side slope. Channel configurations without a sheet pile wall and a 5:1 side slope are referred to as “hybrid” channel alternatives. In situ dredged sediment volumes and dredged debris volumes are broken out in Table 5.7-1. In addition, a bulking factor of approximately 26 percent has been applied to the dredged sediment volumes to expand the sediments to a bulked volume. The bulked sediment volumes were used to determine the capacity required for potential dredged sediments disposal sites.

Table 5.7-1
CMP Configuration Alternatives

Channel Width x Depth Alternative (ft x ft)	In Situ Total Material Volume (cy)	In Situ Debris Volume (cy)	In Situ Sediment Volume (cy)	Bulked Sediment Volume (cy)	*Overcut and Berm Earthwork Volume (cy)
75 x 10	638,000	63,800	574,200	721,202	178,000
100 x 10	720,000	72,000	648,000	813,896	178,000
125 x 10	830,000	83,000	747,000	938,241	178,000
150 x 10	930,000	93,000	837,000	1,051,282	178,000
125 x 15	1,059,167	83,000	976,167	1,226,078	178,000
150 x 15	1,205,000	93,000	1,112,000	1,396,686	178,000
200 x 10	1,160,000	116,000	1,044,000	1,311,277	178,000
75 x 10 (H)	692,455	69,246	623,210	782,759	178,000
100 x 10 (H)	784,455	78,446	706,010	886,757	178,000
125 x 15 (H)	1,140,835	91,167	1,049,668	1,318,396	178,000
150 x 15 (H)	1,286,668	101,167	1,185,501	1,489,004	178,000
200 x 10 (H)	1,214,455	121,446	1,093,010	1,372,833	178,000

(H) – Hybrid Channel Configuration with 5:1 Side Slopes.

* - Overcut and Berm in situ earthwork includes a budget of 178,000 cy (in situ) for overcut from channel dredging (42,000 cy) with the balance (136,000 cy) allotted to earthwork for temporary sedimentation and erosion control berm construction. This is in addition to the channel dredging volumes.

Volume calculations were based upon the assumption of maximizing the mangrove beds within the limits of the project. That is, the entire project footprint was utilized for all channel widths. As the channel widened, the mangroves narrowed. Transversely, as the channel narrowed, the mangrove beds widened. That fixed the cross section at the outer edge of all channel alternatives. The only variable was the increased or decreased volume of the channel "box". Consequently, narrower cross sections should not reduce the earthwork volumes between the sheet pile walls and the upland project line.

Channel volumes were calculated utilizing AutoCAD 3D to overlay the template or cross section of the proposed channel over the topographic survey. This created a relatively accurate estimate of the volume of sediments that must be removed to cut the channel, its adjoining mangrove beds and slope returns to existing grade. The 150-foot-wide channel was initially modeled as it represented a wider channel in the midrange of the channel alternatives. Once this volume was produced, volumes for the other channel widths were then interpolated by adding or removing the appropriate volume from the channel template (width x depth) over the total length of the channel. Volumes for the adjoining mangrove beds and slope returns were assumed to be the same. A cross check was performed using the average end area method where cross sections were taken at 500-foot intervals, their area of cut/fill calculated and applied over the 500-foot length to obtain a volume. After the 100-foot-wide x 10-foot-deep channel was selected as the preferred channel, its volumes were confirmed using AutoCAD 3D.

The "preferred" channel configuration is identified as the 100 x-10-foot plan (100 feet wide and 10 feet deep), requiring the dredging and disposal of 648,000 cy of in situ dredged sediments and 72,000 cy of solid waste. Sloughing of the channel side slopes is expected to generate an additional 42,000 cy of dredged sediments which would be moved from the channel bottom and deposited onto the upland slope for later use as backfill behind the sheet pile wall. The total volume of in situ sediments to be excavated from the CMP-ERP is the 720,000 cy of channel excavation plus the 42,000 cy of side slope sloughing or 762,000 cy.

The basis for this volume was a channel cross section of 10 feet by 100 feet with an adjoining mangrove bed graded to about mean lower low water and then sloping up to existing grade and a transitional channel from the 10-foot-deep rectangular channel within the CMP-ERP into the 6-foot-deep San José Lagoon. Dredged sediment volumes were calculated to include a bulking factor of approximately 26 percent. Ten percent of the bulked volume is expected to be solid waste. Therefore, the total volume of excavated material, minus the solid waste bulked to 126 percent is 813, 896 cy. Volumes were calculated utilizing a digital terrain model.

There was no typical dredge prism as the side areas were dredged back as far as possible to maximize the creation of mangrove planting beds. Their limit was the CMP-ERP boundary line which varies throughout the corridor. Certain deductions were made for the proposed recreation areas. The cross section in Figure 5.7-1 illustrates this condition. There were no allowances for over dredging.

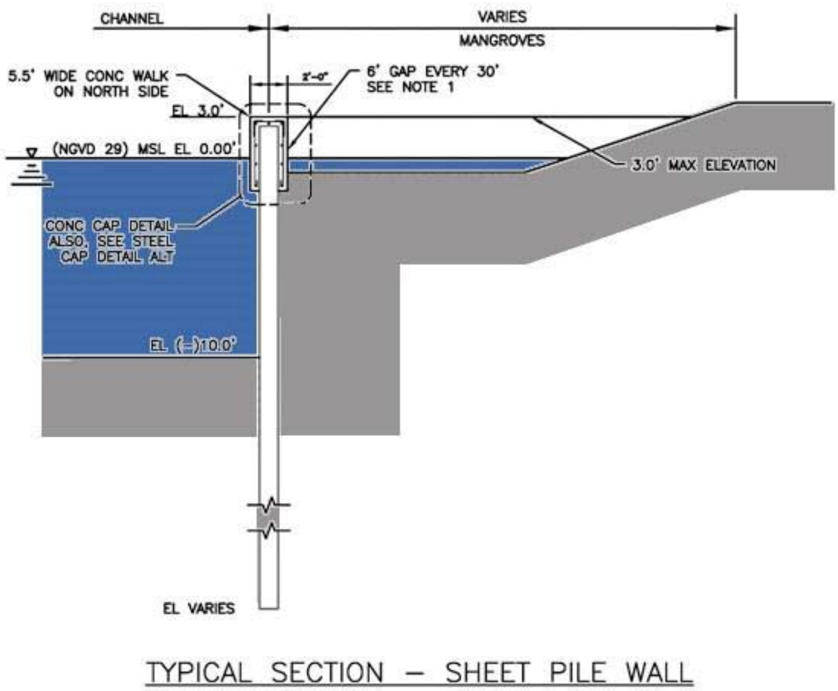


Figure 5.7-1. Dredge Prism

5.7.3 Dredge Platforms

Various dredge types categorized under mechanical and hydraulic dredge platforms were considered for construction of the CMP. Given the restricted physical environment within the CMP (shallow water, low bridge clearances), and the characteristics of the material to be dredged, it was concluded the more likely dredge type to excavate the CMP material is a small clamshell mechanical dredge. The clamshell dredge could easily switch out between an open bucket (to excavate solid waste and stiff sediments) and an environmental bucket (to excavate unconsolidated contaminated sediments). Metal sieves would be placed on top of scows to allow for separating the solid waste from the dredged material. The solid waste would be collected, processed, and transported to a municipal landfill.

Tables 5.7-2 and 5.7-3 present the potential hydraulic and mechanical dredge types and their characteristics, relative to the CMP.

Table 5.7-2
Matrix of Potential Hydraulic Dredge Types for the CMP

Platform/Type	Advantages	Disadvantages	CMP Applicability
HYDRAULIC DREDGES (General)	• Less turbidity at dredged site • Larger production rate • Reduced dredging time • Can discharges directly to open water sites • Precise dredging • Closed system, reduced environmental exposure	• Discharges slurry with 10–20% solids • Dewater dredged material for upland sites • Higher turbidity at open water discharge site • Tends to clog, especially with debris • Discharge pipeline can be navigation obstruction	• Maybe used in areas with limited debris • Proposed to be used for mining & placing sand cap • Utilize silt curtain to contain turbidity at lagoon discharge sites
Plain Suction	• Less turbidity at dredged site • Larger production rate • Reduced dredging time • Precise dredging • Closed system, reduced environmental exposure • Effective at removing unconsolidated sediments	• Discharges slurry with 10–20% solids • Dewater dredged material for upland sites • Higher turbidity at open water discharge site • Tends to clog, especially with debris • Discharge pipeline can be navigation obstruction • Unable to dredge consolidated material	• May be used if solid wastes (solid waste) can be removed first • Will not be effective at dredging consolidated or compacted sediments • Requires use of silt curtains at lagoon discharge sites • Requires dredged material dewatering if placed at an upland site
Cutterhead	• Less turbidity at dredged site • Larger production rate • Reduced dredging time • Precise dredging • Closed system, reduced environmental exposure • Effective at removing compacted sediments	• Discharges slurry with 10–20% solids • Dewater dredged material for upland sites • Higher turbidity at open water discharge site • Tends to clog, especially with debris • Discharge pipeline can be navigation obstruction	• May be used if solid wastes (solid waste) can be removed first • Can dredge compacted sediments • Requires use of silt curtains at lagoon discharge sites • Requires dredged material dewatering if placed at an upland site
Dustpan	• Larger production rate • Reduced dredging time • Precise dredging • Closed system, reduced environmental exposure • Effective at removing unconsolidated sediments • Water jets can dislodge consolidated sediments	• Discharges slurry with 10–20% solids • Dewater dredged material for upland sites • Higher turbidity at both dredge site and open water discharge site • Tends to clog, especially with debris • Discharge pipeline can be navigation obstruction	• Will work like a vacuum • May be used if solid wastes (solid waste) can be removed first • Can be effective at dredging consolidated sediments • Requires use of silt curtains at lagoon discharge sites • Requires dredged material dewatering if placed at an upland site

Table 5.7-2, cont'd

Platform/Type	Advantages	Disadvantages	CMP Applicability
Hopper	• Large production rate • Carries large dredged material volumes • Typically self-propelled • Does not require support equipment (e.g., tugs, scows, or pipelines) • Can transport dredged material long distances • Able to safely transit in ocean environments	• Limited ability to operate in shallow water environments • Typically overflows excess water (including suspended sediments) • Cuts shallow, which requires several passes to dredge to CMP-ERP depth • Not effective at dredging compacted or	• CMP restricted dimensions preclude use of hopper dredges • Overflow of hopper is typical, therefore not ideal for contaminated sediments • Unable to excavate debris
Bucket Wheel	• Solids in slurry greater than cutterhead dredge • Less turbidity at dredged site • Larger production rate • Reduced dredging time • Precise dredging • Closed system, reduced environmental exposure • Effective at removing compacted sediments	• Dewater dredged material for upland sites • Higher turbidity at open water discharge site • Tends to clog, especially with debris • Discharge pipeline can be navigation obstruction • Unable to dredge consolidated material • Mechanically complicated	• May be used if solid wastes (solid waste) can be removed first • Will not be effective at dredging consolidated or compacted sediments • Requires use of silt curtains at lagoon discharge sites • Requires dredged material dewatering if placed at an upland site

Table 5.7-3
Matrix of Potential Mechanical Dredge Types for the CMP

Platform/Type	Advantages	Disadvantages	CMP Applicability
MECHANICAL DREDGES (General)	• High percentages of solids removed • Precise dredging, good in close quarters • Able to excavate consolidated sediments • Able to excavate debris and other bulk material • Can be used in deep water	• Low production rates, compared to hydraulic dredges • Typically high turbidity at dredged site • Difficulty operating in strong currents • Typically requires high overhead clearance	• May be used to dredge both sediments and debris • May be used to excavate sediments from artificial depressions in the lagoons • May require silt curtains at both dredge and disposal (lagoon) sites • Can be used to mine sand for cap material
Clamshell Open Bucket	• High percentages of solids removed • Precise dredging, good in close quarters • Able to excavate consolidated sediments • Able to excavate debris and other bulk material • Can be used in deep water	• Low production rates, compared to hydraulic dredges • High turbidity at dredged site • Difficulty operating in strong currents • Typically requires high overhead clearance	• May be used to dredge both clean sediments and debris • Should not be used for dredging contaminated sediments • May be used to excavate sediments from artificial depressions in the lagoons • May require silt curtains at both dredge and disposal (lagoon) sites • Can be used to mine sand for cap material
Clamshell Envir. Bucket	• Precise dredging, good in close quarters • Closed system, reduced environmental exposure • Low turbidity at dredged site • Able to excavate and contain unconsolidated contaminated sediments • Can be used in deep water	• Low production rates, compared to hydraulic dredges • Difficulty operating in strong currents • Typically requires high overhead clearance • Not able to dredge consolidated, compacted, or debris material	• May be used to dredge soft, loose contaminated material • May require silt curtains at both dredge and disposal (lagoon) sites
Dragline	• High percentages of solids removed • Able to excavate consolidated sediments • Able to excavate debris and other bulk material	• Low production rates, compared to hydraulic dredges • High turbidity at dredged site • Difficulty operating in strong currents	• May be used to dredge both clean sediments and debris • Should not be used for dredging contaminated sediments • May require silt curtains at both dredge and disposal (lagoon) sites

Table 5.7-3, cont'd

Platform/Type	Advantages	Disadvantages	CMP Applicability
Bucket Ladder	• High percentages of solids removed • Able to excavate consolidated sediments • Able to excavate debris and other bulk material • Higher production rates than clamshell and dragline dredges	• High turbidity at dredged site • Difficulty operating in strong currents	• May be used to dredge both clean sediments and debris • Should not be used for dredging contaminated sediments • May require silt curtains at both dredge and disposal (lagoon) sites
Dipper	• High percentages of solids removed • Able to excavate hard, compacted material • Able to excavate debris and other bulk material	• Low production rates, compared to hydraulic dredges • High turbidity at dredged site • Difficulty operating in strong currents	• May be used to dredge clean sediments, rock and debris • Should not be used for dredging contaminated sediments • May require silt curtains at both dredge and disposal (lagoon) sites
Backhoes/ Loaders	• High percentages of solids removed • Able to excavate hard, compacted material • Able to excavate debris and other bulk material	• Low production rates, compared to hydraulic dredges • High turbidity at dredged site • Difficulty operating in strong currents	• May be used to dredge clean sediments, rock and debris • Should not be used for dredging contaminated sediments • May require silt curtains at both dredge and disposal (lagoon) sites

5.7.4 Description of Dredged Material Disposal Alternatives

The five alternatives for the disposal of the dredged materials from the CMP include contained aquatic disposal, existing landfill disposal, permanent upland, ocean disposal, and beneficial use of dredged sediments. Tables 5.7-4a–e display all the disposal alternatives. Final evaluation of these dredged material disposal alternatives will be guided by Code of Federal Regulations (CFR) 33 CFR 335.7 and the following assumptions that will remain constant throughout each alternative:

- Solid waste will be separated from the dredged sediments and disposed of separately.
- All indications are that the solid waste is generally household items and C&D debris materials, and it is assumed that it will not contain hazardous materials and therefore can be trucked to and disposed at a Class III landfill.
- For inland aquatic disposal, sediment testing and concurrence from the PREQB would be necessary in accordance with Section 404 of the Clean Water Act. Due to resource limitations for the non-Federal sponsor, Section 103 and/or Section 404 testing would not be conducted until the PED phase, at the latest, if aquatic disposal is included as part of any recommended alternative. Initial assessments of sediment and solid waste and coordination with regulatory agencies have been conducted.

5.7.4.1 Disposal Alternative 1: Contained Aquatic Disposal

There are four options for subaqueous disposal in Los Corozos Lagoon and San José Lagoon. These options include level bottom capping, contained aquatic disposal, subaqueous diked confinement, and subaqueous geotextile confinement. Each Contained Aquatic Disposal alternative requires the placed dredged sediments to be capped with clean material (alternatives for capping material are discussed in Section 5.7.8).

Table 5.7-4a
Matrix of Dredged Sediments Disposal Alternatives (Contained Aquatic Disposal)

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
CONTAINED AQUATIC DISPOSAL (General) (Alternative 1)	• Sequesters contaminants • Marine-based operation • No dewatering of sediments	• Short-term water quality impacts • Requires cap material source, typically sand • Requires cap material dredging & placement	• Can be sited on ambient bottoms at San José & Los Corozos Lagoons • Can be sited in subaqueous artificial depressions (pits) San José & Los Corozos Lagoons
Level Bottom Capping ALTERNATIVE 1a	• Sequesters contaminants • Marine-based operation • No dewatering of sediments • Can be converted to aquatic habitats in shallow water environments • No lateral confinement required	• Short-term water quality impacts • Requires cap material source, typically sand • Requires cap material dredging & placement • Cap vulnerable to erosion in high energy environments or during storm events	• Can be sited on ambient bottoms at San José & Los Corozos Lagoons • Will require significant quantity of sand for cap • Can involve multiple disposal mounds • May require rehandling of contaminated dredged sediments (shallow water) • May require armoring to prevent erosion • Can be converted to shallow water habitats • May require maintenance
Contained Aquatic Disposal ALTERNATIVE 1b	• Sequesters contaminants • Marine based operation • No dewatering of sediments • No rehandling of contaminated dredged sediments • Typically resistant to storm-induced erosion • Lateral confinement in-place	• Short-term water quality impacts • Requires cap material source, typically sand • Requires cap material dredging & placement	• Can be sited in subaqueous artificial depressions (pits) San José & Los Corozos Lagoons • May require modifying pits to increase disposal capacity • May have short-term impacts to tarpon fishing industry • Will require minimal quantity of sand for cap

Table 5.7-4a, cont'd

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
Subaqueous Diked Confinement ALTERNATIVE 1c	• Sequesters contaminants • Marine based operation • No dewatering of sediments • Typically resistant to storm-induced erosion • May be converted to shallow water habitats	• Short-term water quality impacts • May require rehandling of contaminated sediments • Requires reinforced lateral confinement structures • Requires cap material source, typically sand • Requires cap material dredging & placement	• Can be sited on ambient bottoms at San José & Los Corozos Lagoons • Will require significant quantity of sand for cap • May require rehandling of contaminated dredged sediments (shallow water) • May require armoring to prevent erosion • Can be converted to shallow water habitats • May require maintenance
Subaqueous Geotextile Confinement ALTERNATIVE 1d	• Sequesters contaminants • Marine based operation • No dewatering of sediments • Typically resistant to storm-induced erosion • Minimal short-term water quality impacts • Lateral confinement not required • Variety of sediment types can be used as cap material	• Bottom dump disposal only • Requires capping of geotextile containers • Requires cap material dredging & placement • Increase in logistical complexities • Reduced production rates • Risk of rupturing or tearing during disposal	• Can be sited in subaqueous artificial depressions (pits) San José & Los Corozos Lagoons • Minimal short-term water quality impact during disposal, no silt curtain required • Will require capping with sand or other sediment type • May require modifying pits to increase disposal capacity

Table 5.7-4b
Matrix of Dredged Sediments Disposal Alternatives (Landfill Disposal)

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
LANDFILL DISPOSAL (General) (Alternative 2)	• Sequesters contaminants • Avoids aquatic impacts • Transfer ownership	• Interim processing/transfer area required • Requires water quality control system • Significant number of truck trips • Requires truck liners • Transportation distances • Tipping fees • Compete for disposal capacities • Rehandling of dredged material	• Industrial landfill sites only • Requires multiple landfill sites to gain sufficient capacity • Tens of thousands of truck loads • Transport distance in excess of 70 miles • Requires double handling of contaminated dredged sediments
Industrial Landfill (Trucking/ No Dewater) ALTERNATIVE 2a	• Sequesters contaminants • Avoids aquatic impacts • Transfer ownership • Limited processing/transfer area needed	• Substantial volume of material to dispose • Significant number of truck trips • Requires truck liners • Transportation distances • Tipping fees • Compete for disposal capacities • Rehandling of dredged material	• Industrial landfill sites only • Requires multiple landfill sites to gain sufficient capacity • Tens of thousands of truck loads • Transport distance in excess of 70 miles • Requires double handling of contaminated dredged sediments
Industrial Landfill (Trucking/ Dewater) ALTERNATIVE 2b	• Sequesters contaminants • Avoids aquatic impacts • Transfer ownership • Reduced quantity of solids to transport & dispose	• Flocculate & dewater material • Interim processing/transfer area required • Requires water quality control system • Significant number of truck trips • Requires truck liners • Transportation distances • Tipping fees • Compete for disposal capacities • Rehandling of dredged material	• Industrial landfill sites only • Requires multiple landfill sites to gain sufficient capacity • Tens of thousands of truck loads • Transport distance in excess of 70 miles • Requires double handling of contaminated dredged sediments

Table 5.7-4b, cont'd

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
Industrial Landfill (Trucking/ Geocontainer) ALTERNATIVE 2c	• Sequesters contaminants • Avoids aquatic impacts • Transfer ownership • Reduced quantity of solids to transport & dispose • May not require truck liner	• Flocculate & dewater material • Interim processing/transfer area required • Requires water quality control system • Significant number of truck trips • Transportation distances • Tipping fees • Compete for disposal capacities • Rehandling of dredged material • Logistically complex • Additional costs for material & labor	• Industrial landfill sites only • Requires multiple landfill sites to gain sufficient capacity • Tens of thousands of truck loads • Transport distance in excess of 70 miles • Requires double handling of contaminated dredged sediments
Industrial Landfill (Trucking/ Cement) ALTERNATIVE 1d	• Sequesters contaminants • Avoids aquatic impacts • Transfer ownership • Reduced quantity of solids to transport & dispose • May not require truck liner • May be converted to construction material • Can be placed in municipal landfill sites	• Flocculate & dewater material • Interim processing/transfer area required • Requires water quality control system • Significant number of truck trips • Transportation distances • Tipping fees • Compete for disposal capacities • Rehandling of dredged material • Logistically complex • Additional costs for material & labor	• Can be placed in municipal landfill sites • Requires multiple landfill sites to gain sufficient capacity • Tens of thousands of truck loads • Transport distance may vary between 11 and 32 miles • Requires treatment & double handling of contaminated dredged sediments • Can be sold as construction material

Table 5.7-4c
Matrix of Dredged Sediments Disposal Alternatives (Upland Placement)

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
PERMANENT UPLAND PLACEMENT SITE (Alternative 3)	• Sequesters contaminants • Avoids aquatic impacts • Allows for commercial and recreational development	• Flocculate & dewater material • Requires containment structures • Impervious liners • 10-acre placement site • Requires clean cap material sources • Water & land-based operations • Requires reoccurring maintenance • Gas vents may be required	• Can be placed in the vicinity of the CDRC • Requires over tens of acres of land • Significantly degraded aesthetics • Air quality impacts (H_2S) • Can use cap material as overburden material to consolidate sediments for commercial or recreational development • May require rehandling dredged material • Treat effluent prior to discharge into lagoon

Table 5.7-4d
Matrix of Dredged Material Disposal Alternatives (Ocean Disposal)

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
OCEAN DISPOSAL SITE (Alternative 4)	• Can accept large quantities of dredged sediments • Presents less risk to human health • Minimal effect on marine community	• Contaminated sediments disposal not permitted • Greater safety risk by transiting in ocean environment • Temporary benthic smothering over large area • Requires added remote monitoring of dump scow transit and disposal locations	• Requires sediment chemistry, bioassay, and bioaccumulation testing and analysis • Dredged sediments residing between –10 and –15 feet likely suitable for ocean disposal

Table 5.7-4e
Matrix of Dredged Sediments Disposal Alternatives (Beneficial Use of Dredged Material)

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
BENEFICIAL USE OF DREDGED MATERIALS (General) (Alternative 5)	• Can be used to create aquatic and terrestrial habitats • Additional ecological benefits • Sequesters contaminants if used in conjunction with a contained disposal facility	• Requires containment of beneficial contaminated dredged sediments • Displaces soft bottom habitat, if placed in aquatic environment	• Can be sited on ambient bottoms at San José & Los Corozos Lagoons
Expansion of Current Areas ALTERNATIVE 5a	• Partial lateral confinement structure in-place with existing shoreline • Sequesters contaminants • Marine based operation • No dewatering of sediments • Typically resistant to storm-induced erosion • May be converted to shallow water and terrestrial habitats • Allows for recreational development • Additional ecological benefits	• Short-term water quality impacts • May require rehandling of dredged sediments • Requires reinforced lateral confinement structures • Requires cap material source, sand or other sediment type • Requires cap material dredging & placement	• Can be sited at Guachinanga and Guachinanguita Islands and adjacent on San José ambient bottom • Will require significant quantity of material for cap • May require rehandling of contaminated dredged sediments (shallow water) • Requires construction of containment dikes • May require armoring to prevent erosion • Can be converted to both bird island and marshes • May require maintenance
Diked Bird Island ALTERNATIVE 5b	• Sequesters contaminants • Marine based operation • No dewatering of sediments • Typically resistant to storm-induced erosion • Converts to terrestrial habitats • Allows for recreational development • Additional ecological benefits	• Short-term water quality impacts • May require rehandling of dredged sediments • Requires reinforced lateral confinement structures • Requires cap material source, sand or other sediment type • Requires cap material dredging & placement • Reduced water volume	• Can be sited on ambient bottoms at San José & Los Corozos Lagoons • Will require significant quantity of material for cap • May require rehandling of dredged sediments (shallow water) • Requires construction of containment dikes • May require armoring to prevent erosion • Convert to a bird island • May require maintenance

Table 5.7-4e, cont'd

Disposal Alternative	Advantages	Disadvantages	CMP Applicability
Undiked Bird Island ALTERNATIVE 5c	• Sequesters contaminants • Marine-based operation • No dewatering of sediments • May be converted to shallow water and terrestrial habitats • No lateral confinement required • Allows for recreational development • Additional ecological benefits	• Short-term water quality impacts • May require rehandling of dredged sediments • Requires cap material source • Requires cap material dredging & placement • Cap vulnerable to erosion in high energy environments or during storm events • May require armoring against erosion	• Can be sited on ambient bottoms at San José & Los Corozos Lagoons • Will require significant quantity of material for cap • May require rehandling of dredged sediments (shallow water) • May require armoring to prevent erosion • Can be converted to both bird island and shallow water habitats • May require maintenance
Marsh Mounds ALTERNATIVE 5d	• Sequesters contaminants • Marine-based operation • No dewatering of sediments • Converts to shallow water • Additional ecological benefits	• Short-term water quality impacts • May require rehandling of dredged sediments • Requires reinforced lateral confinement structures • Requires cap material source • Requires cap material dredging & placement	• Can be sited on ambient bottoms at San José & Los Corozos Lagoons • May require containment berms • Will require significant quantity of material for cap • May require rehandling of dredged sediments (shallow water) • May require armoring to prevent erosion • Converts to shallow water habitats • May require maintenance

5.7.4.1.1 Disposal Alternative 1a: Level Bottom Capping

In Alternative 1a (**Level Bottom Capping**), sediments that are separated from the solid waste would be disposed at one or multiple level bottom disposal sites. Level bottom disposal entails placing dredged sediments on the top layer of the lagoon bottom where no depression exists. The sediments would be deposited in mound(s) and then capped with 2 feet of clean sands. Depending on the location and the depth of the water, multiple mounds may be required. The subsequent mound(s) that are created from this process may create a shallow water habitat system for the surrounding ecosystem. This method of disposal would have a larger footprint than the other subaqueous confinement methods and would require more capping material. Because the level bottom capping sites would reside within an open shallow water environment, cap erosion during major storm events may occur, with the potential of dredged sediments becoming exposed. This alternative is not anticipated to impact the tarpon fishing industry in the San José Lagoon.

5.7.4.1.2 Disposal Alternative 1b: Contained Aquatic Disposal

In Alternative 1b (**Contained Aquatic Disposal**), sediments that are separated from the solid waste would be disposed within previously dredged borrow pits or Contained Aquatic Disposal (CAD) pits (Bailey et al. 2002) within San José Lagoon or Los Corozos Lagoon. There are three artificial depressions (pits) located within San José Lagoon identified as San José 1 (SJ1), San José 2 (SJ2), and San José 3 (SJ3), and one artificial depression (pits) in Los Corozos Lagoon identified as Los Corozos 1 (LC1) that could serve in combination as CAD sites for the dredged sediments. If placed within one or more of these pits, the dredged material would likely require a cap. If the material requires a cap, the material would be placed to fill in the depressions up to the –18-foot contour and then capped with 2 feet of clean sand. If no cap is needed, then the depressions could be filled with the dredged sediments up to the –16-foot elevation. These are the maximum fill elevations due to potential spillage from SJ1/SJ2 into SJ3/4/5 if fill above –16 feet. Depending on the volume of material to be dredged and aquatically placed, the existing subaqueous pits may need to be modified to increase the capacity of the pits to receive most of the dredged sediments. Modification of the pits would be in the form of excavating material. CAD sites typically require far less clean sand for capping because the dredged sediments are laterally confined, and as a result have a smaller surface footprint as compared to level bottom capping sites (Alternative 1a). This CAD disposal alternative proposes to fill in the existing subaqueous pits with dredged and capping material up to the –16-foot elevation. Adverse impacts to the tarpon fishing industry are not expected, since the tarpon tend to feed at the halocline interface located in the lagoon at approximately –6 feet.

5.7.4.1.3 Disposal Alternative 1c: Subaqueous Diked Confinement

In Alternative 1c (**Subaqueous Diked Confinement**), sediments that are separated from the solid waste would be disposed within an underwater diked area. The dike will be built on top of the bay bottom and then filled with the dredged sediments. As with the CAD alternative mentioned above, a cap could possibly be required for this option as well. If a cap is required, the material will be filled within 2 feet of the top of the diked area and then capped with 2 feet of clean material. If no cap is required, then the material can simply be filled to the top of the diked area. The deeper the water, the taller the dikes can be, which will decrease the overall footprint of the confinement area and the amount of clean material needed for the cap. Because the surrounding lagoon areas are generally shallow, the following parameters were used to demonstrate size and capping material potentially needed. The containment area would be built where the bay bottom elevation is at or below –10 feet. The diked walls would extend 8 feet in height, leaving, at a minimum, 2 feet of shallow water clearance. If the entire structure were built at this depth of –10 feet, the containment area would need to be approximately 1,723 feet by 1,723 feet (68 acres) which is a particularly large footprint for this lagoon. The fill material would be placed up to 6 feet (–4 feet below the surface) and would then be capped with 2 feet of clean sand. In this scenario, approximately 220,000 cy of clean capping material would be needed. However, unless a deeper lagoon area is identified, this method may prove to be not viable due to the large footprint that would be created, and a larger volume of clean cap material needed.

5.7.4.1.4 Disposal Alternative 1d: Subaqueous Geotextile Confinement

In Alternative 1d (**Subaqueous Geotextile Confinement**), the dredged sediments that are separated from the solid waste would be placed into a geotextile container that would line the interior (hopper) of the dump scow. Geotextile containers have been found to be an effective means of containing sediments during dredging operations. With proper care, little or no rupturing of the geotextile containers should occur. Past occurrences were a result of improper release from the hopper dredge, causing tearing, or improper sewing of the geotextile fabric. The geotextile container would be open at the top and once it was filled with sediments, the container would be sewn together and sealed. This container would then be transported to a disposal site in the lagoon area and placed in the bottom of the lagoon. This process would be repeated until all the material was placed within the subaqueous disposal site. The size and capacity of the containers would determine the footprint, placement, and number of containers needed to dispose all the sediments. The geotextile containers would require bottom dump disposal; therefore, the aquatic placement area should be deep enough to allow for bottom dumping. Since geotextile containers may not be completely effective at interfering with dredged sediments diffusing into the water column, an additional safety measure of capping the geotextile containers in-place with clean sediments may be necessary. The structure of the geofabric material would support the sand cap subsequently requiring less sand. A future study would need to be performed to determine the amount of leaching from the geotextile containers into the water column through the sediment cap and consequently determine the environmental viability of the geotextile container alternative.

5.7.4.2 Disposal Alternative 2: Existing Landfill Disposal

There are four options for existing landfill disposal for all sediment and solid waste: trucking as semisolids; dewatering at a containment area and then trucking; filling geotextile tubes for dewatering and then trucking; and, encapsulation with Portland cement and subsequent disposal of the Portland cement/sediment mixture. Regardless of the method used for existing landfill disposal, the following assumptions are made:

1) Information on the industrial landfills available for the dredged sediments coming from the CMP was provided by staff of the Environmental Quality Board (Junta de Calidad Ambiental) and the Solid Waste Authority (Autoridad de Desperdicios Sólidos). Staff from these organizations stated on February 9, 2011, that there are three industrial landfill sites that can manage the disposal of liquid or semi-liquid dredged materials that may originate from the dredging of the CMP (María V. Rodríguez (JCA) and Mr. Rollon (Autoridad de Desperdicios Sólidos [ADS]) to Dr. Juan Moya (Atkins), personal communication, 2011). These industrial landfills each have the capacity to manage up to 500,000 cy of sediments from the CMP. The three industrial landfills (vertederos industriales) are shown on Figure 5.7-2 and their attributes are described below:

Figure 5.7-2
Potential Landfills that accept up to 500,000 cy of dredged sediments

- **PONCE (Projected Closure Date is 2045, if Expanded)**
  - **Owner/Operator**: Municipality/BFI
  - **Landfill Users (Municipalities)**: Adjuntas, Ponce, Comerío, Aguas Buenas, Cidra
  - **Waste Products**: Municipal Solid Waste, Special Wastes, C&D*, Auto Waste, and Yard Wastes
  - **Average Filling Rate**: 6,620 tons per week (5,300 cy/week semi-solids)
  - **Tipping Fee**: $18/cy (bulk solids)
  - **Distance from CMP**: 71 miles
- **PEÑUELAS (Projected Closure Date is 2026)**
  - **Owner/Operator**: Waste Management/Waste Management
  - **Landfill Users (Municipalities)**: Industrial
  - **Waste Products**: Industrial, C&D*, and Liquid (solidify before disposal). No Resource Conservation and Recovery Act (RCRA) material permitted
  - **Average Filling Rate**: 3,000 ton per week (2,400 cy/wk semi-solids)

  - **Tipping Fee**: $35/ton (semi-solids), $28/cy (semi-solids)
  - **Distance from CMP**: 86 miles

- **YAUCO (Projected Closure Date is Beyond 2030, if Expanded)**
  - **Owner/Operator**: Municipality/L&M Waste
  - **Landfill Users (Municipalities)**: Yauco, Guánica, San Germán, Sabana Grande, Peñuelas, Guayanilla
  - **Waste Products**: Municipal Solid Waste, Special Wastes, C&D*, and Yard Wastes
  - **Average Filling Rate**: 2,410 ton per week (1,928 cy/wk semi-solids)
  - **Tipping Fee**: $22/ton, $7/cy (domestic), $10/cy (C&D*)
  - **Distance from CMP**: 93 miles

  *C&D – Construction & Demolition Debris

2) If the dredged material is placed in a containment area to dewater, chemical flocculants may be used to increase the settling rate of the material and decrease the time it takes for the material to dewater to the proper moisture content.
3) Currently it is being assumed that it is not cost effective to treat the dredged sediments in order to remove or encapsulate COCs so that they can be disposed at a Class III facility.
4) Several existing landfill sites may currently have compliance issues associated with runoff control, landfill gas controls, leachate collection, groundwater and air monitoring, daily cover, and slope gradient. It is assumed only landfill sites that comply with all waste management policies and regulations may be act as candidates to receive the CMP dredged material.

The facilities available in Puerto Rico to properly dispose waste are nearing a critical state. Measures to address the availability of limited landfill capacity include expansion of existing landfills, transferring of wastes to larger, distant landfill sites, and diversion of wastes. Waste diversion can take the form of recycling, reclamation, or through diversifying disposal methodologies (beyond landfill disposal), which results in a reduction of waste material slated for disposal at landfill sites.

To avoid or minimize the CMP's dredged material disposal impact to Puerto Rico's constrained landfill capacity, other disposal alternatives consistent with the Autoridad de Desperdicios Sólidos' solid waste diversion program should be considered before recommending all or a portion of the CMP's dredged material be placed in upland landfill sites.

5.7.4.2.1 Disposal Alternative 2a: Industrial Landfill (Sediment) – No Dewater/Truck

For Disposal Alternative 2a (Landfill – No Dewater), after the sediments are separated from the solid waste, the sediments would be loaded into trucks and taken to a landfill. The material will not be dewatered first and therefore the trucks will need to be lined with an impermeable material so that they do not leak sediments or water on the way to the landfill. Assuming that each truckload can hold 15 cy of material, this would mean 54,260 truckloads would be required in order to dispose the "preferred" channel configuration (100 x 10 feet) alternative bulk sediment volume of 813,896 cy. Impacts caused by Disposal Alternative 2a (Landfill – No Dewater) include significant air emissions, traffic congestion, increased noise levels, and substantial increase in project costs.

5.7.4.2.2 Disposal Alternative 2b: Industrial Landfill (Sediment) – Dewater/Truck

In Disposal Alternative 2b (Landfill – Dewater), the sediments that are separated from the solid waste would be barged to and placed at a constructed dewatering containment area close to the CMP. The sediments would then be allowed to dewater within this diked area. Once the sediments have dewatered they would then be removed from the temporary containment area and placed within trucks and transported to a Class I or Class II landfill. A concern with the viability of this method is the potential leaching of contaminants into the groundwater system or back into the San José Lagoon. Government controls requires that the truck bed be covered and the tailgate be configured with a gasket or other method to prevent the leakage of the sediments. Because the material would be allowed to dewater, the trucks would not have to be lined with impermeable material and the volume of sediments would decrease by half as would the number of truckloads required in order to dispose of the sediments. Impacts caused by Disposal Alternative 2b (Landfill – Dewater) will be similar to impacts caused by Disposal Alternative 2a, significant air emissions, traffic congestion, increased noise levels, and substantial increase in project costs (but to a lesser degree) and potential localized degradation of water quality from the dewatering operations.

5.7.4.2.3 Disposal Alternative 2c: Industrial Landfill (Sediment) – Geocontainer/Truck

In Disposal Alternative 2c (Landfill – Geocontainers), the sediments that are separated from the solid waste would be placed into geotextile containers in order to be dewatered. The geotextile containers would be set up in a temporary land based holding area that would be lined with impermeable material and enclosed in order to contain the effluent. The effluent from these containers would need to be monitored for COCs and will need to be collected and treated to remove any COCs that may have leached from the bags before being discharged. Once the material has dewatered in the geotextile containers, the material may either be transported to a landfill in the geotextile containers or the containers maybe be opened and then material removed and trucked off without the geotextile containers. Assuming the sediments dewater to the same consistency as the sediments that are dewatered in the temporary containment area under Disposal Alternative 2b (Landfill – Dewater), there would be half the sediments that would need to be transported and placed within one of the industrial landfill sites. Impacts caused by Alternative Disposal 2c (Landfill – Geocontainers) will be similar to impacts caused by Disposal Alternative 2b (Landfill – Dewater), significant air emissions, traffic congestion, increased noise levels, and substantial increase in project costs.

5.7.4.2.4 Disposal Alternative 2d: Industrial Landfill (Sediment) – Portland Cement/Truck

In Disposal Alternative 2d (Landfill – Portland Cement), sediments that are separated from the solid waste will be brought to a processing area to dewater. From here a cement mixture will be brought in and the sediments would then be mixed with Portland cement to form a solid and stabilized compound, that binds free liquids, reduces permeability, and encapsulate contaminants. The solidified compound will be in the form of clumps or coarse granules. Cement admixtures may increase the sediment volume by 5 to 30 percent, depending upon the sediment and contaminant characteristics. If this material is considered less hazardous or nonhazardous, finding a landfill that can accept the material may be easier, without any appreciable increase in the dewatered volume following treatment with cement. In some instances, the Portland cement treated sediments may end up with a higher compressive strength, which may allow the treated compound to be used as construction material such as road base. Impacts caused by Disposal Alternative 2d will be similar to impacts caused by Disposal Alternative 2b, significant air emissions, traffic congestion, increased noise levels, and substantial increase in project costs.

5.7.4.3 Disposal Alternative 3: Permanent Upland Placement Site

In Disposal Alternative 3, sediments that were separated from the solid waste would be placed in one or more upland placement sites. Sites in close proximity to the dredged site would receive dredged sediments via hydraulic pumping. Those further away would require trucking of the sediments from a dewatering site near the dredging. For hydraulic dredging, the upland placement site would be bounded by berms. The area would be lined with geotextile material or an impervious material such as high-density polyethylene (HDPE) in order to prevent leaching into the groundwater. The placement site may also need to be capped with clay or a Portland cement mixture to prevent evaporation into the air or transport by inundation or flooring from offsite rainwater. If the placement area is capped, gas vents would need to be installed. Regardless of capping, the placement area would need to be equipped with leachate and stormwater collection systems. Similar to the subaqueous diked confinement alternative, the footprint of the placement area will be determined by the height of the berms. The taller the berms, the smaller the required surface footprint.

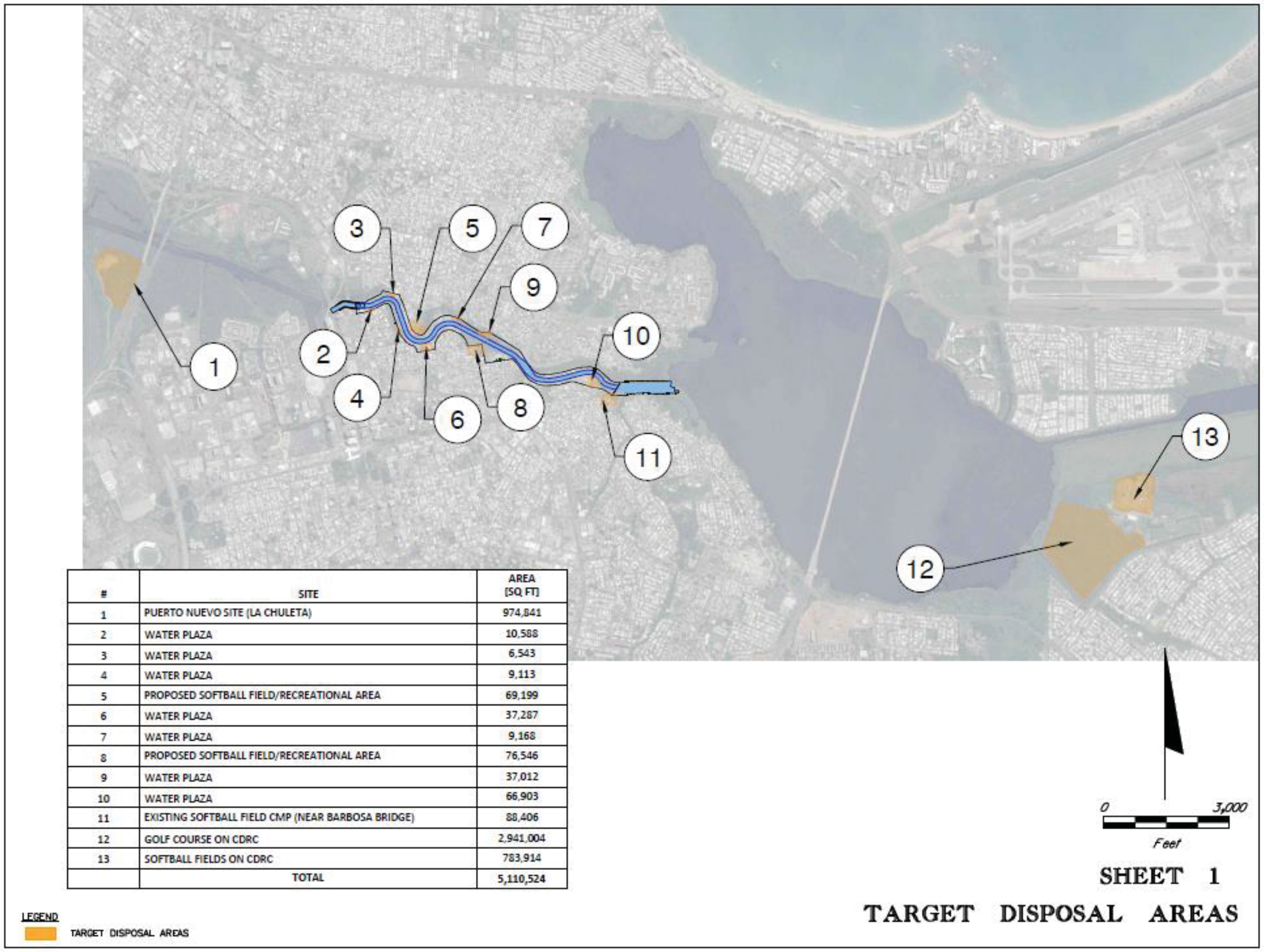
An undeveloped site considered for construction of a permanent upland disposal facility is the land tract for the proposed golf course and the adjoining existing softball fields located between the CDRC (Figure 5.7-3 and 5.7.4) and the east bank of San José Lagoon. The CDRC is a community sports and recreation facility and the Roberto Clemente Stadium is used to host entertainment and professional sporting events. With the exception of this land tract, other upland open areas surrounding the CDRC are primarily classified as estuarine and marine wetlands, according the U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) online database, and therefore are not considered as ideal candidate sites to construct a permanent dredged material placement facility. The USFWS NWI online database can be found at http://www.fws.gov/wetlands/Data/Mapper.html).

Several small sites within the Project's limits were targeted for potential disposal of dredged sediments. These included the proposed water plazas, softball fields and recreational areas and the existing softball field near the Barbosa Bridge. Also, a nearby targeted site was the existing Puerto Nuevo (La Chuleta) disposal site (Figure 5.7-4). With the exception of La Chuleta and the CDRC golf course, capacity at each site was relatively small due to their limited depths of fill. Table 5.7-5 illustrates the potential capacities of each site. Also considered but not fully analyzed was using dredged sediments to raise the elevation of the proposed Paseo.

Numerous other sites at a distance from the Project were evaluated for possible use as permanent upland disposal facilities. Over 60 sites within 10 miles of the project were characterized utilizing broad-based GIS data and ranked using a multi-criteria analysis. The screening criteria used in the analysis included: distance to rivers, presence of inappropriate geological formation, distance to geological faults, 2010 census block population, distance to wetlands, distance to reservoirs, distance to protected areas, distance to aquifers, maximum transit route elevation, historical sites presence, aquifer presence, land use zoning, built up urban areas, access road, vegetation cover, distance to airports, hazardous flood zones, and parcel slopes. The sites were then ranked, and several locations were identified that would be feasible for use as a disposal option for the CMP-ERP. One particular concern for each of the top ranked sites was topography and the resulting level of effort and cost required for site preparation.

It does not appear feasible nor cost effective to pursue a trucked disposal option that does not take advantage of dewatering of sediments prior to transport. Dewatering options could include a large area to stockpile the dredged material over several years (e.g., the CDRC) or allowing the trucks to stay on site for a day or two and let the water drain from the trucks. Of course, for either scenario, a process would need to be further developed, and coordination with the appropriate agencies would need to occur related to the effluent from the dewatering process.

Figure 5.7-3
Upland Placement Site – Vicinity Ciudad Deportiva Roberto Clemente



#	SITE	AREA [SQ FT]
1	PUERTO NUEVO SITE (LA CHULETA)	974,841
2	WATER PLAZA	10,588
3	WATER PLAZA	6,543
4	WATER PLAZA	9,113
5	PROPOSED SOFTBALL FIELD/RECREATIONAL AREA	69,199
6	WATER PLAZA	37,287
7	WATER PLAZA	9,168
8	PROPOSED SOFTBALL FIELD/RECREATIONAL AREA	76,546
9	WATER PLAZA	37,012
10	WATER PLAZA	66,903
11	EXISTING SOFTBALL FIELD CMP (NEAR BARBOSA BRIDGE)	88,406
12	GOLF COURSE ON CDRC	2,941,004
13	SOFTBALL FIELDS ON CDRC	783,914
	TOTAL	5,110,524

Figure 5.7-4
Target Disposal Area

Table 5.7-5
Target Disposal Area Volumes

Location	#	SITE	AREA [SQ FT]	DEPTH [FT]	VOLUME [CU YDS] 1	VOLUME [CU YDS] 3	VOLUME [CU YDS] 6	VOLUME [CU YDS] 12
LA CHULETA	1	PUERTO NUEVO SITE	974,841		36,105	108,316	216,631	433,263
		TOTAL - LA CHULETA	**974,841**		**36,105**	**108,316**	**216,631**	**433,263**
CMP PROJECT SITE	2	WATER PLAZA	10,588		392	1,176	2,353	4,706
	3	WATER PLAZA	6,543		242	727	1,454	2,908
	4	WATER PLAZA	9,113		338	1,013	2,025	4,050
	5	PROPOSED SOFTBALL FIELD/RECREATIONAL AREA	69,199		2,563	7,689	15,378	30,755
	6	WATER PLAZA	37,287		1,381	4,143	8,286	16,572
	7	WATER PLAZA	9,168		340	1,019	2,037	4,075
	8	PROPOSED SOFTBALL FIELD/RECREATIONAL AREA	76,546		2,835	8,505	17,010	34,020
	9	WATER PLAZA	37,012		1,371	4,112	8,225	16,450
	10	WATER PLAZA	66,903		2,478	7,434	14,867	29,735
	11	EXISTING SOFTBALL FIELD CMP (NEAR BARBOSA BRIDGE)	88,286		3,270	9,810	19,619	39,238
		TOTAL - CMP PROJECT SITE	**410,645**		**15,209**	**45,627**	**91,254**	**182,509**
CDRC	12	GOLF COURSE	2,941,004		108,926	326,778	653,556	1,307,113
	13	SOFTBALL FIELDS	783,914		29,034	87,102	174,203	348,406
		TOTAL - CDRC	**3,724,918**		**137,960**	**413,880**	**827,760**	**1,655,519**

Failing the above alternatives, an urban site would have to be cleared, relocating homes and businesses to make room for this site. Impacts caused by Disposal Alternative 3 (Permanent Upland Placement Site) include significant air emissions (carbon and hydrogen sulfide gases), traffic congestion, increased noise levels, potential localized degradation of water quality from the dewatering operations, degraded aesthetics, indirect impacts to recreation, and substantial increase in project costs.

5.7.4.3.1 Disposal Alternative 4: Ocean Disposal

Unconfined open-water disposal requires that the sediments be relatively uncontaminated. If determined suitable for unconfined open-water disposal, the sediments could be placed at the USEPA-approved San Juan, Puerto Rico Ocean Dredged Material Disposal Site (ODMDS). Solid waste would be separated from the sediments during dredge operations, for transport to and disposal at an upland landfill site. The San Juan ODMDS is an approximately 1 square nautical mile area located approximately 2.2 nautical miles (2.5 statute miles) north-northwest of the entrance to San Juan Harbor (Figure 5.7-5) positioned in a rectangle bounded by the following coordinates (EPA/USACE, 2010):

18° 30' 10" N 66° 09' 31" W 18° 30.17' N 66° 09.52' W
18° 30' 10" N 66° 08' 29" W 18° 30.17' N 66° 08.48' W
18° 31' 10" N 66° 08' 29" W 18° 31.17' N 66° 08.48' W
18° 31' 10" N 66° 09' 31" W 18° 31.17' N 66° 09.52' W

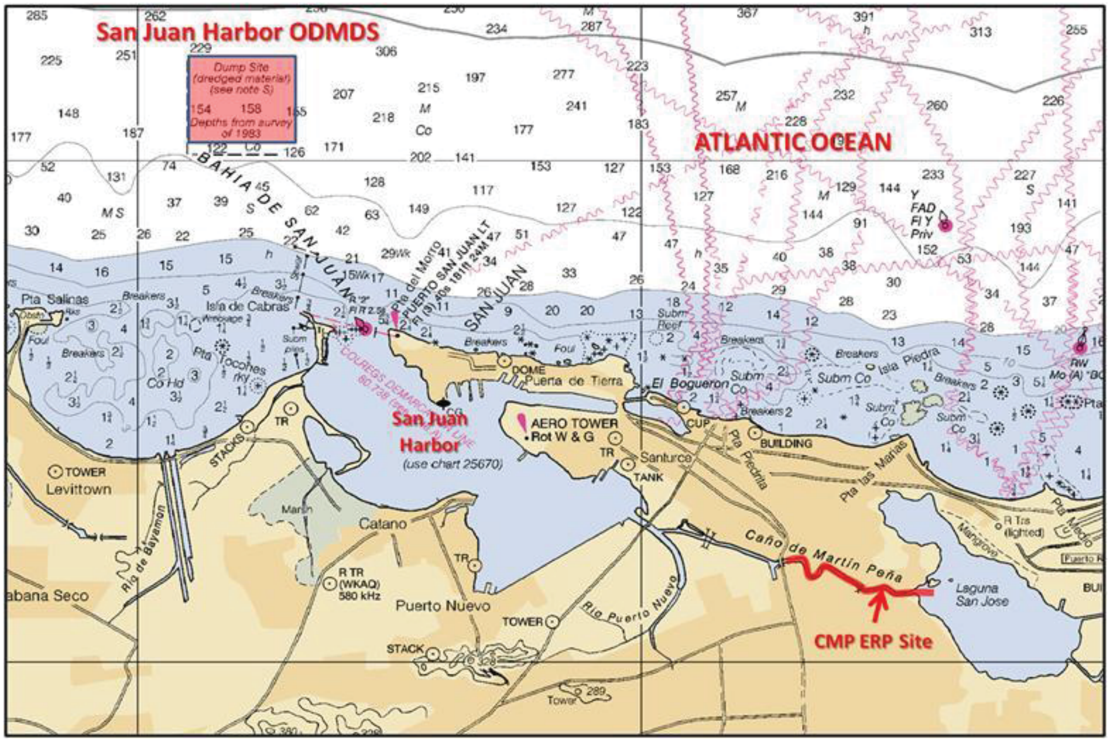


Figure 5.7-5
Location of San Juan Harbor ODMDS – Depths in Fathoms (NOAA, 2008)

The San Juan ODMDS area has existing depths on the average of 965 feet. Bottom depths at the southern boundary are approximately 700 feet and slope moderately to approximately 1,300 feet at the northern boundary (EPA, 1982). The dredged sediments can be placed within the boundaries of the ODMDS with a final disposal mound thickness of less than 10 feet, if the bulk volume of the dredged sediments is less than 1.3 million cy (bulk sediment total volume for the 125-x-15 channel alternative). ERDC's MDFATE model simulates the development of subaqueous dredged material disposal mound at offshore sites from multiple disposal events. The MDFATE model will need to be run to determine an acceptable disposal and positioning sequence to ensure all dredged sediments settle within the boundaries of the San Juan ODMDS, and if applicable, not exceed a designated mound height/thickness. It is anticipated that any material that remains suspended in the water column during disposal operations would be carried by prevailing currents in a westerly direction away from the coast of Puerto Rico.

The Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972 (33 USC Section 1401, et seq.) is the legislative authority regulating the disposal of dredged material into ocean waters, including the territorial sea. The transportation of dredged material for the purpose of placement into ocean waters is permitted by the USACE or in the case of Federal projects, authorized for disposal under MPRSA Section 103(e), applying environmental criteria established by the EPA in the Ocean Dumping Regulations (40 CFR Parts 220–229). Section 102(c) of the MPRSA and 40 CFR 228.4(e)(l) authorize the EPA to designate ODMDSs in accordance with requirements at 40 CFR

228.5 and 228.6. Section 103(b) of MPRSA requires that the USACE use dredged material sites designated by EPA to the maximum extent feasible. Where use of an EPA-designated site is not feasible, the USACE may, with concurrence of EPA, select an alternative site in accordance with MPRSA 103(b).

Prior to receiving authorization to transport and dispose of the dredged sediments at the ODMDS, testing and characterizing of all dredged sediments shall be conducted to determine whether the sediments meets the ocean disposal criteria. Dredged material testing procedures and requirements are contained in the following documents (EPA/USACE, 2010):

- Ocean Dumping Regulations (40 CFR Part 227, "Criteria for the Evaluation of Permit Applications for Ocean Dumping of Materials").
- EPA/USACE, 1991. "Evaluation of Dredged Material Proposed for Ocean Disposal, Testing Manual" as amended (otherwise known as the "Green Book").
- EPA Region 2/USACE, New York District (1992) (or most recent revision). "Guidance for Performing Tests on Dredged Material proposed for Ocean Disposal" (otherwise known as the Regional Testing Manual).

The EPA, Region 2/USACE, New York District (1992) manual (or its most recent) revision would be used to evaluate the suitability of dredged material proposed for disposal at the San Juan ODMDS. The suitability of dredged material for ocean disposal will be determined by USACE, Jacksonville District and concurred with by EPA, Region 2 in writing prior to ocean disposal authorization at the San Juan ODMDS. Per USACE/EPA (2010), the determination of suitability will be valid for three years from the time of testing, unless it is determined that conditions at the dredging site may have changed significantly since that time (e.g., chemical spills). EPA, Region 2 may extend the authorization for an additional period without further testing if 1) conditions at the dredging site are deemed to not have changed significantly since the time of testing (reduced levels of testing effort may, in fact, be required to confirm this); and 2) no unacceptable impacts have occurred or are expected at the dredging and disposal sites.

In general, the analytical work needed to evaluate the suitability of the CMP dredged sediments for disposal at the San Juan ODMDS would consist of chemical analyses of water, sediment, and elutriate samples; suspended particulate and solid phase bioassays; and bioaccumulation assessments. The chemical analyses of the sediment and seawater samples will provide data concerning background levels of specified potential toxins. The chemical analyses of the elutriate samples will provide an indication of any expected release of potential toxins from the sediment into the water column. The suspended particulate phase bioassays are designed to determine the potential impact from dredging and ocean placement to sensitive water column organisms. The solid phase bioassays are designed to determine the potential impact of the placement of the dredged material on designated sensitive marine organisms living on the bottom within the vicinity of the San Juan

ODMDS. The bioaccumulation studies are designed to provide an indication of any uptake of potential toxins by sensitive benthic organisms.

5.7.4.4 Disposal Alternative 5: Beneficial Use of Dredged Material Opportunities

In the case that some clean sediments, safe and free of contamination, are found during the dredging operation and are not able to be used as capping materials, there may be some beneficial use of dredged material opportunities in the area. Additionally, any contaminated dredged sediments could be used beneficially, if properly contained and capped. While these options include the construction of diked and/or containment areas, the ultimate function of these facilities would be for the beneficial use of the dredged material. These options include backfilling behind the sheet pile walls to form mangrove planting areas, expanding current areas within the lagoon(s), creation of a new diked bird island, creation of a new undiked bird island, and creation of marsh mounds. These are discussed in the following subsections.

5.7.4.4.1 Disposal Alternative 5a: Expansion of Current Areas

Current features within the lagoon system would be expanded. An example would be the expansion of Guachinanga and Guachinanguita Islands near Cantera. These features are bird islands and sediment disposal could enlarge, thus further enhancing and restoring the habitat in the lagoon. This is not the most viable alternative given the cost to construct retaining structures; requirements for dewatering; and, the need for a large volume of sand cap.

5.7.4.4.2 Disposal Alternative 5b: Diked Bird Island

A new diked bird island would be created, similar to the subaqueous diked containment alternative that was mentioned above. However, in this option, the dikes would be raised above water level. This is not the most viable alternative given the cost to construct retaining structures, requirements for dewatering, and the need for a large volume of sand cap.

5.7.4.4.3 Disposal Alternative 5c: Undiked Bird Island

An undiked bird island would be built similar to the diked bird island mentioned above; however, there would be no physical structure in place to hold the sediments. The island would be created by disposing of the material on the bay bottom until a free flowing mound is created above the waterline. A sand cap is then placed over the fill. This is not the most viable alternative given the need for a large volume of sand cap, and the vulnerability to damages during major storm events that could result in contaminated sediments being exposed to the environment.

5.7.4.4.4 Disposal Alternative 5d: Marsh mounds

A series of low elevation marsh mounds would be created using the same concepts as the undiked bird island alternative; however, these marsh mounds would be smaller in size and would not have as great of an above water elevation. A sand cap would be required. These marsh mounds would not be physically held in place. This is not the most viable alternative given the need for a large volume of sand cap; and, the vulnerability to damages during major storm events that could result in contaminated sediments being exposed to the environment.

5.7.5 Cap Material (Sand) Source

The potential need for clean sand for the capping material is one of the primary challenges for those alternatives requiring capping. Clean sand would be needed as capping material if contaminated dredged sediments are free dumped into the San José Lagoon's subaqueous pits; however, if the dredged sediments are encapsulated in geocontainers prior to placement in the pits, other clean sediment could possibly be used as capping material in lieu of clean sand. Commercial sand availability is a problem in the San Juan Metropolitan area due to the limited geological resources. Therefore the CMP-ERP may consider some alternatives for obtaining the capping material. "An early source of consideration was one of the remaining mogotes at the Península de Cantera. This source was dismissed because the surrounding area is densely populated, truck access is very difficult, and mining and transportation would cause significant disturbances to nearby residents." There are three alternatives discussed for the acquisition of this clean sand. These alternatives include commercially purchased, San Juan Bay sand source, Los Corozos Lagoon sand source and a San José Lagoon sand source.

5.7.5.1 Commercially Purchased (Upland Quarry) Sand Source

The capping material would be purchased commercially from a private borrow site and transported to staging area where it will then be transported to the final disposal site. Private sources of sand are available in northern Puerto Rico. NIDCO, an aggregates company, provided a price quote for the sand delivered to the staging area, which as of February 2011 averages $22 per cy. The cost of transportation to both the staging area and the final disposal site will need to be taken into account. Based on the preferred CAD disposal alternative, approximately 198,347 cy of clean sand will be needed for the cap. Using 15-cy (20-ton) dump trucks to transport the sand from the quarry to the loading site (35 miles one way), approximately 13,223 truckloads would be needed.

Currently, the best site to manage the sand is at Ciudad Deportiva Roberto Clemente (CDRC). CDRC has about 5 upland acres of existing capacity for different uses, so the amount of sand that can be stock piled (without modifying CDRC) and managed per day would most likely be low. Access to the water would be also an important component, since the trucks would have to get close enough to the water so that they can either off load directly onto scows or into a storage area where a pipeline would be connected to transport the sand.

It is not clear what would be the rate and distance in which the quarries can supply the sand per day in cubic yards. The rate of supply is a factor that can determine the rate of capping in the lagoon. Since the sand might need to be produced, the rate of production for the sand could take months and sand suppliers may require contracts on the month by month basis trying to control the cost of fuel, which can change during the operation. The source would also have to be permitted and tested regularly for quality assurance. The transportation of sand would have to be coordinated with the local police department for safety issues, traffic controls, and security concerns, as well as per the potential environmental concerns that the spills of sand coming from the trucks can create in the streets. The supply and transportation of sand is totally weather dependent and can delay the operation of the disposal.

Finally, the recreational activities at the CDRC would have to be considered during the operation, which can also cause delays in the operation. The operation to remove the solid waste would have been concluded by the time the sand for capping operation is needed, so it is anticipated that these two activities are not going to interfere with each other.

5.7.5.2 San Juan Bay Sand Source

Sand sources to be identified in the vicinity of San Juan Bay could serve as capping material for the SJ1 and SJ2 CAD sites. Depending on the location and characteristics, some geotechnical data may be needed as part of the sediment source analysis. The potential for sand to be available from San Juan Bay is limited, but may be found at the entrance to San Juan Bay (EPA, 1982; USACE, 1982), La Esperanza Peninsula (USACE, 1999), and/or with maintenance dredged material within San Juan Harbor (USACE, 2002). Sand originating from San Juan Bay may require testing and permitting for the quantities needed for the cap. If the sand has the physical characteristics needed for the cap material, the sand would be excavated as a feature of the CMP, and transported and disposed as capping material at the SJ1 and SJ2 CAD sites, a distance of approximately 8 miles (one way). The sandy material could be dredged with a clamshell dredged and barged to the CAD sites, or hydraulic dredged and pumped directly to the CAD site.

5.7.5.3 San José Lagoon and Los Corozos Lagoon Sand Sources

Historically, the Los Corozos and San José Lagoons were dredged for construction fill and sand resources. The presence of the silica sand in the north portion of the lagoon is a positive indication that there may be a presence of sand elsewhere in the system. Two corings from GeoEnviroTech's (2011) geotechnical investigation within San José and Los Corozos Lagoons revealed sand layers that could be sand source capping locations. Boring B-2 in San José Lagoon contained a sand layer of approximately 8 feet in thickness and Boring B-5 in Los Corozos Lagoon contained a sand layer of approximately 17 feet in thickness. A geophysical sub-bottom profile survey would have to be conducted to identify and quantify the potential layers of sand available in the system. In addition, a more robust geotechnical investigation would need to be conducted to verify and test the qualities and quantities of sand. After the surveys are conducted, if the presence of sand turns out to be sufficient or partially sufficient in terms of being used for the capping material, then dredging of the sand from within the lagoon could be an integral part of the DMMP. However, the dredging of this sand has brought up concerns with the local sponsor, ENLACE, their Technical Advisory Committee, and regulatory agencies. After a series of meetings with ENLACE, this alternative source continues to be a concern because new depressions may adversely impact habitat or other parts of the ecosystem.

But, it should be noted that dredging within the Lagoon could occur without creating new pits. Based on the extra aquatic disposal capacity needed for the dredged material, if an appropriate sand source was identified in the lagoon, the dredging of that source would create another pit. That new pit could become the disposal site for other dredged sediments. This would mean that that the amount of sand dredged from the sand source would need to include enough material to cap the material being disposed of in the new pit. This would prevent the creation of a new pit.

Also, if the appropriate amount of capping material cannot be identified in the lagoon, the dredged material may be capped with other sediments; however, another study like the USACE 2002 would need to be conducted based on the material available for capping to determine whether that material could be feasibly used as capping material, the thickness of the cap that would be required, and if that material would sufficiently prevent the leaching of the contaminated sediments back into the water column.

The amount of sand needed for capping will depend on the options selected in the final analysis, but currently it is estimated that 198,347 cy will be needed for the “largest preferred” channel alternative. The consolidation of two San José Lagoon Pits into one pit has been suggested as one of the features of the preferred disposal alternative. If the capping sand is available in the lagoon, the volumes can be managed by manipulating the capacity of the pit(s) and reducing the amount of capping needed. Also, dredging areas where the sand can be found in the lagoon can be managed for minimum impacts by making the dredging of the sand as shallow as possible and then the depressions can be filled with material from different sources, including the sediments coming from the San Antón and Juan Méndez creeks.

New field data shows that the three disposal pits have been partially filled in some since the last bathymetric survey was conducted in 1996. The original contour of –32 feet at the bottom of the SJ2 pit was measured now at –23 feet. The main source of sediments filling the depressions appears to be the San Antón creek, which is also an important source of suspended sediments to the lagoon. In volume, 9 feet thick means a very significant amount of sedimentation in 15 years. The San Antón and Juan Méndez creeks should be considered as an important source of sediment and may be considered for capping material in future projects. In fact, the Juan Méndez creek will dictate the life span of the dredging of the CMP on the east end and the maintenance of that area will need a disposal site, which can be one of the new depressions. The new depressions can be also filled with the sediments removed to make space in the San José 1 and San José 2 Pits.

In order to reduce the impact of the removal of the sand, the operation would be managed by a small hydraulic cutterhead, which will reach only the areas where the sand is available in the geologic profile. The sand removed would be pumped directly to the new SJ1 and SJ2. This alternative is the least environmentally risky operation since it only requires activities from the water and away from any area of concern including homes, business, roads, or habitat areas. The use of sand in the lagoon is not weather dependant except for during big storms or hurricanes.

5.7.5.4 Boca de Cangrejos-Torrecilla Lagoon Sand Source

The Boca of the Cangrejos-Torrecilla Lagoon is potentially an additional sand source for capping material, and may be available by dredging the marina located within the lagoon.

The amount of sediments at the marina is currently not known and will require testing and permits for the quantities needed for the cap. If the sand has the physical characteristics needed for the cap material, the sand would be excavated as a feature of the CMP, and transported and disposed as capping material at the SJ1 and SJ2 CAD sites, a distance of approximately 5 miles (one way). The sandy material could be dredged with a clamshell dredged, trucked and barged (rehandled) to the CAD sites, or hydraulic dredged and pumped directly to the CAD site. The CMP-ERP may require dredging and pumping or trucking the sand about 5 miles. This transport operation would involve crossing public and private properties, roads and navigable channels, which will temporarily and adversely impact traffic, air quality and noise quality within the affected communities.

5.7.5.5 Recycled Glass

There is the potential to use crushed, recycled glass from the island as a source of capping material. If further analysis during PED proves that this option is a more reliable, cost efficient, and ecologically preferable option, ground glass could be recommended to meet part or all of the cap sand requirements.

5.7.6 Staging Area Alternatives

Currently, there are only a few constructions staging and debris management areas that have been identified (figures 5.7-6a and 5.7-6b). The first area would be the CDRC (Location 1) on Figure 5.7-5a. The area has been recommended as the main area for the management of the CMP-ERP. The area would have to be coordinated with the Municipality of Carolina.

A second small but important staging area will be located under the Barbosa Bridge (Figure 5.7-6a, Location 2). The area has access to the Barbosa Avenue and has enough space to manage debris, equipment, and any machinery needed for the CMP-ERP. The third staging area would be at the

Muñoz Rivera Avenue (Figure 5.7-6b, Location 3) just north of the CMP. The last potential staging area is La Chuleta, an undeveloped site shown as Location 4 on Figure 5.7-6b. The site at La Chuleta could be used to stage equipment and materials in support of dredging activities that would start at the western end of the CMP. To avoid impacts to residents within the vicinity of the CMP, no staging areas would be setup in neighborhood streets or in areas that may interfere with the flow of neighborhood traffic.

Figure 5.7-6a. Staging areas available in the CMP and San José Lagoon

Figure 5.7-6b. Staging areas available in the CMP and San José Lagoon

5.7.7 Landfill Disposal (Solid Waste)

It is estimated that 4,000,000 tons/year of solid waste are generated in Puerto Rico. There are currently 32 operating landfills in Puerto Rico, all of them located in different municipalities. Landfills are owned and operated by a private company, owned by a municipality and operated by private companies, and others owned and operated by a municipality. Six landfills are expanded outside of current footprint: Fajardo, Humacao, Ponce, Juncos, Salinas and Yauco for a total additional capacity of 63.4 million tons. For the planning year 2030, ADS 2008 forecasted through a waste capacity Base Case modeling analysis that there would be seven landfills in operation with approximately 34.9 million tons of available disposal capacity and 17.8 years of remaining useful life.

5.7.7.1 Dredged Solid Waste Disposal

Information on the municipal/private landfills available for the debris originating from the CMP was provided by staff of the Environmental Quality Board (Junta de Calidad Ambiental) and the Autoridad de Desperdicios Sólidos. Staff mentioned that as of February 9, 2011, there are several municipal/private landfills that can manage debris. Additional information on landfill availability was extracted from the "Dynamic Itinerary for Infrastructure Projects Public Policy Document" report (ADS 2008). The municipal/private landfills available in close proximity to the CMP are:

- **CAROLINA (Projected Closure Date is 2015)**
  - **Owner/Operator**: Municipality/Landfill Technologies
  - **Landfill Users (Municipalities)**: Carolina
  - **Waste Products**: Municipal Solid Waste (100%)
  - **Material Recovery Facility (MRF)**: Yes, recycles
  - **Average Filling Rate**: 2,356 tons per week
  - **Tipping Fee**: $100/ton (private), $90/ton (state)
  - **Distance from CMP**: 11 miles

- **JUNCOS (Projected Closure Date is 2051)**
  - **Owner/Operator**: Municipality/Municipality
  - **Landfill Users (Municipalities)**: Canóvanas, Aguas Buenas (C&D)*, Trujillo Alto, Juncos, San Lorenzo (C&D)*
  - **Waste Products**: Municipal Solid Waste (61.7%), C&D* (34.6%), Yard Wastes (3.7%), and Auto Wastes (<0.5%)
  - **Material Recovery Facility (MRF)**: No, recycles
  - **Average Filling Rate**: 4,296 ton per week
  - **Tipping Fee**: $21/ton; $7/cy (domestic); $10/cy (C&D)*
  - **Distance from CMP**: 24 miles

- **HUMACAO (Projected Closure Date is 2075)**
  - **Owner/Operator**: E C Waste, Inc.
  - **Landfill Users (Municipalities)**: Gurabo, Caguas, Humacao, San Juan, Las Piedras, San Lorenzo
  - **Waste Products**: Municipal Solid Waste (87.5%), C&D* (10%), Special Wastes (0.8%), and Yard Wastes (0.9%)
  - **Material Recovery Facility (MRF)**: No, recycles
  - **Average Filling Rate**: 13,800 ton per week
  - **Tipping Fee**: $28 cy solids/dried sludge; $45 ton municipal solid waste; $45 ton debris
  - **Distance from CMP**: 32 miles
- **FAJARDO (Projected Closure Date is 2044)**
  - **Owner/Operator**: Municipality/Landfill Technologies
  - **Landfill Users (Municipalities)**: Fajardo, Luquillo, Ceiba, Loíza, Río Grande, Canóvanas, Naguabo
  - **Waste Products**: Municipal Solid Waste (81%), Auto Wastes (1%), C&D* (16%), and Yard Wastes (2%)
  - **Material Recovery Facility (MRF)**: No, recycles
  - **Average Filling Rate**: 4,095 tons per week
  - **Tipping Fee**: $27/ton, $9/cy
  - **Distance from CMP**: 34 miles

*C&D – Construction & Demolition Debris

Collectively, the municipal and private landfills have the capacity to accept the 76,200 cy of solid waste expected to be dredged to implement the CMP "largest preferred" channel configuration plan. They do not, however, have the capacity necessary to accept all of the dredged sediments from the CMP-ERP, only the solid waste. These facilities are boxed on Figure 5.7-7 below. The Carolina, Juncos, and Fajardo landfills have limited weekly solid waste filling rates. Therefore, individually these landfills may not be able to receive all of the CMP-ERP's dredged solid waste. In addition, the Carolina landfill is scheduled to close in 2015; hence, it may not be available during construction of the CMP-ERP. At 13,800 tons per week, the Humacao landfill has the greatest weekly capacity for filling, and thus the greatest certainty of being available to receive all of the CMP-ERP's dredged solid waste.

Figure 5.7-7
Large-Capacity Debris Disposal Facilities in Puerto Rico (ADS 2008)

5.7.7.2 Recycling Facilities

Puerto Rico's waste management situation is trending toward critical status as existing landfill sites approach their useful life. Under a worst case scenario of "Do Nothing," Puerto Rico would run out of disposal capacity by 2018 (ADS 2008); however, other implementable best management measures such as expanding key landfill sites outside of their current footprint, transferring waste to larger landfill sites, and reducing the amount of municipal solid waste through diversions (e.g., recycling) can extend the useful life of landfill disposal in Puerto Rico at least through 2030.

It is anticipated that material dredged from the CMP will include material that can be reclaimed or recycled. As a potential means to contribute to the goal of extending the useful life of Puerto Rico's landfill sites through efficient disposal management of solid wastes, recycling or reclamation of solid wastes generated by the dredging of the CMP should be considered. Construction debris such as fragmented concrete and/or rip-rap can be separated and directly applied to projects needing armor for stream bank or shoreline stabilization, if aesthetically acceptable. Other solid waste or material that cannot be readily processed for reclamation can be transport to existing "Dirty" and/or "Clean" MRFs for recycling. "Dirty" MRFs will accept a mix of solid waste and will separate out the recyclable materials on site. "Clean" MRFs will accept comingled recyclable materials, but require the recyclable material be separated from the other solid waste prior to transporting the recyclable materials to the MRF. Given the limited daily capacities of the MRFs, it would likely be logistically more feasible to separate out the CMP recyclables from the solid waste dredged material at the CMP site. The separated recyclable material would be transported to one or more of the MRFs, with the non-recyclable materials disposed at the larger capacity municipal landfill sites. Table 5.7-6 lists the MRFs that are currently in operation within Puerto Rico, and the approximate distance from the CMP for each MRF.

Table 5.7-6
Operational MRF Facilities (ADS 2008)

MRF Facility	Owner	Municipality	Distance From CMP (miles)
Hatillo MRF	PRIDCO	Hatillo	55
Hormigueros MRF	ADS	Hormigueros	111
Guayanilla MRF	ADS	Guayanilla	86
Pronatura	Private	Bayamón	27
IFCO	Private	Caguas	18
GC Reciclaje Inc.	Private	Humacao	32
Carolina MRF	Municipality	Carolina	11
Guaynabo MRF	Municipality	Guaynabo	8
Ameriplast	Private	Arecibo	47

5.7.8 Preferred Disposal Alternative

The preferred disposal alternative for the CMP's dredged material entails multiple disposal features to account for the varying material characteristics to be encountered within the channel's dredge footprint. Two primary characteristics define the CMP's dredged material: 1) solid waste and 2) sediments. The aforementioned material characteristics are referred to as "dredged solid waste," and "dredged sediments."

The two types of dredged material are proposed to be placed at disposal sites appropriate to receive the individual characteristics of the materials to be dredged. It is proposed that the "dredged solid waste" be placed in the Humacao landfill site; and the "dredged sediments" be placed within the San José Lagoon CAD sites. These disposal sites collectively represent the preferred disposal alternative.

Absent of complete updated data sets, some basic assumptions were used to develop the preferred dredged material disposal alternative to include the following:

- Solid waste makes up 10% of the total material between the existing bottom and −10 feet.

- Dredging would commence concurrently on either side of the Project Channel.
- All the solid wastes within the CMP-ERP are suitable for placement in Class III municipal landfill sites (RCRA/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) classified material are not present in the CMP).

5.7.8.1 Preferred Dredged Sediments – Contained Aquatic Disposal Site

The preferred plan for disposal of the dredged sediments would utilize five existing pits located in the San José Lagoon (SJ) and possibly Los Corozos Lagoon (LC). The dredged sediments, encapsulated in geotextile fabric, would be transported by shallow draft, bottom dump barge and placed in two of the pits, SJ 1/2. The pits would be filled to elevation –16, including a 2-foot-thick sand cap. The basis for utilizing only two of the six pits is the minimization of the surface area needed for the sand cap thereby reducing the quantity of cap material. The two pits selected, SJ 1/2 are the largest of the six. Accommodating the entire volume of dredged material in the two pits requires their enlargement. The material removed, if suitable, would be utilized as the sand cap. The balance of the removed material would be placed in the other pits, SJ 3/4/5. If the material proves unsuitable for use as the sand cap, sand or other suitable material would be imported from an upland quarry or other location requiring that all of the removed material be placed in SJ 3/4/5 as well as the LC. Any material not able to be accommodated would remain in the SJ 1/2 pits, reducing their capacity for future maintenance dredging. Measures to contain turbidity during the placement of the dredged sediments include a turbidity curtain perimeter around the SJ 1/2 pits. Following is a detailed discussion of the contained aquatic disposal site.

There are total of six artificial depressions (pits) located within San José Lagoon and Los Corozos Lagoon (figures 5.7-8 and 5.7-9). Five of the six depressions (pits) reside within San José Lagoon and are identified as San José 1 (SJ1 Pit), San José 2 (SJ2 Pit), and San José 3/4/5 (SJ3/4/5 Pits). One artificial depression (pit) is located within Los Corozos Lagoon and is identified as LC Pit.

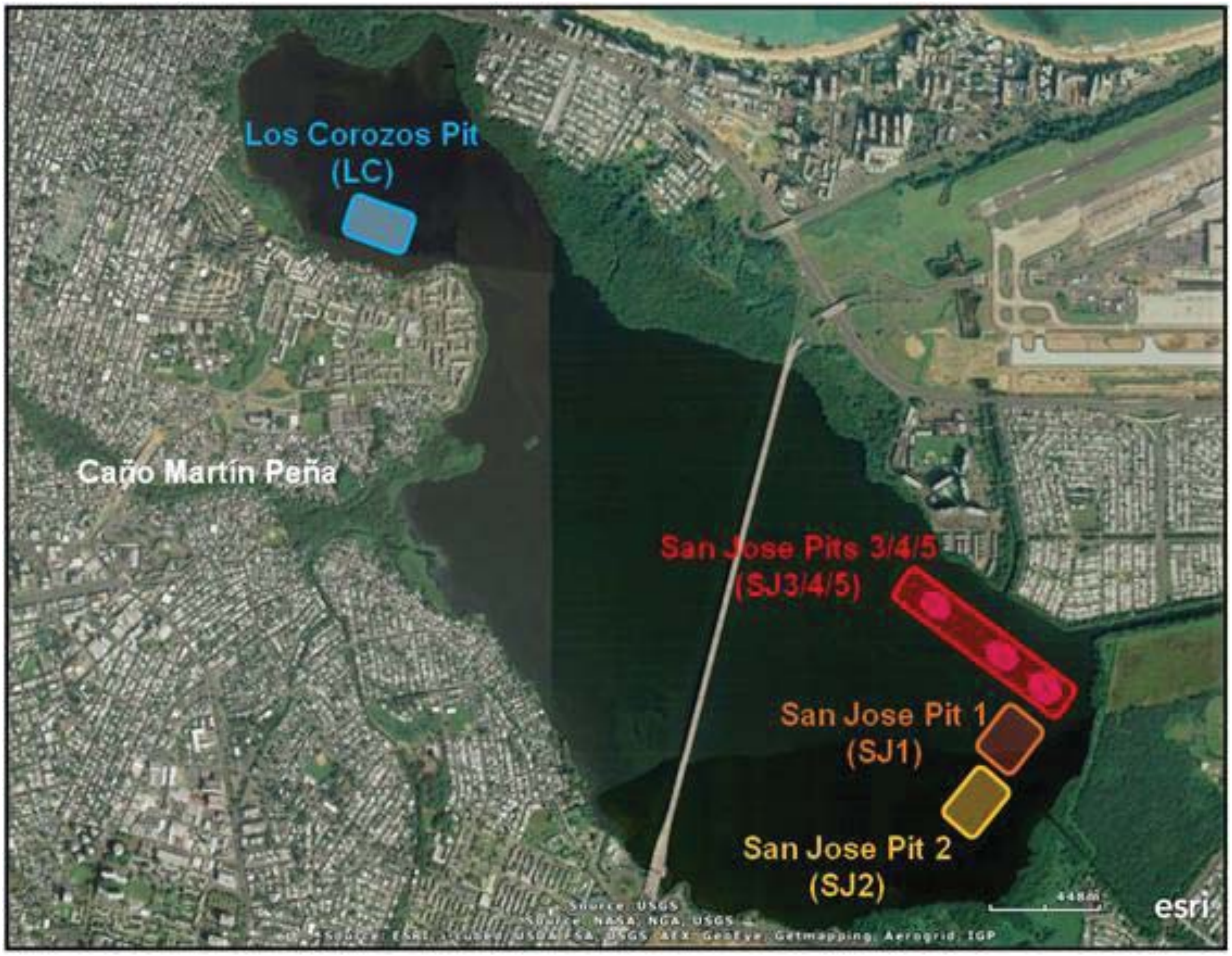


Figure 5.7-8
Artificial Pit Locations – San José & Los Corozos Lagoons

As presented in the Bailey et al. (2002) report, the SJ1, SJ2 and LC pits were analyzed to potentially serve as CAD sites for the CMP dredged sediments not encapsulated with geotextile containers. The analysis concluded that two feet of clean sand is necessary to maintain a physical barrier between contaminates in the dredged sediments, mainly arsenic, selenium, DDD, DDE, DDT, dieldrin, and PCB-1248, and benthic community above. The 2-foot cap would contribute to preventing the release of these contaminants at concentrations above water quality standards. In addition, an analysis of the currents and water circulation occurring in the lagoon was performed and it was established that the energy within the lagoon and around the CAD sites is low, which means there is a very low risk of erosion of the cap within the CAD sites.

The report also analyzed the long-term pore water flux from the three CAD sites due to consolidation following the mechanical disposal of dredged material and its capping with clean sand. The cumulative flux for the CAD sites is large enough to displace at least two pore volumes in the caps (nearly five pore volumes for Los Corozos cap). However, it was concluded that the pore water flux through the cap decreases significantly in 2 to 3 years and virtually goes to zero in about 5 years. Therefore, if constructed correctly, no long-term adverse water quality impacts from contaminants are anticipated from the three CAD sites. The organic contaminants have limited mobility and are predicted to move a maximum of only about 15 cm (0.5 foot) into the cap.

The required storage volume for placing all of the bulked dredged sediments is 813,896 cy. For purposes of this analysis, the volume has been rounded to 814,000 cy. Collectively the six artificial pits would need to have sufficient capacity to receive the full bulked volume of sediments, plus the volume of material needed to cap the geoencapsulated sediments within the artificial pits.

The available existing capacities within each artificial pit to a controlled fill depth of −16 feet (for SJ1, SJ2, and SJ3/4/5 Pits) and −6 feet (for LC Pit) are shown in Table 5.7-7. For the San José Lagoon artificial pits, a −16-foot top-of-fill was selected to ensure uncontrolled dredged and cap sediments spill over into adjacent pits does not occur. For the LC Pit, a −6-foot top-of-fill was selected to ensure the dredged and cap sediments do not protrude above the natural bottom depth.

Table 5.7-7
Artificial Pit Existing Capacities – San José & Los Corozos Lagoons

Artificial Pit	Existing (Max) Floor Depth (feet)	Fill Depth (feet)	Existing Pit Capacity (cy)*
SJ1	–27	–16	260,516
SJ2	–27	–16	245,450
SJ3/4/5	–24	–16	275,373
LC	–18	–6	166,210
	TOTAL		**947,549**

* Capacities derived from 1996 bathymetric survey.

The total existing capacity (947,549 cy) for the six artificial pits is sufficient to receive the bulked dredged sediments volume (814,000 cy), however, additional capacity of approximately 86,000 cy would be needed to allow for the geoencapsulated sediments to be capped with 2 feet of clean sediments. This additional capacity can be achieved by modifying the depth and/or width of the artificial pits by excavating sediments from within the pits.

If it is determined in subsequent studies that sand will be the necessary material to cap the geoencapsulated dredged sediments and, since the availability of sand for capping material is limited, the best combination of pits to modify was determined based upon an objective to minimize the amount of capping material needed resulting from the modifications. This was preliminarily accomplished by comparing the surface area at the final fill depth for each CAD site, initially without expanding the pits. Table 5.7-8 displays the surface areas for each pit at the targeted fill depths, prior to any expansion or modification.

Based upon surface areas at the targeted fill depths, the combination of SJ1 and SJ2 (prior to expansion) would result in least amount of capping material. Therefore, the SJ1 and SJ2 pits were evaluated to determine the viability of modifying the two pits to increase their cumulative capacity. Modification of the SJ1 and SJ2 pits would entail excavating the pits to their original borrow depths of –32 and –30 feet, respectively. Existing side slopes of 17H:1V would be maintained for stability purposes as the SJ1 and SJ2 pits are deepened. The geoencapsulated dredged sediments would be placed within the modified pits to a fill elevation of –18 feet. The placed geoencapsulated dredged sediments would be capped with 2 feet of clean sand to an unconsolidated fill depth of –16 feet.

Table 5.7-8
Surface Areas of Artificial Pits – Prior to Expansion/Modification

Artificial Pit	Existing (Max) Floor Depth (feet)	Fill Depth (feet)	Surface Area (square feet)
SJ1	–27	–16	897,190
SJ2	–27	–16	956,000
SJ3/4/5	–24	–16	1,591,070
LC	–18	–6	1,624,865

Table 5.7-9 provides the dimensional and volumetric details of the modified SJ1 and SJ2 pits, up to the fill depth of –18 feet for geoencapsulated dredged sediments.

Table 5.7-9
Dredged Sediments – Modified SJ1 and SJ2 Pits to Fill Depth of –18 feet (Side Slopes 17:1)

CAD Site	Modified Bottom Depth (feet)	Fill Depth (Dredged Sediments) (feet)	New Pit Capacity (cy)	Required Capacity (Dredged Sediments Volume) (cy)
SJ1	–31	–18	421,000	421,000
SJ2	–30	–18	459,000	393,000
TOTAL			**880,000**	**814,000**

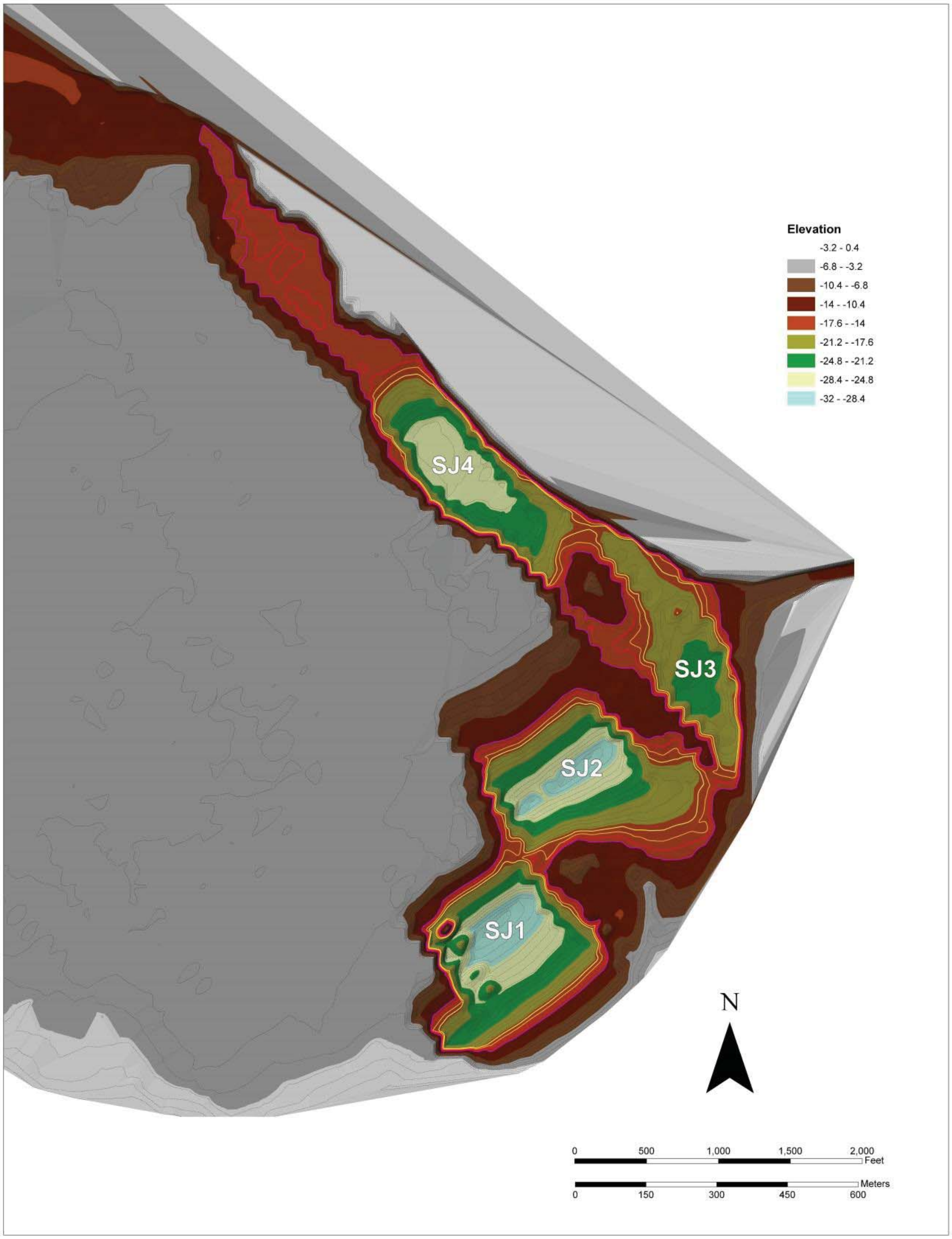


Figure 5.7-9
San José Lagoon Existing (1996) Pit Bathymetry (elevations in feet)

Table 5.7-10 provides the dimensional and volumetric details of the modified SJ1 and SJ2 pit, to accommodate 2 feet of capping material to a fill depth of –16 feet.

Table 5.7-10
Cap Material (2 feet) – Modified SJ1 and SJ2 Pits to Fill Depth of –16 feet (Side Slopes 17:1)

CAD Site	Fill Depth (Dredged Sediments) (feet)	Fill Depth (Cap Material) (feet)	Modified Surface Area (square feet)	Cap Material Required Volume (cy)
SJ1	–18	–16	1,296,465	96,034
SJ2	–18	–16	1,381,219	102,313
TOTAL			**2,677,684**	**198,347**

Comparison of the SJ1 and SJ2 modified surface areas with the unmodified SJ3/4/5 and LC surface areas, concludes combining the modified SJ1 and SJ2 pits would remain as the pit combination that would require the least amount as capping material, and would provide the required capacity necessary for disposal and capping of the dredged sediments, without adversely affecting the tarpon feeding zone at the –6-foot halocline interface.

The existing pit capacities for SJ1 and SJ2 to the –16-foot fill depth are 260,516 cy and 245,450 cy, respectively, for a total existing capacity of 505,966 cy. The revised capacities of the modified SJ1 and SJ2 pits to the –16-foot fill depth are 880,000 cy for the dredged sediments and 198,347 cy for the capping material, for a total of 1,078,347 cy. This provides sufficient capacity to place the 814,000 cy of dredged sediments and the 198,347 cy sand cap with an excess capacity of 66,000 cy. Therefore a total of 506,381 cy of sediments would need to be excavated from the SJ1 and SJ2 pits to acquire the total capacity needed to place the geoencapsulated dredged sediments and capping material within the two pits.

It is assumed that the excavated pit material is clean and therefore is suitable for unconfined open-water disposal. If the excavated pit material was suitable for use for the sand cap, 198,347 cy less sediments need be placed in SJ 3/4/5/LC. If the excavated pit material is not suitable for use for the sand cap, it would be placed in SJ 3/4/5/LC. 64,798 cy would not be accommodated and would consume the majority of the 66,000 cy of excess capacity in the SJ1/2 pits.

5.7.8.2 Preferred Dredged Solid Waste – Upland Landfill Disposal Site

The Humacao landfill is the preferred solid waste disposal site because of the higher certainty that Humacao affords to receive all the solid waste originating from the CMP-ERP. A total of 72,000 cy of solid waste is expected to be encountered during dredging operations. The process of screening the solid waste from the dredged sediments would also remove the water from the solid wastes. The dewatered solid wastes would be barged to docking areas, either at temporary staging/processing sites along the channel or at the CDRC. The collected solid waste would then be transported by truck to the Humacao landfill.

5.7.8.3 Preferred Cap Material Source

Due to the possibility that the excess material to be removed from the SJ1/2 pits may not be suitable capping material, the preferred cap material source is quarried sand. However, if suitable sand is found in the excess material proposed to be removed from the SJ1/2 pits to increase their capacity, it would be utilized. The artificial pits within San José Lagoon and Los Corozos Lagoon were originally created as a result of mining operations to extract sand for construction fill material. It is generally accepted that most of the sand has been removed from the lagoons, but there may be areas of sand remaining that could provide the necessary sand quantities to cap the SJ1 and SJ2 CAD sites. Because sand within the San José and Los Corozos Lagoons are the most readily accessible and logistically viable cap material sources for the SJ1 and SJ2 CAD sites, the San José Lagoon/Los Corozos sand sources are preferred over other possible sources. However, if it is definitively determined through future investigations that there is no longer sufficient quantity of sand remaining in the pits, then both San Juan Bay and upland quarry sites are reasonable secondary alternatives for cap material sand sources.

5.7.8.4 Preferred Construction Staging/Management Area

The preferred construction staging and dredged solid waste management area is a 35-acre site (Figure 5.7-9) located between the CDRC recreational park and the east bank of the San José Lagoon. Approximately 5 acres of this site would be utilized to accommodate portable facilities including trailers, offices, provide access to San José Lagoon and to process the dredged solid waste for shipment to landfills. Additionally, approximately 1 acre of the shoreline would be utilized to construct a temporary barge dock and an existing 0.3-mile-long dirt access road would be improved and stabilized for the truck access to the adjoining public roads for hauling solid waste to landfill at Humacao and for delivering construction materials.

Crushed rock or other materials may be required to improve the roadway soil conditions due to the traffic of heavy trucks loaded with debris. The final dimensions and structure of the access road would be established by the construction contractor through direct coordination with the CDRC Administrator and the Municipality of Carolina. To transfer dredged solid waste from the barges to shore, a temporary pier/dock would be constructed at the CDRC Management area along the San José Lagoon eastern shoreline (Figure 5.7-10). No dredging would be required within the lagoon to provide for a barge access channel to the pier/dock since water depths immediately adjacent to the shoreline of the CDRC staging/management area are expected to be sufficient to allow fully loaded shallow-water barges to navigate safely to the constructed pier/dock. These depths are a result of the existing artificial subaqueous pits in close proximity to the CDRC staging/management area shoreline. In addition, access to the dock/pier areas may require partial removal/pruning of mangroves (approximately 1 acre) along the shorelines of the CDRC staging/management area. It is expected the construction contractor would coordinate with the the Department of Natural and Environmental Resources (DNER) and any other pertinent agency prior to selecting the final site for the dock/pier area to ensure impacts to the mangroves are kept to a minimum.

Figure 5.7-10. Ciudad Deportiva Roberto Clemente (CDRC) Staging Area

Since the vicinity of the staging/management area has already been impacted as a result of its past use, it is anticipated that the preparation of the land for truck access and traffic should not represent any concern. The processing of dredged solid waste along with other construction related support activities at the staging/management area would be a continuous operation throughout most of the construction duration. Because the CDRC is used extensively for recreation purposes and is within close proximity to the preferred staging/management area, it is anticipated that recreational and construction traffic would share a common access route (Avenida Iturregui). Therefore, permits for traffic and safety may be required, along with implementing an approved access control plan to manage public access to the staging area and to the temporary docking area.

5.7.8.5 Preferred Dredging Procedures

Dredging would start at the canal's confluence with the San José Lagoon so that the debris may be barged to the CDRC staging site. Dredging systems would be barge mounted, floating on the waters of Lagoon or the newly dredged channel. Dredging would involve mechanically excavating the sediments, dumping them onto a rigid screen within a hopper to filter out the solid waste, allowing the sediments to fall through the screen and into the hopper. The screened and dewatered solid waste would be removed and placed in a barge for upland disposal. The sediments in the hopper that are separated from the solid waste would be placed into the geotextile fabric lined hopper of the dump scow. The geotextile container, once filled and sealed, would be transported to a disposal site in the lagoon. This process would be repeated until all the dredged sediments have been placed in the subaqueous disposal site. The size and capacity of the containers would determine the footprint, placement, and number of containers needed to dispose all the sediments. The geotextile containers would require bottom dump disposal; therefore, the aquatic placement area should be deep enough to allow for bottom dumping. Since geotextile containers may not be completely effective at interfering with dredged sediments diffusing into the water column, an additional safety measure of capping the geotextile containers in-place with clean sediments may be necessary. The structure of the geofabric material would support the sand cap subsequently requiring less sand.

Subsurface investigations indicate that rock outcrops may be encountered at depths of -10.5 in the eastern end of the proposed channel. With a proposed channel depth above -10.5, it may be possible to avoid the need to dredge rock from the channel section by allowing the rock to remain in place and slightly adjusting the channel's configuration to maintain the design cross section.

The dredging operation may involve two excavators, one to sift and pick out large pieces of solid waste in the area being dredged and a second to excavate sediments for dumping onto the screen. The picker may also be used to move solid waste from the screen into the staging area scow.

Turbidity controls would be employed at the site of the dredging, the hopper loading, sediment screening, debris loading/unloading areas, and dewatering areas. Turbidity controls may take the form of turbidity barriers, booms and other devices. Allowable turbidity limits would be monitored at each end of the Project and at the pipeline discharge point.

Secondary activities include setting aside some of the mechanically dredged sediments for backfilling behind the sheet pile wall after it has been installed. Top sediments must then be placed over the rough graded backfill to form the bed for the mangrove plantings.

The dredged solid waste would be barged to the CDRC staging area across the San José Lagoon and then trucked on to the landfill. Shallow drafting barges would be needed to transit the lagoon. The collected trash and debris would then be transported by truck to the Humacao landfill. After all solid waste has been disposed in the upland landfill, the 5-acre staging area would be restored with native upland vegetation, and the 1 acre of mangrove fringe would be restored with mangroves.

It is recognized that recyclable material may compose a portion of the solid waste to be encountered in the CMP-ERP. It is also recognized that riprap and fragmented concrete may also be present in the CMP-ERP's dredged solid waste. Given Puerto Rico's cumulative landfill disposal capacity is forecasted to be significantly strained in the near future, recycling of solid wastes is preferable when feasible. Where feasible, recyclable material would be separated from solid waste at the CMP-ERP's staging/processing sites, and then transported to and disposed at an appropriate MRF. Any riprap or fragmented concrete (rebar free) that is encountered could be directly recycled to provide shoreline or streambank protection, or potentially used to create aquatic habitats. MRFs available to receive recyclable materials are listed in Table 5.7-4. The nearest and preferred MRF is the Guaynabo MRF located approximately 8 miles from the CMP.

The disposal management of the solid waste should be included in the construction specifications as a special item and should be responsibility of the dredging contractor. The dredging contractor should be required to have a contingency plan developed for the management of large amounts of metal, rebar, household appliances, cars and other large debris that could be encountered.

Table 5.7-11 displays volumes of dredged material to be generated by dredging the preferred configuration. The dredged sediments volumes are broken out by in situ sediment quantities and bulked sediment quantities. Also shown in Table 5.7-11 is the volume of solid wastes expected to be encountered.

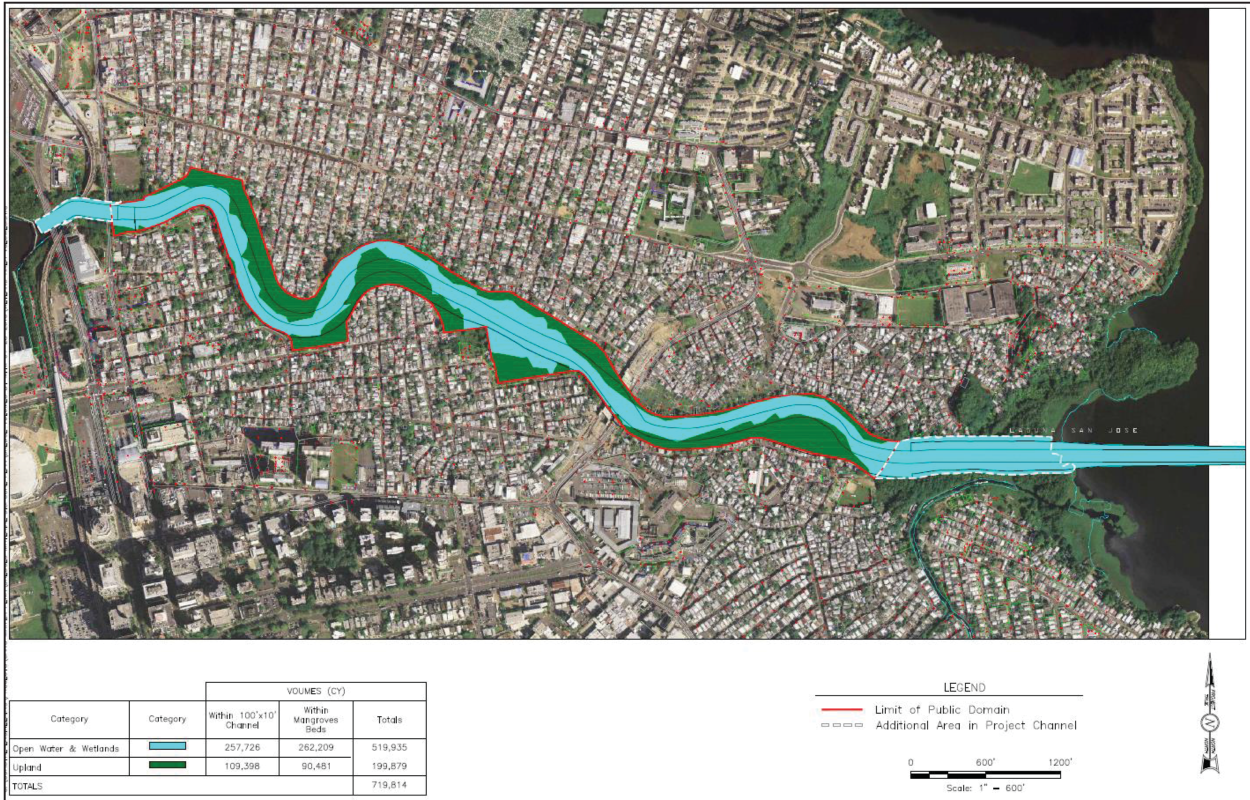
Table 5.7-11
"Preferred" Channel Configuration (Dredged Material Volumes*)

Channel Width x Depth Alternative (ft x ft)	Dredge Depths Range	In Situ Total Material Volume (cy)	In Situ Debris Volume (10%) (cy)	In Situ Sediment Volume (cy)	Bulked Sediment Volume (cy)
100 x 10	Existing Depth to –10 feet	762,000	76,200	685,800	861,373

*These calculations include dredging the channel template plus the 42,000 cy removed from the side wall sloughing and placed on the upland slope for later use as behind-the-wall and mangrove bed backfill.

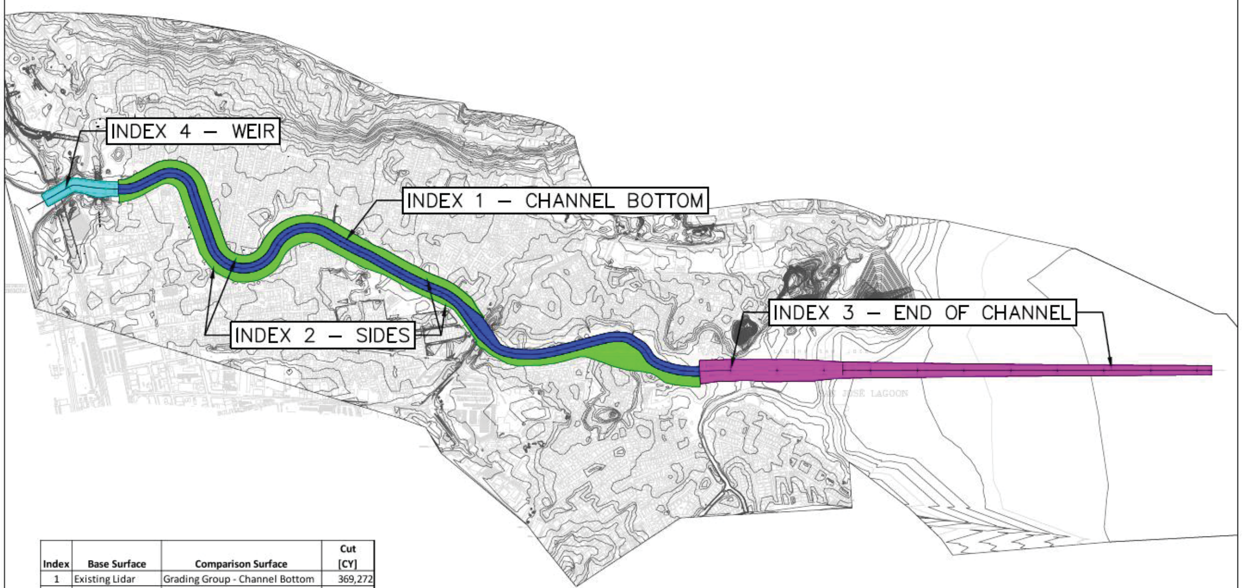
By land category, approximately 72% (519,935 CY) of the dredged volume is taken from open water and wetland with the remaining 28% (199,879 CY) from uplands (Figure 5.7-11).

By comparison of volumes by the four grading groups within the Project, Channel Bottom is 51% (369,272 CY), Sides are 19% (136195 CY), the eastern End of Channel is 23% (46,866 CY) and the Weir on the western end is 7% (46,866 CY) (Figure 5.7-12).



		VOUMES (CY)		
Category	Category	Within 100'x10' Channel	Within Mangroves Beds	Totals
Open Water & Wetlands	(light blue)	257,726	262,209	519,935
Upland	(dark green)	109,398	90,481	199,879
TOTALS				719,814

Figure 5.7-11. Dredged Volumes by Land Category



Index	Base Surface	Comparison Surface	Cut [CY]
1	Existing Lidar	Grading Group - Channel Bottom	369,272
2	Existing Lidar	Grading Group - Sides	136,195
3	Existing Lidar	Grading Group - End of Channel	167,481
4	Existing Lidar	Grading Group - Weir	46,866
		Subtotal	**719,814**

Figure 5.7-12. Dredged Volumes by Grading Group

5.7.9 Dredge and Disposal Operation Considerations

5.7.9.1 Site Specific Constraints

- Construction must occur within the CMP-ERP's narrow boundary limits.
- Temporary relocations and impacts during construction to communities along the CMP-ERP must be reduced as much as possible.
- Possible temporary impacts include noise, odors, release of hydrogen sulfide (H_2S), and damage to structures resulting from poor soil conditions.
- Proximity to the urban development limits construction strategies and access from land.
- Existing bridges have low navigation clearance and shallow foundations.
- Avoidance of dispersing contaminated sediments during construction.
- Avoidance of damage to existing sheet piles on the 2-mile-long western half of the CMP, whose dimensions are 200 feet wide by 10 feet deep.
- Avoidance and minimization of impacts to environmental and cultural resources.
- Shallow draft in San José Lagoon and the Western CMP limits the types of construction equipment.
- Limitations for transporting large volumes of wet dredged material on public roads.

5.7.10 Consideration of Existing Structures during Construction

The proposed channel passes under four bridges along its path to the San Juan Harbor. Toward the eastern end is the Barbosa Avenue Bridge and on the western end of the CMP-ERP are the Martín Peña (Ponce de León Avenue) Bridge, the Tren Urbano Guideway, and the Luis Muñoz Rivera Avenue Bridge. Just beyond the western limits is the Linear Park pedestrian bridge. East of the proposed channel, the Teodoro Moscoso Bridge spans the San José Lagoon and further west, on the Suárez Canal is the Baldorioty De Castro Avenue Bridge (Figure 5.7-13).

5.7.10.1 Luis Muñoz Rivera Avenue Bridge, Highway 1

The Luis Muñoz Rivera Avenue Bridge carries two lanes of traffic from Luis Muñoz Rivera Avenue and three lanes of traffic from Fernandez Juncos Avenue in the southbound direction, as well as a dedicated northbound bus lane. Curb and gutter with sidewalks exist on both sides of the south approach and along Fernandez Juncos Avenue to the north. No sidewalks are currently provided on the bridge. The total bridge deck is 24.42 meters (80.1 feet) wide. The total bridge length is 246.9 meters (810 feet), as measured between the face of the abutments. Existing vertical clearance measures approximately 3.2 meters (10.5 feet) (HDR, 1999). The bridge has two piers within the channel. The bridge shows evidence that additional lanes have been added to its structure. Also evident are signs of considerable deterioration (figures 5.7-14 and 5.7-15)

5.7.10.2 Tren Urbano Guideway

The Tren Urbano aerial guideway carries the Puerto Rico Department of Transportation and Public Works heavy rail system that serves the metropolitan area of San Juan, including the municipalities of San Juan, Bayamón, and Guaynabo. That portion of the structure over the Caño Martín Peña includes three spans varying in length from 89.24 feet to 157.45 feet. Clearances above the water surface are more than 40 feet. The guideway is supported by cylindrical concrete columns on concrete pile caps (figures 5.7-16 and 5.7-19).

5.7.10.3 Ponce de León Avenue Bridge, Highway 25 (Martín Peña Bridge)

The Ponce de León Avenue Bridge (figures 5.7-20 and 5.7-21) carries Highway 25 traffic in the northbound direction, with a dedicated southbound bus lane. It was built in 1939 and has many distinctive features. The Ponce de León Avenue Bridge is 16.9 meters (55.4 feet) wide and carries four northbound lanes with a raised sidewalk and a pedestal and decorative rail type barrier on both sides. The structure is comprised of five spans for a total length of 73.5 meters (241 feet) as measured between the face of the abutments. Existing vertical clearance measures approximately 3.1 meters (10.2 feet) (HDR 1999). As-built plans were not available to determine the depths and configuration of foundations. Consequently, it must be assumed that dredging to the design channel depths under the bridge must be avoided. Existing channel bottom elevations were in the range of less than –1 to nearly –5 feet (RLDA 1996).

Source: , ENLACE & Puerto Rico Planning Board

Figure 5.7-13. Bridges in the surrounding area

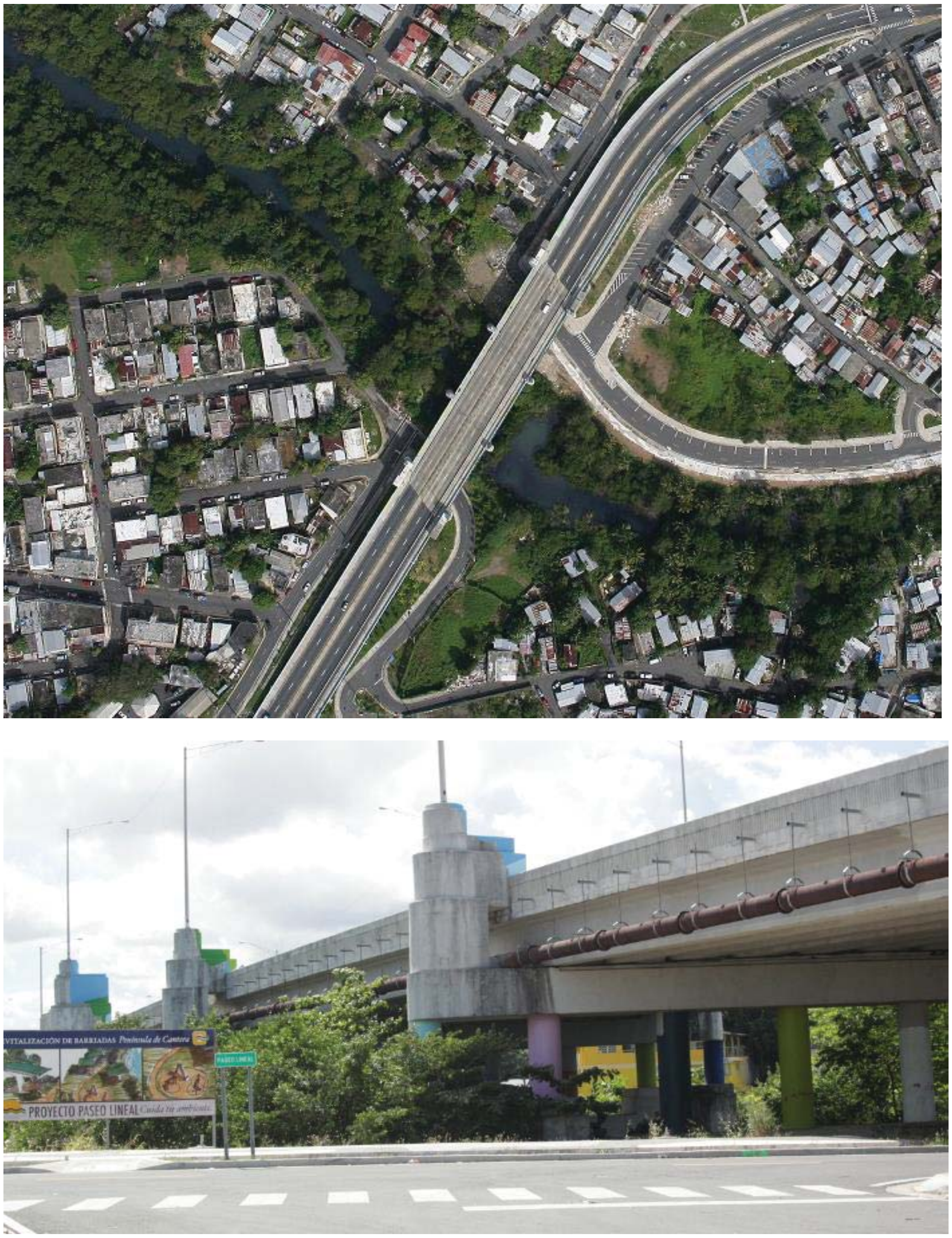
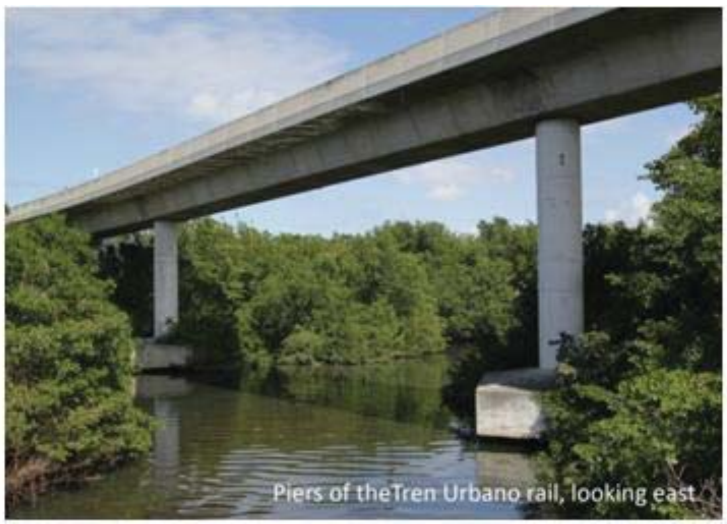


Figure 5.7-14. Channel Under Barbosa Avenue Bridge

Figure 5.7-15. Channel Under Western Bridges

Linear Park Bridge

Luis Muñoz Rivera Bridge



Tren Urbano Bridge

Ponce de León Avenue Bridge

Figure 5.7-16. Channel Under Western Bridges

Figure 5.7-17. Luis Muñoz Rivera

Figure 5.7-18. Luis Muñoz Rivera

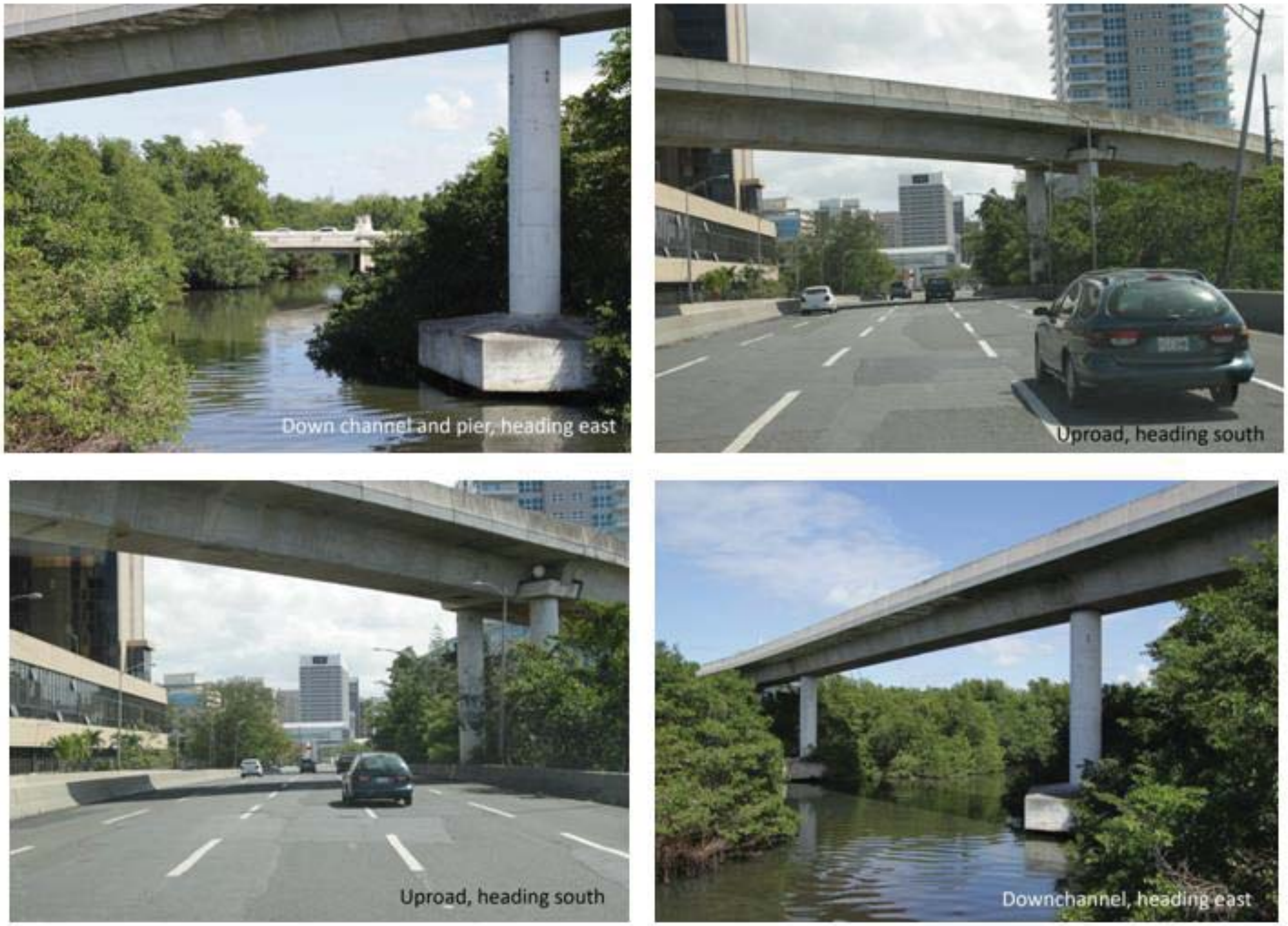


Figure 5.7-19. Tren Urbano

It was found that the elevation of the pile caps for the Ponce de León Avenue Bridge will allow for up to 8-foot-deep channel excavation. Because the channel widens here to provide adequate flow area, this depth under the bridge should provide the tidal flushing required for the improved channel (USACE 1999) (figures 5.7-17 and 5.7-18).

5.7.10.4 Linear Park Pedestrian Bridge

The Martí Coll Linear Park is part of a 1-mile-long raised pedestrian walkway connecting the Hato Rey financial district to the Central Park in Santurce. The structure is an 8-foot-wide concrete walkway with metal railing supported on concrete piles running along the existing Martín Peña channel (figures 5.7-16 and 5.7-22).

The structure is outside of the CMP-ERP limits but immediately adjacent. Work vessels will have to navigate under the bridge span.

5.7.10.5 Dr. Barbosa Avenue Bridge, Highway 27

The Dr. Barbosa Avenue Bridge carries Highway 27 traffic in both the northbound as well as the southbound direction. It was constructed in 2007, immediately west of its predecessor. The bridge is 24.35 meters (79.9 feet) wide and carries two lanes and a sidewalk in each direction plus one bike lane. The structure is comprised of three spans for a total length of 108.42 meters (355.6 feet) as measured between the face of the abutments. Its highest point is elevation 10.82 meters (35.5 feet) (Figure 5.7-14 and 5.7-23).

5.7.10.6 Potential Impacts to Bridges During Construction

Potential impacts to the existing bridges were identified (USACE 1999) as those caused by dredging and sheet pile wall construction. The effects of dredging on the existing bridges could not be assessed because as-built plans of the existing bridge foundations did not exist; however, it was known that the pile caps for the Luis Muñoz Rivera were at an elevation of –3 feet. Since the CMP-ERP called for dredging to below –10 feet and the pile tip elevations of the existing bridge foundations were not known, it was not possible to determine the impact that the CMP-ERP dredging would have on the capacities of the pile foundations of these bridges.

The report (USACE 1999) recommended that these bridges be replaced before dredging within 100 feet. For the Ponce de León Bridge, the pile cap elevations were at –8 feet. However, because of the width of the proposed channel at this bridge location it was determined that the necessary hydraulic performance could be achieved even if the channel excavation under the bridge was limited to –8 feet. Apparently, the channel in this vicinity once had a depth of at least –8 feet. For that reason, it was anticipated that dredging of sediments to this elevation would not have an impact on the foundation capacity of the existing bridge. Therefore, replacement of the Ponce de León Avenue Bridge would not be required for hydraulic considerations.

Figure 5.7-20. Ponce de León

Figure 5.7-21. Ponce de León

Figure 5.7-22. Linear Park

Figure 5.7-23. Barbosa Bridge

5.7.10.7 Dredging Procedures under the Western Bridges

5.7.10.7.1 Proposed Channel

The portion of the CMP channel discussed herein would be constructed under the Linear Park Bridge, the Luis Muñoz Rivera Bridge, the Tren Urbano Guideway, and the Martín Peña (Ponce de León) Bridge. The channel constructed under the bridges would be that section of the CMP-ERP described as the weir. The channel would be 115 feet wide with a depth to elevation -6.5. The channel bottom would be paved with articulated concrete mat (ACM) and its sides with riprap. On the eastern end of the weir, the channel would transition from the 100-x-10-foot channel to the western bridges' 115-x-6.5-foot cross section then opening up to the wider deeper existing navigation channel in the Western CMP.

5.7.10.7.2 Bridge Characteristics Affecting Constructability

The primary elements of the channel work are dredging and installation of the armored sides and bottom. Dredging will require excavating the channel, separating solid waste from the sediments and removal of both from the project area. Adequate clearances and water depths will be needed for the floating vessels to work and pass under the bridges. Table 5.7-12 summarizes the primary characteristics of the bridges.

Table 5.7-12
Western Bridges
(dimensions and depths are approximate)

Bridge	Bridge Width (feet)	Clearance to Water Surface (feet)	Existing Channel Depth (feet)	Proposed Channel Depth (feet)
Luis Muñoz Rivera	82	10.5	-2 to -3.2	-6.5
Ponce de León	60	10.2	-1 to -5	-6.5
Tren Urbano Guideway	34	+40	-0.4 to -3.6	-6.5
Linear Park Pedestrian Bridge	8	+/- 19	-4.3 to -5.7	-6.5

Equipment needed for construction of the channel would have to be selected based upon the maximum depth of water and maximum clearance from the water's surface to the underside of the bridges. It is assumed that the bottom of the excavation or design dredge depth would be measured to the channel design bottom elevation of –6.5 plus 1-foot. The 1-foot allows for a nominal thickness of the ACM which would be added later during channel construction. Measuring from MLLW elevation –0.77, a maximum work channel depth of 6.73 feet is derived. Table 5.7-13 summarizes these figures.

Table 5.7-13
Western Bridges

Description	Elevation	Depth (feet)
Mean Lower Low Water	-0.77	0.0
Channel Invert (bottom)	-6.5	5.73
Channel Paving (ACM)	-7.5	6.73

Allowing for 1 foot of bottom clearance, maximum vessel drafts would be 5.73 feet at MLLW. Without dredging, none of the existing western bridges' channels provide adequate depths to support the floating equipment with the possible exception of the Linear Park Pedestrian Bridge.

Regarding bridge heights and clearances, the Luis Muñoz Rivera and Martín Peña (Ponce de León) bridges clearances are low, at just over 10 feet, and 82 and 60 feet wide, respectively. These low clearances and large widths pose the greatest challenges to working in the shadow of the bridges.

Clearance for the Linear Park Pedestrian Bridge is approximately 19 feet and the Tren Urbano Guideway's is over 40 feet and both have narrow widths at 8 and 34 feet, respectively, making these the easier structures to work under.

5.7.10.7.3 Equipment Limitations

Equipment anticipated for use on the main channel project would include:

- Excavator riding on a barge,
- Hopper barge with grizzly screen for separating solid waste from sediments,
- Hoist barge for installation of the articulated concrete mat (ACM),
- Barges to haul away solid waste and possibly sediments,
- Barges for the ACM, geotextiles, base course aggregate and other construction materials,

Alternately, should it be deemed appropriate to move solid wastes, sediments, and construction materials overland because the constructed eastern channel has not yet reached the weir, trucks, rather than barges, may be employed.

These low bridges prevent large dredge and pile-driving equipment from entering the Project Channel from the western end of the channel. From low to high height are the scow, the tug, the excavator and the pile driver, such that the scow would have the lowest profile and the excavator and pile driver the highest. Although excavators can lower their boom and the pile driver's mast could be taken apart for transit, probably clearing the Linear Park Bridge and certainly the Tren Urbano Guideway, it is doubtful that either would clear the Luis Muñoz Rivera and Martín Peña bridges. As such, the channel work under the western bridges would have to be performed with equipment sized and scaled for low clearances and shallow drafts. The equipment would also have to be able to operate with appropriate sensitivity to avoid damaging the existing bridge structures. Furthermore, no sheet pile work can be performed under the bridges. These activities would have to be based and accessed from the eastern end of the Project Channel. Equipment staging would take place on barges moored next to the AcuaExpreso Ferry Terminal (Figure 5.7-24).

Figure 5.7-24. AcuaExpreso Ferry Terminal Barge Staging Area

The channel work under the western bridges would have to be performed with equipment sized and scaled for low clearances and shallow drafts. The equipment would also have to be able to operate with appropriate sensitivity to avoid damaging the existing bridge structures.

5.7.10.7.4 Production Constraints

Given the use of smaller-sized equipment and tight working quarters, production is expected to proceed at a slower pace than that for the main Project Channel. Constructing the western bridges channel concurrently with the main Project Channel would help keep the project schedule compact. However, since dredged sediments and solid waste cannot be transported to their respective disposal sites until the channel east of the bridges has been dredged, any dredging taking place in advance would require either temporarily stockpiling the dredged materials or trucking it overland.

5.7.10.7.5 Construction Methodology

5.7.10.7.5.1 Turbidity Containment Temporary Dam

Prior to dredging, a temporary dam must be constructed west of the proposed weir. The dam would serve to minimize stormwater flows entering the construction zone under the bridges and reduce the movement of turbid water. The cofferdam would likely be constructed of steel sheet pile. It may not be feasible to deploy a pile driver to this location given the shallow water depths and low clearances under the bridges. Consequently, it may be necessary to construct the cofferdam utilizing a smaller excavator that would trench and backfill the sheetpile into place and fortify it with backfilled embankment material collected from the existing channel.

5.7.10.7.5.2 Dredging and Solid Waste Removal

The construction equipment operating under the bridges would be smaller scaled for operating with low clearances and shallow channel depths. Dredging would be performed utilizing a small excavator mounted on a barge that collects the dredged sediments, drops them onto a grizzly screen with the solid waste separating to the top of the screen and sediments filtering through to a hopper. The solid waste would be picked up by the excavator or another mechanical picker and placed along the upland shoreline for its eventual removal and transport by barge when the eastern channel dredging progresses to this location or trucked overland. The sediments in the hopper would be geoencapsulated and transported to the disposal pits via the newly dredged eastern channel.

5.7.10.7.5.3 Articulated Concrete Mat Construction

Construction of an ACM is typically performed utilizing a large crane outfitted with a hook beam comprised of two hooks spaced apart with a spreader beam (Figure 5.7-25). Mat sections are offloaded and stored in a laydown area adjacent to the work until needed. The laydown area may take the form of work barges where no upland area is available. The subgrade or bed where the mat would be placed is prepared by grading it smooth, when necessary, undercutting it and backfilling with graded aggregate and then geotextile fabric is placed. A crane then lifts a section of mat into place and the process is repeated.

In the case of the work under the bridges where a crane cannot operate, a special rig would be assembled comprised of two smaller barges “lashed” together with I-beams to form a sort of catamaran. Two small hoists or davits would be mounted on the barges and the lift hooks attached, minus the long hook spreader beam. The mats are staged on a larger materials barge outside of the bridge’s shadow. The lift barges move to the materials barge, pick up a mat and place it under the bridge. The process is repeated until the entire armored bottom is installed.

Figure 5.7-25. Typical Installation of Articulated Concrete Mat
(Courtesy of CONTEC Engineering Solutions)

5.7.10.7.6 Construction Sequence

A temporary cofferdam would be installed prior to commencement of dredging activities within the footprint of the weir. Once the weir is fully dredged, the contractor would install the ACM, moving from west to east. Upon completion of both the work under the bridges and the channel east of the weir, the cofferdam would be removed. Should the eastern channel construction not be completed when dredging is ready to begin at the bridges, an alternative method would involve transporting the dredge equipment overland to the site of the weir.

The following sequence applies to the channel construction under the western bridges.

- Prepare the barge staging area at the AcuaExpreso ferry terminal.
- Install a temporary sheet pile dam west of the proposed weir.
- Prepare San José Lagoon pits (if concurrent dredging from east and west ends of the Project Channel).
- Dredge west to east under bridges until the terminus of the weir.

- Install ACM and riprap sidewalls starting at the western end of the weir.
- Upon completion of the bridge channels and when no longer needed to support construction of the main CMP Project Channel, remove the temporary sheet pile dam.
- Dispose of the stockpiled dredged solid waste and dredged sediment through barges to the Humacao landfill (via the CDRC) and the SJL pits, respectively, or by overland truck hauling to the Humacao landfill.

5.7.11 Factors Affecting Productivity

The proposed procedures are somewhat unique due to the location of the CMP-ERP and the characteristics of the sediments to be dredged. These factors result in a number of challenges. Production rates may be affected by the following:

- The production capabilities of the dredging equipment, especially during the dredging and completion of the weir under the four western bridges.
- The hours per day that operations are permitted.
- The solid waste must be separated from the sediments prior to disposal.
- Shutdowns due to the discovery of cultural artifacts and human remains are to be expected.
- The sifting of solid waste will require a reduced production rate.
- Shallow draft in the western CMP channel (10 feet) and the San José Lagoon (6 feet) will limit the size of barges and dredging equipment, and constrain navigation routes from the CMP to the CDRC.

5.7.12 Sedimentation Rates and Maintenance Schedules

Areas of potential concern for channel sedimentation after construction are the channel corridor and extended channels on either end. Although average rates of sedimentation within the channel corridor are expected to be approximately 1.5 inches per year, sediment is not expected to accumulate due to the anticipated velocities. The western end of the channel is expected to be similarly self-cleaning due to its high exit velocities; however, due to deposits (6.7 feet per year) from a contributing stream at the eastern end of the proposed channel, Quebrada Juan Méndez (Quebrada), maintenance dredging will be necessary at this location.

The Quebrada and the eastern end of the Project Channel (extended channel) meet at their confluence with San José Lagoon. The two existing channels are separated by a narrow band of mangroves, growing on built up sediment deposits from the Quebrada (Figure 5.7-26). The portion of the Project Channel paralleling the Quabrada has a trapezoidal configuration with a 10-foot-wide bottom and 5 to 1 earthen side slopes. To minimize silt laden flow from the Quebrada entering the extended channel, construction would include preserving and enhancing the earthen berm between the channels. In this manner, the need for maintenance dredging of the extended channel would be reduced. Following is a detailed discussion.

Estimates of the sedimentation rates at the CMP-ERP were developed by Moffatt & Nichol (2003) using flow models and sediment data. The study developed a model that compared discharges and watershed sediment data available from the U.S. Geological Survey gauge stations on sediment concentrations. The Moffatt & Nichol (2003) report established that the average sedimentation rate within the main CMP is approximately 1.5 inches (0.125 foot) per year; however, a recent evaluation of the circulation parameters for each channel configuration alternative performed as part of this feasibility study effort indicate the peak velocity associated with the "largest preferred" CMP channel configuration may result in insignificant sedimentation within the eastern segment of the improved main channel. The hydrodynamic model used to perform the circulation analysis was the CH3D-WES model.

This Engineering Appendix preliminarily concludes that future sediments discharged into the eastern segment of the CMP, following construction of the CMP-ERP, will be further transported to and eventually deposited within the lower energy environments located at both ends of the eastern channel. The eastern segment of the main CMP is anticipated to be self-maintaining at the "largest preferred" improved depth; however, sedimentation is expected to occur at the transitional area between the channel entrance (mouth of the CMP) and San José Lagoon and possibly at the interface between the eastern and western main channel located at the Luis Muñoz Rivera Avenue Bridge.

Moffatt & Nichol (2003) further describes the sedimentation potential within the mouth of the eastern CMP. Contributors to sedimentation within the CMP mouth include sediments transported and deposited by the main channel and sediments discharged by the Quebrada Juan Méndez (Figure 5.7-26). The Quebrada Juan Méndez flows into San José Lagoon immediately south of the channel's outlet, acting to some extent as a confluence to the CMP. Therefore, a dredged channel tapering to the San José Lagoon's existing bottom depth would act as a sink for sediments discharged by the Quebrada Juan Méndez.

With limited flow and sediment concentration data available in the lower reaches of the Quebrada Juan Méndez, Moffatt & Nichol (2003) developed a conservative estimate of the average sedimentation rate within an assumed CMP-ERP cross-section. This estimated in-fill rate was calculated as 6.7 feet per year, but this estimate is recognized as likely being higher than actual given other variables were not considered as part of the calculation, to include channel velocities which would affect the settling rate of sediments.

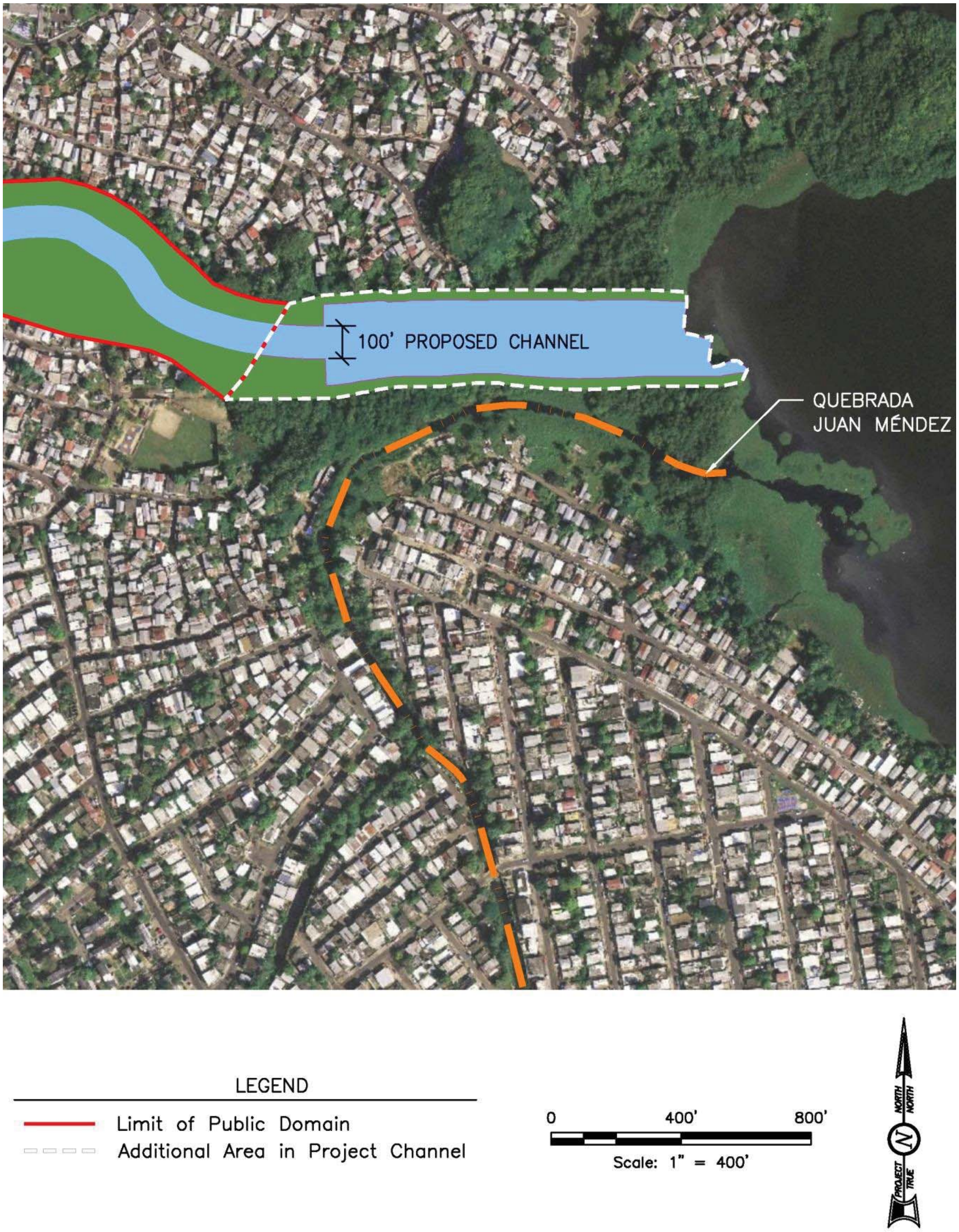


Figure 5.7-26
Outlet Locations (CMP and Quebrada Juan Méndez)
Source: Google Earth, Image October 31, 2004

Absent of collecting a complete data set and performing a more detailed analysis, Moffatt & Nichol's 6.7 feet per year conservative sedimentation rate will be used as a basis to forecast future maintenance dredging needs for the CMP-ERP outlet. Simplistically assuming the length of channel outlet receiving in-fill sediments from Quebrada Juan Méndez is 1,800 feet, and the channel's outlet tapers from –15 to –6 feet in the lagoon with 5 to 1 cross-sectional side slopes, the annual volume of sediment deposition requiring maintenance dredging is approximately 35,000 cy.

To ensure the CMP-ERP outlet to San José Lagoon remains unobstructed for tidal flows, it is suggested based on Moffatt & Nichol's conservative sedimentation rate estimate to perform maintenance dredging on the channel outlet at an annual frequency; however, a major portion of the costs associated with dredging is mobilization, site preparation and demobilization. A more cost-effective approach is recommended that would over dredge the areas found to be receiving deposition to create sediment basins capable of storing several years of accumulated sediments, thereby allowing for a deferred dredging schedule.

After construction is completed, the channel will be monitored annually to determine rates of sedimentation. The first maintenance dredging would be determined necessary when the channel has lost 15 percent or more of its depth at any location. These areas would then be dredged to a depth that would provide for the extended storage of future depositions. The assumed schedule would be to repeat dredging at intervals of 5 years.

Based on the circulation patterns modeled for the "largest preferred" channel configuration, velocities within the eastern segment of the main Project Channel will be high enough to likely prevent buildup of sediments within the main channel. Therefore, maintenance dredging of the main Project Channel may not be required during the 50-year life of the CMP-ERP.

The CMP-ERP outlet to the western end of the existing CMP is expected to similarly be self-maintaining due to high exit velocities; however, any maintenance dredging that would become necessary would require the use of low profile, shallow drafting vessels and dredges to gain access under the western bridges.

The CAD pits have capacity for 1 or 2 years of depositions from the Juan Méndez. After that, the dredged sediments would have to go elsewhere. As these sediments are not expected to be contaminated, disposal should not require contained disposal techniques. The sediments could be loaded into scows and transported to the San Juan ODMDS or to the remaining artificial dredged pits left in the San José Lagoon for unconfined open-water disposal. Conveyance of the dredged sediments to the ODMDS would require either pumping over the proposed weir at the western bridges or the use of light-loaded, shallow-drafting scows. Alternatively, the sediments could be offloaded at the CDRC and trucked to an upland site. All necessary Regulatory permits would be secured at that time. A sensible solution for consideration would be determining the necessary stabilization measures needed to prevent the transport of sediments from the Juan Méndez into the eastern CMP in the first place.

5.7.13 Construction Issues

5.7.13.1 Dredgeability

The proposed CMP-ERP entails dredging accumulated and native material. Based on a review of the existing geotechnical data, it is concluded that the material has a large range of soil characteristics to include soft to very soft black organic mud, clays, silts with some lenses of sandy material, hard sandy clay and hard silty clay. Cores taken near the area of Cantera encountered limestone in the channel at depths as shallow as –10.5 (USACE, 2001). Although a concern, it is not expected that blasting will be required for the limestone formation if the formations present and are small enough to be excavated mechanically or with a cutterhead hydraulic dredge. Gravels, cobbles and boulders in the channel coming from the limestone formation on the eastern side of the CMP may be possible. However, the sedimentary material within the channel reaches is likely to consist of soft clays with pockets of sand. The zero blow counts in several cores predict, in general, very soft material along the entire channel. The unpredictability of the volume and location of debris, trash and riprap will be the main concern during the excavation and the management of the sediments, but the dredging of this material should be possible with a mechanical clamshell dredge.

5.7.13.2 Channel Stability

The USACE (2001) report included the geotechnical design for the sheetpile walls and channel dredging. The channel and channel banks would be dredged considering the local conditions. When dredging, it was determined that temporary construction channel bank slopes of 1V:3H (vertical: height) were considered safe from 0 to –5 feet and dredge slopes of 1V:5H in the channel from –5 to –10 feet were considered acceptable. It was determined that the sheet pile could be installed with a vibratory hammer and a diesel, steam or hydraulic pile hammer for sections of sheet pile that may not be able to be driven completely to the required tip elevation. During dredging operations, temporary slope angles will be kept until the installation of the sheet pile. These actions will have to be managed from the water or from the shores of the channel.

5.7.14 Hydrogen Sulfide Management Plan

Results of the modeling indicate that potential ambient concentrations of hydrogen sulfide may be relatively high; however, the basis and assumptions used to arrive at these predicted concentrations were conservative, and thus, the actual impacts may be much less than this value. To confirm the actual ambient concentrations of hydrogen sulfide released from the sediments during dredging, it is recommended that a sulfide monitoring program be developed and implemented during dredging operations. Prior to construction, the dredging and sampling of test pits to better understand potential hydrogen sulfide concentrations that may be generated during full-scale operations should be considered.

During the dredging of the sediments and when the dredged sediments are mechanically separated from large debris, gas releases are expected. A separate management plan (outside of the scope of this report) is recommended for the management/mitigation of any release of hydrogen sulfide. Confirmed, high concentrations of hydrogen sulfide will require aggressive management efforts. These efforts may include some or all of the following strategies:

- Water sprays near the source to reduce concentrations.
- In situ chemical treatment of the sediments to sequester the hydrogen sulfide or convert it into a less harmful substance.
- Collection of the air at the site of sediment disturbances followed by air scrubbing to sequester hydrogen sulfide.
- Collection of the air at the site of sediment disturbances and transmission to a safe zone (e.g., high above the ground or to the middle of the bay) where dilution/dispersal can occur safely.
- As a last resort, temporary relocation (evacuation) of individuals located in the areas anticipated to be impacted by unsafe levels of hydrogen sulfide.

The management plan should address the health and safety of the public, the construction workers and equipment subject to hydrogen sulfide related corrosion. It should include recommendations for personal protective equipment for workers such as respirators and/or SCUBA gear, as well as air monitoring equipment and procedures. Education and training about the symptoms and dangers of hydrogen sulfide poisoning should also be provided for all individuals entering the work area.

5.8 SITE WORK FOR MANGROVE RESTORATION

5.8.1 General

This section of the report discusses the requirements for preparation of soil beds adjacent to the channel to support the growth of mangroves. As part of the CMP-ERP's requirements, a portion of the land set aside must be utilized to replace mangroves lost during construction of the channel. This section addresses the design to plant the mangroves at the appropriate elevation, in the proper soils, and with the best methods to ensure their growth to maturity and beyond.

5.8.2 Hydrology to Support Mangrove Development

The term "Mangrove" refers to numerous species worldwide in coastal intertidal communities, but for the purposes of this project, four species will be considered, *Rhizophora mangle* (Red Mangrove), *Avicennia germinans* (Black Mangrove), *Laguncularia racemosa* (White Mangrove, and the associated species, *Conocarpus erecta* (Buttonwood). Each of these species is specific to micro-typography and the associated levels of tidal inundation, period and salinity. The delicate interface between freshwater runoff and tidal inflow provides the estuarine habitat for mangrove succession and must be carefully studied prior to any restoration efforts.

The single most important factor in designing a successful mangrove restoration is determining the normal hydrology (depth, duration, and frequency of tidal flooding) of existing natural mangrove plant communities in a reference site located closely to the restoration site (Lewis 2004). Mangrove forests typically exist on a sloped platform above MLLW, with typical surveyed elevations for mangrove species in the range of +30 to +60 cm (1–2 feet) above MLLW (Lewis 2004), but specific information from the reference site must be replicated exactly for restoration success. The existing mangrove beds in the Western CMP will be utilized as the reference site.

The flow of water from the channel to the mangrove planting bed will be facilitated by building lowered wall sections or windows in the bulkhead at regular intervals. The top of the window will be set at mean low water so that tidal exchanges are facilitated to the mangrove beds. The width of the planting bed will vary depending upon land availability but in general, will extend from the channel wall to the line of public domain. Exceptions to this are areas set aside for community recreation.

5.8.3 Soils in the Mangrove Planting Beds

Construction of the sheet pile walls for the channel would require the removal, to considerable depths, the existing soils and solid waste behind the wall. The dredged excavation would be temporarily shaped with a side slope in the range of 1:1 to 2:1 (horizontal:vertical), starting from the invert elevation of the proposed channel. Screened dredged sediments would be stockpiled immediately upland of the wall excavation. The sheet pile wall would be constructed and the stockpiled soils utilized to backfill behind the wall. The excavation would be of sufficient depth to insure at least 3 feet of screened sediments cover any remaining solid waste under the mangrove bed. Surface soils would be placed to proposed finished grade at or about MLLW (Figure 5.10-1). Care should be taken in the selection of the replacement soils to insure that they closely replicate the existing condition in the reference site selected for the CMP-ERP.

5.8.4 Planting Methods

The evidence to date indicates that rooted seedlings have no advantage over unrooted propagules and seedlings showed no advantage over propagules in terms of growth or transplant (Lewis 1982). The expense of full nursery propagation of seedlings may be an unnecessary step in successful restoration. Greater benefit may be derived from direct planting of a nurse crop of *Spartina alterniflora* (cordgrass) and *Batis maritima* (saltwort) in the likelihood of a primary succession environment which then will serve to trap natural recruited mangrove propagules in tidal flow.

The preferred methodology is to use the nurse crop, planting 30 percent coverage with nursery propagated seedlings and overseeding with propagules. The nurse crop will help stabilize the soils and entrap propagules to encourage their rooting in at the ideal elevations. Careful monitoring should occur after construction to document the progress of succession and natural recruitment and to insure that exotic invasive species do not return to exclude the planted nurse crop or natural mangrove recruits. If nursery grown seedlings are utilized, it is recommended that planting schedules coincide with commercial availability of propagules and that specific protocols for germination and planting of each species be closely researched and followed.

5.8.5 Reference Site

The reference site for mangrove restoration would be in the Western CMP along the Agua Guagua channel. Water elevations would be monitored to determine the optimum elevations for the proposed mangrove restoration areas, as well as the determination of locally preferred soils for the new mangrove beds.

5.9 RECREATION

The Comprehensive Development Land Use Plan and State Comprehensive Recreational Opportunity Plan are the foundation of recreational features selected for the CMP-ERP. The local community and non-Federal sponsors interest, as well as the Corps regulations on ecosystem restoration recreation further defined the recreational features proposed for the CMP-ERP.

The following is a list of the recreational features identified as acceptable for the Federal recreation plan.

- Trails
- Walks
- Steps/ramps
- Footbridges
- Picnic tables
- Trash receptacles
- Benches
- Entrance/Directional Marker
- Instructional signs
- Interpretive markers
- Gates
- Guardrails and Handrails
- Lighting
- Walls

5.9.1 Recreation Plan Access Areas

The linear nature of the CMP-ERP allows for the placement of recreational features along the length of the CMP to maximize the benefit of the local community and reduce the impacts to the restored ecosystem (Figure 5.9-1). The CMP-ERP team, using the list of potential recreational features listed in Exhibit E-3 of ER 1105-2-100, identified three types of recreation access areas. The three types allow for major recreational use in some areas and median use in others areas both adjacent to the Paseo that follows the CMP-ERP. This approach allows for large uninterrupted areas of restoration with major recreation areas that have access to the water and median use areas along the smaller neighborhoods while connecting to the Paseo along the CMP-ERP. The recreation access areas are designed to discourage improper use and facilitate educational programs to increase environmental stewardship of the restored ecosystem.

5.9.1.1 Linear Park

This recreation area would consist of a trail, walk, and/or footbridge that extends the existing linear park located to the west of the Project Channel. The extended linear park trail would be constructed over the sheet pile bulk head in the channel (with the mangrove fringe between the linear park trail and the Paseo), and would be located on the southern side of the CMP, extending past the four western bridges in the project area and terminating at the first recreation access area in the Parada 27 community. In the vicinity of the western bridges, where the sheet pile wall is replaced with a riprap edge, the trail would be constructed on piles. If possible, benches may be placed in strategic locations to provide rest and or observation areas. The area would have an entrance sign, instructional signs and interpretive signs to educate the public on the CMP-ERP, proper use of the recreational area, and educational facts about the restored ecosystem. A gate and fence, or wall, would be placed along the CMP for safety and to discourage the disposal of materials into the CMP. Guardrails, handrails, steps, ramps, and lighting would be used, as appropriate, to maintain a safe and accessible recreation area. The linear park would fall within the navigational servitude.

5.9.1.2 Recreation Access Park

This type of recreational area would have open access to the restored CMP and would be scaled to accommodate more than 100 persons for passive recreation (Figure 5.9-2). The nine recreation access parks would provide visual openings through mangrove forest to the CMP, providing a strong community connection at these strategic locations. Each would be located strategically at the intersection of the Paseo del Cano walkway and an important community transportation artery. They would include picnic tables and benches to encourage educational gatherings and nature enthusiasts to enjoy the restored ecosystem. Each recreation access park would have an entrance sign, instructional signs and interpretive signs to educate the public on the CMP-ERP, proper use of the recreational area, and educational facts about the restored ecosystem. A gate and fence, or wall, would be placed along the CMP for safety and to discourage the disposal of materials into the CMP. Guardrails, handrails, steps, ramps, and lighting would be used, as appropriate, to maintain a safe and accessible recreation area. The recreation access parks would provide for navigation access to the CMP.

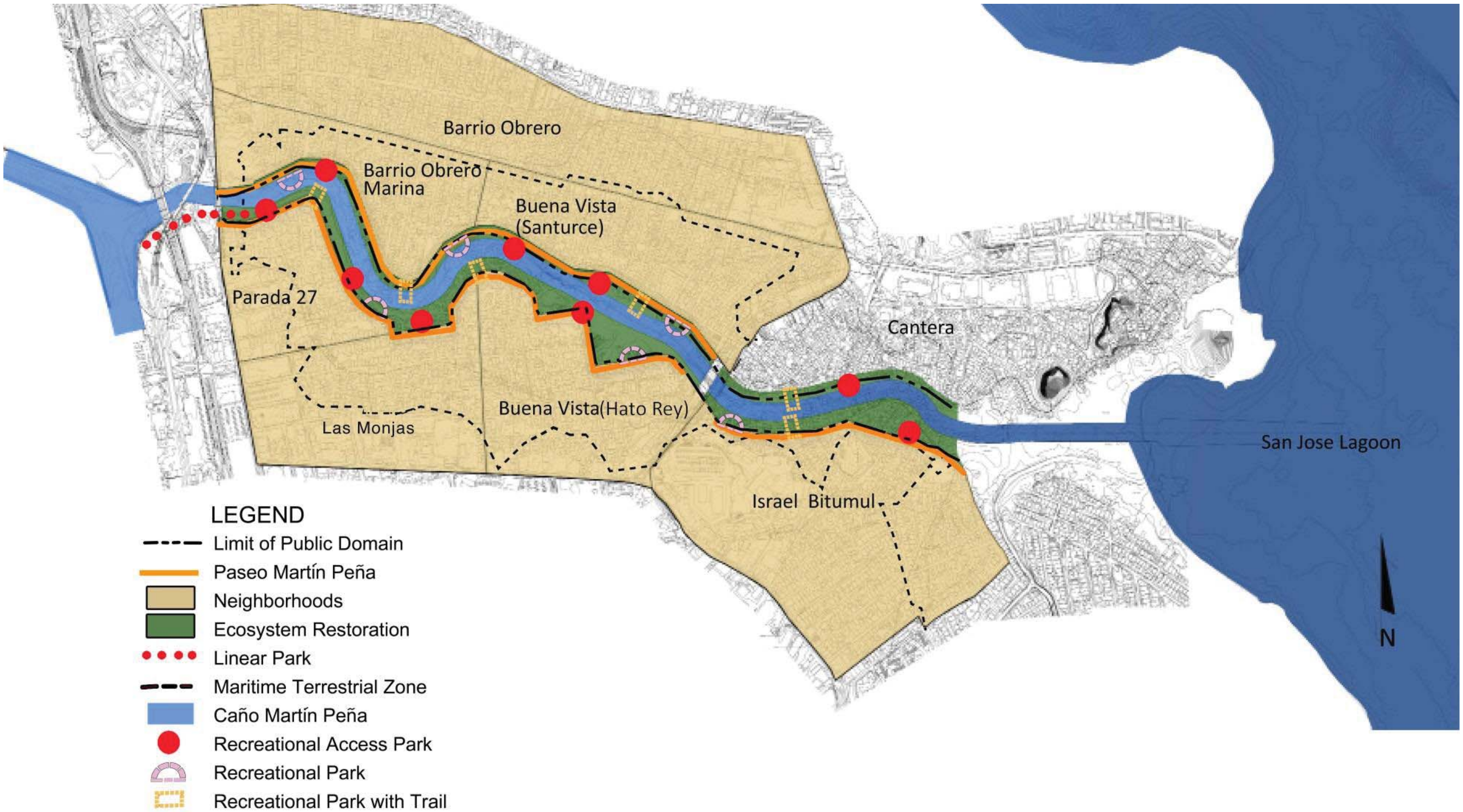


Figure 5.9-1. Proposed Federal Recreation Plan

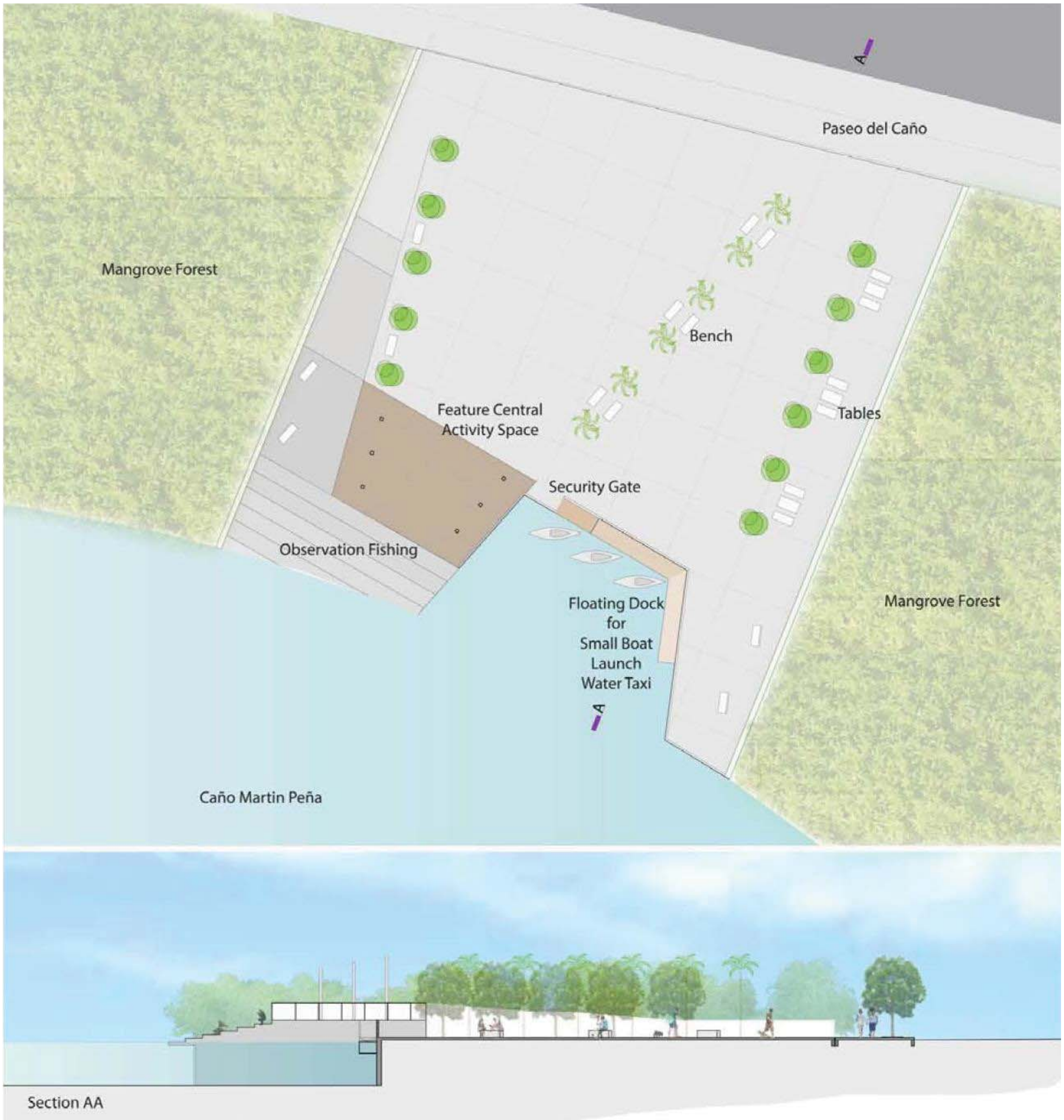


Figure 5.9-2. Sample design of recreation access park

5.9.1.3 Recreation Park

This type of recreational area would be smaller in scale than the proposed recreational access park, and would be scaled to accommodate less than 100 persons for passive recreation. With the natural mangrove forest serving as a backdrop, the twelve recreation parks would be strategically located along the Paseo del Cano walkway corridor to serve immediately adjacent blocks (Figure 5.9-3). In six of the recreation parks, a trail would be built through the forest to allow access to CMP (Figure 5.9-3). The recreation parks would include benches to create an outdoor classroom and be strategically positioned to enhance nature watching. They would have an entrance sign, instructional signs and interpretive signs to educate the public on the CMP-ERP, proper use of the recreational area, and educational facts about the restored ecosystem. A gate and fence, or wall, would be placed along the recreation park and CMP where applicable for safety and to discourage the disposal of materials into the CMP. Guardrails, handrails, steps, ramps, and lighting would be used as appropriate to maintain a safe and accessible recreation area.

Figure 5.9-3. Prototype Recreation Park Design (a) no trail (b) with trail

5.9.1.4 Proposed Non-Federal Recreation Features

The non-Federal sponsor, ENLACE, will continue to work with the local community to implement the CDLUP. As part of the CDLUP, ENLACE proposes to include improvements to aesthetics and additional opportunities in the Federal recreation plan areas. ENLACE will continue to refine improvements and additional opportunities with the community so as to incorporate them, at 100 percent non-Federal cost and in a timely manner into the construction of the Federal recreation plan. ENLACE is currently considering the addition of betterments to lights, including figures or statues, and incorporating exercise stations, fishing, and kayak or canoeing opportunities. Navigation access would be provided through the Federal recreation access parks.

5.9.2 Recreational Facility Maintenance

Maintenance activities include daily/weekly activities and capital repair and replacement of park assets.

Daily/weekly maintenance activities

A full time maintenance crew will be needed to perform regular maintenance of the parks. It is anticipated that two full time employees will be needed for these efforts. The work will include the following:

Removal of litter, fertilization of trees and shrubs; management of disease and/or insects in trees and shrubs either by cultural or chemical methods; sweeping, blowing, and power washing of walkways, and other hardscape surfaces; visual and physical examination of facilities to ensure compliance, safety, and proper operation; maintenance of equipment including drinking fountains, tables, trash receptacles, benches, bike racks, boat docks and gangways.

Capital repair and replacement of assets

Over time, the park assets will require repair of damages resulting from the heavy wear and tear normally associated with the heavy use of park facilities. Eventually, these assets will reach the end of their service life and require replacement. Following (Table 5.9-1) is the schedule:

Table 5.9-1
Capital Repair/Replacement Schedule for Recreation Facilities

Asset	Description	Capital Repair / Replacement Schedule
Utility infrastructure	Lighting	5 years repair/20 years replace
Central feature	Structures	5 years repair/25 years replace
Park amenities	Handrails, bollards, tables, benches, trash receptacles, and bike racks	3 years repair/10 years replace
Paving and hardscapes	Pavement, seawalls, and boardwalks	10 years repair/25 years replace
Waterfront equipment	Floating docks and gangways	5 years repair/20 years replace

5.10 SEA LEVEL CHANGE CONSIDERATIONS

The effect of sea level change (SLC) on the CMP project provides information guided by the U.S. Army Corps of Engineers recommending that sea level change be calculated and reported as a low, intermediate, and high rate for consideration of project impacts. The following revisions are made to address Engineer Regulation (ER) 1100-2-8162 “Incorporating Sea-Level Change Considerations in Civil Works Programs,” released in December 2013.

The “low” sea level change rate is defined as the historic rate of relative sea level change at the local tide station. NOAA has evaluated sea level change trends for each tide station (NOAA 2008) and provides the data for the mean sea level trend at the San Juan tide gauge, station 9755371. The mean sea level trend has been calculated by NOAA to be 0.00541 feet/year.

The "intermediate" sea level change rate is defined as the rate of local mean sea level change using the modified Natural Research Council (NRC) Curve I. The "high" sea level change rate is defined as the rate of local mean sea level change using the modified NRC Curve III. Both the "intermediate" and "high" rates include a consideration for the future acceleration of sea level change that is not considered when evaluating the historical ("low") rate of relative sea level change.

Assuming a project life of 50 years, with construction beginning in October 2018 and completing in December 2020, sea level change was calculated. It is noted that as the CMP-ERP moves through design development and PED, this calculation should be updated to the latest ER and construction schedule. Using the updates to the NRC Equations and extending the calculation 50-years from a construction completion date of 2020, Table 5.10-1 provides the revised summary of all estimated sea level change rates.

Table 5.10-1
Summary of Sea Level Change Estimates
(U.S. Army Corps of Engineers 2013)

SLC Estimate		
(feet)	**Method**	**Estimate**
0.36	Tide Gauge Trend	Low
0.76	NRC Curve I	Intermediate
2.03	NRC Curve III	High

As further reference, the Puerto Rico Climate Change Council (PRCCC 2013) recommends planning for a rise of 0.5–1.0 meter (1.64–3.28 feet) by 2100.

It is estimated that the increase in water level elevation as a result of sea level change will not affect future navigation or maintenance of CMP because the depth of the channel would be constructed and maintained as measured from the water surface. As the sheet pile wall begins to reach the end of its service life, SLC may overtop the wall requiring navigational marker placement or other means to delineate the navigation channel.

As discussed in Section 4.3.6, tidal amplitude will increase water levels by 0.64 foot. This will place MHHW at or slightly above the top of the sheet pile cap. With the addition of 2.03 feet SLC, water levels at MHHW will overtop the cap. A summary of these figures incorporating SLC follows:

Table 5.10-2
Sea Level Change Estimates – Relative to Proposed Top of Sheet Pile Wall

Location	Top of Sheet Pile Cap	MHHW (pre-construction)	MHHW (SLC) (pre-construction)	MHHW (post-construction)	MHHW (SLC) (post-construction)
San Juan Bay	3.0	1.12	3.15	1.76	3.79
San Jóse Lagoon	3.0	0.80	2.83	1.44	3.47

The potential exists that sea level change will overtop the elevations necessary to maintain the existing and planned mangrove planting areas. The extent of the existing mangroves and planned mangrove planting areas would be limited by the CMP channel and infrastructure within the CMP-ERP area. This situation does not allow the mangroves to naturally adapt to sea level change by extending further inland. A solution to prevent the loss of the existing mangroves and planting areas due to a change in sea level includes adaptive management that will allow for raising the bed elevation of the planting area to maintain the function of the mangroves. However, if the mangrove bed is initially constructed with a variable surface with high and low elevations, ranging from the current mean sea level to, say 3.0 feet or so higher. The mangroves are initially planted at MLLW and over time, as the plants become too wet and cannot dry out, the plant or its replacement migrates to the upper hummocks of this microtopography. With this approach, there is no need to raise the beds and the mangroves are self-sustaining as the sea level changes. This method of grading also provides opportunities for supporting a greater diversity of species, as well as adaptive management to water level variations (Figure 5.10-1).

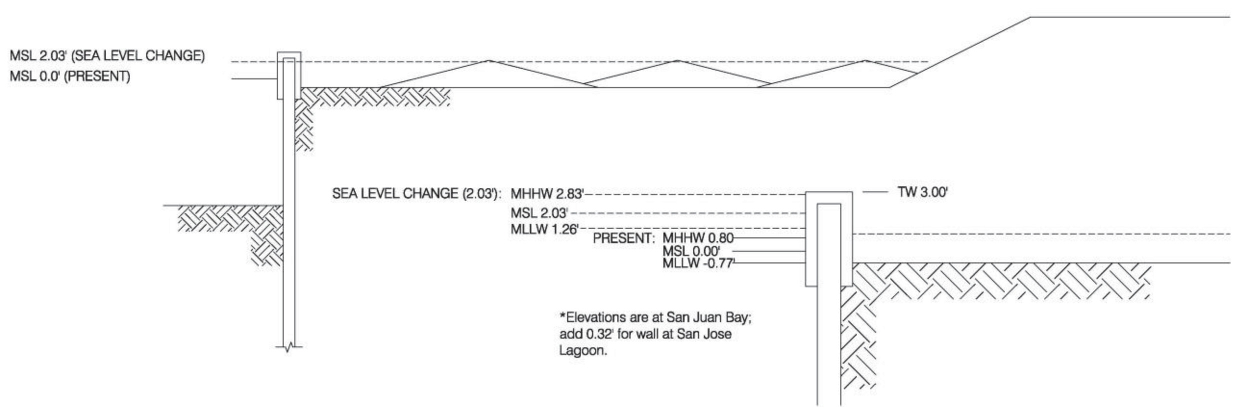


Figure 5.10-1. Mangrove planting bed modifications for sea level change

Flooding

As can be anticipated by the discussion on sea level change, the combined effects of the change in sea level and increased rainfall occurring from climate change could exacerbate flooding that is already occurring in the CMP-ERP area; however, the CMP-ERP will result in a net positive effect through reducing residence time of tidal waters and increasing the capability of water to be removed from the basin to tide. Design elevations for the perimeter roadways and infrastructure outside of the Project limits should take into consideration high tide elevation with SLC incorporated.

5.11 SEDIMENTATION CONTROL

5.11.1 General

The section of this report discusses CMP-ERP activities, their potential to cause sedimentation and erosion and best management practices for their control. The nature of the CMP-ERP activity is demolition of structures and land clearing of upland areas, dredging for channel and adjacent mangrove bed creation and upland grading for drainage improvements and utility relocations. By the nature of the topography, the majority of runoff from areas of earth disturbances occurring during construction will be directed towards the channel and handled as part of the dredging operation as turbidity controls. To a lesser extent, runoff from the minor portions of uplands within the CMP-ERP will be managed with land-based best management practices (BMPs).

All of the proposed alternatives involve the same construction activity, only differing by the width of the channel excavation. Consequently, the same sedimentation and erosion control devices would be employed no matter which channel alternative is constructed.

5.11.2 Sedimentation, Erosion, and Turbidity Control Devices

To minimize the short-term and long-term sedimentation and erosion and turbidity and total suspended solids (TSS) in the water, BMPs would be implemented at appropriate stages during construction. These devices may include temporary seeding, retention blankets, silt fence, and earthen diversions. Stormwater dispersion systems, paved discharges, blankets, matting, vegetative filter strips, and berms would be employed to minimize the long-term turbidity and TSS in the waters.

Sedimentation and erosion control devices will be deployed at the interface of the channel dredging and the uplands. Stormwater from the CMP-ERP uplands will be filtered through these devices prior to discharge to the channel corridor. Stormwater from existing community storm sewers will be directed into the channel corridor through temporary channels and flumes. Further treatment within the channel corridor will be handled as turbidity control.

5.11.3 Turbidity Control Devices

Turbidity controls will focus on minimizing the dispersal of silt laden water from the CMP-ERP limits. To minimize the dispersal of turbid water from the channel, temporary sheet pile coffer dam(s) will be constructed. Locations include just east of the Ponce de León Avenue Bridge and possibly, at the channel's entrance into San José Lagoon. The later would not be employed if access to the lagoon is required.

Silt curtains should be deployed at 1) sites where dredging is active; 2) at the barge staging area near the AcuaExpreso ferry terminal; and 3) at the CDRC debris disposal offloading dock. Within the channel corridor and around active dredging and excavations adjacent to the water, silt curtains will be deployed. Silt curtains are vertical, flexible structures that extend downward from the water surface to a specified water depth. Typically fabricated of flexible, polyester-reinforced thermoplastic (vinyl) fabric, the curtain is maintained in a vertical position by flotation material at the top and a ballast chain along the bottom. In critical areas, the curtains may double ring the active area for additional precautions. The curtains would be constructed to the full depth of the water where they are placed.

A turbidity monitoring plan will be incorporated into the construction contract documents to include sampling and analyses. Turbidity monitoring equipment and personnel trained to use it shall be available on site at all times during construction activities that could result in CMP-ERP-generated turbidity. During all activities that may create turbidity, turbidity levels shall be monitored at least twice daily as follows:

A. Monitoring samples shall be taken at the following locations:
    1. Background Sample(s): One background sample station, at least 150 meters up-current of the work area(s), in each adjacent channel/wetland/area, collected outside of containment barriers, and outside any visible plume generated by the construction; and
    2. Compliance Sample(s): One monitoring station located in each channel/wetland/area adjacent to the work area and outside of the turbidity controls, no greater than 150 meters down-current from the work area within the densest portion of any visible plume generated by construction.

B. Turbidity monitoring results shall be compiled daily. Beginning with the first calendar month that construction occurs that could generate turbidity in waters adjacent to the construction site, a report containing the summarized turbidity monitoring results for the CMP-ERP shall be submitted quarterly. If no construction occurs that could generate turbidity during the quarterly monitoring period, the report shall be so noted.

In the event that CMP-ERP-generated turbidity levels exceed allowable levels above background in the receiving waters, CMP-ERP activities contributing to elevated turbidity levels shall immediately cease, and the appropriate authorities shall be notified. Work shall not resume until the work can be conducted in compliance with these turbidity limits or an accompanying variance, where applicable.

5.12 VIBRATION AND NOISE MITIGATION DURING CONSTRUCTION

Construction of the CMP-ERP presents unique challenges due to the type of construction and its close proximity to the community. The work will generate noise and construction vibrations from the operation of heavy machinery and pile driving equipment. Construction vibrations may not only annoy people but have detrimental effects on structures and sensitive equipment. The potential for these effects is dependent upon numerous variables, including distance from the source, types of soil, frequency of vibration and other factors. Additionally, construction generated noise may annoy nearby occupants.

It is recommended that prior to initiating construction, a vibration and noise mitigation plan be developed and put into effect. The plan will likely include the preparation of pre-construction surveys of adjacent structures and if appropriate, distant structures with sensitive equipment like hospitals or businesses utilizing precision instruments. It may be determined advisable to monitor vibrations during construction and have plans in place to take action, should certain thresholds be crossed. In the event that damage is reported, the pre-construction survey becomes the baseline for comparing the pre and post construction conditions. Noise mitigation would involve the installation of temporary sound barriers that would follow the dredging operations through the Project Channel. Dredging and construction operations would be limited to 12 hours a day, with no dredging or construction activities to be conducted on Sundays. Other measures may include mandating the use of heavy equipment that is less likely to create noise and vibration issues.

5.13 POTENTIAL IMPACTS TO LOW LYING STRUCTURES WITHIN THE CMP-ERP AREA DURING CONSTRUCTION

The proposed channel along with its sheet pile walls and adjoining mangrove beds forms the floodway for the frequent storm events described in the Hydraulics and Hydrology report. In its existing topographic condition, there are areas, such as Barrio Obrero Marina, with poor drainage as a result of their low elevations (near mean lower low water) or because they lack an adequate receiving channel. As dredging is initiated, water, influenced by the tides and storms, will backflow into the new channel. Without proper controls, structures in these low lying areas may be at risk of adverse impacts from high-water events. During PED, a “sequence of events” based upon performance standards must be established and incorporated into the construction contract documents. The basis for the standards will be that back flowing waters over specified elevations be contained within the limits of construction, ensured in the form of a suitable protective structure between the channel waters and the adjoining low areas. In most cases, this is anticipated to simply involve grading the upland edge or embankment of the mangrove bed to its final proposed elevations, thereby containing the channel waters. Where this is not feasible due to phasing conflicts or because there is insufficient land to create an embankment, an alternative may include the installation of a temporary sheet pile wall with local select backfill to buttress the structure (such as the case for the protection of Barrio Obrero Marina). These temporary flood protection solutions would remain in place until the proposed sheet pile channel wall and upland embankment is installed. The most suitable alternative is to flood-proof the structure or remove it from the affected low-lying Barrio Obrero Marina and other areas.

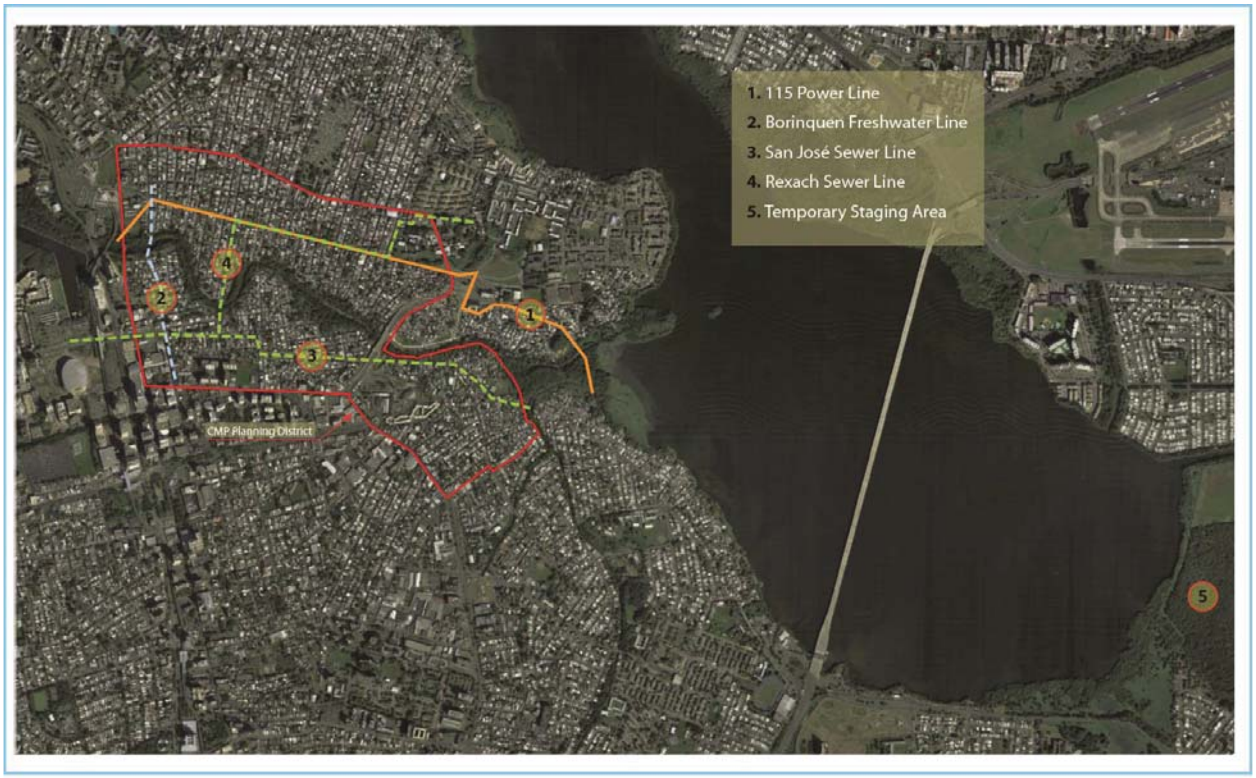
5.14 RELOCATIONS

This section of the appendix describes major infrastructure affected by the CMP-ERP and the necessary work necessary to maintain their continuing function. Puerto Rico Aqueduct and Sewer Authority (PRASA) infrastructure facilities that need to be relocated to allow for the dredging of the CMP are a segment of the San José Trunk Sewer, a segment of the Rexach Trunk Sewer, and a segment of the Borinquen Water Transmission Line. All these infrastructure facilities are principal components of PRASA's system due to the high flow that they convey and the number of clients they serve. The relocation of these facilities requires careful planning as to avoid service interruptions and affecting PRASA's system. A description of each of the systems follows (ENTECH/CH Caribe, 2008). Also discussed are impacts, relocations and closures to minor infrastructure systems (Figure 5.13-1). The relocation of the Rexach Trunk Sewer, and a segment of the Borinquen Water Transmission Line would be conducted as part of the CMP-ERP; however, the relocation of the San José Trunk Sewer would not be included as part of the CMP-ERP.

5.14.1 San José Trunk Sewer

The San José Trunk Sewer is one of the principal San Juan area trunk sewers. This trunk sewer conveys wastewater from Trujillo Alto, Santurce, Barrio Obrero, Isla Verde, and Hato Rey to the Puerto Nuevo Wastewater Treatment Plant. A segment of this trunk sewer, approximately 800 meters (2,624.8 feet), runs from east to west within the CMP-ERP limits (Figure 5.13-1). Portions of the 66-inch-diameter pipe lie very close to the construction limits for the CMP-ERP and may require reinforcement prior to construction of the CMP-ERP as it is outside, but immediately adjacent to the Project Area.

In 2013, PRASA determined that was feasible for the line to remain in place, and reinforced the 60-inch and 66-inch diameter pipe in order to established security measures and precautions to minimize vibrations and impacts to the trunk sewer. In December 2014, PRASA finished the reinforcement of San José Trunk Sewer with a construction cost of $5,579,390.00.



Source: ENLACE & Puerto Rico Planning Board

Figure 5.13-1. Utility Relocations

An as-built drawing of the reinforced segment of the trunk sewer was prepared, including the diameter and location of the trunk sewer and its manholes. According to the as-built drawing titled San José Trunk Sewer Rehabilitation, that correspond to the reinforced segment, the trunk sewer remains outside the construction limits for the CMP-ERP and its lifespan was extended with a better hydraulic capacity. This project is part of PRASA capital investment plan and produced 100 direct and indirect employments. Also this project benefits 23,100 families within the Municipality of San Juan.

5.14.2 Rexach Trunk Sewer

Similar to the San José Trunk Sewer, the Rexach Trunk Sewer is also one of the main San Juan area trunk sewers and conveys wastewater from areas that include Isla Verde, Santurce, and Barrio Obrero to the San José Trunk Sewer. The Rexach Trunk Sewer flows from north to south along Street 13 of the Barrio Obrero-Marina community, crosses the channel, and continues along the Luna Street of the Parada 27 community until it connects to the San José Trunk Sewer. According to the drawings titled San Juan Sewer System Evaluation Survey prior to crossing the CMP, the Rexach Trunk Sewer has a diameter of 48 inches and right before crossing the CMP, the pipe diameter changes to 66 inches until connecting to the San José Trunk Sewer. But based on the drawings titled Completion of the Avenida Rexach Trunk Sewer, that same segment has a diameter of 48 inches. To confirm the diameter and elevation of this segment, GeoBoundaries prepared an as-built of the area, but due to the high flow level and high accumulation of solid waste, neither the pipe diameter nor the invert elevations could be accurately determined. Based on the discussion with PRASA Staff and drawings titled As-built San José Trunk Sewer Part II and Completion of the Rexach Trunk Sewer, it appears that the affected segment of the Rexach Trunk Sewer has a diameter of 48 inches.

In summary, the Rexach Trunk Sewer has a diameter of 48 inches when it crosses the CMP and is encased in concrete (approximately of 1.82 x 1.77 meters). The top of the concrete encasement has an elevation of approximately –2.3 meters and an invert elevation of –4.0 meters. Once the trunk sewer crosses the CMP, it connects to a manhole with an overflow structure. This manhole is located just north of the Luna and Prudencio Rivera Martinez Street intersection, from there the sewer continues along the Luna St. until it connects to the San José Trunk Sewer at the intersection of the Pepe Díaz and the Luna Streets. The Rexach Trunk Sewer connects to the San José Trunk Sewer at an invert elevation of –3.97 meters.

Based on the available information, it is estimated that the trunk sewer was constructed between 1961 and 1965. Based on this data, it is estimated that the Rexach Trunk Sewer was constructed over 40 years ago. As part of the CMP-ERP, a flow monitoring study was conducted on a portion of the Rexach Trunk Sewer from March to June 2005. The purpose of the study was to determine the dry weather and wet weather flows conveyed by the Rexach Trunk Sewer just before crossing the channel. The study revealed that at this location, the Rexach Trunk Sewer conveys an average daily flow of 9.4 million gallons per day (mgd) during dry weather and a peak flow of approximately 24 mgd during wet weather. The segment of the trunk sewer that crosses under the CMP is shallow and is located above the bottom of the proposed channel. The crown of the trunk sewer in the channel area is at an elevation of 2.3 meters below MSL and the proposed channel bottom has an elevation of 3.0 meters below MSL. Therefore the portion of the Rexach Trunk Sewer that crosses under the channel needs to be relocated to allow the construction of the proposed channel. Based on the available information, approximately 80 meters (262.5 feet) of 48-inch pipe needs to be relocated prior to the dredging and channeling (ENTECH 2008).

The relocation of the existing 48-inch-diameter Rexach Trunk Sewer will consist of an inverted siphon to provide enough depth to allow the dredging and channelization of the CMP. The project will begin on 13th Street with a new sanitary manhole, which will be installed above the existing 48-inch sanitary trunk sewer, and continues with a new 48-inch sanitary sewer gravity pipe segment until it reaches the new inverted siphon inlet structure. The new inverted siphon will consist of three 36-inch pipes with a concrete protection that will cross 6 feet below the future CMP proposed bottom elevation (–3 meters) and connects to the outlet structure. From the outlet structure the new sanitary trunk sewer will continue with a 48-inch sanitary sewer gravity pipe along Santiago Iglesias Street until Uruguay Street intersection and towards the south through Uruguay Street to connect to the existing 66-inch San José Trunk Sewer on Pepe Díaz Street. Due to the magnitude and depth of the excavations the existing sanitary sewer of these streets will have to be removed and a new vertical parallel sanitary pipe will have to be installed to connect the existing house connections. Several sanitary by-passes will be necessary to divert the existing sanitary flows and allow for the construction of the new Trunk Sewer and replace the affected house connections.

Plan and Profile drawings for the Rexach Trunk Sewer Siphon, as provided by PRASA, are illustrated on Figure 5.13-2. The Rexach Trunk Sewer Siphon crossing will include the installation of the sheet pile walls and dredging of the channel. The typical detail for the channel is a driven cantilevered sheet pile wall, free of tie-backs, wallers and king piles. At the crossing, sheet pile lengths are 30 feet long on the north side of the channel and 40 feet on the south side. Below the channel bottom, the sheets embedment depths are approximately 17 and 27 feet, respectively.

In the vicinity of the pipe crossings, the sheet pile panels will be driven to lesser depths and stopped above the top of the pipes. These shortened sheets will require supplemental support. The means of support may be a combination of king piles installed on either side of the shortened piles, tie-backs with deadmen anchors, thickened sheets, wallers or other methods. It is anticipated that these will be detailed during PED.

5.14.3 Borinquen Water Transmission Line

The Borinquen Water Transmission Line is a 36-inch-diameter pipe that travels from south to north along the Uruguay and Gardel Streets of the Parada 27 community, crosses the CMP, and continues on Argentina Street of the Barrio Obrero-Marina community, as shown in Figure 5.13-3. The transmission line has only 0.91 meter (3 feet) of cover where it crosses the channel. Since the proposed channel depth is approximately 3 meters (10 feet) or more, this segment of the Borinquen Water Transmission Line needs to be relocated prior to the dredging and channeling of the CMP. It is estimated that 80 meters (263 feet) of this pipe need to be relocated to allow for the dredging and channeling of the Martín Peña Channel (ENTECH 2008).

PRASA has commissioned the design of the Borinquen Water Transmission Line relocation, and advance drawings corresponding to 90 percent design completion are finished. The proposed relocation will consist of a siphon of 42-inch-diameter pipe of TR Flex Restrained Joint Ductile Iron Class 250 with standard cement mortar lining recommended for water distribution pipelines. An asphaltic layer will be used for the outside protection and a concrete beam protection will be provided to the complete new pipeline section. Pipe invert on the valve box on Gardel Street will be at a –5.33 meters elevation and the pipe at the Argentina Street box will be at a –4.718 meters elevation.

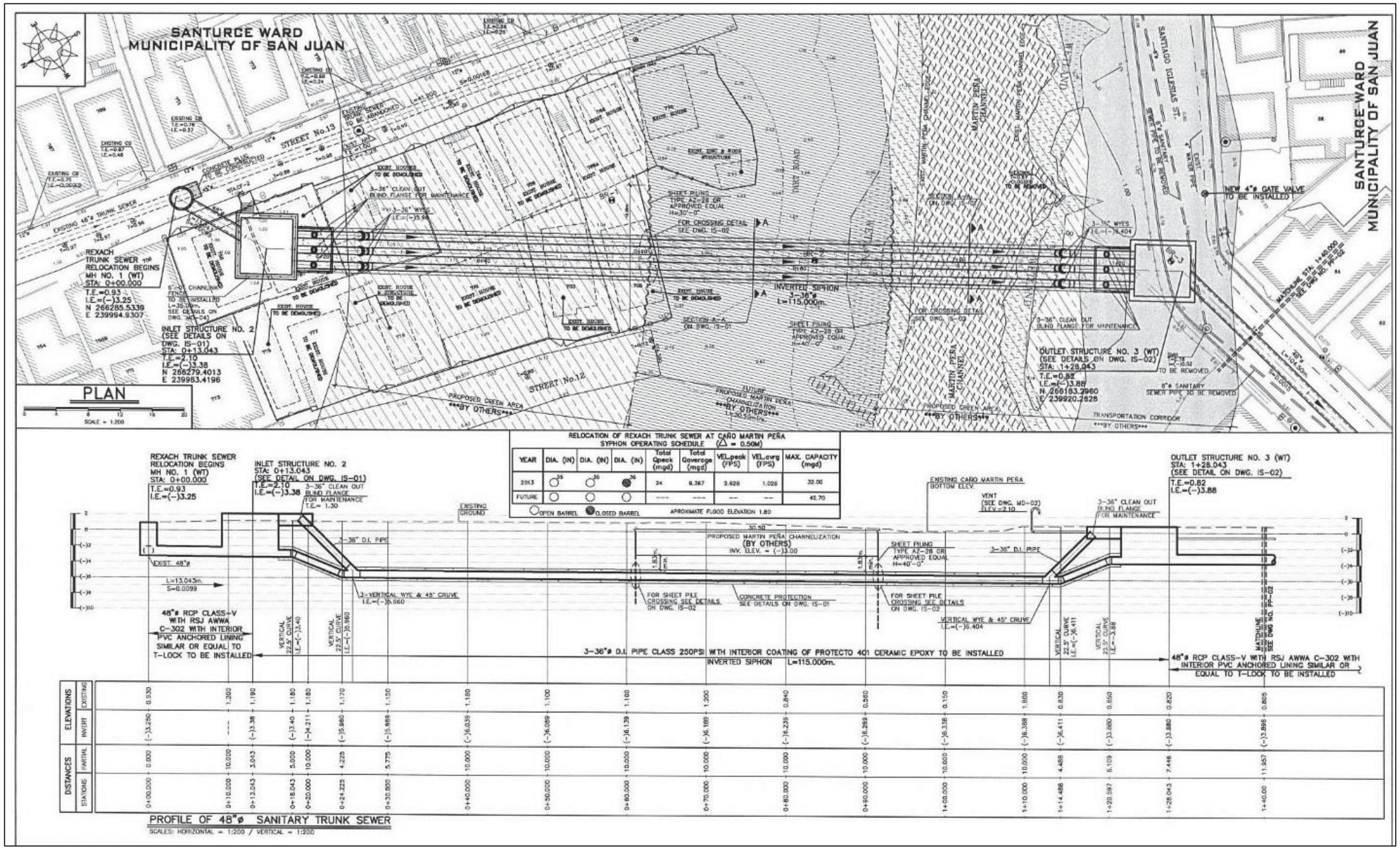


Figure 5.13-2. Rexach Trunk Sewer Siphon

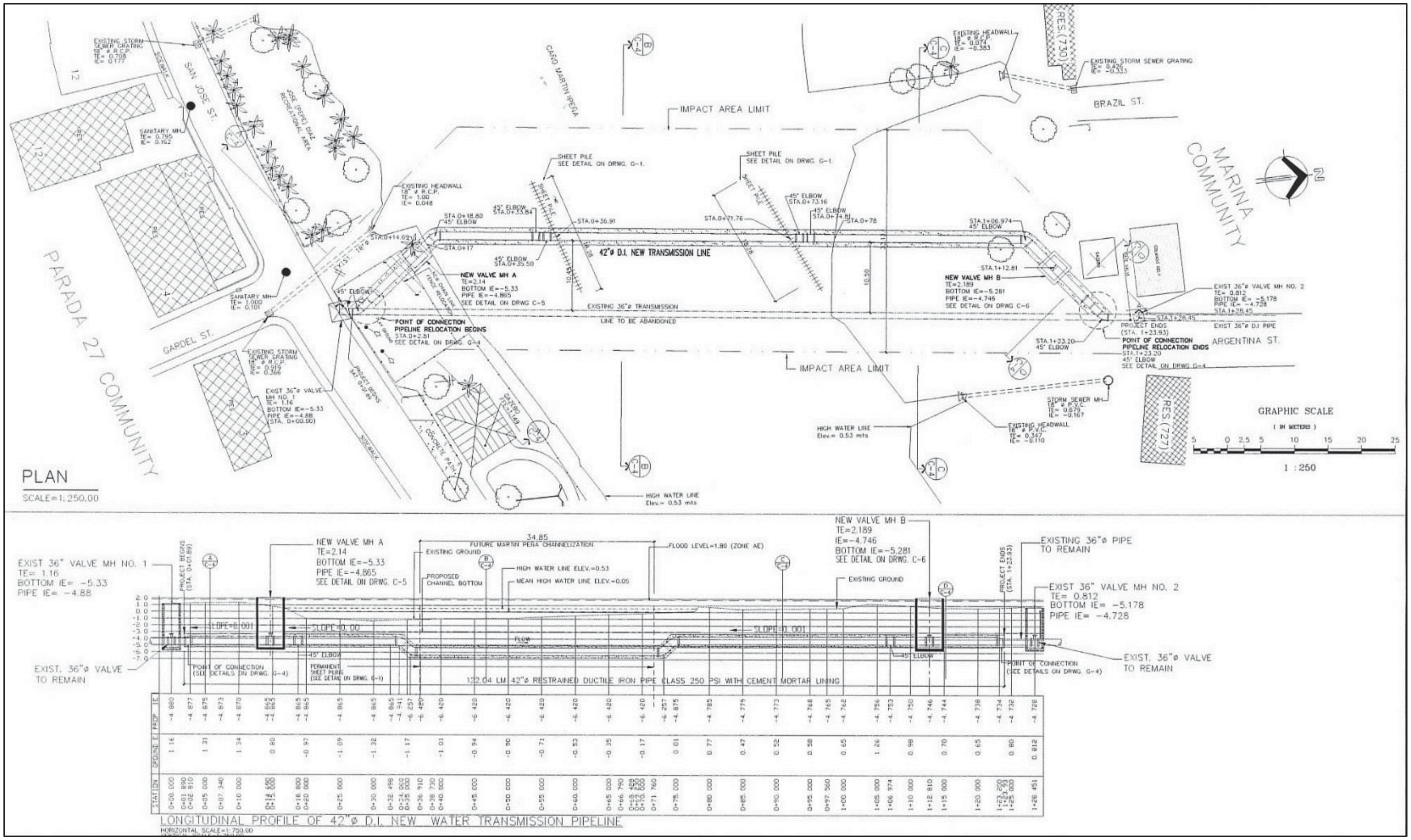


Figure 5.13-3. Borinquen Water Transmission Line

The invert of the new pipeline will be at an approximated depth of 22 feet in order to comply with the required depth proposed on the channel, pipe cover, protection, bedding and safety factors. Across the CMP, approximately at a length of 30.5 meters, the pipeline will be installed at an approximate depth of 22 feet from the current channel bed and at a depth of 6 feet from the proposed dredge channel bed. The connection point for the new pipeline will be performed approximately at these elevations. The design will also require installation of new air release valves which will also be installed on the high point of the new pipeline near or inside the existing valve boxes manholes. On site only one air release valve was observed, at Argentina Street valve box manhole with ½-inch diameter, which is considered not suitable for this pipeline diameter. The connection point for this new pipeline section will be performed before these existing valves.

5.14.4 Community Stormwater

The majority of stormwater flowing towards the CMP-ERP is runoff from the adjacent communities. The runoff arrives at the channel either from overland flow from streets and yards or as discharge from storm sewers. Plans will be needed to make the necessary repairs to these impacted storm pipes and provide a protected channel or piping to a new point of discharge.

Local codes do not require the management of stormwater quantity or quality so all upland stormwater runoff may be discharged directly into the proposed channel. The design concept employs the dispersal of low flow runoff from the community into the mangrove beds, providing opportunities to infiltrate the first flush contaminants. Further treatment is described below.

Future plans call for the construction of a perimeter road, the Paseo del Caño, between the CMP-ERP and the community. This roadway will incorporate new storm sewers to intercept overland flow and the existing storm piping and then direct it into the channel. Construction of the CMP-ERP requires demolition of structures and roadways adjacent to the channel and interruption of the existing stormwater conveyance systems. To accommodate stormwater until the future Paseo is constructed, the CMP-ERP could either do nothing, allowing runoff to flow overland and into the mangrove restoration area or construct a collection system.

Uncontrolled overland flow could result in erosion and loss of upland soils and cause siltation in the mangrove beds, resulting in impacts to the restoration. Silt could also flow into the channel, causing shoaling and accelerating the timeline for maintenance dredging.

Collecting stormwater at the point of discharge and carrying through underground piping to the channel would prevent the erosion and sedimentation impacts described above. The preferred alternative for the CMP-ERP is the construction of a structure within the Public Domain, near its interface with the future Paseo. The structure will be an oil/water/sediment separator. Storm sewer piping interrupted by construction would be extended to the structure. Outflow from the structure would discharge to the channel via a low profile parabolic armored channel. Low flows would be allowed to exfiltrate into the mangrove bed, providing a mix of salt and fresh water to the wetland and helping with filtering of the urban runoff. Larger storm flows would bypass the mangroves and discharge directly into the channel through an opening in the bulkhead. Removal and the proper disposal of the oil, debris and sediments collected in the structure would periodic maintenance. These structures would be constructed as required to facilitate drainage of the new Paseo. For purposes of this study, one at the terminus of every intersecting community street is proposed (figures 5.13-5 and 5.13-6).

5.14.5 Sanitary Sewer Mains

Similar to the storm sewer infrastructure, many of the streets within the demolition limits contain underground sanitary sewer collection piping that will be impacted. The CMP-ERP will remove lengths of piping requiring appropriate plugging at the new terminus and repairs to affected laterals adjoining the CMP-ERP. This work would preferably occur during construction of the new street adjacent to the CMP-ERP to ensure its installation is coordinated with all other underground street improvements. If the street is constructed after the CMP-ERP, the relocations may have to be temporary (Figure 5.13-5).

5.14.6 Water Mains

Water distribution lines dead-ended by demolition should be terminated with blow-offs or hydrants. This method allows for the periodic flushing of the lines to prevent later problems with poor water quality in the dead end lines.

The plan would require termination and relocation of some water lines affected by the channel right-of-way. Water lines in seven unnamed narrow streets on the south bank, east of Barbosa Avenue, in Israel community would be affected. Water lines east of Calle Pachín Marín and West of the Calle D on the south bank, in Hato Rey Ward would require termination and relocation. Water lines for Calle 8, 9, 10, 11, 12, 13, 14, and Calle 15 in Barrio Obrero would be impacted by the channel dredging.

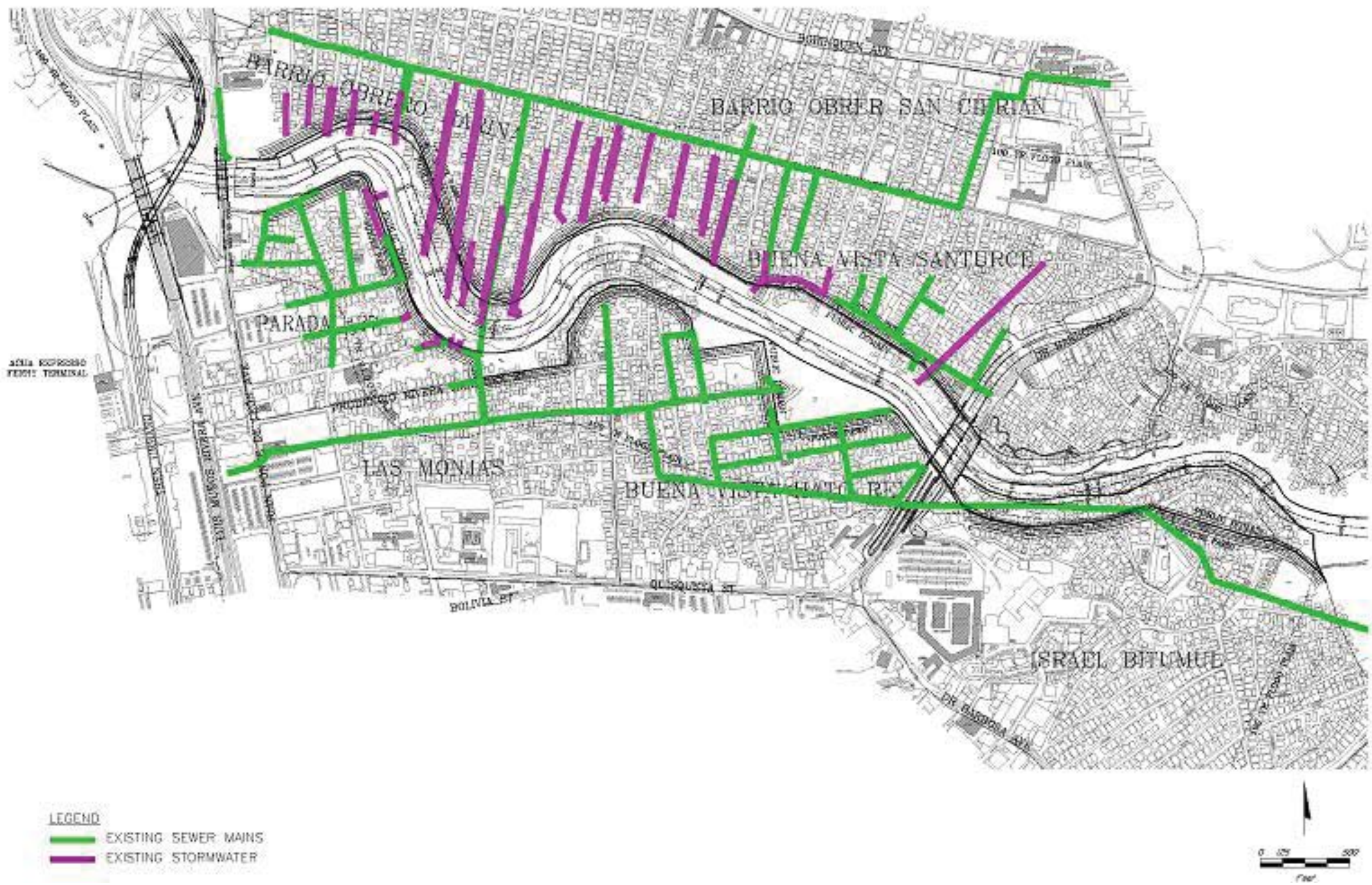


Figure 5.13-4. Existing Sanitary and Storm Sewer

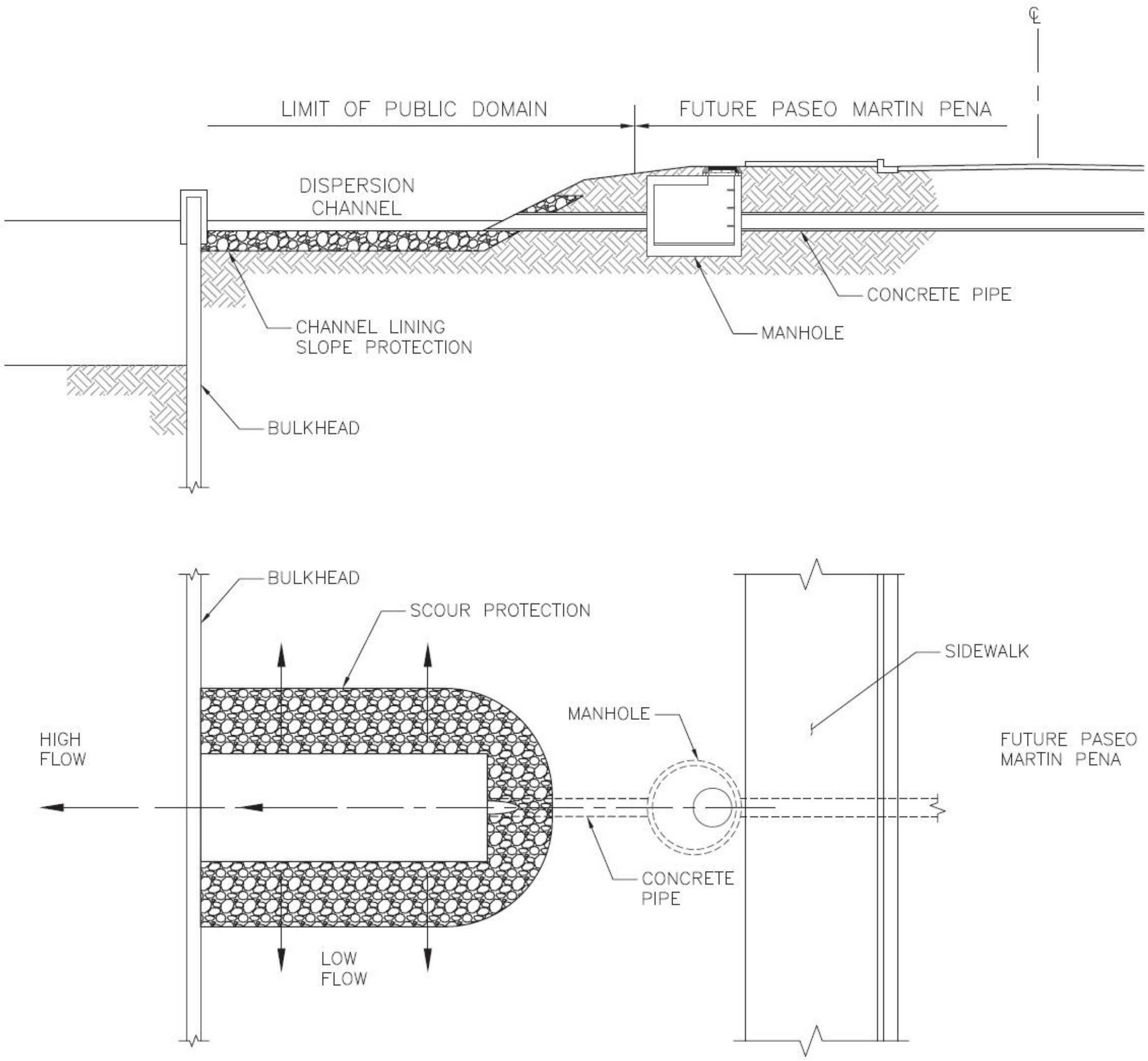


Figure 5.13-5 Storm Sewer Dispersal

This would necessitate termination and relocation of lines affected by the channel right-of-way. As with sanitary sewer, relocations would have to be coordinated with the street construction outside of the CMP-ERP.

5.14.7 115-Kilovolt Electrical Transmission Line and Distribution Lines

UNIPRO prepared the study, "Electrical and Communications Installations Study, ENLACE Caño Martín Peña Project, 2002. Following is a summary of the electrical system taken from the study.

The subject line is a 115-kilovolt (kV) overhead transmission line that runs from a substation near the Tren Urbano guiderail on the western end of the CMP-ERP, east via Rexach Avenue and then south to the channel and San José Lagoon. According to UNIPRO (Electrical and Communications Installations Study, ENLACE Caño Martín Peña Project. the 115-kV line crossing the CMP-ERP channel could be impacted by channel dredging. The support tower on the north bank of the channel, Cantera Peninsula, is close to the channel footprint. Dredging near this tower would require close coordination with the Puerto Rico Electrical and Power Authority (PREPA) and may require soil reinforcement. It was further reported that most of the transmission systems infrastructure is dated and in poor condition and that the entire transmission and distribution system be reconstructed to bring it up to current code (figure 5.13-6 and 5.13-7).

With respect to the current plans and alignment of the CMP-ERP channel, the location of the support tower at the crossing appears to be well outside of the proposed dredging limits and is not likely to pose any problems during construction. Concerns have been expressed that the sag of the power line at the crossing may impede the movement of construction vessels navigating the channel. For this purpose, PREPA as part of Phase 1 of an agreement with ENLACE, completed the construction of new support towers and elevated the power line to a save height that will allow movement of construction vessels.

It is the desire of ENLACE that the other segment of the transmission line be relocated from its present high profile location on Rexach Avenue to a place along the CMP. The preferred location would be underground, within the corridor of the future Paseo del Caño Norte. PREPA has indicated that an underground relocation is not feasible. As a temporary measure, it is desired that it be relocated overhead just inside of the Public Domain Limit (figures 5.13-1 and 5.13-8).

In addition to the transmission line, about 438 residential services require electrical service demolition. Seven unnamed streets on the south bank, east of Barbosa Avenue at Israel Community, Calle 10, 11, 12, 13, and Calle 14 on the north bank at Barrio Obrero, and Calle Pachín Marín, Calle 4, and Calle 5 on the south bank at Hato Rey Ward, have residences also requiring demolition and service termination. Prior to initiating these activities, the affected service lines would be de-energized. Through service lines slated for termination would be relocated first.

Figure 5.13-6. Existing 115-kV Electrical Transmission Lines

Figure 5.13-7. Existing 115-kV Electrical Transmission Lines

Figure 5.13-8. 115-kV Electrical Transmission Line Relocation

5.14.8 Telephone Lines

Services to 438 structures would require demolition. Specifically, seven unnamed streets on the south bank, east of Barbosa Avenue at Israel ward, have multiple residences that would be demolished. Calle 10, 11, 12, 13, and 14 on the north bank at Barrio Obrero, Calle Pachín Marín, Calle 4, and 5 on the south bank at Hato Rey Ward have multiple residences which would be demolished. The services feeding these streets would require termination.

5.14.9 Cable TV Lines

Cable service to about 100 residential services would require demolition. Specifically, Calle 10, 11, 12, 13, and Calle 14 on the north bank at Barrio Obrero, and Calle Pachín Marín, Calle 4, and Calle 5 on the south bank at Hato Rey Ward have multiple residences which would be demolished. The services feeding these fourteen streets would require termination.

5.15 SECONDARY IMPACT PREVENTION

The proposed CMP-ERP will see the restoration of the CMP and provide numerous enhancements to the quality of life for members of the adjoining community. Factors that caused the degradation of the CMP included the following:

- Dumping of solid waste.
- The gradual closure of the channel through dumping activities causing restricted flows needed to maintain water quality and provide an outfall for stormwater.
- Siltation along the channel.
- Domestic sewage discharges into the surface waters.
- Unregulated construction of homes in open areas.
- Unacceptable activities (vandalism, criminal acts and misconduct)

Following is a discussion on each of these activities and why the CMP-ERP would help prevent their recurrence.

5.15.1 Dumping

The habitual dumping of solid waste in the CMP came from the desire to find more land for the construction homes. Many Puerto Ricans migrating from the countryside in search of jobs found themselves with nowhere to live but the lowlands along the waters of the CMP. The filling of the lowlands opened new lands for development. Once a parcel of land was sufficiently raised to allow construction, a home was added; thence, the adjoining lands were filled. The pattern continued until flow in the CMP was severely impeded.

Whereas most of this progression was without a clear plan, the CMP-ERP presents a clearly defined solution. The channel would be defined by steel sheet pile walls. Offset from the channel walls by some distance would be a perimeter roadway with sidewalks. Between the roadway and the channel walls would be a vegetated buffer of mangroves. These contemporary structures would define boundary limits and discourage the perception that these are open dumping grounds. The proposed raised curbs of the future perimeter road and sidewalks, as well as the potential use of bollards, would discourage vehicular access to the vegetated mangrove buffer for dumping of solid waste as well.

5.15.2 The Gradual Closure of the Channel Through Dumping

Given that the purpose of the dumping was to create lands for new home construction, the fact that vehicular access to the channel for dumping would be restricted by the adjoining roadway and sidewalk construction and the fact that solid waste dumped into the rapidly moving waters of the channel would tend to disperse, it is unlikely that dumping activities would continue.

5.15.3 Siltation Along the Channel

Siltation along the channel is the result of overland stormwater flow scouring the disturbed soils of the areas adjoin the channel. The CMP-ERP and the future perimeter roadway would stabilize the adjoining soils. Overland flow would be collected in underground storm sewers and discharged through controlled outfalls into the channel. Consequently, opportunities for soil scouring and transport into the CMP would be minimized.

5.15.4 Domestic sewage discharges into the surface waters

A study entitled "Potable Water and Sanitary Sewer Installations Study, ENLACE Caño Martín Peña Project" was completed in December 2002. Its purpose was to evaluate the communities' existing potable water and sanitary sewer systems within the CMP project and determine how the community systems would be affected by related works of dredging and widening of the CMP. Part of the intent was to determine whether both systems were adequate according to actual and future projected use. In addition, compliance with the Design Norms of the PRWC, Puerto Rico Health Department, and other agencies having jurisdiction would have to be determined. The study concluded that the existing transmission and distribution potable water system as well as the sanitary sewer system had deteriorated, were neither adequate nor reliable, and were not in compliance with standards of the agencies having jurisdiction. Because the sanitary sewer system was combined with the storm water system, the hydraulic capacity of both was reduced, resulting in direct discharges of untreated water to the CMP. Furthermore, a sanitary sewer system was nonexistent in several communities in and around the Project Area.

Much of the developed lands adjoining the CMP do not have the necessary infrastructure to properly collect and convey sewage effluent to treatment facilities. In many cases, sanitary sewer lines also collect stormwater runoff. Storm events overwhelm sewer lines with limited capacities, resulting in the overflow of the combined effluent into the community and the CMP. Some sanitary sewer mains outfall untreated sewage effluent directly into the existing CMP channel.

The adjoining communities have plans proposed with some underway to construct new sanitary sewers to collect and convey effluent to treatment facilities and new storm sewers that would collect runoff and discharge it into the channel. As part of the Comprehensive Development Plan, construction of these improvements would precede completion of the CMP and precede dredging operations. For example, the PRASA is working on a project to separate the combined sewer/ stormwater trunk serving the areas of Hato Rey and Río Piedras into sanitary and storm water sewers. In addition, the San José Trunk Sewer was reinforced in-place and, with the repairs and improvements, would help mitigate sewage discharges that currently affect the Israel-Bitumul community. Another example of a sanitary sewer system project nearby the Project Area is the construction of the Barrio Obrero Marina vacuum sewer system, which is located to the north of the CMP in the adjacent Barrio Obrero Marina community.

5.15.5 Unregulated Construction of Homes in Open Areas

CMP-ERP and community proposals provide clearly defined land uses for the CMP-ERP. The channel is defined by walls; the adjoining mangroves are confined by the channel on one side and the perimeter road along the other. Community parks will be developed within the context of an urban setting with paved edges and durable surfaces. The resulting development would be one of fully occupied, clearly defined spaces leaving no room for the insertion of unregulated home construction.

5.15.6 Unacceptable Activities (Vandalism, Criminal Acts and Misconduct)

One of the best means of discouraging unacceptable activity is to apply the eyes of the community to the public spaces. The CMP-ERP places numerous urban parks throughout the CMP. These public spaces would provide opportunities to view the water and the naturalized mangrove edge and courtyards and seating for the gathering of a few or a group. The perimeter roads include walkways providing promenades the entire length of the CMP-ERP. These improvements would encourage the community to frequent the public spaces and self-police the CMP-ERP.

6.0 DESCRIPTION OF CONSTRUCTION ACTIVITIES

Prior to the commencement of construction activities, all real estate activities would be completed, including the identification of real estate structures and issues, acquisition of structures, relocation of affected residents, and demolition and/or relocation of the structures. Concurrent with this activity would be the execution of agreements with one or more construction contractors to complete the CMP-ERP, typically preceded by a solicitation period to prospective bidders, receipt and review of bid submittals, selection of a successful bid, final negotiations and construction contract award.

Upon giving a Notice to Proceed to the selected contractor(s), the start and completion dates for the construction are finalized. Mobilization and site preparation activities would then commence. Mobilization is the period or periods during which the contractor deploys personnel and equipment to the site. These periods may take place in phases over various times during the construction. These activities would typically include the initial installation of construction fencing, sediment and erosion control devices, and the establishment of staging areas. Staging for the eastern end of the channel would be constructed at the CDRC. Staging for the western bridges would be a floating platform, comprised primarily of barge mounted equipment. The boats, barges, cranes, dredges, grizzlies, and other dredge equipment would be deployed. It is anticipated that equipment to be utilized for the dredging of the eastern channel would be brought in through San José Lagoon, and equipment slated for work under the western bridges would enter via the western branch of the Caño Martín Peña. This work would be performed in close conjunction with the clearing and grubbing activities. Should construction at the western bridges precede the eastern channel, the pits would have to be prepared and dredge equipment deployed overland.

During clearing and grubbing activities, trees, brush, root balls, and grasses would be stripped from the surface. All of the vegetation, sediment, and solid waste within an average of 12 inches throughout the Project Area would then be hauled to the upland landfill for disposal (Humacao). The stripped vegetation, including root balls, sediment, and solid waste evident on the surface and within the 12 inches, would be removed, loaded into trucks, and hauled to the upland landfill. Final adjustments to the construction fencing, sediment and erosion control devices, and staging areas would be completed during this activity. During clearing and grubbing activities, the turbidity curtain(s) would be installed by the SJ pits, and the preparation and dredging of the SJ pits 1/2 would commence.

Upon completion of the above activities, staging areas and driveways for temporary placement of solid waste and dredged sediment from construction of the weir would be constructed near the western portion of the CMP project footprint. Temporary sheet pile dams would be placed to the west of the last of the four western bridges and along segments of low-lying areas along the Project Channel, particularly the bend at Barrio Obrero Marina.

With the completion of the temporary sheet pile dams, the excavation (dredging) and earthwork associated with the Project Channel would begin. Dredging activity would begin on both ends of the Project Channel. On the western end of the Project Channel by the four western bridges, dredging and related activities would take place to install the weir. Tasks associated with the installation of the weir include the preparation of the channel subgrade, placement of geotextile fabric, and the articulated concrete mat. Concurrent with this operation is the placement of scour protection (riprap) around the bridge abutments, bridge pile caps and bridge columns, and along the channel side slopes. At the eastern end of the Project Channel, the 4,300-foot channel from the CMP into the San José Lagoon would be dredged, and dredging activities would take place in the Project Channel, from east to west, eventually connecting with the completed weir by the four western bridges. The equipment utilized for the installation of the weir would be scaled down for working near and under the bridge structures.

During the dredging of the channel, solid waste would be separated from the sediments and hauled by shallow-draft barge to the CDRC, where it would be offloaded onshore and reloaded into trucks for disposal at the upland landfill (Humacao). In the event that construction of the weir begins prior to the eastern channel, all barge related activieis would become overland trucking tasks. The remaining sediments and small pieces of debris would be encapsulated within geotextile fabric bags, moved by shallow-draft barges, and dumped in SJ pit 1 and SJ pit 2. Sediments that slough off the side of the channel would be dredged up and placed upland for use as backfill behind the sheet pile wall. In order to manage stormwater and tidal flows, the work under the bridges, including construction of the weir, must be completed prior to opening of the channel east of the weir.

In addition to the dredging, earthwork activities would be conducted upland of the dredged excavation to shape the surface of the soil along the project boundary and to collect and divert stormwater to a temporary protected outfall into the channel. Earthwork would also involve backfilling behind the sheet pile wall after the concrete wall cap for the sheet pile has been installed.

Following behind the dredging activity in the channel would be a concurrent process to install the sheet pile walls for bank stabilization starting from the east end of the Project Channel. After sufficient length of channel has been dredged, installation of the sheet pile would begin, with further dredging proceeding to the west. The sheet piles would be barged to the site and driven into place. After the wall construction has progressed sufficiently, forming and pouring of the concrete cap would occur, followed by the backfilling of the wall discussed above under earthwork. The wall openings for tidal conveyance to and from the mangrove bed would then be constructed. After the bank stabilization activities have been completed, the mangrove planting beds would be constructed.

Construction of the recreation areas would begin concurrently with the construction of the channel. The recreation component would include the upland recreational structures, paving and landscaping, and the walls and steps that form the interface between the parks and the sheet pile wall of the channel.

Upon notification by the construction contractor that substantial completion has been reached, the work would be inspected by those with oversight of the project. It is possible that the work would be broken into phases with each phase having separate and distinct inspections and close out activities. Work deemed incomplete or not constructed in accordance with the construction contract documents would be documented in the form of a punch list. The contractor would be required to perform the necessary corrective actions to remedy the items on the punch list. Follow-up inspections would be performed to ensure that all punch list items have been completed. Upon completion of the punch list items and delivery by the construction contractor of all documents required for closeout, project acceptance would be issued, ending the construction contract. The following schedule outlines the operational as well as the calendar timeline.

Table 6-1. CMP-ERP Construction Schedule

Dredge/ Disposal Event	Details	Operational Duration (Days)	Operational Start (No. Days From NTP)	Operational Finish (No. Days from NTP)	Calendar Finish Date (Month)
Start Construction		0	0	0	0
Channels and Canals	Mobilization & Site Preparation	150	0	150	5
Channels and Canals	Clearing and Grubbing	213	150	363	13
Channels and Canals	Dredge Excavation and enlarge SJ1 & SJ2 pits	350	163	513	18
Channels and Canals	Dredge, separate solid wastes and haul to Humacao Landfill	520	163	683	23
Channels and Canals	Dredge sediments and place in SJ1 & SJ2 pits	520	163	683	23
Channels and Canals	Upland Excavation and Earthwork	248	193	441	15
Channels and Canals	Install Weir	122	283	405	14
Channels and Canals	Prepare mangrove beds and plant mangroves	90	441	531	189
Recreation	Recreation Structures	720	0	720	24
Bank Stabilization	Sheet Piling	382	283	665	23
Cultural Resource Preservation	Ongoing	810	0	810	27
Complete Construction	Final Inspection, Demob. and Acceptance	90	720	810	27

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7.0 CONCLUSIONS

The Caño Martín Peña consists of two reaches: the eastern CMP within the project area of the CMP-ERP, and the western CMP, which consists of the existing navigation channel linking the AcuaExpreso ferry terminal to the San Juan Harbor. At present, and as a result of siltation and the dumping of solid wastes into its channel, the eastern reach of the CMP conveys very limited flows into and out of San José Lagoon, which in turn, results in little to no tidal exchange between San Juan Bay and San José Lagoon. As a result of the reduced flushing and wastewater loads, water quality within the CMP and San José Lagoon are poor.

Construction of the CMP-ERP includes the dredging of the eastern CMP, installation of a steel sheet pile bulkhead with a concrete cap, the planting of mangroves and other similar wetland species, the relocation of families within the Public Domain Limit, the relocation of community utilities and storm drainage, and the installation of recreation features. Adjacent work planned by others involves the construction of a perimeter road and major utility relocations, and stormwater improvements. The work necessary to construct these improvements must be performed in the immediate proximity of the densely populated communities of the CMP.

This report finds that channel widening and deepening would cause dramatic increases in tidally driven flows through the CMP where little flow existed before, resulting in significant reductions in residence time; the combined effect being a doubling of the benthic index score for the San José Lagoon. The following discussion summarizes the results of this analysis.

7.1 HYDRODYNAMIC MODEL

Ten (10) rectangular channel configurations were initially considered for the CMP Project Channel. Channel widths ranged from 75-foot to 200-foot with depths of either 9 or 15 feet; all with earthen channel bottoms. Existing and proposed channel configurations were modeled using the USACE-approved CH3D-WES model to determine their hydraulic characteristic. CH3D-WES is a 3-dimensional hydrodynamic model that calculates velocity and tidal amplitude based on boundary conditions in the Atlantic Ocean. This model included tidal flow through San Juan Harbor and the La Torrecilla Lagoon and into the San José Lagoon. The model has been shown to adequately describe the hydrodynamic characteristics of the existing condition and proposed channel configurations.

CH3D-WES measures volume in 3-foot depth increments so channel depths modeled were 3, 9, and 15 feet. Later in the report, channel design geometry for the 9-foot depth was increased to 10 feet to account for the more complete removal of solid wastes expected to found at the 10-foot depth. The resulting hydrological responses in the design channels are expected to be minor.

7.1.1 Velocities

Water velocities were calculated by the model for each channel configuration along the top, middle and bottom of the channel. Velocities in each reach are different due to the geometry of the existing or proposed channels. Velocities in the channel are cyclic and out of phase with tidal elevations. High and low tide correspond to zero velocity. The middle of the tide cycle is the highest flow period.

Bottom velocities at the eastern CMP increased from 1.25 fps (existing condition) to 4.22 fps or less (for larger proposed channels). Bottom channel velocities within the eastern CMP channel are a factor of flow and cross sectional areas, with the smallest cross sections producing the highest velocity (4.22 to 3.13 fps for 75 to 200 feet, respectively).

Where the eastern CMP enters the existing western CMP, peak bottom velocities increased from 0.74 fps (existing condition) to 4.49 (proposed channels). At the CMP's outfall into the western channel, bottom velocities are a factor of the volume of flow from the east with higher flows producing higher bottom velocities in the western channel (2.20 to 4.49 fps). These are lower due to the large cross section in this reach. Because of the cyclic nature of the flows, these velocities are only at the highest tide for short periods.

Based on the known geotechnical information, the western channel soils are soft whereas the eastern channel bottom soils are hard. The recommended maximum channel bottom velocities for the eastern and western channels are 3.5 to 4.0 fps and 2.0 to 2.5 fps, respectively, with preference for the lower end of the ranges.

With consideration for the velocity constraints within the eastern CMP, all of the proposed channel cross sections except the 75-x-9-foot channel fall sufficiently below the maximum velocities to permit their use with earthen bottoms. With a paved bottom, the 75-x-9-foot channel could be used as well. For flows entering the existing western channel, only the 75-x-9-foot channel falls within the allowable maximum velocity. All other conditions with greater flows would require a paved bottom and weir at the four western bridges to mimic the cross sectional area of the 75-foot alternative.

7.1.2 Tidal Amplitude

Should the CMP be opened up, there would be an increase in tidal amplitude in San José Lagoon.

7.1.3 Residence Time

Increased tide ranges induce increased flow into and out of the San José Lagoon through the CMP. Residence time is the time necessary to exchange the volume in a body of water. Higher flows reduce residence time. Lower residence times allow for the water body to flush more frequently.

Residence time for each alternative was computed by determining the volume of water exchanged through the CMP and the Suárez Canal and into the San José Lagoon.

Residence time for the San José Lagoon was reduced from an existing condition of 16.9 days to 3.86 days for the 75-foot channel and less for the larger channels. (3.86 to 2.19 days for the 75 to 200-foot channel, respectively).

7.1.4 Benthic Index

A benthic indexing calculation was used as a predictor of water quality responses to changes in hydrology within the CMP and the San José Lagoon. The methodology looked at the benthic community for major portions of the San Juan Bay estuary. The residence times or flushing rates were used to predict Benthic Index scores.

The Benthic Index study ranks the ecological health of San José Lagoon considerably below that of La Torrecilla Lagoon and San Juan Bay proper. With channel widening and deepening, benthic index scores for the San José Lagoon were shown to more than double from existing conditions to the 75-foot-wide channel. As the channel further widened, residence time decreased and benthic index scores increased; however, the benthic uplift achieved by further channel widening above 75 feet was marginal.

7.2 CHANNEL HYDRAULICS AND HYDROLOGY

The 100-year flood zone extends well into the community along either side of the CMP-ERP. The CMP was modeled to include a "plugged condition" considering construction of a temporary dam near the western bridges to control turbidity during dredging. For the 2-, 5-, 10-, 25-, 50-, and 100-year return periods, with and without-storm surge conditions, the 75, 100, and 125 feet wide channels returned water surface elevations lower than the existing condition. The water surface elevations for existing condition without and with-storm surge were 0.0 to 0.98 and 5.9 to 6.33 feet, respectively. Water surface elevations for proposed conditions ranged from 0.0 to 0.49 and 5.9 to 6.23 feet, without and with-storm surge, respectively.

Although construction of the project cannot significantly reduce flooding caused by storm surge or major storm events, it is expected that the project would provide positive outlets not currently present for localized low level stormwater flows from the community. Modeling concludes that the improvements would reduce flooding at the beginning of the storms but not for storm surge conditions.

7.3 WEIR AT THE WESTERN END OF THE EASTERN CMP

As described above, the 75-x-10-foot channel is the only alternative that has a velocity low enough to prevent unacceptable scour in the western CMP. Thus, in order to remain as viable, feasible alternatives, larger channel configurations must include a design component that would reduce water flow at the western end of the eastern CMP consistent with the 75-x-10-foot. The inclusion of a weir would enable the larger channel alternatives to replicate the cross-sectional area of the smaller 75-x-10-foot alternative, and, in turn, maintain the same flow characteristics as the 75-x-10-foot alternative. As a result, the potential for unacceptable scour in the western CMP from larger alternatives would be resolved.

7.3.1 Weir Configuration

Due to potential conflicts with the existing western bridge foundations, placement of a channel under the bridges would require raising its invert elevation. In this case, a 6.5-foot bottom elevation with a 115-foot width has been estimated as an equivalent section forming a submerged broad-crested weir. Since vertical sheet pile walls cannot easily be installed under the bridges, the channel would have sloping rip-rapped sides. The bottom would be armored with articulated concrete mat.

The 75-x-10-foot alternative provides the required velocity reductions for scour protection of the western CMP and for that reason, does not require a weir; however, the weir is included on the 75-x-10-foot alternative as well to raise the channel's invert elevation as it passes under the bridges.

For the 75-x-10-foot alternative, the weir would transition into a paved bottom for the remainder of the project area to protect the eastern reach from unacceptable scouring. For the larger alternatives, the weir would instead transition into an earthen bottom for the remainder of the project area because the greater channel widths result in acceptable flows, and thus prevent scour in the eastern CMP, and preclude the need to incorporate expensive channel bottom paving.

7.3.2 Influence of the weir on channel alternatives

Although the western and eastern CMP channel segments have different cross-sectional areas and bottom elevations, water flow through the CMP is, and would continue to be, restricted by the smallest cross-sectional area. In a riverine system not influenced by tides, water flow would normally be traveling in one direction, and the restricting channel would raise the head upstream from a channel constriction. As this head increases, water flow through the constriction would increase. In case of the CMP, however, water flow is tidal, peaking every 12 hours, and then reversing direction, not permitting large accumulations of flow or head beyond the weir. Head is generated by the standing tidal wave and does not increase with a constriction. Consequently, for larger channel alternatives associated with the CMP-ERP, the geometry of the submerged broad-crested weir would become the control section for the entire reach of the open channel. More specifically, the water flow characteristics of any large channel alternative with the weir would be almost identical as those associated with the smaller 75-x-10-foot alternative.

In light of these considerations, the rationale for retaining larger channel alternative configurations in the analysis would be to control scour in the eastern segment of the CMP without the need for features such as expensive articulated concrete matting, which is required for the 75-x-10-foot alternative because of its high velocities and unacceptable scour. Modeling results demonstrate that larger channel alternatives with earthen bottoms can reduce fixed and/or peak velocities for represented tidal cycles to approximately near or below the maximum for scour.

With respect to benefits derived from the various channel alternatives, the report concludes that there is a significant benefit to the San José Lagoon (based on the benthic index score) once the CMP channel is widened to 75 feet due to tidal amplitude, or volume of water flowing into and out of the lagoon. Increasing channel widths to 100, 125, 150, and 200 feet would progressively result in additional, albeit marginal, benefit as a result of the increased water flows and reduced water residence times; however, as discussed previously, once the weir is included, larger channel alternatives would, in essence, restrict water flow to the level identified for the 75-x-10-foot channel. Accordingly, the benthic uplift in the San José Lagoon resulting from larger alternatives with a weir would remain nearly identical to the uplift identified for the 75-x-10-foot alternative. The benthic index is therefore a straight line at the level indicated for the 75-x-10-foot channel. With NER benefits capped at a near-constant level, cost and other considerations become the main factors in alternative design selection.

7.4 POTENTIAL FOR INDUCED FLOODING DURING AND AFTER CONSTRUCTION

Existing flooding in the vicinity of the Project has been documented at various levels. During community meetings, residents have indicated observations of overflowing storm and sanitary sewers and flooding in streets and low lying areas of the community. FEMA mapping places much of the adjoining community within the 100-year flood plain with a base flood elevation of 5.9 MSL.

Water levels along the CMP are directly influenced by the storm surge at San Juan Bay and San José Lagoon. Hydraulic analysis with storm surge compared the water levels in the channel prior to and during construction. During construction, the channel flow would be plugged. Storms lower than 25-years in return interval had virtually the same surface elevation for the existing and plugged condition. Storms 25 years or greater experienced maximum increases of 0.5 feet for the existing condition and 0.86 feet for the plugged condition. Storm events without storm surge are the ones most affected by the blocking of channel flow with the 100-year event increasing the water surface from 1.28 feet for the existing condition and 3.94 feet for the plugged condition, a change of 2.66 feet.

Modeling indicates that under the proposed condition, that is, after the channel has been constructed, storm surge elevations controls water levels for all return interval rainfall events. During rainfall events without storm surge, water levels are less than the existing condition due to the reestablishment of the direct connection between water levels at CMP, the San Juan Bay and San José Lagoon because standing water levels at CMP would be lower at the beginning of the storm event.

Tidal amplitude within the CMP and the San José Lagoon would increase as a result of construction of the channel. The Lagoon's tide range is expected to increase 1.28 feet, from 0.33 feet preconstruction to 1.61 feet after construction. This represents a 0.64-foot increase to the high spring tide.

The following summarizes the change in tide range and surface elevations as a result of construction of the new channel.

Tide Range at San José Lagoon:

- 1.61 feet post-construction
- 0.33 feet pre-construction
- 1.28 feet greater after construction

Surface Elevation Increase at San José Lagoon:

- 1.28 feet increased tide range
- 1.28 feet / 2 = 0.64 foot increased tide

Furthermore, tidal amplitude decreases from west to east. That is, increases are expected to be higher at the weir than at the San José Lagoon. The 0.64-foot increase is representative of conditions where the channel meets the lagoon. Surface elevations across the lagoon are expected to be somewhat lower. A refined modeling exercise would better delineate tide changes across the Project and the lagoon.

Other changes in surface elevation after construction of the Project are a result of predicted sea level change, currently estimated to rise 2.03 feet over the next 50-year period. These increases would be over and above those caused by increases in tidal amplitude.

The water surface rise could affect extremely low lying structures around the San José Lagoon. Storm sewers from the airport, north of the Suárez Canal, outfall into the Lagoon. The airport has been present for decades and presumably operating prior to the filling of the CMP. The airport is higher than its outfalls and thus could build up a hydraulic head in its conduit to offset these monthly events.

The proposed channel along with its sheet pile walls and adjoining mangrove beds are intended to form the floodway to contain the frequent storm events. In its existing topographic condition are low lying areas with poor drainage due to their low elevations (near mean lower low water) or their lack of adequate receiving channels. As dredging is initiated, water, influenced by the tides and storms, will backflow into the new channel. Without proper controls, structures in these low lying areas may be at risk of adverse impacts from high water events. During PED, a “sequence of events” based upon performance standards, must be established and incorporated into the construction contract documents. The basis for the standards will be that back flowing waters over a specified elevation would be contained within the limits of construction, insured in the form of a suitable protective structure between the channel waters and the adjoining low areas. In most cases, this is anticipated to simply involve grading the upland edge or embankment of the mangrove bed to its final proposed elevations, thereby containing the channel waters. Where this is not feasible due to phasing conflicts or because there is insufficient land to create an embankment, an alternative may include the installation of a temporary sheet pile wall with local select backfill to buttress the structure. These temporary flood protection solutions would remain in place until the proposed sheet pile channel wall and upland embankment is installed. The more suitable alternative would be the flood proofing of the structure or removing it from the affected low lying area.

Earthwork activities involving removal and placement of fill would probably be required for the foundations of the Paseo del Caño roadway. These works would be performed outside of the CMP-ERP footprint, and thus, would not be part of the Federal project. An elevated road could perform as an inland levee, depending on how high or elevated it is finally designed. Thus, it would help control flood waters rising from the dredged channel and its fringing mangroves that would be restored as part of the restoration project, protecting adjacent communities from these floods. However, if the elevation of the Paseo del Caño is higher than that of nearby areas, it could impact adjacent structures and cause runoff waters to pond in low lying areas. This would require additional infrastructure measures to address this potential problem.

Additional hydraulic and hydrologic (H&H) modeling and/or analyses are needed to assist with the completion on preconstruction engineering and design, as described in this Appendix.

7.5 DREDGING AND DREDGED MATERIAL MANAGEMENT

Sediments to be dredged are mostly peat, organic clays, and silts mixed with sludge and solid waste. The release of hydrogen sulfide gas during dredging and earthmoving activities may be problematic, requiring mitigation to prevent harm to workers, residents and sensitive equipment. Dredging operations and the driving of sheet pile may create vibrations harmful to nearby structures and sensitive equipment, requiring monitoring and corrective actions. Existing low clearance bridges, shallow waters, and narrow channels will restrict the use of large dredging equipment.

The "largest preferred" channel configuration identified in the DMMP is the 100-x-10-foot plan (100 feet wide and 10 feet deep). Approximately 10 percent of the total dredged volume is expected to be solid waste. Most of the solid waste is expected to be encountered above the 10-foot depth.

During construction, the channel would be closed ("plugged") to help prevent the flow of sediment laden waters from the CMP-ERP. The preferred dredged material disposal alternative consists of dredging of the sediments from east to west, mechanically excavating the sediments, screening to remove solid waste, encapsulating the sediments in geotextiles, placing the sediments in the SJ1 and SJ2 pits and capping with sand. Solid wastes would be separated from the sediments, transported to the CDRC and hauled to the Humacao landfill. Concurrent with the start of dredging activities in the eastern Project Channel, dredging and construction of the weir would occur at the western end of the Project Channel.

7.6 RECREATIONAL FACILITIES

Proposals for recreation presented in this study were developed as prototypes for purposes of reserving CMP-ERP lands and establishing construction budgets. The proposed Federal recreation plan will consist of nine recreation access areas, six recreation parks with trail and six recreation parks without a trail, as well as the linear park within the CMP-ERP limits.

7.7 UTILITY RELOCATIONS

Major utility relocations include segments of the Rexach Trunk Sewer and the Borinquen Water Transmission line. A portion of the San José Trunk Sewer would be reinforced; however, its relocation would not be conducted as part of the CMP-ERP. The Rexach Trunk Sewer, the Borinquen Water Transmission line, and the 115-kV electrical transmission line would be relocated as part of the CMP-ERP Water, electric, and cable TV service and sanitary sewer collection lines within the demolition limits of the CMP-ERP will require termination and in some cases, relocation.

8.0 REFERENCES

Autoridad de Desperdicios Sólidos (ADS). 2008. “Dynamic Itinerary for Infrastructure CMP-ERPs Public Policy Document.” Prepared by MP Engineers of Puerto Rico, P.S.C. May 2008.

Bachhuber, Jeffrey L., James V. Hengesh, Sean T. Sundermann. Liquifaction Susceptibility of the Bayamón and San Juan Quandrangles, Puerto Rico. U.S. Geological Survey, National Earthquake Hazards Reduction Program, Award 03HQGR0107. January 2008.

Bailey, S.E., P.R. Schroeder, C.E. Ruiz, M.R. Palermo, and B.W. Bunch. 2002. “Design of Contained Aquatic Disposal Pits for CMP San Juan, Puerto Rico.” U.S. Army Engineer Research and Development Center, Vicksburg, MS. December 2002.

Barnes, Harry H. 1967. “Roughness Characteristics of Natural Channels.” U.S. Geological Survey Water Supply Paper 1849. U.S. Govt. Printing Office, Washington, D.C.

Bunch, B. W., Cerco, C. F., Dortch, M. S., Johnson, B. H., and Kim, K. W. Hydrodynamic and Water Quality Model Study of San Juan Bay Estuary, ERDC TR-00-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS. 2000.

Chow, Ven Te. 1959. “Open Channel Hydraulics.” McGraw Hill Book Company, New York.

CMA Architects and Engineers. 2003. “Hydrologic-Hydraulic Study, Caño Martín Peña Rehabilitation CMP-ERP, Puerto Rico Highway and Transportation Authority Dredging of Caño Martín Peña, San Juan, Puerto Rico.” San Juan. PR.

CMA Architects and Engineers. 2003. “Estudio de Instalaciones de Alcantarillado Pluvial.” San Juan. PR.

Das, Braja M.; Southern Illinois University at Carbondale; “Principles of Geotechnical Engineering,” Second Edition; 1990.

ELSEVIER. 2004. Ecological engineering for successful management and restoration of mangrove forests, *Ecological Engineering* 24 (2005) 403–418.

ENTECH/CH Caribe. Enlace Caño Martín Peña, San Juan, Puerto Rico, Preliminary Engineering Report. 2008.

Environmental Protection Agency (EPA). 1982. “Environmental Impact Statement (EIS) for the San Juan Harbor, Puerto Rico Dredged Material Disposal Site Designation.” Prepared by Headquarters, EPA. December 1982.

Environmental Protection Agency (EPA)/U.S. Army Corps of Engineers (USACE). 2010. “Site Management and Monitoring Plan for the San Juan Harbor Puerto Rico Dredged Material Disposal Site (Final Draft).” Prepared by USACE, Jacksonville District and EPA, Region 2. May 12, 2010.

Fagerburg, T. L. San Juan Bay Estuary study: hydrodynamic field data collection. Miscellaneous Paper CHL-98-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 1998.

Federal Emergency Management Agency (FEMA). November 18, 2009. "Flood Insurance Study (FIS), Volume 1of 5," Commonwealth of Puerto Rico.

Federal Highway Administration's (FHWA) Hydraulic Engineering Circular(HEC)-15, Third Edition, 2005 "Design of Roadside Channels with Flexible Linings."

Florida Oceans and Coastal Council. 2009. The effects of climate change on Florida's ocean and coastal resources. A special report to the Florida Energy and Climate Commission and the people of Florida. Tallahassee, FL. 34 pp.

GeoEnviroTech, Inc. 2011. Limited Soil/Sediment Sampling for Ecosystem Restoration of the Caño Martín Peña/Dredging of the Caño Martín Peña Proyect, San Juan, Puerto Rico. June 2011.

HDR Engineering, Inc. Bridges on the Caño Martín Peña San Juan, Puerto Rico: A Reconnaissance Level Conceptual Study and Cost Estimate. Contract Number: DAC17-98-D-0019. December, 1999.

Intergovernmental Panel on Climate Change (IPCC), 2007a. Fourth Assessment Report, Climate Change 2007: Synthesis Report.

———. 2007b. Climate Change 2007 – The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC.

Lewis, III, Roy R. Creation and Restoration of Coastal Communities, Chapter 8, Mangrove Forests, CRC Press, Inc. 1982.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder, 1995. Incidence of adverse biological effects within ranges of chemistry concentrations in marine and estuarine sediments, Environmental Management 19(1):81–97.

Moffatt & Nichol Engineers. 2003. "Caño Martín Peña Waterway Improvements" Final Report. Prepared for UNIPRO Architects, Engineers and Planners, San Juan, Puerto Rico. September 2003.

National Oceanic and Atmospheric Administration (NOAA). 2006. "Precipitation-Frequency Atlas of the United States." National Oceanic and Atmospheric Administration Atlas 14, Washington DC.

———. 2008. "North Coast of Puerto Rico, Nautical Chart No. 25658," U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Coast Survey, Washington, D.C. October 2008.

———. http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9755371 San Juan, PR. Webpage revised on December 9, 2008.

———. http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=9755371 San Juan, PR. Webpage revised on December 9, 2008.

———. http://www.srh.noaa.gov/sju/?n=mean_annual_precipitation. Webpage revised on April 29, 2009.

———. http://www.srh.noaa.gov/sju/?n=tropical02. Webpage revised on September 4, 2009.

———. http://www.srh.noaa.gov/sju/?n=climo_san_juan. Webpage revised on September 28, 2010.

———. http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms. Webpage revised on March 30, 2011.

PBS&J Caribe LLP. 2011. Draft Engineering Appendix Caño Martín Peña Ecosystem Restoration CMP-ERP San Juan, Puerto Rico. A report to Proyecto ENLACE Del Caño Martín Peña. 81 p.

PBS&J. Draft Technical Memorandum, Task 6.0 – Hydrodynamic and Water Quality Modeling Efforts: Caño Martín Peña Ecosystem Restoration CMP-ERP San Juan, Puerto Rico. March 2011.

———. Dredged Material Management Report. April 2011.

———. Recreational Assessment. March 2011.

PBS&J Caribe, LLP. Draft Recreation Resources Assessment: Caño Martín Peña: Ecosystem Restoration CMP-ERP: San Juan, Puerto Rico. Document No. 110014. January 2011.

Pease, M.H., and W.H. Monroe. 1977, Geologic map of the San Juan Quadrangle, Puerto Rico: U.S. Geological Survey Miscellaneous Investigations Map I-1010, scale 1:20,000.

Puerto Rico Climate Change Council (PRCCC) 2013. "Puerto Rico's State of the Climate, Assessing Puerto Rico's Social-Ecological Vulnerabilites in a Changing Climate, 2010–2013.

Puerto Rico Planning Board. 1975. "Normas de Diseño para Sistemas de Alcantarillado Pluvial." Commonwealth of Puerto Rico.

RLDA R. Lopez de Azua and Associate, Caño de Martín Peña Flood Control CMP-ERP, Topographic Bridge, utility and Core Boring Survey, 1996.

Roy F. Weston, Inc. 1997. "Preliminary Site Characterization CMP San Juan, Puerto Rico." August 1997.

San Juan Bay Estuary Program. Plan Integral de Manejoy Conservacion para el Estuario de la Bahia de San Juan. San Juan Bay Estuary Program. San Juan, Puerto Rico. 433 pp. 2000.

Sheng, Y. P. A three-dimensional mathematical model of coastal, estuarine and lake currents using boundary-fitted grid. Report No. 585, A.R.A.P. Group of Titan Research and Technology, Princeton, NJ. 1986.

Singhofen P.J., and L.M. Eaglin. 1995. "ICPR Advanced: User's Manual." Streamline Technologies Inc., Winter Park, FL.

UNIPRO/CMA, Project Enlace of Caño Martín Peña. Study of Installations of Infrastructure of Potable Water and Sanitary Sewer, December 2002.

U.S. Army Corps of Engineers (USACE). Dredging of Caño Martín Peña, Puerto Rico, Final CMP-ERP Design Report and Environmental Impact Statement. Department of the Army, Jacksonville District, Corps of Engineers, Jacksonville, Florida. 1999.

———. 1982. "San Juan Harbor, Puerto Rico, General Design Memorandum, Phase I Reevaluation Report." Revised by USACE, Jacksonville District. March 1982.

———. 1999. "Section 1135, Environmental Restoration Report, La Esperanza Peninsula at Catano, Puerto Rico." Prepared by USACE, Jacksonville District. June 1999.

———. 2001. "Dredging the Caño Martín Peña, CMP-ERP Design Report (PDR) and Environmental Impact Statement (EIS), Appendix B, Geotechnical Investigations. Prepared by USACE, Jacksonville District. March 2001.

———. 2002. "Draft Environmental Assessment, Maintenance Dredging, Graving Dock Turning Basin and Berthing Areas 15 & 16, San Juan Harbor, Puerto Rico." Prepared by USACE, Jacksonville District. August 2002.

———. Engineering Circular No. 1165-2-211. Incorporating Sea-Level Change Considerations in Civil Works Programs. July 2009.

———. Engineering Circular No. 1165-2-212. Incorporating Sea-Level Change Considerations in Civil Works Programs. November 2011.

U.S. Department of Agriculture, Soil Conservation Service. 1986. "Technical Release 55 (Urban Hydrology for Small Watersheds)." Washington D.C.

U.S. Department of Homeland Security, Flood Insurance Rate Map (FIRM), Commonwealth of Puerto Rico and Municipalities, Map Number 720000370J, revised November 18, 2009.

Welcome to Puerto Rico! http://www.topuertorico.org/geogra.shtml. Webpage revised on January 4, 2011.

Westerlink, J.J., R.A. Luettich, A.M. Baptista, N.W. Scheffner, and P. Farrar, P. Tide and storm surge predictions using a finite element model,. Journal of Hydraulic Engineering, Am. Soc. Civil Eng, 118, 1373–90. 1992.

Yoshiura, L.M. and C. Lilyestrom. San José – Torrecillas Lagoon Creel Survey. Final Report from the Commonwealth of Puerto Rico Department of Natural and Environmental Resources. 16.