RIO CULEBRINAS AT AGUADILLA AND AGUADA, PUERTO RICO
SECTION 205
FINAL DETAILED PROJECT REPORT
AND ENVIRONMENTAL ASSESSMENT

APPENDIX A
HYDROLOGY AND HYDRAULICS

RIO CULEBRINAS
AGUADA/AGUADILLA, PUERTO RICO
DETAILED PROJECT REPORT

APPENDIX A
HYDROLOGY AND HYDRAULICS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

I. INTRODUCTION

This appendix presents the basic hydrologic data and analyses used to define the flooding conditions for the Rio Culebrinas Detailed Project Report.

II. DRAINAGE BASIN INFORMATION

A. Location

The Rio Culebrinas basin is located in the northwestern part of the island of Puerto Rico, about 130 kilometers from the City of San Juan. The basin is bordered to the north and east by the Rio Guajataca basin, to the south by the Rio Culebra and Rio Grande de Añasco basins, and to the west by Aguadilla Bay. There are no impounding reservoirs within the river basin. The drainage area of the watershed is about 322.6 square kilometers. Figure A-1 shows where the study area is located in Puerto Rico along with the basin and subbasins of Rio Culebrinas.

B. Topography

The basin is considered a fairly gently sloping basin with elevations ranging from sea level at Aguadilla Bay, to over 300 meters near Juncal, at the basin divide between Rio Culebrinas and Rio Guajataca. A prominent feature of the basin is a 100-meter high limestone escarpment that extends along its northern boundary.

C. Geology, Soils and Vegetation

The principal soil associations found in the Rio Culebrinas watershed area are the Voladora-Moca, Colinas-Soler, Caguabo-Mucara, and the Consumo-Humatas, in the uplands and the Coloso-Toa and Bejucos-Jobos in the lower flood plain. These soils are mostly of the D type with a high runoff potential. Type B soils with moderate degree of drainage potential are also found in this basin. The flood plain is composed of alluvial deposits of sands silts, clays and gravels of various sizes.

The forest and pasture areas are located in the eastern hilly part of the watershed and the urban area is located near the ocean. Land use within the flood prone area is urban with commercial and light industrial areas.

D. Climate

The climate in this area is characteristically tropical. Mean annual temperature in this region varies from approximately 21 degrees centigrade to 26 degrees centigrade. Mean annual precipitation for the region varies from 115 to 205 centimeters. The annual pattern of rainfall in the basin is such that the wettest period of the year is the hurricane season, which occurs in the latter part of the summer and the early part of fall.

E. Main Streams and Tributaries

The Rio Culebrinas originates in the western part of the Cordillera Central (the central mountain range of Puerto Rico) at an elevation of about 300 meters above mean sea level and flows in a westerly direction through the towns of San Sebastian and Moca to discharge into the Aguadilla Bay. The major tributaries for Rio Culebrinas are Rio Guatemala, Rio Cano, Rio Sonador and Quebrada Grande. The total length of Rio Culebrinas is about 44 kilometers.

The Cano Madre Vieja is a distributary of Rio Culebrinas and is about 2.1 kilometers long. This is an old river outlet that flows across the study area and discharges into the Aguadilla Bay. This small intermittent stream is the boundary dividing the municipality of Aguadilla to the east from the community of Espinar to the west.

F. Available Hydrologic Data

The US Geological Survey (USGS), in cooperation with local and other federal agencies, collects and maintains a large amount of water resources data in Puerto Rico. There is one USGS gage recording peak flows and/or peak stages in Rio Culebrinas. This USGS gaging station numbered 50147800 is located at PR Hwy 404 near Moca, Puerto Rico. Approximate location is shown in Figure A-1.

G. Historical Floods

Since the turn of the century there have been at least 38 damaging floods in the Rio Culebrinas Basin. The largest flood of record occurred on September 16, 1975. This flood had an estimated recurrence interval of approximately 25 years. The discharge associated with this flood was estimated at 1,954 cubic meters per second (cms) and stages just downstream of PR Hwy 2 were 7.2

meters, mean sea level (msl), about 3.2 meters of water depth.

The most outstanding recent floods in the Aguadilla area for which stream gaging station records exceeded 850 cms were those which occurred during October 1972, May 1980, October 1981, May 1985, May 1986 and August 1988. There are twenty-three other large floods in the Rio Culebrinas for which records at the stream gaging station exceeded 566 cms. These are indicated in Table A-1.

H. Flood Flow Frequency Analysis

A log-Pearson Type III frequency analysis was performed on the 35-years of annual peak discharge data listed in Table A-1. The US Army Corps of Engineers computer program Flood Frequency Analysis (FFA) was used for the analysis. The estimated discharge-frequency curve is shown in Figure A-4 along with the expected probability adjustments. The plotting positions of the discharge data are included in the figure for comparison. The frequency curves corresponding to the 5% and the 95% confidence limits are also shown in Figure A-4.

I. Rainfall

The National Weather Service (NWS) operates several rain gages in Puerto Rico. The NWS Technical Paper No. 42 (TP-42) shows generalized estimates of the Probable Maximum Precipitation (PMP) and rainfall depth-frequency data for Puerto Rico and the US Virgin Islands. Contained in the report are isopluvial maps of precipitation contours for selected frequencies. The maps indicate rainfall increases toward the central mountain region of Puerto Rico. Point rainfalls representing Rio Culebrinas basin were obtained from TP-42 and are listed in Table A-2.

The Standard Project Storm (SPS) is defined as the most severe flood-producing rainfall depth-area-duration relationship and the isohyetal pattern of any storm that is considered reasonably characteristic of the region.

The PMP is defined as the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year. The SPS was assumed to be 50 percent of the PMP.

III. HYDROLOGIC ANALYSIS

A. Computer Programs

The US Army Corps of Engineers HEC-1 computer program was used to calculate the flood hydrographs for various sub-basins. The HEC-1 estimates surface runoff resulting from synthetic or observed storm events. Several choices of estimating the rainfall-runoff relationships are available in HEC-1. The Soil Conservation Service (SCS) runoff curve number methodology was selected for the Rio Culebrinas basin. Runoff curve numbers are functions of soil types, land uses and Antecedent Moisture Conditions (AMC).

Flood routings were performed for the Rio Culebrinas by the Hydrologic Engineering Center computer program entitled UNET. The UNET is a one-dimensional unsteady flow model that can simulate dendritic and network (looped) system.

B. Formation of HEC-1 and UNET Models

1. Drainage Area

Available USGS quadrangle maps on a scale of 1 to 20,000 were used to delineate drainage boundaries for the Rio Culebrinas basin. Surveys collected in February and March 1995 were also used. The watershed was divided into 30 sub-basins as shown in Figure A-1.

2. Curve Numbers

Runoff curve numbers were estimated for each sub-basin by considering soil types, land uses, and the AMC, appropriate for the rainfall frequency events. AMC I conditions were used for 50, 20, and 10 percent chance flood; AMC II conditions for 4 and 2 percent chance floods; AMC III conditions were adopted for 1 percent and events rarer than 1 percent. Estimated curve numbers for various sub-basins and AMC conditions are listed in Table A-3.

3. Lag Times

The lag times were computed for each sub-basin by dividing each stream into several reaches and applying the following formula:

$$L = \frac{X^{0.8} * (S+1)^{0.7}}{1900 * Y^{0.5}}$$

where

L = Lag in hours

X = Hydraulic length of watershed in feet

S = (1000/Curve Number) - 10

Y = Average watershed land slope in percent

4. Rainfall

The TP-42 point rainfall data for various durations were adjusted for the drainage area of the entire basin by HEC-1. Necessary corrections were also made to convert partial duration to equivalent annual series rainfall. Balanced storms were then generated by HEC-1 for various frequencies. Calculations were performed at 5-minute intervals.

5. Flood Routings

A UNET model was used in combination with HEC-1 generated sub-basin hydrographs for flood routing through the Rio Culebrinas valley. Cross section data were taken from surveys and available USGS quadrangle maps. Manning's roughness values and other loss coefficients were initially estimated and calibrated to historical events documented in the USGS flood atlas.

6. Discharge for Existing Conditions with Future Land Uses

The peak discharge-frequency data estimated by the HEC-1/UNET model along Rio Culebrinas and at the mouth of Cano Madre Vieja are listed in Table A-4. A flood hydrograph estimated for 24-hour storm for the 100-year event at the mouth of Rio Culebrinas and the mouth of Cano Madre Vieja are plotted in Figure A-2 and Figure A-3, respectively.

C. Hydrology of Interior Flooding

This analysis addresses the management of interior surface runoff from areas that are protected by project levees, reflecting future conditions development. Culvert outlet structures that allow for drainage of the interior areas to Cano Madre Vieja are provided through each levee segment. US Army Corps of Engineers Hydrologic Engineering Center Interior Flood Hydrology (HEC-IFH) Package was used for the analysis of the interior flooding hydrology.

HEC-IFH is a comprehensive computer program that performs all of the components of an interior flooding analysis. It is a framework on which the analyst can model rainfall-runoff, routing, interior ponding, and gravity outlet performance, as a dynamic, interactive simulation that includes changing flood conditions in the receiving stream. For this study, interior area flood elevation-frequency relationships were determined for various alternative gravity outlet configurations by using design storm event analysis in combination with interior area runoff parameters that reflect future conditions development. The resulting runoff was routed through existing interior ponding areas adjacent to the project levees, and then through gravity outlet culvert structures draining to Cano Madre Vieja. Coincident exterior flood stage 10-year hydrograph for the with-project condition was used for the tailwater boundary condition affecting each culvert.

No minimum facilities for interior drainage were identified in the pre-project condition. Existing conditions flood stages were used to define minimum gravity outlet facilities that would drain the protected areas before those stages were exceeded. Hydraulic design data for interior drainage structures are listed in Table A-8. Interior flood hydrology data and residual flood elevations are presented in Table A-11 and Table A-12, respectively.

D. Other Sources of Flooding

The detailed study area can also be flooded by hurricane tides from the ocean. Tidal flooding effects were not considered in the analysis. Tidal flood protection was not within the scope of the riverine protection project.

IV. HYDRAULICS

A. Existing Conditions

1. Hydraulic Model

Hydraulic modeling of existing conditions flood stages and post project stages were complied by using UNET.

From the upstream side of PR Hwy 2 to the coastline the area was divided into three reaches. Once floodwaters pass the PR Hwy 2 crossing, the overbank flow is divided between the outlets of Cano Madre Vieja and Rio Culebrinas. Reach 1 was identified upstream of PR Hwy 2. Reach 2 went from PR Hwy 2 to the mouth of Rio Culebrinas and Reach 3 went from PR Hwy 2 to the mouth of Cano Madre Vieja. A rating curve was used between Rio Culebrinas and Cano Madre Vieja. This rating curve is shown in Figure A-5.

2. Survey Data

The Rio Culebrinas area was surveyed in February and March 1995. Detailed topographic maps were prepared to a scale of 1 to 2,000 with a .5-meter contour interval. Detailed information of the bridges and culverts were obtained from the surveyor's field books. A site visit to the area in August 1995 also helped verify the topographic information on the maps. All elevations are referenced to the National Geodetic Vertical Datum (NGVD). The horizontal and vertical datums are referenced to the North American Datum of 1983 and 1929, respectively.

3. Roughness Coefficients

A Manning's roughness value of 0.10 was used for the overbank areas of the flow way, while a value of 0.035 was used for the channel sections. These values were based on aerial photographs, site inspection and engineering judgment.

4. Starting Conditions

Stage-discharge curves at the first cross section were computed using both normal depth and critical depth analyses. A high tide level of 0.6 meters was assumed in the Aguadilla Bay. The stage-discharge curve corresponding to the normal depth analysis was chosen for this study based on the high water elevations listed in Hydrologic Investigations Atlas HA-457 which discusses the flood of November 27, 1968 and shows the limits of that flood delineated for the Aguada/Aguadilla area.

5. Model Verification

A flood atlas prepared by the USGS for the flood of November 27, 1968 that affected the Aguada/Aguadilla area showed high water marks and estimated flood stage contours. The USGS gage station 50147800 at PR Highway 404 recorded an estimated discharge of 850 cms. From Figure A-4 this would be less than a 10-year event.

6. Flood Stages

The existing conditions flood stages were simulated by the HEC-1 and UNET models developed for the basin. Table A-6 shows the water surface elevations under existing and with project conditions in the study area. Plate A-1 shows the flooded area for the 5 and 100-year events under existing conditions.

B. Sediment Assessment

1. Existing Conditions

Computer modeling of the existing flood plain showed that most flood flow is conveyed through the overbank areas of the floodplain. The existing channel is small and is overtopped by storms events with a 50% chance of exceedance (1 in 2-years frequency). The existing natural dominant discharge channel is very small relative to the conveyance required at design storm rates. Base flow in the existing channel is small.

Tropical and farm vegetation covers most of the floodplain and reduces sediment potential. Soils in the floodplain are a mixture of course sand, silt and clay with tropical vegetation as ground cover.

2. With Project Conditions

The average channel velocity during a 100-year event in Rio Culebrinas would range between .75 and 6.60 meters per second (mps). For Cano Madre Vieja the average channel velocity would range between .6 and 3.33 mps. Higher velocities would be expected near the bridges. The short duration of higher velocity flows and erosion resistant nature of the channel soil type should resist large erosion related sediment movement within the channel.

The average overbank velocity along Rio Culebrinas would range between .2 and 3.75 mps. For Cano Madre Vieja the average overbank velocity would range between .46 and 2.21 mps. Vegetative cover and soil type should resist sediment movement under proposed conditions.

Sediment transport in the floodway is not expected to increase or decrease due to this project. The proposed levees would not significantly alter the current sedimentation regime within the basin.

V. HYDRAULIC DESIGNS

A. Hydraulic Design Criteria

Hydraulic design criteria and procedures used herein are in accordance with standard engineering practice and applicable provisions of Corps Engineering Manuals and the Waterways Experimental Station "Hydraulic Design Criteria" relative to design and construction of Civil Works Projects. Engineering criteria adopted to meet special local conditions are in accordance with that previously approved for similar projects.

B. Design Objective

The main flood control feature for this study consists of two levee segments and a levee spur designed for a 100-year level of protection. Each levee segment will be provided with drainage structures and all levees will have an interior drainage channel. Road ramps will be provided where the proposed levees intersect existing roads. A cutoff channel will also be provided since one of the proposed levees segments would intersect Cano Madre Vieja.

C. Levees

The 100-year level of protection with the proposed levee alignment was determined to be the most beneficial alternative. The existing condition UNET model was modified to represent the with project conditions by terminating cross sections at stations which would cross the proposed levee alignment. Plate A-2 shows the recommended plan. The two levee segments are identified as the Aguadilla levee and the Espinar levee with a levee spur.

1. Aguadilla Levee

This proposed levee segment starts at the coastline and ends at PR Hwy 2. It is approximately 1,836 meters long and has an average levee height of about 2.60 meters. There will be three drainage structures and two road ramps for this levee segment. An interior drainage channel would be required along the protected side of the levee. A culvert will be provided where the road ramps intersects the interior drainage channel. An existing concrete box culvert over Cano Madre Vieja would be impacted by one of the road ramps. This box culvert will be extended to accommodate the proposed road ramp. Plate A-2 shows the layout of the Aguadilla levee. Plate A-4 is a profile of the Aguadilla levee with the design water surface profile.

2. Espinar Levee

This proposed levee segment starts at the edge of the coastal barrier zone and ties into high grounds south of the community of Espinar. It is approximately 1,496 meters long and has an average levee height of about 2.49 meters. There will be one drainage structure through this levee and a road ramp would also be required. An interior drainage channel would be required along the protected side of the levee. A culvert will be provided where the road ramp intersects the interior drainage channel. The Espinar levee will also have a levee spur. The Espinar levee spur starts from Espinar levee Station 2+10 and ties into high grounds north of the community of Espinar. Plate A-2 shows the layout of the Espinar levee and connecting levee spur. Plates A-5 and A-6 are profiles of the Espinar levee and Espinar levee spur with the design water surface profile, respectively.

3. Side Slopes

Side slopes of the proposed levees were based on existing soil conditions, type of material used in construction and a stability analysis. The levee side slopes on the flood side and protected side would be 1 vertical to 2.5 horizontal.

4. Levee Crest Elevations

The levee crest elevations were determined by selecting the highest profile that resulted from a worst case scenario. The 100-year water surface profile was computed with the following combinations:

a. Design discharge with the design "n" values
b. Design discharge with 20 percent increased "n" values.
c. 20 percent increased discharge hygrograph with design "n" values.

Bridge openings were reduced by 20 percent to account for debris accumulations. The 100-year water surface profile computed with a 20 percent increased discharge is slightly higher than the other profile and it was selected as the minimum levee grade.

Wave heights, periods, and durations caused by several wind speeds were computed by a shallow water wave forcasting model "SHALWAVE" described in the Coastal Engineering Research Center Instruction Report 86-2. Wave runup and wind setup calculations were performed using the Shore Protection Manual and are listed in Table A-5. A smooth levee surface was assumed in the calculations.

The 100-year levee crest elevation for the Aguadilla levee and the Espinar levee with the levee spur are presented in Table A-7.

5. Levee Overtopping Analysis

An overtopping analysis was performed on the Rio Culebrinas according to ETL 1110-2-299 dated 22 August 1986. The levees were evaluated as one system and an overtopping reach was identified for each levee segment. Overtopping water surface profiles were computed by considering the uncertainties in "n" values, bridge openings, discharge hydrographs and wind speeds.

For the Aguadilla and Espinar levees the overtopping reach is located between corresponding levee stations 0+00 and 0+50. Each overtopping reach was identified as the least critical site where initial failure would occur during severe floods. The least amount of damage in the region would be sustained if initial levee overtopping occurred at this location. Superiority is provided to insure overtopping at the proposed reach. The overtopping reach is 50 meters long and would be given 1 foot of superiority less than the remainder of the levee segment.

6. Reliability Analysis of the Selected Levees

This study was granted a waiver from doing a full risk analysis. However, a reliability analysis to determine probability of stage non-exceedance was conducted. The risk analysis computer program, available from the Hydrologic Engineering Center (HEC), was used for the reliability analysis. This analysis was conducted following ER 1105-2-101 to determine the reliability of the selected levees. Cross section 1568 was selected for this analysis, which takes into consideration the uncertainty in discharge-frequencies, stage-discharges, and cross section data. Five thousand interations were made with Latin Hypercube sampling method to determine the reliability.

The discharge-frequency data required for the reliability analysis were taken from the results of the UNET analysis. The logarithmic mean, standard deviation, and skew were determined, as per the Water Resources Council Bulletin 17B, from 1 percent, 10 percent and 50 percent chance flood events.

The stage-discharge rating curve was developed for the design "n" values from the UNET analysis. Water surface profiles were computed for possible high and low "n" values. A minimum standard deviation of 0.274 meter was required as per Table A-3 of the EC 1105-2-205.

Input data and results of the reliability analysis of the proposed levees at cross section 1568 for the SPF, 1 percent and 2 percent flood events are shown in Table A-13.

D. Channels

1. Cutoff Channel

The proposed Aguadilla Levee would intersect Cano Madre Vieja at various locations. In order to continue the flow in Cano Madre Vieja to the coastline a cutoff channel would be required. The conveyance capacity of this cutoff channel would be the same as in the existing Cano Madre Vieja channel. Hydraulic design data for the cutoff channel are shown in Table A-10.

2. Interior Drainage Channels

An interior drainage channel would be provided along the protected side of each levee segment and along the Espinar levee spur. Hydraulic design data for the interior drainage channels are provided in Table A-9.

E. Drainage Structures

There will be a total of four drainage structures as part of the recommended plan. The Aguadilla levee will have three drainage structures and the Espinar levee will have one drainage structure. The culverts at each drainage structure consist of corrugated metal pipes (CMP) with a bituminous coating and each culvert will have a flap gate on the levee flood side. Hydraulic design data of the drainage structures are indicated in Table A-8. Locations of the proposed drainage structures are shown on Plate A-2. The following describes each drainage structure:

1. Aguadilla Levee

a. AL-S-1

The drainage structure at Aguadilla levee station 1+39.5 consists of three-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 15 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

b. AL-S-2

The drainage structure at Aguadilla levee station 6+05.5 consists of six-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 19 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

c. AL-S-3

The drainage structure at Aguadilla levee station 10+52.9 consists of three-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 20 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

2. Espinar Levee

a. EL-S-1a

The drainage structure at Espinar levee station 2+50 consists of two-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 27 meters. The two-1.52 meter diameter culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

F. Road Ramps

Road ramps would be required where PR Hwy 418 and PR Hwy 115 intersects the proposed Aguadilla levee. Another road ramp would be required where PR Hwy 442 intersects the proposed Espinar Levee. A .91 meter diameter CMP would be provided where each road ramp intersects the interior drainage channel. Hydraulic design data for the interior drainage channels is shown in Table A-9.

The proposed road ramp at PR Hwy 418 would impact an existing concrete box culvert at Cano Madre Vieja. This culvert would be extended to accommodate the flood side of this road ramp.

G. Borrow Area

For this project there will be one source for borrow material. However, suitable excavated material from the construction of the drainage structures, the interior drainage channels and the cutoff channel could also be used for the construction of the proposed levees. The proposed borrow area does not impact the drainage of the existing floodway. The location of the borrow area is indicated in the Geotechnical Appendix, Plate B-2.

H. Performance

1. Levee Design Protection

Design discharge water surface elevations within the floodway up to and including the 1% chance flood will be prevented from overtopping the levees. Events that exceed the design capacity are rare but could occur. In the event of a flood greater than design discharges overtopping of one or both levees could occur. Each levee would be provided with a 50 meter long overtopping segment with a lower levee crest elevation. Paragraph C.5. provides a description of that design. Overtopping flows would discharge to an undeveloped area. These overtopping reaches were selected to minimize damage and provide warning that a design event has been exceeded.

2. Residual Flooding

Runoff from the protected side of the levees would collect in designated residual areas and discharge to the flood plain through culverts. The culverts at the drainage structures would be fitted with flap gate controls that would prohibit flow from the flood plain into the protected area. Analyses of various rainfall and flood events were compiled to determine the extent of residual flooding in those areas. Plate A-3 indicates the extent of the area flooded due to the 1% chance flood event in the floodway and a 10% chance flood event in the protected areas. The residual flooded areas are an essential part of the interior drainage plan for each levee segment.

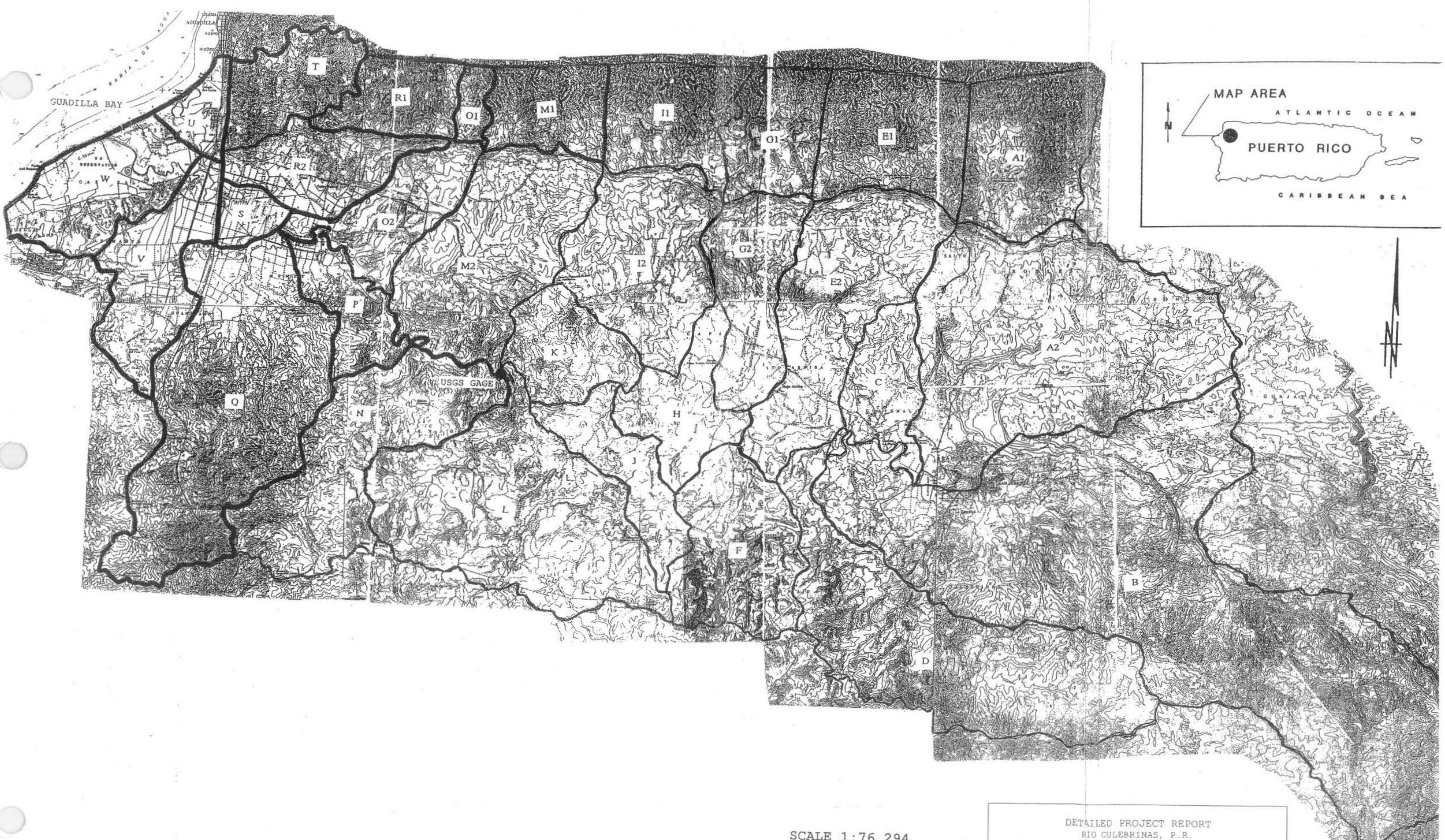
The residual flooded area shown on plate A-3 was based on analyses of design rainfall levels applied to the sub-basin upstream of the levee. The rainfall runoff was routed through the sub-basin to the levee site. Runoff reaching the levee would be conveyed thorough the levee and to the floodplain by outlet structures. The size of the outlet structure is designed to drain water trapped behind the levee as quickly as possible. The structures are unusually fitted with gates that automatically close in the event that the stage in the floodplain exceeds the stage behind the levee. This prevents backflow through the inlet structure when stages in the floodway are higher than stages upstream of the levee. However, discharge to the floodway is terminated and all flow entering the area behind the levee is effectively trapped until the gates open. The trapped floodwater is called residual flooding and is a direct function of that volume of the trapped water. The area covered by trapped floodwater is called the residual flooded area.

The shaded area shown on plate A-3 represents lands that would be inundated under the existing geometry of the area. Should it become necessary or desirable for the sponsor to utilize all or part of the lands designated as the residual flooded area, the area must be studied and reevaluated. Changes in the geometry of the residual flooded area shown in the report will have a direct effect on the predicted residual flood stages, and surface area of the residual flooded area. If the originally predicted stage or land area designated for flood retention cannot be changed, engineering analyses must be performed to determine alternative means to contain the predicted flood volume without damage to adjacent properties. Measures could include larger outlet structure capacity, construction of a pump station to augment the design outlet structures, or excavation within the remaining residual flooded area to contain the design volume of floodwater at the design stage for the original residual flooded area.

3. People at Risk

Events are of a "flashflood" nature with little time available for warning people in the area. Overtopping would first occur at a designated segment of levee. Overtopping flow at the Aguadilla levee would discharge into a residual flooded area and convey along a interior drainage channel that will be connected with the other drainage structures. Overtopping flow at the Espinar levee would discharge into an uninhabited area. Peak discharges for the Rio Culebrinas basin occur within 7 hours after initial rainfall and last only about 30 minutes. Therefore overtopping is expected to be brief. However, initial water velocities as a result of overtopping could be high until the tailwater stage increase. At the north end of the Espinar levee floodwaters would flank the levee and reach the western side of the community of Espinar. Residual flooding related to a 10-year event would also impact the protected side of the community of Espinar. Plate A-3 shows the interior flooded areas for the 10-year event.

If development and/or fill were placed within the interior flooded areas the design volume of water will be displaced and the interior stage would increase. This stage increase would be above the damage elevation used for the interior drainage analysis and damages within the protected area would start to occur. Residual flooded areas are waters trapped within a protected area when the flapgates at the drainage structures are closed during a flood event. This is a design volume of water that reaches a computed stage and this stage is related to a specific rainfall event as determined from an interior drainage analysis. Residual flooded areas are needed so that the interior drainage would function as designed.



SCALE 1:76,294

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RIO CULEBRINAS, P.R.
FIGURE A-1
LOCATION MAP WITH
BASIN AND SUB-BASINS
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

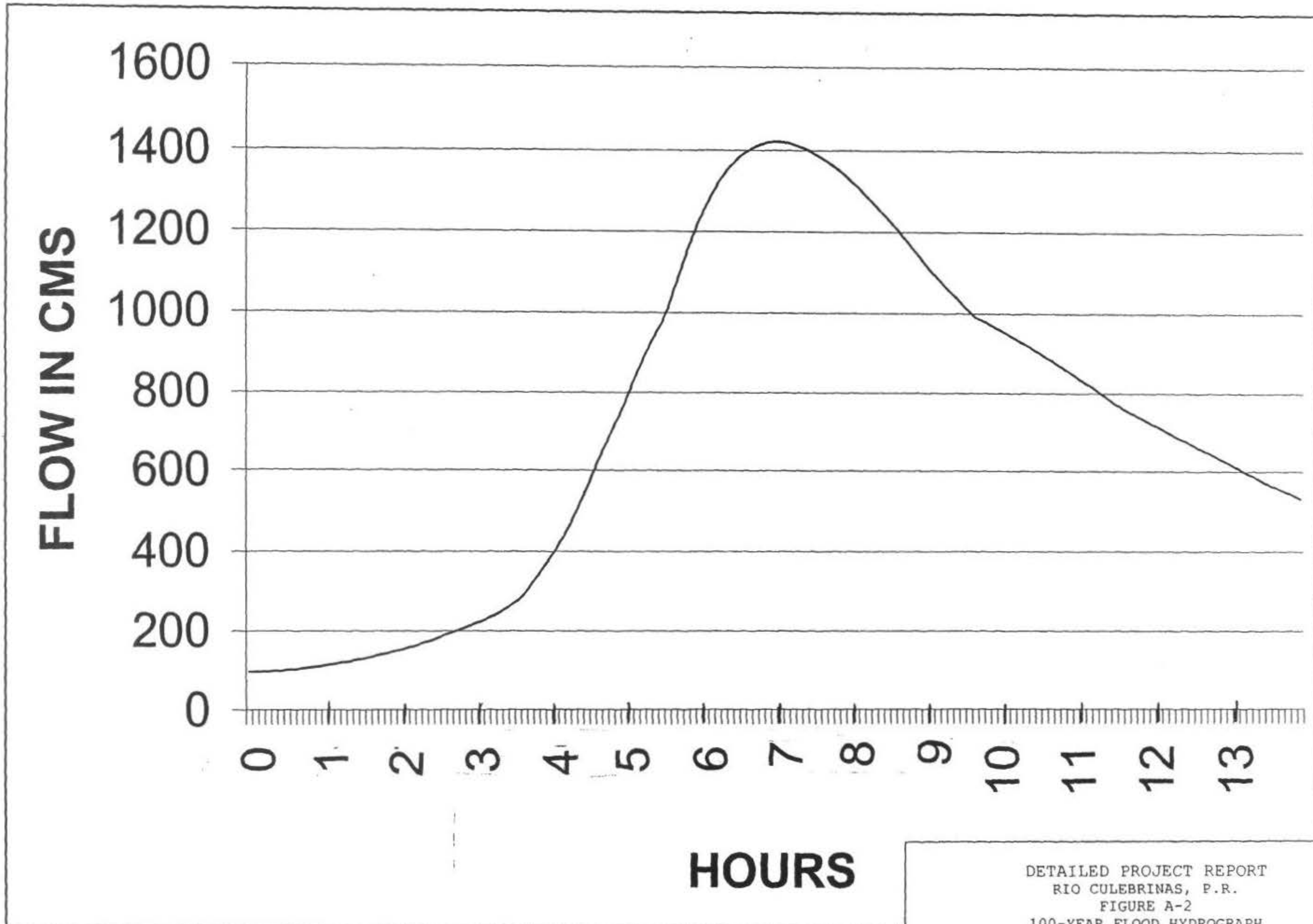

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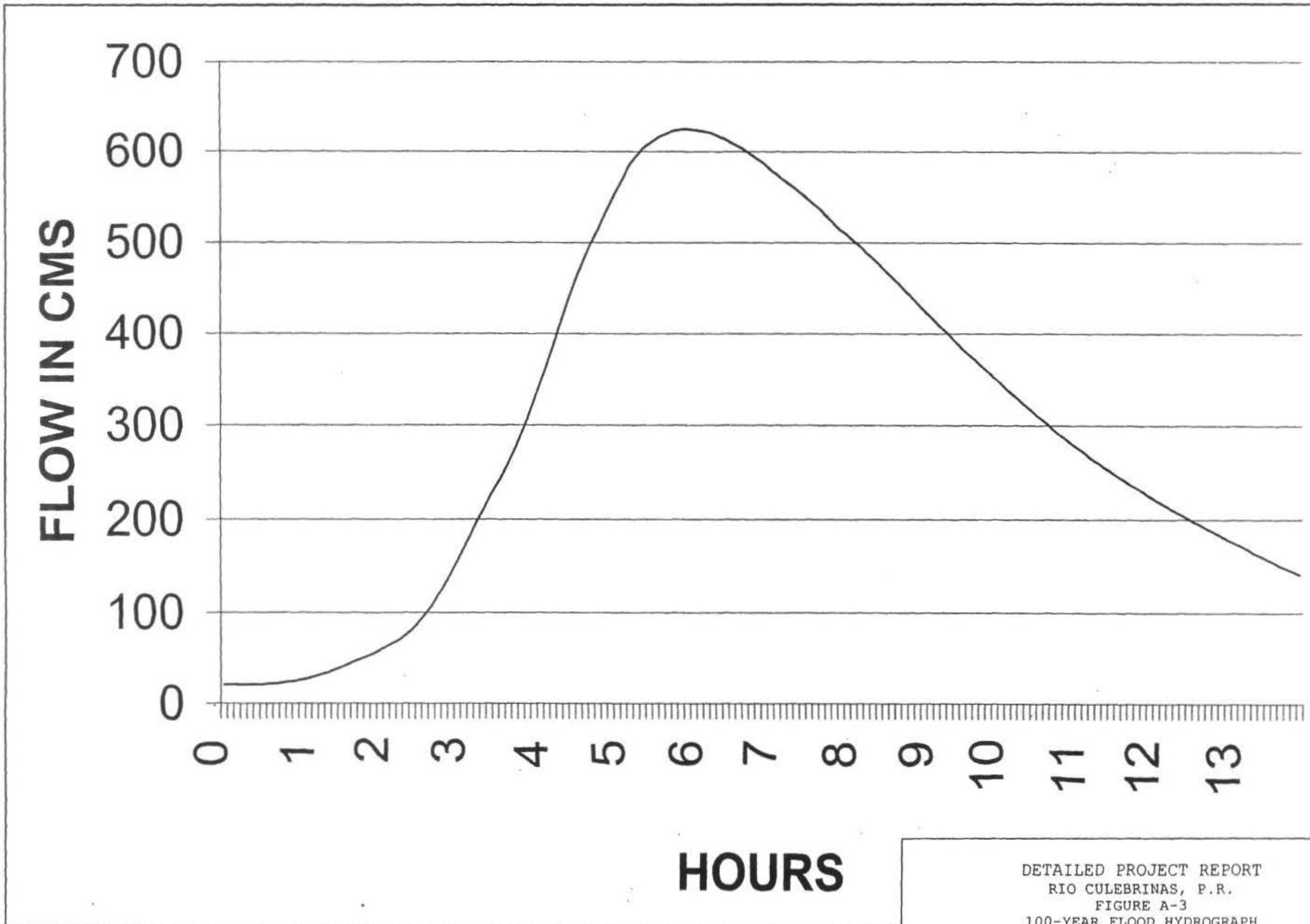
FIGURE A-2
100-YEAR FLOOD HYDROGRAPH
AT MOUTH OF RIO CULEBRINAS
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



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RIO CULEBRINAS, P.R.
FIGURE A-3
100-YEAR FLOOD HYDROGRAPH
AT MOUTH OF CANO MADRE VIEJA
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

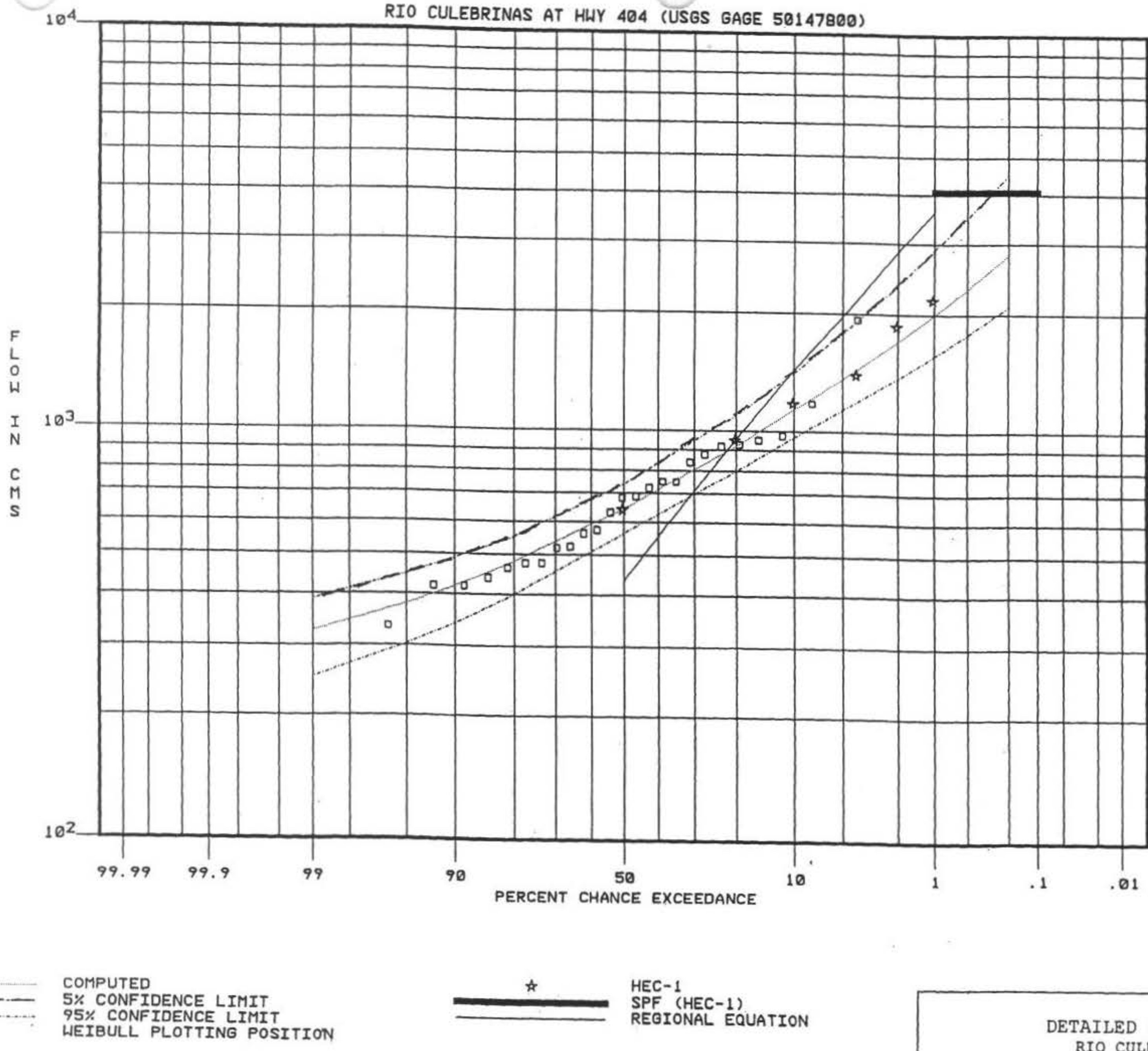

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FIGURE A-4
FLOW FREQUENCY AT
USGS GAGE 50147800
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

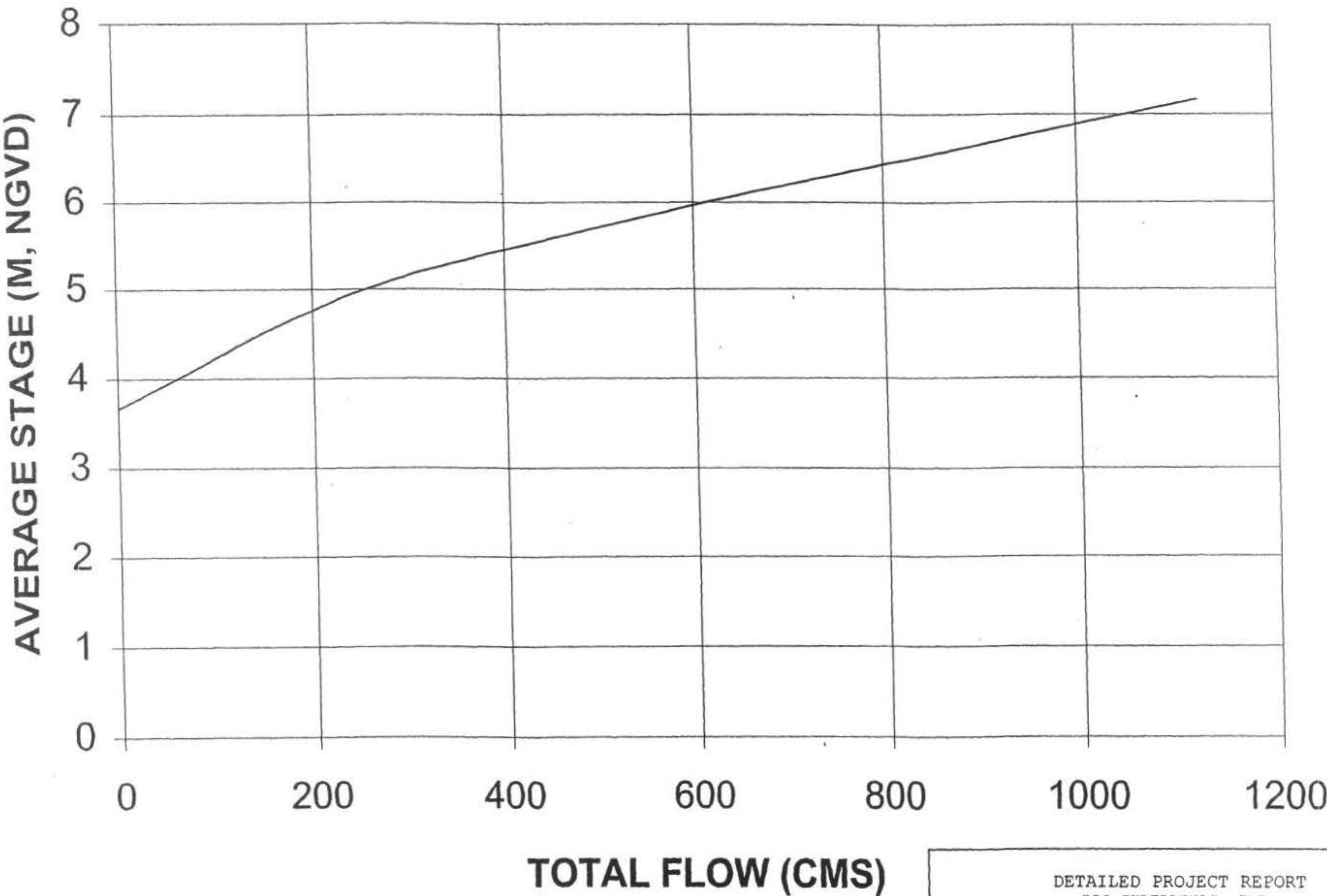

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FIGURE A-5
RATING CURVE BETWEEN
RIO CULEBRINAS AND CANO MADRE VIEJA
DEPARTMENT OF THE AR[illegible]
JACKSONVILLE DISTRICT, CORPS O[illegible] ENGINEERS
JACKSONVILLE, FLORIDA

TABLE A-1

RIO CULEBRINAS DETAILED PROJECT REPORT
HISTORICAL FLOODS DATA FOR RIO CULEBRINAS
AT USGS GAGING STATION 50147800
AT PR HIGHWAY 404, NEAR MOCA, PUERTO RICO

DATE OF FLOOD	DISCHARGE CMS	WATER SURFACE ELEVATION METERS, NGVD
November 27, 1968	850	73.7
October 30, 1969	700	72.4
May 7, 1970	575	71.1
June 13, 1972	700	72.4
October 21, 1972	960	74.6
September 16, 1975	1955	84.6
November 4, 1977	680	72
September 23, 1978	640	71.6
September 25, 1978	730	72.6
May 19, 1980	690	72.3
May 27, 1980	890	74.3
February 15, 1981	570	71
October 24, 1981	935	74.7
July 20, 1982	685	72.3
June 5, 1984	690	72.4
September 15, 1984	760	73
October 6, 1984	675	72.2
May 18, 1985	930	74.7
May 19, 1985	705	72.5
June 25, 1985	730	72.8
October 1, 1985	580	71.1
October 7, 1985	660	72
November 3, 1985	720	72.7
April 27, 1986	780	73.2
May 3, 1986	665	72.1
May 5, 1986	985	75.1
May 6, 1986	685	72.3
May 13, 1986	845	73.9
October 18, 1986	670	72.2
October 19, 1986	660	72
December 1, 1986	635	71.8
September 11, 1987	760	73.1
October 7, 1987	730	72.8
August 24, 1988	1200	76.8
October 26, 1988	640	71.8

TABLE A-2

RIO CULEBRINAS DETAILED PROJECT REPORT
RAINFALL FOR VARIOUS FREQUENCIES AND DURATIONS

PERCENT CHANCE STORM	RAINFALL IN MM							
	DURATION IN HOURS							
	0.083	0.25	1	2	3	6	12	24
50	14	29	53	61	72	86	104	117
20	17	36	66	79	91	107	132	155
10	19	41	72	91	104	127	146	180
4	21	45	79	104	117	150	178	198
2	24	51	91	114	127	155	191	229
1	26	55	99	124	150	180	216	249
SPF	29	61	114	203	264	381	445	508

TABLE A-3

RIO CULEBRINAS DETAILED PROJECT REPORT
WATERSHED PARAMETERS

SUB-BASIN IDENTIFICATION	DRAINAGE AREA (SQ KM)	CURVE NUMBER		LAG IN HOURS
		AMC II	AMC III	
A1	9.24	80	91	0.82
A2	28.72	80	91	0.59
B	56.51	80	91	1.40
C	4.84	80	91	0.17
D	21.85	80	91	1.02
E1	8.84	80	91	0.49
E2	14.12	80	91	0.36
F	10.31	80	91	0.27
G1	4.35	80	91	0.57
G2	7.15	80	91	0.28
H	5.80	80	91	0.08
I1	6.85	80	91	0.39
I2	11.47	80	91	0.31
J	5.10	80	91	0.27
K	5.41	80	91	0.21
L	19.63	80	91	0.28
M1	5.73	80	91	0.23
M2	15.51	81	92	0.30
N	13.86	81	92	0.30
O1	1.14	80	91	0.23
O2	6.25	81	92	0.19
P	4.41	85	94	0.04
Q	22.35	86	94	0.63
R1	4.34	84	93	0.23
R2	5.85	86	94	0.22
S	1.67	84	93	0.28
T	4.94	80	91	0.44
U	2.05	86	94	0.30
V	7.31	85	94	0.37
W	7.00	85	94	0.35
TOTAL	322.60			

TABLE A-4

RIO CULEBRINAS DETAILED PROJECT REPORT
SUMMARY OF PEAK DISCHARGES
ESTIMATED BY HEC-1/UNET ROUTING MODEL

PERCENT CHANCE STORM EVENTS	PEAK DISCHARGES IN CMS			
	USGS GAGE 50147800	UPSTREAM LIMIT OF STUDY	PR HWY 2	MOUTH
50	652	701	334	143
20	964	1036	473	240
10	1193	1313	573	312
4	1411	1587	693	397
2	1893	2102	941	536
1	2206	2508	1098	625
SPF	4111	5214	3016	1221

TABLE A-5

RIO CULEBRINAS DETAILED PROJECT REPORT
WAVE RUNUP AND WIND SETUP

LEVEE SEGMENT	LEVEE STATION	FETCH LENGTH (M)	WIND SPEED KM/HOUR	WAVE PERIOD (SEC)	WAVE HEIGHT (M)	WAVE RUNUP (M)	WIND SETUP (M)	TOTAL (M)
AGUADILLA	4 + 00	538	25	0.99	0.10	0.13	0.01	0.14
			48	1.23	0.18	0.22	0.02	0.24
	13 + 00	1003	25	1.21	0.13	0.19	0.01	0.20
			48	1.48	0.24	0.30	0.04	0.34
ESPINAR	6 + 80	991	25	1.19	0.13	0.18	0.01	0.19
			48	1.47	0.23	0.30	0.04	0.34

RIO CULEBRINAS DETAILED PROJECT REPORT

EXISTING AND WITH PROJECT WATER SURFACE ELEVATIONS

REACH	BRIDGE	CROSS SECTION	MILE	2-YEAR WITH PROJECT	2-YEAR EXISTING CONDITIONS	5-YEAR WITH PROJECT	5-YEAR EXISTING CONDITIONS	10-YEAR WITH PROJECT	10-YEAR EXISTING CONDITIONS	25-YEAR WITH PROJECT	25-YEAR EXISTING CONDITIONS	50-YEAR WITH PROJECT	50-YEAR EXISTING CONDITIONS	100-YEAR WITH PROJECT	100-YEAR EXISTING CONDITIONS	SPF WITH PROJECT	SPF EXISTING CONDITIONS
Reach 1 EAST OF PR HWY 2			5.82	7.18	7.18	7.81	7.81	8.18	8.18	8.46	8.45	9.00	9.00	9.30	9.30	11.12	11.12
			5.07	6.91	6.91	7.50	7.50	7.83	7.83	8.09	8.09	8.60	8.60	8.90	8.90	10.92	10.92
			4.39	6.40	6.40	6.91	6.91	7.25	7.25	7.52	7.52	8.06	8.06	8.40	8.43	10.66	10.66
			3.68	5.78	5.78	6.28	6.27	6.61	6.60	6.92	6.90	7.57	7.55	7.95	8.04	10.43	10.43
		202	3.00	5.17	5.15	5.76	5.73	6.14	6.11	6.50	6.90	7.25	7.21	7.66	7.80	10.24	10.24
		104	2.93	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
Reach 2 - Rio Culebrinas		4090	2.93	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
	PR Hwy 2	3992	2.87	4.79	4.74	5.15	5.08	5.35	5.26	5.51	5.41	6.09	6.05	6.38	6.59	8.36	8.36
		3821	2.77	4.92	4.88	5.34	5.29	5.59	5.53	5.81	5.74	6.21	6.13	6.44	6.24	7.57	7.38
		3705	2.68	4.73	4.68	5.13	5.06	5.36	5.27	5.58	5.47	5.96	5.84	6.18	5.98	7.36	7.13
		3428	2.52	4.55	4.50	4.94	4.84	5.18	5.07	5.40	5.27	5.78	5.63	5.98	5.77	7.17	6.91
	PR Hwy 418	3214	2.39	4.28	4.20	4.68	4.55	4.95	4.79	5.19	5.02	5.57	5.38	5.78	5.54	6.95	7.13
		3187	2.38	4.23	4.14	4.63	4.50	4.91	4.73	5.15	4.97	5.53	5.34	5.74	5.49	6.91	6.63
		3154	2.35	4.22	4.14	4.63	4.49	4.90	4.73	5.15	4.96	5.52	5.34	5.74	5.49	6.90	6.62
		3116	2.33	4.21	4.12	4.61	4.48	4.89	4.71	5.13	4.95	5.51	5.32	5.72	5.47	6.88	6.60
		3055	2.29	4.19	4.09	4.59	4.45	4.87	4.69	5.11	4.92	5.48	5.30	5.70	5.44	6.84	6.56
		2712	2.08	4.15	4.05	4.56	4.42	4.84	4.66	5.09	4.90	5.45	5.27	5.66	5.41	6.79	6.52
		2614	2.04	4.12	4.02	4.53	4.39	4.81	4.63	5.06	4.87	5.42	5.24	5.63	5.39	6.75	6.48
	PR Hwy 115	2570	2.00	3.63	3.54	3.99	3.87	4.39	4.07	4.75	4.51	5.17	4.97	5.39	5.13	6.58	6.30
		2440	1.92	3.33	3.24	3.68	3.57	3.89	3.75	4.09	3.93	4.51	4.28	4.72	4.47	5.88	5.63
		2377	1.88	3.18	3.10	3.51	3.39	3.73	3.58	3.94	3.77	4.38	4.14	4.59	4.34	5.73	5.48
		1950	1.29	2.94	2.85	3.32	3.17	3.55	3.39	3.79	3.60	4.26	4.01	4.46	4.22	5.55	5.31
		1451	0.91	2.88	2.78	3.26	3.12	3.50	3.33	3.73	3.55	4.20	3.96	4.40	4.17	5.45	5.23
		1353	0.84	2.87	2.77	3.25	3.11	3.49	3.32	3.72	3.54	4.19	3.95	4.39	4.16	5.42	5.21
		1286	0.80	2.86	2.77	3.25	3.10	3.48	3.32	3.72	3.53	4.19	3.94	4.38	4.15	5.41	5.20
		1091	0.68	2.85	2.75	3.24	3.09	3.47	3.30	3.70	3.52	4.17	3.93	4.36	4.13	5.37	5.16
		850	0.53	2.83	2.73	3.22	3.07	3.46	3.29	3.69	3.50	4.16	3.92	4.35	4.12	5.34	5.13
		721	0.45	2.79	2.71	3.20	3.05	3.44	3.28	3.68	3.49	4.15	3.91	4.34	4.11	5.31	5.11
		604	0.38	2.74	2.65	3.17	3.01	3.41	3.25	3.65	3.47	4.13	3.89	4.31	4.09	5.27	5.08
		403	0.25	2.60	2.49	3.08	2.91	3.35	3.17	3.60	3.41	4.08	3.84	4.26	4.05	5.18	4.99
		163	0.10	2.40	2.30	2.93	2.75	3.23	3.02	3.51	3.29	4.00	3.76	4.17	3.97	5.00	4.85
		44	0.03	2.04	1.94	2.58	2.38	2.92	2.70	3.26	2.99	3.84	3.59	4.02	3.81	4.81	4.67
Reach 3 - Cano Madre Vieja		3573	2.54	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
		3463	2.47	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
		3280	2.36	4.76	4.73	5.16	5.10	5.39	5.32	5.60	5.51	5.96	5.86	6.17	5.99	7.31	7.07
		3240	2.33	4.67	4.54	5.07	4.86	5.30	5.04	5.51	5.20	5.88	5.52	6.09	5.65	7.25	6.65
		3134	2.27	4.60	4.53	4.97	4.84	5.20	5.01	5.41	5.17	5.77	5.48	5.98	5.60	7.15	6.59
	PR Hwy 418	3101	2.25	4.51	4.42	4.89	4.74	5.13	4.94	5.35	5.12	5.73	5.45	5.95	5.57	7.14	6.58
		3085	2.24	4.32	4.31	4.66	4.60	4.88	4.80	5.07	4.98	5.37	5.28	5.53	5.41	6.40	6.32
		2993	2.18	4.31	4.26	4.67	4.52	4.89	4.71	5.09	4.89	5.41	5.17	5.59	5.29	6.56	6.18
	Old Narrow Bridge	2948	2.15	4.11	3.97	4.47	4.24	4.71	4.44	4.92	4.62	5.24	4.91	5.42	5.02	6.39	5.89
	PR Hwy 115	2891	2.11	3.70	3.62	4.04	3.92	4.23	4.11	4.43	4.30	4.71	4.60	4.87	4.72	5.74	5.58
		2826	2.07	3.16	3.24	3.51	3.67	3.75	3.89	3.96	4.11	4.29	4.44	4.44	4.55	5.32	5.41
		2545	1.81	2.83	2.95	3.20	3.42	3.46	3.67	3.68	3.91	4.02	4.25	4.18	4.36	5.09	5.19
		2491	1.78	2.74	2.86	3.10	3.31	3.35	3.57	3.58	3.81	3.91	4.16	4.08	4.26	4.99	5.07
		2424	1.74	2.66	2.78	3.03	3.23	3.28	3.48	3.51	3.72	3.85	4.06	4.01	4.17	4.91	4.97
		2307	1.67	2.57	2.67	2.94	3.11	3.19	3.36	3.42	3.59	3.75	3.92	3.91	4.02	4.76	4.80
		2200	1.60	2.45	2.53	2.83	2.97	3.08	3.22	3.32	3.42	3.65	3.74	3.80	3.84	4.65	4.61
		2095	1.53	2.39	2.46	2.78	2.89	3.03	3.15	3.26	3.35	3.59	3.65	3.74	3.76	4.57	4.51
		1568	1.10	2.32	2.35	2.72	2.82	2.97	3.08	3.21	3.28	3.53	3.57	3.68	3.67	4.48	4.40
		1482	1.04	2.29	2.31	2.69	2.78	2.93	3.04	3.17	3.24	3.49	3.52	3.63	3.62	4.41	4.33
		1112	0.78	2.25	2.25	2.64	2.73	2.89	3.00	3.13	3.20	3.43	3.46	3.58	3.56	4.33	4.25
		480	0.30	2.20	2.20	2.60	2.70	2.84	2.97	3.08	3.16	3.39	3.41	3.52	3.51	4.25	4.17
		381	0.24	2.08	2.15	2.47	2.65	2.70	2.91	2.93	3.10	3.22	3.33	3.34	3.41	3.97	4.02
		255	0.16	2.02	2.10	2.39	2.59	2.62	2.86	2.84	3.05	3.13	3.27	3.24	3.34	3.83	3.94
		209	0.13	1.97	2.07	2.34	2.56	2.56	2.82	2.78	3.02	3.08	3.24	3.18	3.32	3.75	3.91
		163	0.10	1.88	2.02	2.21	2.49	2.41	2.74	2.60	2.98	2.88	3.21	3.01	3.28	3.58	[illegible]
		74	0.05	1.71	1.79	2.07	2.23	2.29	[illegible]	2.51	2.69	2.80	3.06	2.94	3.15	3.52	[illegible]
		17	0.01	1.53	1.64	1.86	2.05	2.06	[illegible]	2.26	2.55	2.59	2.86	2.72	2.97	3.28	[illegible]

N[illegible]R SURFACE ELEVATIONS ARE IN METERS, NGVD

TABLE A-7

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
100-YEAR LEVEE CREST ELEVATIONS

LEVEE SEGMENT	ROAD RAMP	DRAINAGE STRUCTURE	LEVEE STATION	MINIMUM LEVEE PROFILE TO ACCOMMODATE 20 PERCENT INCREASE IN DISCHARGE OR "N" VALUE M, NGVD	WAVE RUNUP AND WIND SETUP FOR 48 KM/HOUR WIND METERS	SUPERIORITY METERS	LEVEE CREST ELEVATION M, NGVD	AVERAGE GROUND ELEVATION M, NGVD	LEVEE HEIGHT METERS	DESIGN WATER SURFACE ELEVATION M, NGVD
AGUADILLA										
			0 + 0.00	2.81	0.24	0.00	3.05	1.00	2.05	2.72
			0 + 32.54	2.81	0.24	0.00	3.05	2.20	0.85	2.72
			0 + 76.23	3.19	0.24	0.09	3.52	1.50	2.02	2.94
		AL-S-1	1 + 39.50	3.34	0.24	0.09	3.67	1.70	1.97	2.98
			1 + 79.72	3.43	0.24	0.15	3.82	1.72	2.10	3.01
			2 + 25.58	3.51	0.24	0.30	4.05	1.30	2.75	3.18
			2 + 68.05	3.55	0.24	0.30	4.09	1.22	2.87	3.24
			3 + 44.59	3.63	0.24	0.30	4.17	1.80	2.37	3.34
			5 + 27.92	3.78	0.24	0.30	4.32	1.00	3.32	3.52
		AL-S-2	6 + 05.50	3.83	0.24	0.30	4.37	2.06	2.31	3.58
			6 + 07.29	3.83	0.24	0.30	4.37	1.00	3.37	3.58
			7 + 71.41	3.88	0.34	0.30	4.52	2.00	2.52	3.63
			8 + 65.06	3.93	0.34	0.30	4.57	2.00	2.57	3.68
			9 + 44.83	3.98	0.34	0.30	4.62	1.68	2.94	3.74
		AL-S-3	10 + 52.90	4.04	0.34	0.30	4.68	2.98	1.70	3.80
			10 + 54.61	4.04	0.34	0.30	4.68	2.50	2.18	3.80
			11 + 28.82	4.14	0.34	0.30	4.78	2.60	2.18	3.91
			11 + 91.52	4.24	0.34	0.30	4.88	2.68	2.20	4.01
			12 + 39.36	4.63	0.34	0.30	5.27	2.22	3.05	4.40
			13 + 30.31	4.69	0.34	0.30	5.33	3.00	2.33	4.46
	PR HWY 115		13 + 66.80	5.36	0.34	0.30	6.00	2.91	3.09	5.14
			13 + 80.59	5.62	0.34	0.30	6.26	2.91	3.35	5.39
			14 + 12.01	5.84	0.34	0.30	6.48	3.18	3.30	5.63
			15 + 06.36	5.87	0.34	0.30	6.51	3.04	3.47	5.66
			16 + 13.66	5.90	0.34	0.30	6.54	3.85	2.69	5.70
	PR HWY 418		16 + 16.60	5.91	0.34	0.30	6.55	3.85	2.70	5.71
			16 + 31.19	5.99	0.34	0.30	6.63	3.85	2.78	5.78
			17 + 15.70	6.20	0.34	0.30	6.84	3.28	3.56	5.98
			18 + 00.81	6.38	0.34	0.30	7.02	3.66	3.36	6.18
			18 + 19.59	6.61	0.34	0.30	7.25	4.00	3.25	6.44
			18 + 36.00	6.61	0.34	0.30	7.25	5.82	1.43	6.44
			18 + 40.00	6.61	0.34	0.30	7.25	7.25	0.00	6.44
ESPINAR										
			0 + 00.00	3.30	0.34	0.00	3.64	1.23	2.41	2.97
			0 + 47.13	3.43	0.34	0.00	3.77	1.30	2.47	3.01
			0 + 91.40	3.51	0.34	0.30	4.15	1.10	3.05	3.18
			1 + 36.82	3.55	0.34	0.30	4.19	1.00	3.19	3.24
			2 + 00.64	3.63	0.34	0.30	4.27	1.00	3.27	3.34
		*	2 + 10.00	3.65	0.34	0.30	4.29	1.00	3.29	3.37
		EL-S-1a	2 + 50.00	3.76	0.34	0.30	4.40	1.00	3.40	3.50
			2 + 58.14	3.78	0.34	0.30	4.42	1.00	3.42	3.52
			3 + 39.73	3.83	0.34	0.30	4.47	1.00	3.47	3.58
			4 + 22.14	3.88	0.34	0.30	4.52	1.00	3.52	3.63
			4 + 99.25	3.93	0.34	0.30	4.57	1.66	2.91	3.68
			5 + 91.60	3.98	0.34	0.30	4.62	1.50	3.12	3.74
			6 + 80.98	4.04	0.34	0.30	4.68	2.80	1.88	3.80
			7 + 98.79	4.14	0.34	0.30	4.78	2.70	2.08	3.91
			8 + 81.23	4.24	0.34	0.30	4.88	3.24	1.64	4.01
	PR HWY 442		9 + 55.80	4.38	0.34	0.30	5.02	4.00	1.02	4.19
			10 + 78.67	4.60	0.34	0.30	5.24	4.00	1.24	4.38
			11 + 60.58	4.61	0.34	0.30	5.25	3.61	1.64	4.39
			13 + 41.89	4.61	0.34	0.30	5.25	3.69	1.56	4.39
			14 + 80.00	4.61	0.34	0.30	5.25	4.00	1.25	4.39
			14 + 96.00	4.61	0.34	0.30	5.25	5.25	0.00	4.39
ESPINAR LEVEE SPUR										
			0 + 00.00	3.30	0.34	0.30	4.29	1.00	3.29	2.97
			0 + 50.00	3.30	0.34	0.30	3.94	1.00	2.94	2.97
			1 + 00.00	3.30	0.34	0.30	3.94	1.10	2.84	2.97
			2 + 00.00	3.30	0.34	0.30	3.94	1.00	2.94	2.97
			2 + 66.00	3.30	0.34	0.30	3.64	3.64	0.00	2.97

* re Espinar levee spur ties into Espinar levee

TABLE A-8

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
INTERIOR DRAINAGE STRUCTURES

LEVEE SEGMENT	DRAINAGE STRUCTURE	LEVEE STATION	AVERAGE GROUND ELEVATION (M, NGVD)	LEVEE CROWN ELEVATION (M, NGVD)	CULVERT INVERT ELEVATION (M, NGVD)	CULVERT LENGTH* (M)	CULVERT N0. - DIA (M)	TYPE OF CONTROL
AGUADILLA	AL-S-1	1+39.5	1.70	3.67	-0.3	15	3 - 1.52	FLAPGATE
	AL-S-2	6+05.5	2.06	4.37	-0.3	19	6 - 1.52	FLAPGATE
	AL-S-3	10+52.9	2.98	4.68	-0.3	20	3 - 1.52	FLAPGATE
ESPINAR	EL-S-1a	2+ 50.0	1.00	4.40	-0.3	27	2 - 1.52	FLAPGATE

NOTE: *Computed with a levee crown width of 3.0 meters and 1V:2.5H side slopes.
Culverts are corrugated metal pipes (CMP) with bituminous coating.

TABLE A-9

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
INTERIOR DRAINAGE CHANNELS

LEVEE SEGMENT	LEVEE STATION	AVERAGE GROUND ELEVATION M, NGVD	ROAD RAMP	DRAINAGE STRUCTURE	COMMENT No. - Dia. (M)	CHANNEL INVERT M, NGVD
AGUADILLA						
	0 + 0.00	1.00				
	0 + 32.54	2.20			Slope =.005	0.24
	0 + 76.23	1.50				0.02
	1 + 39.50	1.70		AL-S-1	3 - 1.52 CMP	-0.30
	1 + 79.72	1.72				-0.30
	2 + 25.58	1.30				-0.30
	2 + 68.05	1.22				-0.30
	3 + 44.59	1.80				-0.30
	5 + 27.92	1.00				-0.30
	6 + 05.50	2.06		AL-S-2	6 - 1.52 CMP	-0.30
	6 + 07.29	1.00				-0.30
	7 + 71.41	2.00				-0.30
	8 + 65.06	2.00				-0.30
	9 + 44.83	1.68				-0.30
	10 + 52.90	2.98		AL-S-3	3 - 1.52 CMP	-0.30
	10 + 54.61	2.50				-0.29
	11 + 28.82	2.60				0.08
	11 + 91.52	2.68				0.39
	12 + 39.36	2.22				0.63
	13 + 30.31	3.00				1.09
	13 + 66.80	2.91	PR HWY 115		1 - 0.91 CMP**	1.27
	13 + 80.59	2.91				1.34
	14 + 12.01	3.18				1.50
	15 + 06.36	3.04				1.97
	16 + 13.66	3.85				2.50
	16 + 16.6	3.85	PR HWY 418		1 - 0.91 CMP**	2.52
	16 + 31.19	3.85				2.59
	17 + 15.70	3.28				3.01
	18 + 00.81	3.66				3.44
	18 + 19.59	4.00				3.53
	18 + 36.00	5.82			Slope =.005	3.62
	18 + 40.00	7.25				
ESPINAR						
	0 + 00.00	1.00				
	0 + 47.13	1.60				
	0 + 91.40	1.40				
	1 + 36.82	1.22				
	2 + 00.64	1.10				
*	2 + 10.00	1.00				
	2 + 50.00	1.00		EL-S-1a	2 - 1.52 CMP	-0.30
	2 + 58.14	1.00				-0.10
	3 + 39.73	1.00				-0.01
	4 + 22.14	1.00				0.12
	4 + 99.25	1.00				0.23
	5 + 91.60	1.00				0.40
	6 + 80.98	1.66				0.56
	7 + 98.79	1.50				0.72
	8 + 81.23	2.80				0.90
	9 + 55.80	2.70	PR HWY 442		1 - 0.91 CMP**	1.08
	10 + 78.67	3.24				1.32
	11 + 60.58	4.00				1.48
	13 + 41.89	4.00				1.63
	14 + 80.00	3.61				1.88
	14 + 96.00	3.69			Slope =.002	2.04
ESPINAR LEVEE SPUR						
	0 + 00.00	1.00				
	0 + 50.00	1.00				-0.30
	1 + 00.00	1.10				-0.20
	2 + 00.00	1.00				0.00
	2 + 50.00	3.00				0.10
	2 + 66.00	3.64			Slope =.002	

* Where Espinar levee spur ties into Espinar levee.

** Corrugated Metal Pipe (CMP) at road ramps will not have a flap gate.

Channel bottom width and side slopes are 1 meter and 1V:3H, respectively.

Espinar levee spur channel will drain toward EL-S-1a

TABLE A-10

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
CUTOFF CHANNEL

LOCATION	EXISTING GR. ELEV. M-NGVD	CHANNEL INVERT M-NGVD	BOTTOM CHANNEL WIDTH (M)	SIDE SLOPE	TYPE OF CHANNEL
UPSTREAM END	5.64	0.52	15.2	1V:3.5H	EARTHEN
	3.97	0.46	15.2	1V:3.5H	EARTHEN
DOWNSTREAM END	3.61	0.36	15.2	1V:3.5H	EARTHEN

TABLE A-11

RIO CULEBRINAS DETAILED PROJECT REPORT
INTERIOR FLOOD HYDROLOGY

LEVEE SEGMENT	DRAINAGE STRUCTURE	DRAINAGE AREA SQ KM	PEAK FLOWS IN CMS PERCENT CHANCE FLOOD EVENTS						
			50	20	10	4	2	1	SPF
AGUADILLA	AL-S-1 AL-S-2 AL-S-3	3.18	9	21	49	56	77	84	108
ESPINAR	EL-S-1a	0.34	1	3	7	8	13	14	17

TABLE A-12

RIO CULEBRINAS DETAILED PROJECT REPORT
INTERIOR DRAINAGE - RESIDUAL FLOOD ELEVATIONS

LEVEE SEGMENT	DRAINAGE STRUCTURE	RESIDUAL FLOOD ELEVATIONS IN METERS, NGVD PERCENT CHANCE FLOOD EVENTS		
		10	4	2
AGUADILLA	AL-S-1 AL-S-2 AL-S-3	2.22	2.31	2.40
ESPINAR	EL-S-1a	1.99	2.06	2.14

TABLE A-13

RIO CULEBRINAS DETAILED PROJECT REPORT
RELIABILITY ANALYSIS
AT LEVEE CROSS SECTION 1568

LOG PEAK DISCHARGE STATISTICS

MEAN = 3.7243
STD DEV = 0.2500
SKEW = 0.2454
EVENTS = 31

STAGE-DISCHARGE RELATIONSHIP

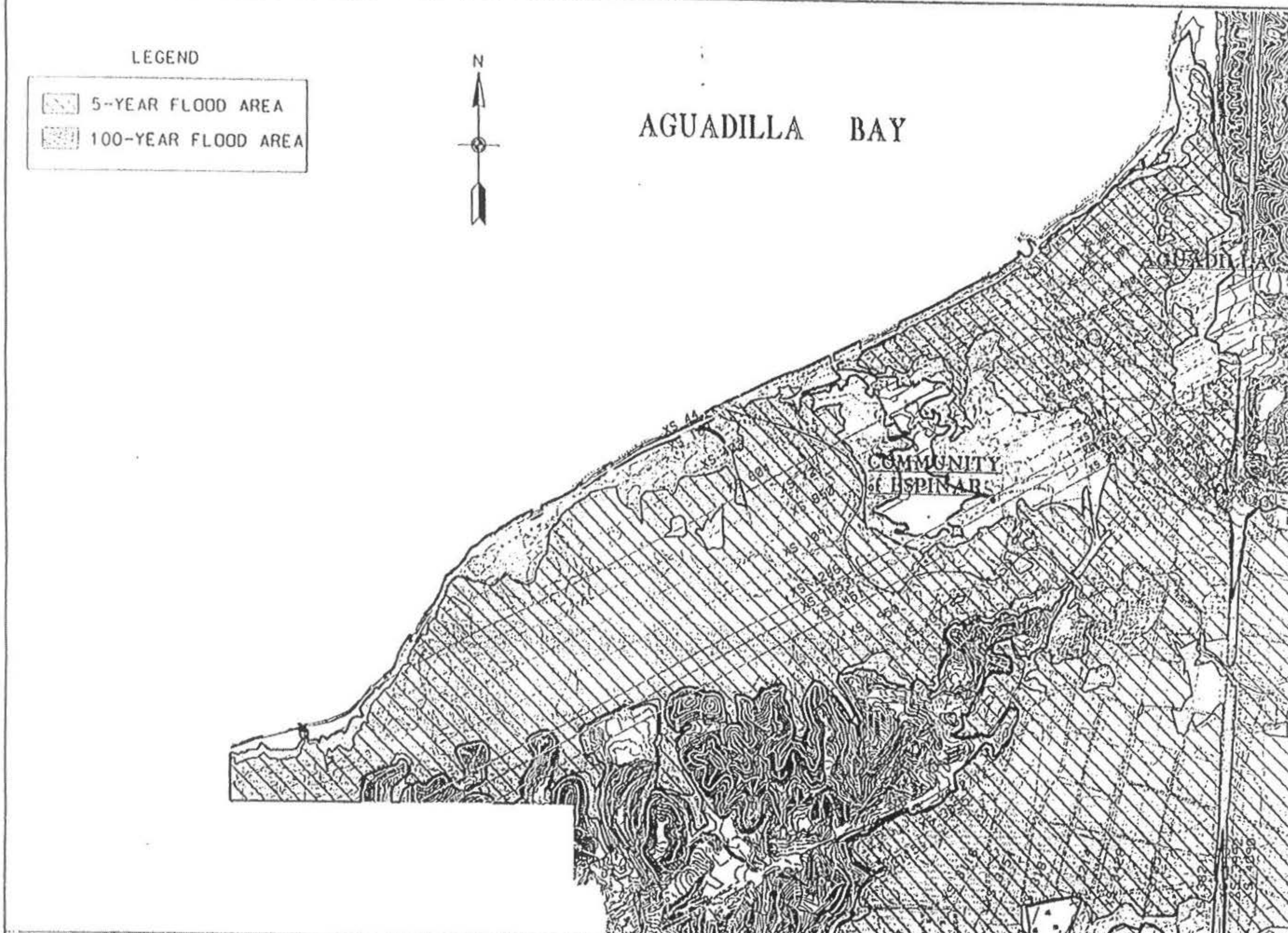
DISCHARGE CMS	STAGE METERS
147	2.34
249	2.77
317	3.04
402	3.30
530	3.62
623	3.78
1218	4.63

STD DEV OF STAGE FLUCTUATIONS 0.274 METERS

DATA FOR LEVEE

LEVEE CREST ELEVATION = 4.57 METERS
WAVE RUNUP AND WIND SETUP = 0.34 METERS
MINIMUM LEVEE GRADE + SUPERIORITY = 3.93 METERS
DESIGN WATER SURFACE ELEVATION = 3.68 METERS

STAGE METERS	PERCENT PROBABILITY OF STAGE NON-EXCEEDANCE		
	SPF	.01 EVENT	.02 EVENT
3.50	2.54	18.21	37.14
3.93	21.87	62.95	82.92
4.50	72.82	95.64	98.71
4.57	78.34	96.59	99.13
5.00	97.59	99.62	99.85



RIO CULEBRINAS at AGUADA/AGUADILLA PUERTO RICO EXISTING CONDITIONS FLOODED AREAS 5-YEAR and 100-YEAR	File name: Reference files:	Designed by: Dwn by: Ckd by: Dated: JULY 1999 D.O NO.	Scale: Plot date: Plot scale: 700:1

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

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Jacksonville District

PLATE A-1

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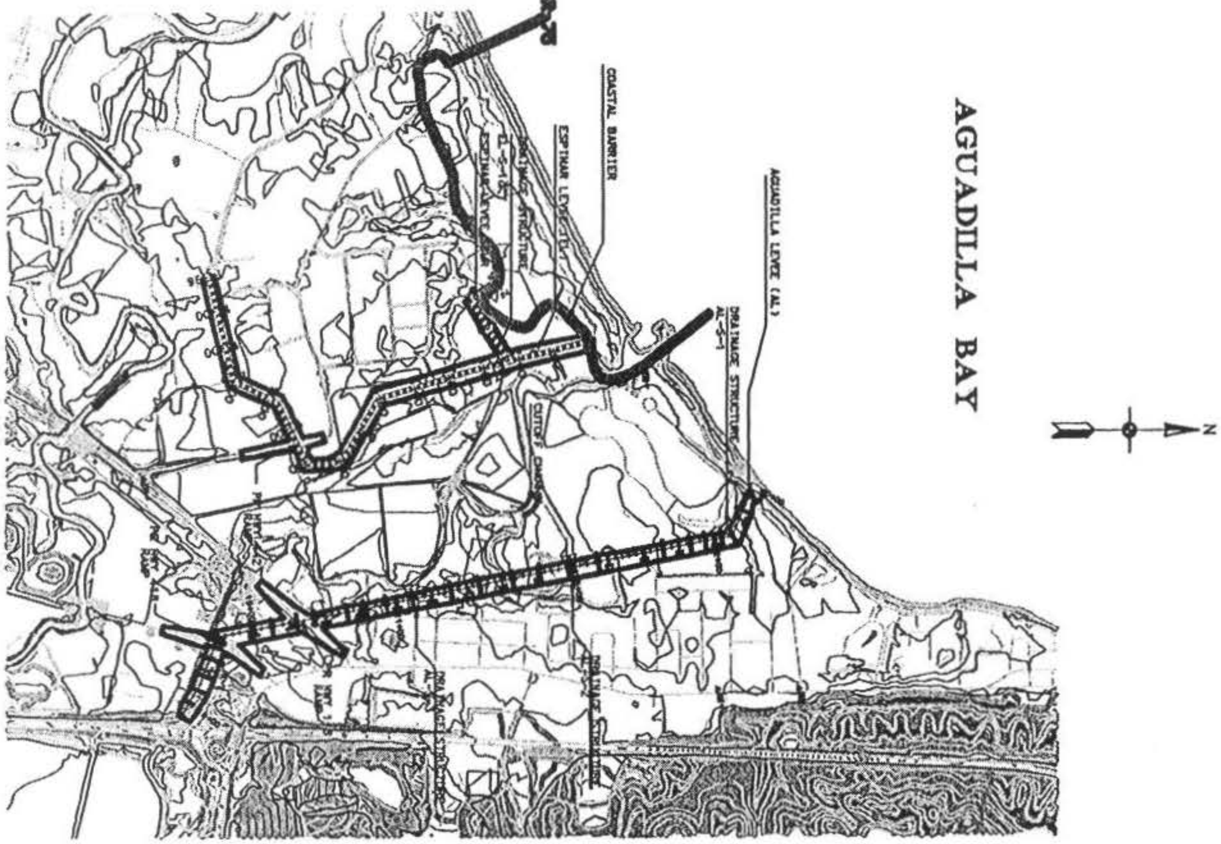


PLATE A-2	RIO CULEBRINAS AT AGUADA/AGUADILLA PUERTO RICO DETAILED PROJECT REPORT RECOMMENDED PLAN	File name: Reference files:	Designed by: Dwn by: Ckd by: Dated: JULY 1999 D.O.FILE NO.	Scale: Plot date: ___ Plot scale: 400:1	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA

US Army Corps of Engineers
Jacksonville District.

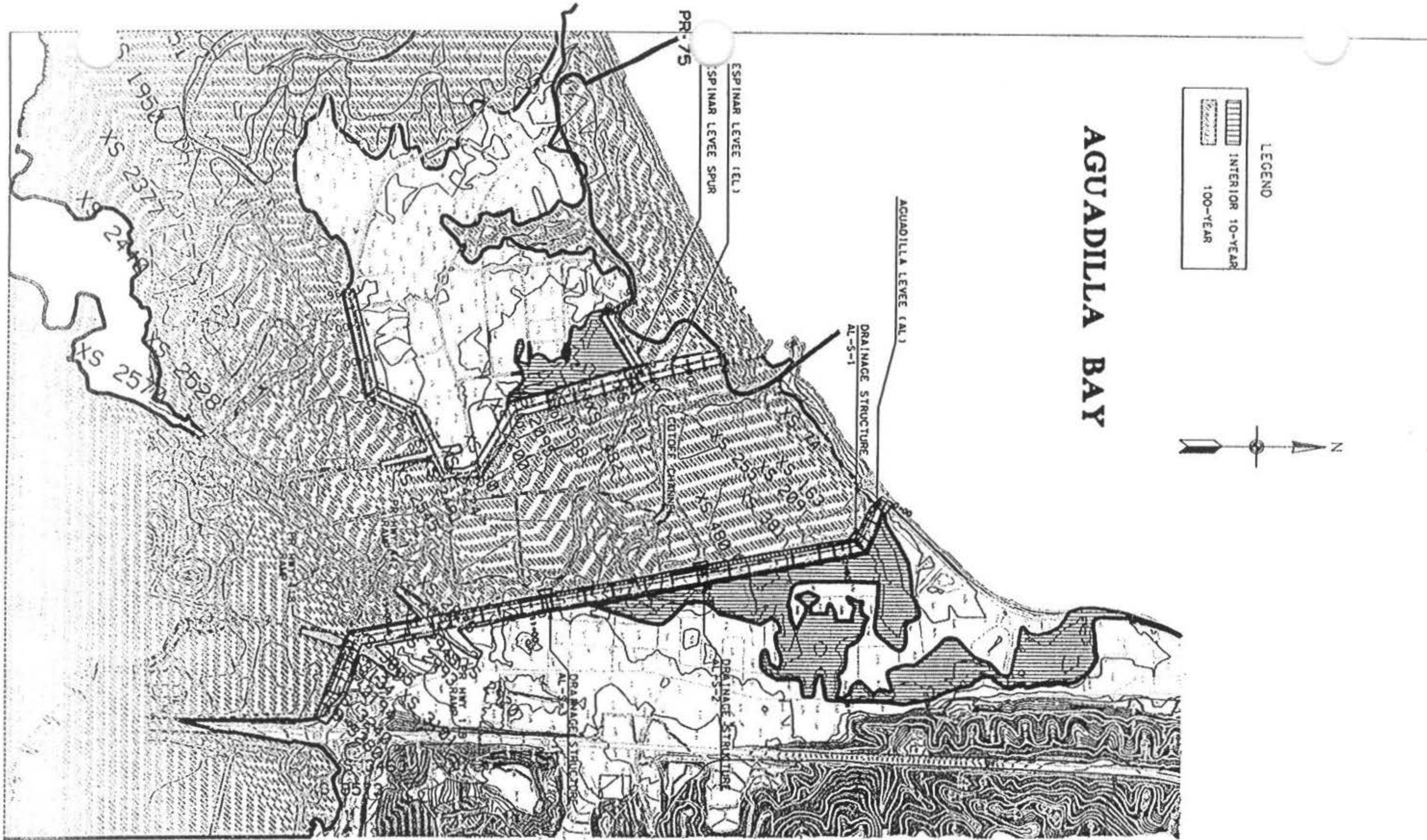
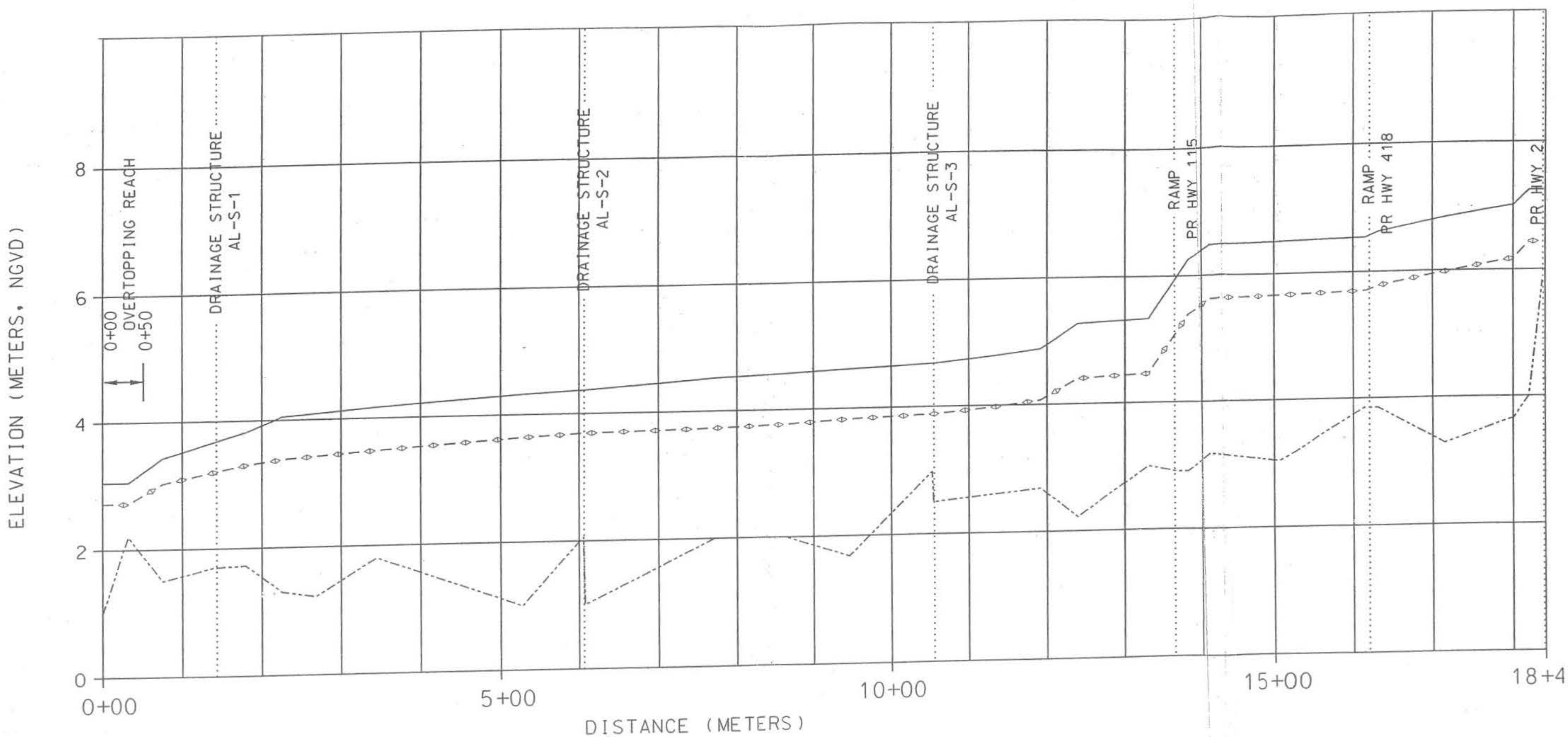


PLATE A-3	RIO CULEBRINAS AT AGUADA/AGUADILLA PUERTO RICO DETAILED PROJECT REPORT RESIDUAL FLOODED AREA	File name: Reference files:	Designed by: / Dwn by: / Ckd by: / Scale: Plot date: ...... Plot scale: 400:1 Dated: JULY 1999 D.O.FILE NO.	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA

US Army Corps of Engineers
Jacksonville District



LEGEND

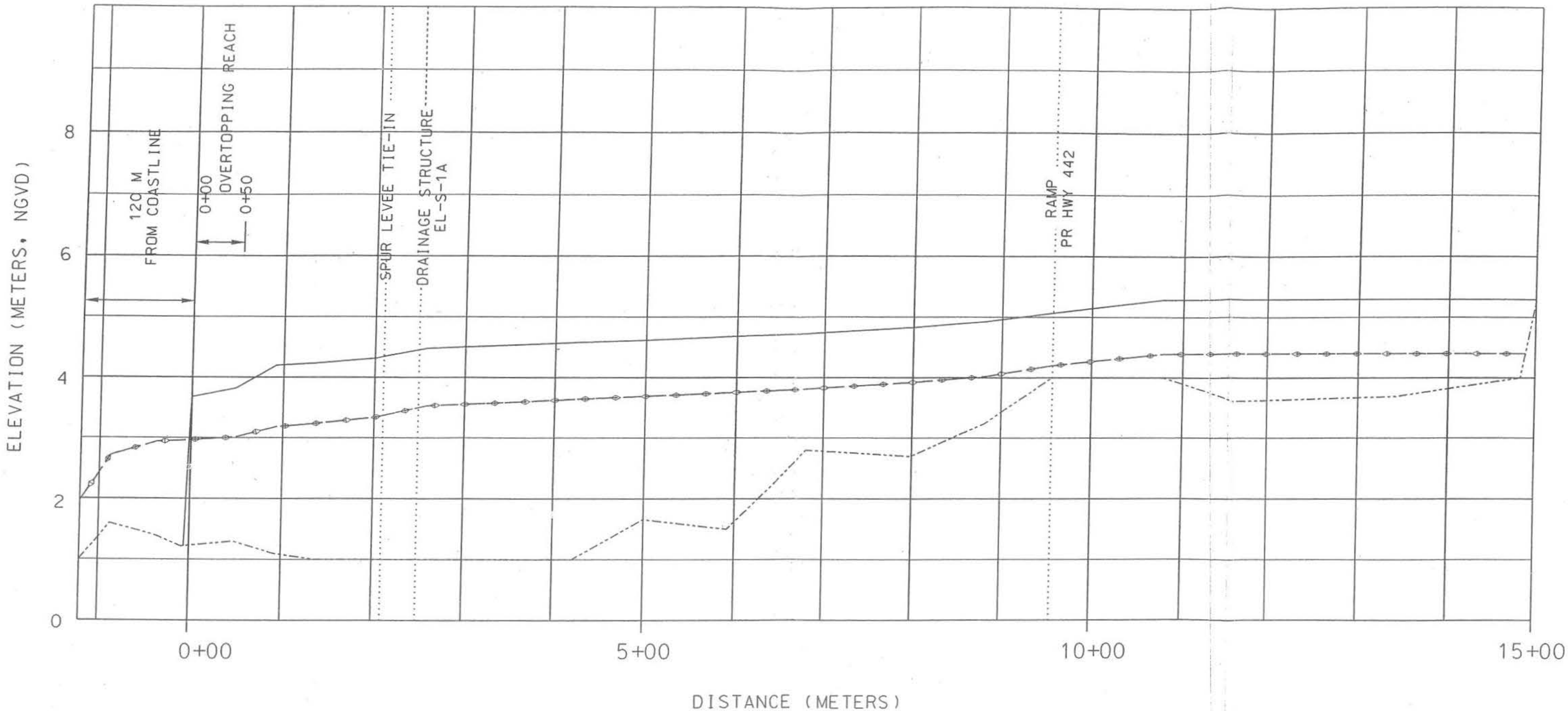
EXISTING GROUND ELEVATION

LEVEE CREST ELEVATION

DESIGN WATER SURFACE ELEVATION

NOTE: EXISTING WATER SURFACE ELEV. SAME AS DESIGN WATER SURFACE ELEV.

REFERENCE FILENAMES:	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA
	AQUADA/AQUADILLA, PUERTO RICO RIO CULEBRINAS AQUADILLA LEVEE PROFILE 100-YEAR
DESIGN ENG.:	INV. NO. / SIZE / DWG. NO.
CHECKED BY:	DATED:
DRAWN BY:	SCALE: AS SHOWN / DATED: JUNE, 1999 / PLATE A-4



LEGEND

-··-··-··-··-	EXISTING GROUND ELEVATION
-◇-◇-◇-◇-◇-	DESIGN WATER SURFACE ELEVATION
————————	LEVEE CREST ELEVATION

REFERENCE FILENAMES:	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA AQUADA/AQUADILLA, PUERTO RICO RIO CULEBRINAS ESPINAR LEVEE PROFILE 100-YEAR
DESIGN ENG.:	INV. NO. / SIZE / DWG. NO.
CHECKED BY:	DATED:
DRAWN BY:	SCALE: AS SHOWN / DATED: JUNE, 1999 / PLATE A-5