RUST LICHLITER/JAMESON

Environment & Infrastructure
Consulting Engineers, Scientists and Planners

FLOOD PROTECTION PLAN

Submitted to:

City of Brownsville, Texas

November, 1996
Revised January, 1997

FLOOD PROTECTION PLAN

FOR THE

CITY OF BROWNSVILLE, TEXAS

Rust Lichliter/Jameson
2929 Briarpark, Suite 600
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Project No. 68589

November, 1996
Revised January, 1997

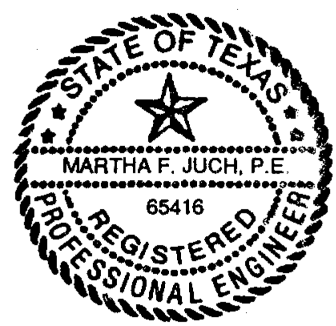
I hereby certify these engineering documents were prepared by me or under my direct personal supervision and that I am a duly registered Professional Engineer under the laws of the State of Texas.

Signature: Martha F Juch

Name (typed or printed): Martha F. Juch, P.E.

Date: 1/13/97　　　Reg. No. 65416

My registration renewal date is December 31, 1997.



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LIST OF EXHIBITS

1.0 INTRODUCTION

1.1 Background

Localized flooding that hinders transportation and threatens residential and commercial structures has occurred frequently in the last forty years throughout the City of Brownsville and its ETJ. Severe storm events in 1967, 1984, and 1996 caused extensive flood damage in areas throughout the City. The flooding has also posed a potential health hazard by interfering with pedestrian and vehicular traffic in critical areas near schools and residential communities. As the first step in reducing the flooding problem, the City of Brownsville requested planning grant assistance from the Texas Water Development Board in September 1995. The grant assistance was targeted toward the development of a Plan for the City and its ETJ. This Plan is the subject of this report and consists of the following objectives:

- Identify the causes of flooding.
- Update the 1987 Master Drainage Plan.
- Develop a plan for the orderly implementation of cost-effective solutions to the flooding problems.
- Eliminate flooding conditions, resulting flood damages, safety and access problems and health hazards.
- Develop a plan for the future anticipated growth of Brownsville to insure properly controlled drainage.

1.2 Scope of Services

The City of Brownsville contracted with Rust Lichliter/Jameson (referred to in this report as the Engineer) in January 1996 to perform a drainage study of the City and its ETJ and to develop a Plan for the area. Five watersheds were originally included in the study; North Main Drain, CCDD No. 1 Ditch, Town Resaca, Resaca de la Guerra, and Resaca del Rancho Viejo. The scope of engineering services summarized below was developed to identify the causes of flooding and recommend appropriate solutions to the flooding problems.

Task 1.0 Data Compilation

The Engineer met with City staff and Cameron County Drainage District No. 1 to discuss the existing data sources, maps, reports and other potential sources of data for the study as well as known problem areas and their thoughts on potential solutions. Available hydrologic and hydraulic models were obtained from the previously developed 1987 Master Drainage Plan. A map was developed to show existing watershed and drainage systems as well as the identified problem areas. A field reconnaissance of hydraulic structures and flood prone areas in the watersheds was completed.

Task 2.0 Flooding Analysis

Originally, the scope of services in the Grant Application to the Texas Water Development Board identified five watersheds to be studied in the Plan project. Four of these watersheds are located either wholly or partially within the City of Brownsville and are therefore included to some extent in the City's jurisdictional authority. The fifth watershed, served by the Resaca del Rancho Viejo is located well north of the City and is mostly undeveloped.

Upon completion of Task 1.0 of the study, it was determined that the models used to simulate flow conditions on the three resacas during the 1987 Master Drainage Plan study were unavailable and/or inappropriate for use in this current analysis. Therefore, the Engineer and the City agreed to revise the scope to allow for new modeling of the Town Resaca and Resaca de la Guerra. The Resaca del Rancho Viejo was excluded from further study for several reasons:

1. No surveying information was readily available to use in the hydraulic modeling of the channel system.
2. Due to the channel's remote location, poor accessibility and overgrowth of dense vegetation, surveying by City or County crews during their regular work schedule was not practical. (This was done for other channels to supplement data as described later in this report.) Surveying by a private company would be time consuming and expensive and was not included in the original budget.
3. The watershed is sparsely developed and therefore is not a high priority for the implementation of costly flood control projects. The 1987 Master Drainage Plan indicated that no serious flooding problems exist in this watershed.
4. Neither the City nor County expressed interest in pursuing a study on Resaca del Rancho Viejo at this time.
5. By eliminating this watershed from the study, the analysis on the other four watersheds could continue within the current budget by expanding the scope to include the preparation of new models for two remaining resacas.

The scope was revised by letter to eliminate the Resaca del Rancho Viejo from the remainder of the study and to include new modeling for the Town Resaca and Resaca de la Guerra.

The Engineer updated the previously developed hydrologic models in all four watersheds and hydraulic models in two of the watersheds for the existing primary drainage channel system identified in Task 1.0. The hydrologic models were developed based on existing 1995 development patterns and hydraulic gradients were developed for the 5-, 10- and 100-year design frequency. The hydraulic models for North Main Drain and CCDD No. 1 Ditch were updated to reflect recently constructed channel structures and culvert crossings. New hydraulic models were developed for the two resacas. Each system was evaluated to determine the problem flooding areas. The Engineer identified and analyzed alternative methods of addressing the existing problem areas and potential future problem areas due to new development, in terms of engineering feasibility, cost, resulting benefits and potential environmental impacts.

Task 3.0 Flood Planning Criteria

The Engineer reviewed the City's, Cameron County's and Cameron County Drainage District No. 1's current flood planning and design criteria and made recommendations regarding potential changes in criteria. The Engineer also evaluated potential revenue sources for funding the recommended Plan.

Task 4.0 Implementation Plan

The Engineer prioritized the improvements into a 5-year and 10-year capital improvement plan (CIP). The financial requirements associated with the recommended CIP were identified and were related to potential funding sources.

Task 5.0 Final Report and Deliverables

A draft final report was prepared which describes the study results, proposed solutions and recommended CIP. After receiving comments, a final report will be prepared and 25 copies of the final report will be submitted to the City.

1.3 Related Previous Studies

As required by the Texas Water Development Board, the availability of previous Flood Protection Planning studies in Brownsville or adjacent Cities was researched. Although a comprehensive Master Drainage Plan was completed in July of 1987 by Hogan & Rasor in association with R. J. Brandes and Mejia, Hampton & Rose, no other cities adjacent to Brownsville were identified by the Texas Water Development Board as participating in the Planning Grant program.

2.0 DATA COLLECTION

2.1 Planning Area

The planning area is shown on Exhibit 2-1 and encompasses the City of Brownsville, its ETJ, and the surrounding drainage areas. The boundaries of the planning area are generally the International Boundary on the south, F.M. 511 on the east, F.M. 3248 on the west and F.M. 511 on the north. U.S. Highway 77 and 83 traverse the City from north to south. Based on the United States Geological Survey's *East and West Brownsville, Texas Quadrangle* 1:24000 7.5 minute series topographic map, ground elevations in the planning area range from approximately 35 feet mean sea level (msl) at the western edge of the planning area, to 10 feet msl at the Brownsville Ship Channel.

A comprehensive collection of data pertaining to drainage within the boundaries of the planning area was completed by the Engineer. This collection of data included obtaining current and future land use data, identifying flood prone areas, collecting subdivision plans and storm sewer calculations for subdivisions constructed after 1986, obtaining drainage criteria manuals and regulations, researching sedimentation data and collecting other data including proposed Texas Department of Transportation (TxDOT) projects. Several field reconnaissance trips were made by the Engineer to the four watersheds in the planning area. Photographs and field measurements were made of most of the hydraulic structures along each channel. The City of Brownsville provided land use data, previous studies, and subdivision plans. Table 2-1 is a listing of the subdivision plans and storm sewer calculations compiled for this phase of the project. Information collected from TxDOT on the numerous channel crossings in the planning area are shown in Table 2-2. In addition, drainage studies, surveying data and sedimentation data were obtained from the sources listed below:

1. Master Drainage Plan by Hogan & Rasor in association with R.J. Brandes and Mejia, Hampton & Rose, July 1987

2. Rancho Viejo Watershed, Watershed Protection and Flood Prevention Projects by Lockwood, Andrews and Newnam, Inc., November 1965.

3. City of Brownsville, An Overview of a Comprehensive Stormwater Program by Henningson, Durham and Richardson, January 1981.

4. City of Brownsville, Urban Waterways Study, by Hogan and Rasor, Inc., February 1985.

5. City of Brownsville, Urban Waterways Study, by Balli and Associates in association with Henningson, Durham and Richardson, July 1976.

6. Survey data obtained by the City of Brownsville of North Main Drain, CCDD No. 1 Ditch, Town Resaca, and Resaca de la Guerra selected cross sections.

7. Survey data obtained by Cameron County of CCDD No. 1 Ditch selected cross sections.

8. Land Use Plan, Brownsville, Texas by Harland Bartholomew and Associates, October 29, 1975.

9. City Zoning Ordinance as amended through August 20, 1991, City of Brownsville, Texas.

10. Population, Housing, and Employment Projections for the Brownsville Urban Transportation Study Area, 1995-2015, by Population and Survey Analysts, December, 1994.

11. Subdivision Ordinance as amended through December 16, 1992, City of Brownsville, Texas.

12. Building Regulations as Required by the National Flood Insurance Act Title 42, The County of Cameron, August 23, 1994.

13. City of Brownsville Manual on Drainage Design, City Engineering Department, undated.

14. Article XI. Floodplain Management of Chapter 26. Planning and Development of City Code, City of Brownsville, Texas, undated.

TABLE 2-1
DATA COLLECTION
SUBDIVISION PLANS AND CALCULATIONS

Name	Plans	Drainage Calculations
Agua Dulce	X	
Big Business	X	
Briarwyck	X	X
Brownsville Country Club, Sec. XIII	X	
Colonia Galaxia, Sec. VII	X	X
Doctors' Place Professionals'	X	
Ebony Estates	X	X
El Chaparral, Sec. III	X	
El Lago, Sec. I Phase A&B, II, III, VI	X	
El Lago, Sec. IV, V	X	X
El Valle, Phase II	X	
Hacienda del Norte, Sec. I	X	X
Hacienda Estates, Sec. III	X	X
Helen	X	X
Houston Estates	X	
Hunters Quest	X	X
Hunter's Ridge	X	X
Isla de Palmas, Sec. II, III, IV, V & VI	X	X
La Posada South, Sec. V	X	X
Lakeway, Sec. II	X	X
Mesquite Grove, Sec. I	X	X
Mission Trails, Sec. III	X	
Monte Escondido	X	
N & G		X
Padre Estates	X	X
Palm Gardens, Sec. III	X	X
Paso Real Unit IV	X	X
Resaca Jardin	X	X
Rio del Sol, Sec. IV	X	X
Roosevelt Estates, Sec. V	X	X
Rose Gardens	X	X
Simon Place	X	X
Sunnyside Acres, Sec. III	X	X
Tesoro Escondido		X
Villa Ensenada, Villa Valencia, Villa Vera	X	X
Virgo Sub. & Elca Ind. Park, Sec. II		X

TABLE 2-2
CROSSING INFORMATION COLLECTED FROM TXDOT

Bridge/Culvert Designation*	Description
North Main Drain (7)	
NM12	U.S. 77/83 Access Rd. @ North Main Drain, at Price Rd
NM13	U.S. 77/83 @ North Main Drain, south of Price Rd.
NM14	U.S. 77/83 Access Rd. @ North Main Drain, near Los Ebanos
NM20	Boca Chica @ North Main Drain, east of Old Port Isabel
NM25	Southmost @ North Main Drain, between Morningside and La Vilita
NM34	Indiana @ North Main Drain, east of the Airport
NM35	Boca Chica @ North Main Drain, east of Medford
Cameron County Drainage District No. 1 Ditch (7)	
CC1	FM 3248 @ Cameron County D.D. # 1 Ditch, near the reservoir
CC3	U.S. 77/83 @ Cameron County D.D. # 1 Ditch, south of Tandy
CC5	Paredes Lines (1847) @ Cameron County D.D. # 1 Ditch, near B.C.C.
CC11	Coffee Port (802) @ Cameron County D.D. # 1 Ditch, near Central
CC13	Port (48) @ Cameron County D.D. # 1 Ditch, at intersection w/ Minnesota
CC14	Coffee Port (802) @ Cameron County D.D. # 1 Ditch, SE of 48
CC16	FM 511 @ Cameron County D.D. # 1 Ditch, SE of 48
Town Resaca (3)	
TR7	Boca Chica @ Town Resaca, east of Coria
TR22A	U.S. 77/83 northbound entrance ramp @ Town Resaca, NW of 11th
TR23	International Blvd. (48) @ Town Resaca, at the south end of U.S. 77/83
Resaca de la Guerra (also noted as Resaca de la Palma on some maps) (8)	
RG?	FM 3248 @ Resaca de la Guerra, north of Hwy. 281
RG4F	Old Hwy. 21 @ Resaca de la Guerra, near Central
RG5	Local Rd. @ Resaca de la Guerra, between Central and Old Hwy. 21
RG6	Central @ Resaca de la Guerra, near Old Hwy. 21
RG7	U.S. 77/83 @ Resaca de la Guerra, south of Coffee Port (802)
RG12	Paredes Lines (1847) @ Resaca de la Guerra, north of Price Rd.
RG18	Port (48) @ Resaca de la Guerra, north of Boca Chica
RG19	Boca Chica @ Resaca de la Guerra, near Cowan Terrace
Resaca Del Rancho Viejo (4)	
RV6B	Hwy. 1732 @ Resaca del Rancho Viejo, near the town of Olmito
RV19	U.S. 77/83 @ Resaca del Rancho Viejo, north of Tandy
RV27	Paredes Lines (1847) @ Resaca del Rancho Viejo, near Hwy. 3248
RV36	FM 511 @ Resaca del Rancho Viejo, near Port Brownsville

* Bridge/Culvert Designation from 1987 Master Drainage Plan

2.2 Existing Drainage System

The City of Brownsville's storm drainage system, like all urban storm drainage systems, consists of two separate and distinct elements, the primary system and the secondary system. The primary drainage system includes the major ditches, resacas, drainage channels, streams or rivers in the studied watershed. The secondary system includes open and closed conduits intended to convey runoff from frequent, low intensity storms to the primary system while causing relatively minor public inconvenience. The secondary system is supplemented in urban areas by a street system that conveys sheet flow runoff when the conduits of the secondary system have insufficient capacity during large storm events. At many locations, the streets may be graded inadequately to convey the excess flow from heavy rainfall events and the result is extended periods of street ponding and possible structural flooding. When both drainage systems and the local street system are properly designed and maintained, a high level of flood protection can be provided, even during significant storm events. The existing primary and secondary drainage systems in the City of Brownsville and its ETJ are described below.

2.2.1 Primary Drainage System

The primary drainage system serving the City of Brownsville is a series of improved ditches and resacas. The resacas were originally formed as active channel meanders of the Rio Grande. Overbank flooding of the river over time caused the deposition of sediment along the banks of the channel which lead to the high banks which characterize the resaca system. As the Rio Grande changed course, the resacas remained as abandoned oxbows. Today, the resacas are characterized as shallow series of connected ponds with constant pool water levels. The levels are controlled by weir structures built in the old channel meanders. The resacas have become attractive amenities for developments within the City of Brownsville and are therefore no longer considered just drainage channels. Two of the resacas serving the City of Brownsville were included in this study, Town Resaca and Resaca de la Guerra.

Between the high banks of the resaca systems, ditches have been constructed to drain the overland runoff which cannot reach the resaca systems. The two major drainage channels serving areas within the City of Brownsville which were studied in this project are the North Main Drain and the CCDD No. 1 Ditch. The ditches are trapezoidal in shape and some reaches contain concrete side slopes to convey the water more efficiently and prevent erosion.

The planning area includes four watersheds, North Main Drain, CCDD No. 1 Ditch, Town Resaca and Resaca de la Guerra. The Resaca del Rancho Viejo was eliminated from further study as discussed in Section 1.2.

Town Resaca is the southern most watershed in the planning area as shown on Exhibit 2-1. The resaca traverses in a northwest to southeast direction through the downtown area and outfalls into North Main Drain downstream of the Impala Pump Station. The Impala Pump Station discharges excess water from the Town Resaca watershed over the Rio Grande Levee to the Rio Grande. The total drainage area for the watershed is 3,581 acres. The Resaca consists of a series of ponds and ditches connected by culverts. Seven weirs control static water levels and maximize detention storage in the resaca. Information from the 1987 plan, field investigation and supplemental surveying information provided by the City was used to model the watershed.

Located to the north of Town Resaca, the North Main Drain traverses the City of Brownsville from west to east though heavily urbanized areas as shown on Exhibit 2-1. The drainage area for the watershed within the planning area upstream of F.M. 511, east of the airport, is 5,580 acres. An additional 9,750 acres drain into the North Main Drain before it outfalls into the Brownsville Ship Channel, giving the ditch a total drainage area of 15,330 acres. Flows from the Town Resaca and Resaca de la Guerra outfall into the North Main Drain between Stations 450+00 and 550+00 east of the downtown area. Information from the 1987 Master Drainage Plan in conjunction with field investigations was used to model this watershed as described in Section 3.0.

The Resaca de la Guerra drains the area in the northern sections of the City of Brownsville. The associated watershed encompasses 3,158 acres and is located in the area between the North Main Drain watershed and the CCDD No. 1 Ditch watershed. The resaca traverses in a northwest to southeast direction and outfalls into North Main Drain through a weir structure. The main drainage channel of the Resaca is comprised of an approximately 72,000-foot chain of ponds and ditches connected by culverts with six weirs serving to control static water levels and maximize detention storage. Information from the 1987 plan, field investigation and supplemental surveying information provided by the City was used to model the watershed. This watershed is shown on Exhibit 2-1.

CCDD No. 1 Ditch is located in the northern portions of the planning area as shown on Exhibit 2-1. The total drainage area for the watershed is 13,913 acres making the watershed the largest in the Plan study. The ditch traverses from west to east and outfalls into the Brownsville Ship Channel. Information used to study the watershed to taken from the 1987 Master Drainage Plan and field reconnaissance.

2.2.2 Secondary Drainage System

Within the City of Brownsville, the secondary drainage system consists of valley gutters along most streets and limited storm sewer systems. Local pump stations exist which drain stormwater from isolated areas during times of street flooding or high intensity rainfalls, including the Amigoland Pump Station and several stations located at street intersections which are flood prone. Other pump stations are located throughout the City and serve to feed water to isolated lakes, ponds and resacas as well as supply water to the local Public Utility Board (PUB); however, their overall capacity is negligible during the extreme storm events used in the flood analysis discussed within this report.

An analysis of the secondary drainage system, including the local pump stations, was not in the scope of work for the Plan study. Problem areas associated with localized street flooding which can be attributed to inadequate capacity in the secondary drainage system were mapped for reference during the study and are shown on Exhibit 2-2. Further information on the secondary drainage system in the City of Brownsville may be obtained from the 1987 Master Drainage Plan.

2.3 Historical Flooding

The Flood Insurance Rate Map (FIRM) for the Brownsville area reflects the flooding that occurred due to Hurricane Beulah in 1967. Several areas shown on the FIRM are located away from the resaca's main channel and were identified by City staff to be flood prone areas. However, these off-channel areas of flooding were not apparent in the results of the analysis discussed in Section 3.0 of this report for Town Resaca or Resaca de la Guerra, leading to the conclusion that the localized flooding is not caused by overflow from the resacas.

Localized flooding of streets and intersections within the City of Brownsville can be attributed to the extremely flat terrain found along the Gulf Coast of Texas and the inadequacy of the secondary drainage systems within the heavily developed portions of the City. If, for example, the tailwater condition in an outfall channel for a storm sewer is above the design level for the pipe system, the storm sewer cannot function at design capacity and water will pond in the street until the water levels in the outfall channel recede. Street ponding can also occur if the tailwater is low and the intensity (inches per hour) of a storm is greater than the intensity used to design the pipe system. In either case, if the street system cannot convey the excess runoff to the channel system, property damage may occur.

The City of Brownsville compiled information from different sources showing areas throughout the City which are considered flood-prone problem areas (see Exhibit 2-2). Most of the flooding problems in the City are related to severe street flooding with relatively few actually flooded structures. During field reconnaissance trips to the studied watersheds, the Engineer visited each of the problem areas. Table 2-3 lists the Engineer's intuitive explanation of the different causes of flooding within the problem areas identified by the City staff. Field investigation of the various sites shown on Exhibit 2-2 indicated that an inadequate secondary drainage system is causing the flooding in many of these off-channel areas. Many of the flood-prone areas either did not have a storm sewer system or did not have enough storm water inlets to convey the gutter flow into the closed conduit system. If the inlets are unable to discharge the design flow to the sewer system, then that system will not be used to its design hydraulic capacity. If no storm sewer system is constructed, then the streets function as the storm water conveyance system and may be expected to flood briefly during intense rainfall events. It may not be economical to provide a storm sewer system large enough to totally carry the runoff from infrequent, severe storm events; however, optimum storm sewer design which considers the interaction of the primary and secondary drainage systems and the conveyance of the street system can minimize the nuisance ponding that occurs in these areas.

TABLE 2-3
PROBLEM AREA DESCRIPTIONS

Number	Description
1	No inlets or storm sewer
2	Low spot area, no storm sewer
3	Limited storm sewer, drainage restricted
4	Limited storm sewer, no outfall
5	Lack of inlets
6	Lack of inlets, storm sewer less than 24 inches in diameter
7	Clogged drainage ditch - North Main Drain
8	Clogged inlets, 24" storm sewer
9	No inlets, depressed intersection, no storm sewer
10	No storm sewer
11	Low spot area, low crossing, no storm sewer
12	Valley section, limited inlets, inadequate storm sewer
13	Bad grading, inadequate inlets, 12" storm sewer
14	Small inlets, 18" storm sewer
15	No storm sewer
16	Lack of inlets, inadequate pipe capacity
17	Lack of inlets, inadequate pipe capacity
18	Lack of inlets, inadequate pipe capacity
19	Problem not readily apparent
20	Low area
21	Lack of inlets
22	Recent improvements, intersection of runoff from park
23	Receives street runoff from 3 directions, 14" pipe
24	Lack of inlets (existing box inlets), 12" storm sewer
25	Lack of inlets (existing box inlets), 12" storm sewer
26	No inlets
27	Lack of inlets, inadequate storm sewer
28	Lack of inlets
29	Low spot, small inlets, inadequate storm sewer
30	Inadequate storm sewer
31	Inadequate storm sewer
32	Lack of inlets, no inlets, inadequate storm sewer
33	Lack of inlets, 18" storm sewer
34	No inlets, no storm sewer
35	Low water crossing, flooding from lake (no storm sewer)
36	No storm sewer system
37	Lack of inlets
38	Lack of inlets, poor street grading
39	No inlets, flooding from North Main Drain

TABLE 2-3
PROBLEM AREA DESCRIPTIONS
(continued)

Number	Description
40	Small inlets, inadequate storm sewer
41	No inlets, no storm sewer
42	Lack of inlets
43	No storm sewer
44	No storm sewer
45	Lack of inlets, inlets too small, inadequate storm sewer
46	Lack of inlets, inlets too small, inadequate storm sewer
47	No storm sewer
48	Not enough inlets, poor road grade, 18" storm sewer
49	Not enough inlets, poor road grade, inadequate storm sewer
50	Ditch not graded correctly
51	Low water crossing, flooding from ditch
52	Generally, low, lack of inlets, poor roadside ditch, experiences flooding due to the backup of water in the Chicago Rd. drain which leads northward to CCDD No. 1 Ditch. Backwater is high enough that flooding will occur at the airport.
53	Large drainage area draining to intersection, lack of inlets, low area
54	Inadequate storm sewer
55	Inadequate storm sewer
56	Ditch capacity, clogged culverts
57	Ditch capacity, clogged culverts

Most of the flooding in Brownsville appears to be nuisance street flooding, although some structural flooding has occurred during severe flood events. The City of Brownsville is protected from widespread flooding from the Rio Grande by a levee. In addition, extreme flood flows on the Rio Grande are diverted into the North Floodway and Arroyo Colorado upstream of Brownsville. Historical flooding can be attributed to intense storm events which cause surcharging of the local channels and of the storm sewer/street drainage systems.

Significant historical rainfalls are summarized in Table 2-4:

TABLE 2-4
HISTORICAL RAINFALL
NATIONAL WEATHER SERVICE RAINFALL GAUGE AT AIRPORT

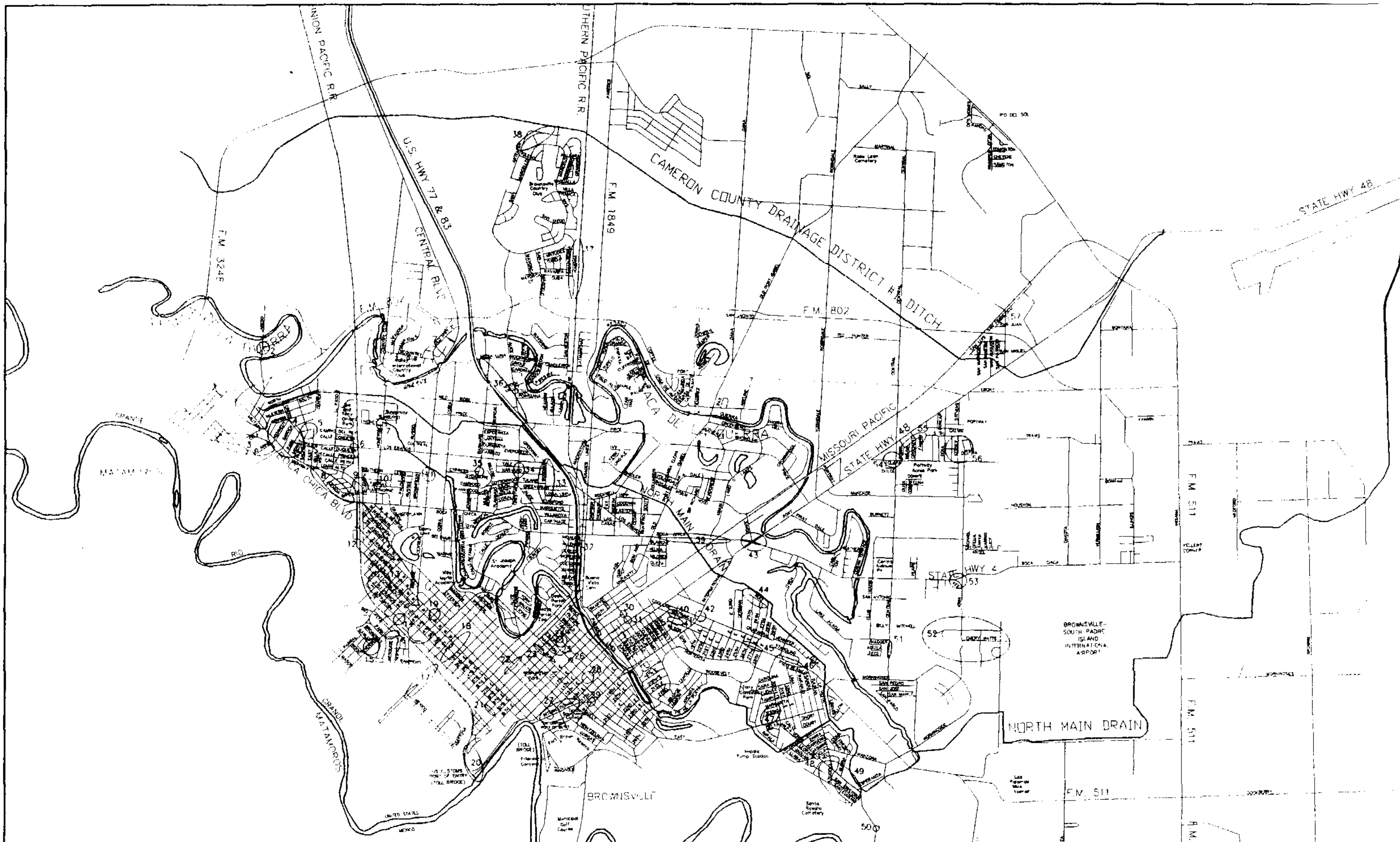
Date	Storm Rainfall (inches)		Remarks
	Total	Maximum Daily	
September 1967	15.4	12.1	Hurricane Beulah
August 1980	6.9	5.5	Hurricane Allen
September 1984	15.2	7.9	--
September 1988	5.4	4.7	Hurricane Gilbert
October 1996	10.6	10.6	Tropical Storm Josephine

The September 1967 daily value of 12.1 inches was the highest daily rainfall for the period 1896 to 1991, and exceeded the 100-year rainfall of 11.7 inches in 24 hours for Brownsville. For the period, two daily totals were greater than 10 inches, two daily totals were between 7 and 8 inches, two daily totals were between 6 and 7 inches, and 11 daily totals were between 5 and 6 inches. The 10.6 inches in 24 hours in October 1996 was the second highest daily historical rainfall. Several citizen rainfall observers reported between 10.7 and 14.0 inches of rainfall in 24 hours during the October 1996 event. Significant street flooding and some structural flooding were reported within the City and its ETJ during the October 1996 and September 1984 storm events.

2.4 Land Use Data

The land use data for 1995 was received from the City of Brownsville Planning Department. This data was compared to aerial photos taken the same year to verify the different land uses. The various land use classifications were then digitized onto the base map for the area as presented in Exhibit 2-3. The changes in land use over the next ten years were projected to the year 2005 as shown on Exhibit 2-4. The City has hired a consultant to analyze existing land use patterns and provide long-range development predictions. Although the projections for the next ten years had not yet been developed, the consultant recommended that the year 2000 land use currently mapped by the City's Planning Department would adequately represent a ten-year land use projection to the year 2005 based on their preliminary review of the current trends of development in the City. The City agreed with this recommendation. Exhibit 2-4 is reprinted using the 2000 land use map provided by the City of Brownsville. The land use categories shown on Exhibit 2-4 were consolidated into the six categories shown on Exhibit 2-3 in order to determine the changes in percent impervious cover in the watersheds' subareas.

DRAWN	D.V.	RUST LICHLITER/JAMESON	CITY OF BROWNSVILLE, TEXAS	
DESIGN	T.J.	Environment & Infrastructure	DRAINAGE STUDY	2-1
CHECKED	C.W.	Consulting Engineers, Scientists and Planners		
PM	M.J.	2929 Briarpark Drive, Suite 600, Houston, Texas 77042-3703	PLANNING AREA	PROJECT NO.
SCALE: 1" = 3500'				68589
DATE: NOVEMBER 1996				



LEGEND

(20) FLOOD PRONE AREA IDENTIFIED BY THE CITY STAFF

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 2000'
DATE	NOVEMBER 1996

RUST LICHLITER/JAMESON

Environment & Infrastructure
Consulting Engineers, Scientists and Planners
2929 Briarpark Drive, Suite 600, Houston, Texas 77042-3703

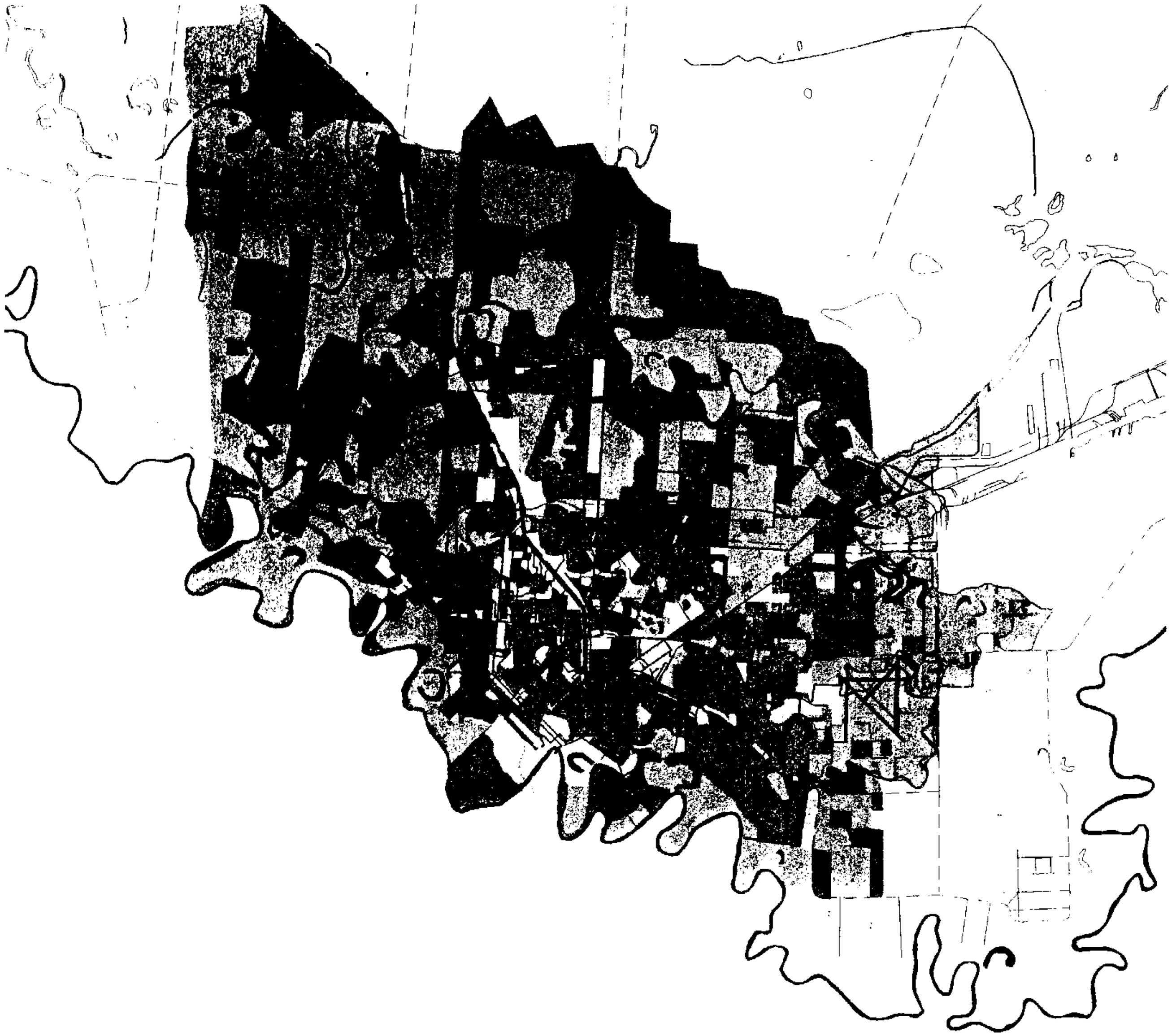
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

LOCALIZED FLOOD PRONE AREAS

2-2

68589



LEGEND

RESIDENTIAL	UNDEVELOPED
COMMERCIAL	PAVEMENT
AGRICULTURAL	WATER

DRAWN:	D.V.
DESIGN:	J.C.
CHECKED:	C.W.
PM:	M.J.
SCALE:	1" = 4000'
DATE:	NOVEMBER 1996

RUST LICHLITER/JAMESON

Environmental & Infrastructure
Consulting Engineers, Scientists and Planners
2949 Briarpark Drive, Suite 600, Houston, Texas 77042-3283

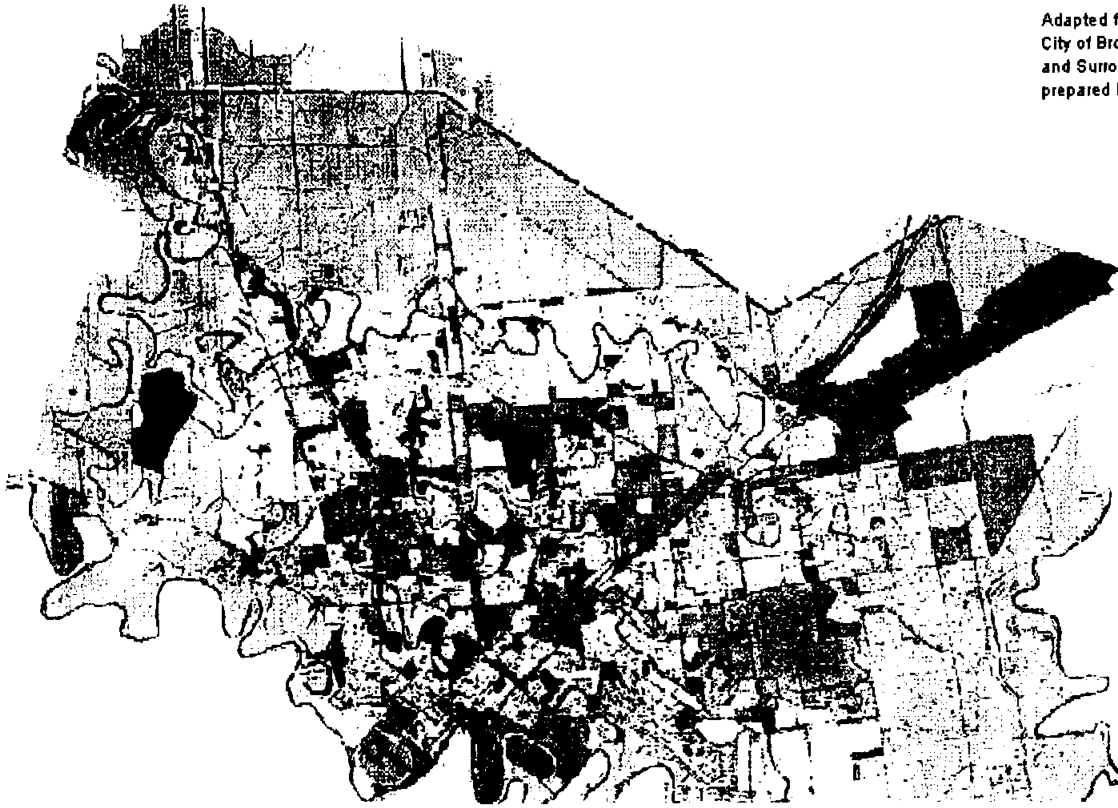
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

YEAR 1995 LAND
USE MAP

EXHIBIT NO. 2-3

PROJECT NO. 68589



Adapted from Year 2000 Land Use Assumptions
City of Brownsville, Texas
and Surrounding Rural Areas
prepared by Wilber Smith Associates

LEGEND

Single Family	Retail	Public Facilities	Agriculture	Water
Multi-Family	Industry	Parks	Transportation	Open Space

DRAWN	D.V.
DESIGN	C.G.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 4000'
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CITY OF BROWNSVILLE, TEXAS
DRAINAGE STUDY

YEAR 2005 PROJECTED LAND USE MAP

68589

3.0 FLOODING ANALYSIS

3.1 Analysis of the Existing Primary Drainage Systems

As described in Section 2.2.1, two man-made ditches and two resaca systems form the primary drainage system for the City of Brownsville and its ETJ. The Town Resaca and the Resaca de la Guerra outfall into the North Main Drain channel. Some of the flood waters in the Town Resaca are discharged into the Rio Grande through the Impala Pump Station. Both North Main Drain and CCDD No. 1 Ditch outfall into the Brownsville Ship Channel. The study of the four primary drainage systems (North Main Drain, CCDD No. 1 Ditch, Town Resaca and Resaca de la Guerra) involved two forms of analysis. The two man-made ditches, North Main Drain and CCDD No. 1 Ditch, were analyzed by using the HEC-1 and HEC-2 programs for the hydrology and hydraulics of the systems, respectively. The two resacas, Town Resaca and Resaca de la Guerra, were analyzed with the SWMM program package which contains both the hydrology and hydraulics functions.

3.1.1 Hydrology

3.1.1.A. Description of Models

The U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) in Davis, California, has developed a series of hydrologic and hydraulic computer models which enable engineers and scientists across the United States to select appropriate methodologies for given regional parameters and then simulate rainfall, runoff and channel flow under various conditions. The hydrologic program used in the study to develop flows for the North Main Drain and CCDD No. 1 Ditch is the HEC-1 "Flood Hydrography Package" computer model.

The HEC-1 program can simulate the precipitation-runoff process and compute flood hydrographs at desired locations in a watershed. The physical characteristics of the watershed are represented by an interconnected system of geographic and hydrologic components. The watershed boundaries are delineated, and the land area is divided into sub-watersheds based on the study objectives and hydrologic characteristics. The runoff from each subarea is calculated using the Soil Conservation Service Method for computing a runoff hydrograph from precipitation data. After the rainfall-runoff process is simulated, runoff from the sub-watersheds is linked using channel routing. The basic hydrologic components of the model include land-surface runoff from each sub-watershed, the combination of hydrographs at confluences and channel and reservoir routing. HEC-1 was used for the development of the North Main Drain and the CCDD No. 1 Ditch flows used in this study.

The second hydrologic program used in the study to develop flows for Town Resaca or Resaca dela Guerra is the EPA's Storm Water Management Model, or SWMM. SWMM was originally developed in 1971 for the simulation of water quality associated with urban runoff and for the prediction of flows, stages, and pollution concentrations in combined sewer systems, but it has been applied in a wide range of urban drainage problems in the past fifteen years.

The SWMM program uses a series of links and nodes to simulate the hydrologic and hydraulic response of a watershed to input from observed or design rainfall hyetographs and from upstream inflow hydrographs. Downstream water levels can be accounted for with the use of outfall nodal boundary conditions. Nodes are the points in the model at which inflows are input and at which storage and depth characteristics of the system are calculated. At each time step SWMM maintains nodal continuity, balancing inflow, outflow and storage at each node. SWMM was selected to model conditions in the two resacas due to its ability to simulate flow in both directions in a channel, which occurs in the series of ponds characterized by the resacas.

Each node is defined with a RUNOFF operational block. The RUNOFF block generates runoff from rainfall and, optionally, routes flows to combining points. In this application, runoff was developed from Soil Conservation Service (SCS) unit hydrographs using Curve Numbers (CN) based on United States Department of Agriculture (USDA) hydrologic soil types and time of concentration estimated from channel and overland flow velocities

The XP-SWMM program was used for the development of the Town Resaca and the Resaca de la Guerra models used in this study. The XP-SWMM modeling system is a proprietary shell that interfaces with the public domain US-EPA Stormwater Management Model Version 4. The shell employs an expert system to facilitate the entry of data that is used as input by the public domain program and provides a graphical interface to view model input and output.

3.1.1.B. Application of Models to Watersheds

The North Main Drain watershed was divided into 39 subwatersheds coinciding with the areas used in the 1987 Master Drainage Plan as shown on Exhibit 3-1. The CCDD No.1 Ditch watershed was divided into 19 subwatersheds coinciding with areas in the same master drainage plan as shown on Exhibit 3-2. The SCS method was used for the HEC-1 hydrologic analysis for North Main Drain and CCDD No.1 Ditch. This method employs four parameters to compute runoff, the CN, the percent of impervious cover, the SCS lag and the subasin area. The Engineer reviewed the hydrologic parameters used in the 1987 Plan and made some changes due to changes in land use from 1987 to 1995 and new measurements for time of concentration and lag parameters. The CN for the various sub-basins was determined using the SCS soil classification and the land use(s) within each sub-basin. The percent of impervious cover in each subarea was determined by reviewing aerial photographs and calculating the percentage for each land use type. Residential areas were assigned a 45 percent impervious cover value, commercial areas were assumed to be 85 percent impervious, agricultural areas were assigned 5 percent impervious cover, undeveloped areas were assumed to be zero percent impervious and standing water surfaces were assumed to be 100 percent impervious.

The percent impervious cover and CN values for each subarea are listed on Table 3-1 and Table 3-2 for North Main Drain and CCDD No.1 Ditch, respectively.

TABLE 3-1
EXISTING HYDROLOGIC PARAMETERS
NORTH MAIN DRAIN

Subarea	Drainage Area (Acres)	Percent Impervious	CN Value
NM1-NM11	761.6	44.80	74
NM12	11.9	79.62	78
NM13	185.3	73.15	77
NM14	206.3	62.01	68
NM15	25.7	44.98	60
NM16	101.4	50.48	60
NM17	43.9	42.89	62
NM18	33.8	60.98	64
NM19	138.8	49.03	72
NM20	235	56.21	75
NM21	250.7	48.86	74
NM22	99.6	65.32	78
NM23	91.3	58.73	74
NM24	491.8	37.25	73
NM25	144	51.98	64
NM26	201	44.99	68
NM27	46.5	45.00	64
NM28A	25.4	45.00	60
NM28B	108.1	33.55	59
NM29	71.5	47.57	64

TABLE 3-1
EXISTING HYDROLOGIC PARAMETERS
NORTH MAIN DRAIN
(continued)

Subarea	Drainage Area (Acres)	Percent Impervious	CN Value
NM30	80.9	14.07	64
NM31	11.9	40.46	68
NM32A	242.9	22.29	68
NM32B	172.1	38.44	62
NM33	1596.4	23.96	73
NM34	94.4	19.55	68
NM35	101.5	6.21	68
NM36	801.9	10.67	66
NM37	205.9	9.78	66

TABLE 3-2
EXISTING HYDROLOGIC PARAMETERS
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Subarea	Drainage Area (Square Miles)	Percent Impervious	CN Value
CC1	0.64	5.77	64
CC2	0.64	3.37	76
CC3	0.38	15.01	70
CC4	5.47	26.15	75
CC5	0.53	38.91	76
CC6	1.81	16.49	75
CC7	1.72	16.48	73
CC8	0.16	23.63	76
CC9	0.28	1.99	78
CC10	1.31	4.78	74
CC11	0.02	5.00	78
CC12	1.15	3.81	77
CC13	5.72	28.26	68
CC14	0.22	33.86	64
CC15	0.77	23.06	62
CC16	0.04	85.00	72
CC17	0.06	19.93	78
CC18	0.45	24.57	71
CC19	0.38	10.70	77

The SCS Dimensionless Unitgraph method in HEC-1 calculates how much of the rainfall actually becomes storm runoff. Rainfall was simulated as uniform over the entire watershed with the dimensionless unit hyetograph used in the 1987 Study. A total of 6.4, 7.5, and 11.7 inches of rainfall in 24 hours was used for the 5-, 10-, and 100-year storm events, respectively.

The peak runoff flowrate used in the HEC-2 model for flows in the channel of North Main Drain and CCDD No.1 Ditch for the 5-, 10-, and 100-year events is tabulated in Table 3-3 and Table 3-4, respectively.

TABLE 3-3
EXISTING CONDITIONS PEAK FLOWS
NORTH MAIN DRAIN

Station	Location	Cumulative Drainage Area (Square Miles)	Channel Peak Flowrate (cfs)		
			5-Year	10-Year	100-Year
1000	South Port Rd.	23.95	1550	1820	4050
12688	Oklahoma	10.14	735	784	1180
15688	Browne	9.82	710	745	1120
20458	Boca Chica	8.56	620	650	1020
25688	FM 511	8.40	620	650	1020
26088	Utah Ave.	8.40	620	650	1020
41387	Minnesota Ave.	5.91	510	580	770
45894	Apollo	5.24	510	580	770
46888	Southmost Road	5.24	510	580	770
48169	Ramada Drive	4.80	510	580	770
48915	La Posada Road	4.80	460	550	770
49727	Esperanza Road	4.80	460	550	770
51410	Manzano Road	4.72	460	550	770
55640	Southmost Road	4.41	410	460	770
58645	30th Street	4.18	410	460	770
63243	International Blvd.	3.41	410	460	770
63803	14th Street	3.27	410	460	770

TABLE 3-3
EXISTING CONDITIONS PEAK FLOWS
NORTH MAIN DRAIN
(continued)

Station	Location	Cumulative Drainage Area (Square Miles)	Channel Peak Flowrate (cfs)		
			5-Year	10-Year	100-Year
64853	Southern Pacific RR	3.12	410	460	770
65541	Boca Chica	3.12	410	460	770
67494	Old Port Isabel Road	2.36	390	440	730
68626	Renfro Street	2.14	390	440	730
69646	Rockwell	2.09	390	440	730
71240	Paredes Line Road	2.02	390	440	730
72185	Mackintosh	1.86	390	440	680
72382	Southern Pacific RR	1.86	390	440	680
72699	Access Road	1.82	390	440	680
74143	US 77/83	1.82	390	440	680
76393	Above 7 x 7 Box	1.19	310	370	625

TABLE 3-4
EXISTING CONDITIONS PEAK FLOWS
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Station	Location	Cumulative Drainage Area (Square Miles)	Channel Peak Flowrate (cfs)		
			5-Year	10-Year	100-Year
7979	Highway 48	21.37	1131	1405	2143
9993	Mopac RR	20.92	1120	1395	2134
10923	FM 511	20.86	1120	1395	2134
11648	Harbor Road	20.82	1120	1396	2134
16380	FM 802	20.05	1078	1348	2079
18207	Highway 48	19.83	1074	1346	2080
20546	Railroad	14.11	856	1061	1541
22880	FM 802	12.96	768	950	1359
23887	Central Avenue	12.94	768	950	1379
27984	Robindale Ave.	11.63	707	874	1311
29700	Flume	11.35	704	870	1311
29989	Old Port Isabel	11.19	702	868	1371
32540	Dana Road	9.47	615	759	1320
39327	Paredes Line Road	7.66	483	596	1040
40496	Southern Pacific RR	7.13	458	565	989
48955	US 77/83	1.66	59	75	141
51493	Union Pacific RR	1.28	76	96	174
57650	FM 3248	0.64	64	85	173

The Town Resaca watershed was divided into 48 subwatersheds using the areas defined in the 1987 Master Drainage Plan as shown in Exhibit 3-3. Similarly, the Resaca de la Guerra watershed was divided into 27 subwatershed using the same master drainage plan as shown in Exhibit 3-4. The Engineer reviewed the hydrologic parameters used in the 1987 Plan and made revisions due to updated land use and new measurements of the parameters. These hydrologic parameters were then used in the RUNOFF block of XP-SWMM to generate rainfall runoff hydrographs for each subwatershed. All hydrographs were developed using SCS methodology. The watershed parameters entered directly into the XP-SWMM program include area, percent impervious, width, slope, Runoff CN, shape factor and time of concentration. Rainfall was simulated as uniform over the entire watershed with the dimensionless unit hyetograph used in the 1987 Study. A total of 6.4, 7.5, and 11.7 inches of rainfall in 24 hours was used for the 5-, 10-, and 100-year storm events, respectively.

Using USDA Soil Maps for Cameron County, an area-weighted CN value was determined for each subwatershed based on the SCS hydrologic soil type of that area. Impervious cover percentages for developed areas were estimated from land use maps and aerial photography. Residential areas were considered 45 percent impervious, commercial areas 85 percent impervious, agricultural areas five percent impervious and lakes or ponds 100 percent impervious.

The Lag Time was estimated for each subwatershed using the hydrologic length, overland slope, and channel velocity of 0.5 feet per second. Because of the flat overland gradients found in Brownsville, a hydrograph shape factor of 300 was used. The width of each subwatershed was determined by dividing the total area by the hydraulic length of the watershed. The watershed slope was determined from aerial topography and USGS 24000:1 Quadrangle maps.

Selected hydrologic parameters used in the development of the synthetic hydrographs for each subwatershed of the Town Resaca drainage system modeled in this study are shown in Table 3-5. The hydrologic parameters for the Resaca de la Guerra subareas are shown in Table 3-6.

XP-SWMM uses these parameters to calculate the cumulative depth of runoff from the pervious and impervious sections of each subwatershed as a function of the total depth of precipitation and storage, which is a function of the CN value. Peak runoff is then estimated based on watershed area and time of concentration. The peak runoff generated for each subwatershed in Town Resaca and Resaca de la Guerra for the 5-, 10-, and 100-year events is tabulated in Table 3-7 and Table 3-8, respectively. The flowrates vary significantly between Resaca pools and in some cases are so low that the models simulate the runoff as being contained within the pool with no flow occurring over the weirs (flow equal to zero). Cumulative drainage area is not shown on Tables 3-7 and 3-8 because the resaca pools act as detention basins for the immediate contributing areas. Maximum flows in the resacas are less dependent on upstream contributing basins than are the channel flows for the North Main Drain and CCDD No. 1 Ditch watersheds.

TABLE 3-5
EXISTING HYDROLOGICAL PARAMETERS
TOWN RESACA

Subarea	Drainage Area (Acres)	Percent Impervious	CN Value
TR1	220.9	27.1	64
TR2	150.6	46.9	62
TR3	100.0	56.0	62
TR4	52.1	45.0	68
TR5	67.0	48.8	58
TR6	55.0	46.8	58
TR7	74.2	45.0	58
TR8	39.2	45.0	58
TR9	56.4	62.2	58
TR10	52.3	44.8	58
TR11	23.7	45.0	58
TR12	82.0	45.0	58
TR13	71.8	45.0	58
TR14	32.3	43.2	58
TR15	269.4	60.3	58
TR16	70.6	59.4	58
TR17	66.2	71.7	58
TR18	92.8	57.4	58
TR19	22.7	49.2	58
TR20	36.1	51.7	58
TR21	23.1	59.4	58
TR22	30.1	45.9	58

TABLE 3-5
EXISTING HYDROLOGICAL PARAMETERS
TOWN RESACA
(continued)

Subarea	Drainage Area (Acres)	Percent Impervious	CN Value
TR23	9.8	58.0	58
TR24	36.0	69.9	58
TR25	26.9	51.5	58
TR26	47.5	48.3	58
TR27	10.3	60.0	58
TR28	161.2	54.4	62
TR29	107.3	62.5	58
TR30	136.3	46.1	58
TR31	151.1	49.8	62
TR32	49.8	85.6	58
TR33	62.5	55.8	58
TR34	48.7	37.9	58
TR35	108.6	53.4	58
TR36	82.5	52.5	58
TR37	42.6	47.2	58
TR38	66.4	51.8	58
TR39	12.4	60.8	58
TR40	43.9	56.3	58
TR41	41.8	57.1	58
TR42	17.0	54.2	58
TR43	56.5	31.1	58
TR44	46.8	45.0	62

TABLE 3-5
EXISTING HYDROLOGICAL PARAMETERS
TOWN RESACA
(continued)

Subarea	Drainage Area (Acres)	Percent Impervious	CN Value
TR45	70.1	27.1	58
TR46	61.9	52.8	58
TR47	41.2	53.2	58
TR48	331.1	46.8	72

TABLE 3-6
EXISTING HYDROLOGIC PARAMETERS
RESACA DE LA GUERRA

Subarea	Drainage Area (Acres)	Percent Impervious	CN Value
RG41 Upper	368	20.1	64
RG41 Lower	365	20.1	64
RG40	7	26.7	58
RG39	35	33.8	58
RG38	30	41.0	58
RG37	234	40.5	58
RG36	21	73.2	58
RG35	6	45.0	58
RG35 A	10	45.0	58
RG34	10	78.5	58
RG33	118	45.5	62
RG32	123	45.5	60
RG31	128	48.2	60
RG30	47	60.1	58
RG29	87	47.7	64
RG28	94	44.1	60
RG27	26	75.2	77
RG26	216	48.8	62

TABLE 3-6
EXISTING HYDROLOGIC PARAMETERS
RESACA DE LA GUERRA
(continued)

Subarea	Drainage Area (Acres)	Percent Impervious	CN Value
RG25	82	46.4	70
RG24	186	56.3	62
RG23	32	64.1	68
RG22	47	61.5	62
RG21	210	46.7	60
RG20	52	31.0	63
RG19	260	37.4	62
RG15	359	48.7	61
RG8	46	58.3	58

TABLE 3-7
EXISTING CONDITIONS PEAK FLOWS
TOWN RESACA

Structure Designation	Location	Upstream Peak Flowrate (cfs)		
		5-Year	10-Year	100-Year
IM1	Tulipan Dr.	189	377	634
IM2	Calle Milpa Verde	247	496	836
IM3	Impala	134	261	434
IM4	East Avenue	27.0	401	568
TR24	Station 155+50	2.31	219	381
TR23	Highway 4	11.3	217	358
TR22E	14th Street	17.0	201	324
TR22D	13th Street	12.0	190	305
TR22C	12th Street	11.3	190	305
TR22A	Highway 77	11.3	186	298

TABLE 3-7
EXISTING CONDITIONS PEAK FLOWS
TOWN RESACA
(continued)

Structure Designation	Location	Upstream Peak Flowrate (cfs)		
		5-Year	10-Year	100-Year
TR22	7th Street	11.3	215	291
TR21	Railroad	11.3	179	289
TR20	6th Street	0	179	286
TR19	Ringgold	2.0	174	273
TR17	Gladys Porter Zoo	4.50	178	260
TR15	Palm Boulevard	1.31	159	231
TR14	Railroad	0	156	242
TR13	Calle Retama (1)	5.0	161	288
TR12	St. Joseph's	10.0	169	316
TR10	Calle Retama (2)	16.0	241	408
TR8	Belthair Street	0.76	41.0	50.5
TR7	Boca Chica	0.74	46.2	59.5
TR4	Central Boulevard	2.60	46.2	72.5

TABLE 3-8
EXISTING CONDITIONS PEAK FLOWS
RESACA DE LA GUERRA

Structure Designation	Location	Upstream Peak Flowrate (cfs)		
		5-Year	10-Year	100-Year
RG2	Mercedes Road	35	44	49
RG3		18	34	47
RG4B		4	6	7
RG6	Central Blvd.	35	37	39
RG7	U.S. 83/77	36	42	43
RG8		37	42	51
RG9		31	33	36
RG10		50	54	62
RG11	Railroad	58	69	91
RG12*		22	68	101
HWY1847	Hwy 1847	50	57	114
RG13	Palo Verde Road	26	30	38
RG14*		40	47	78
RG15	Port Isabel Road	161	162	165
RG16		87	105	160
RG17	Price Road	90	109	161
RG18	14th Street	92	109	154
RG19	Boca Chica	104	112	199
RG20	Billy Mitchel	90	108	161
RG21		85	104	152
RG22	Morning Side Drive	35	42	58
RG23	Morning Side Road	32	38	47
RG24BOXWEIR	Outfall Structure	32	38	47
Outfall Channel	North Main Drain	494	561	708

* Combined weir and culvert flow.

3.1.2 Hydraulics .

3.1.2 A. Description of Models

As stated above two different hydraulics programs (HEC-2 and SWMM) were used to analyze the four primary drainage systems. The following paragraphs describe each of the programs and how they were applied in the Flood Protection Plan Study.

The HEC-2 computer program was developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) for calculating water surface profiles for steady, gradually varied flow in natural or manmade channels. The program allows the effects of obstructions to flow, such as bridges, culverts, weirs, and buildings in the floodplain, to be modeled. Generally, the water surface profiles are calculated with the standard step method, which sequentially solves the one-dimensional energy equation between cross-sections. At some bridges, where more complex flow conditions exist, the program may use momentum and other hydraulic equations to determine changes in the water surface elevations.

HEC-2 has a variety of applications and many options for defining input and specifying output. This feature allows the Engineer to create models with several different channel or culvert improvement options. HEC-2 was used for the development of the North Main Drain and the CCDD No.1 Ditch models used in this study.

SWMM was selected to simulate the movement of flow in the more complex resaca systems. In the hydraulic routing portion of the SWMM model, the flow between nodes through ponds, channels, and structures is simulated by links. Implicit finite-difference forms of the transient one-dimensional hydrodynamic flow equations are solved for each link at each time step. Options are available for modeling gravity flow through open channels with standard geometric and natural stream sections, and through closed conduits of round, rectangular and other geometric forms. SWMM also models flow over weirs and pumped flow in drainage systems.

The use of links and nodes allows the modeling of complex, branched drainage systems with any number of control structures. This allows the evaluation of the effect of each structure on the overall performance of the system regardless of its complexity.

Each link may be defined with each of four different operational blocks available within the SWMM package:

- The TRANSPORT Block routes flows through the watershed based on the kinematic wave method. The Transport Block was not used in this study because the assumptions of the kinematic wave method (steep slopes and negligible backwater) are not appropriate for this site.

- The EXTRAN Block routes channel flow using an implicit solution of the full dynamic equations which can account for very mild slopes and the backwater caused by tailwater conditions and the effect of weirs and culverts within the system. It is frequently used as a stand-alone modeling element for the analysis of complex hydraulic systems.

- The STORAGE/TREATMENT Block is for water quality simulations and was not used in this application.

- The STATISTICS Block is used to separate hydrographs, calculate statistics, and perform frequency analysis for continuous flow records. It was not used in the single-event models developed for this study.

3.1.2.B. Application of Models to Watersheds

The HEC-2 program was used to calculate the water surface elevations in the North Main Drain and CCDD No.1 Ditch. Mannings "n" values ranged from 0.04 to 0.045 in the channels and from 0.05 to 0.065 in the overbanks in order to simulate roughness as observed during trips to the watersheds. The special bridge method was used to simulate the hydraulic conditions present at bridge crossings for both ditches. Culverts were modelled using the special culvert method. Tables 3-9 and 3-10 show the hydraulic structures in the channels, respectively. The location of each of these structures is shown on Exhibits 3-5 and 3-6. Information on the configuration of the channel reaches and the hydraulic structures was obtained from limited field surveys, field reconnaissance, construction drawings and previous studies/models as described in Section 2.2.1.

TABLE 3-9
HYDRAULIC STRUCTURES
NORTH MAIN DRAIN

Structure No.	Street Name	Station	Type	Number	Culvert Size
NM 38	South Port Road	10+00	RCP	8	60"
NM37	Oklahoma	126+88	Bridge	1	
NM36	Browne	156+88	Bridge	1	
NM35	Boca Chica	204+58	Box	3	9' x 8'
NM34	FM 511	256+88	Bridge	1	
NM33	Utah Avenue	260+88	Bridge	1	
NM32	Minnesota Avenue	413+87	Bridge	1	

TABLE 3-9
HYDRAULIC STRUCTURES
NORTH MAIN DRAIN
(continued)

Structure No.	Street Name	Station	Type	Number	Culvert Size
NM31	Apollo Drive	458+94	Bridge	1	
NM30	Southmost Road	468+88	Bridge	1	
NM29	Ramada Drive	481+69	Bridge	1	
NM28	La Posada Drive	489+15	Box	4	9' x 8'
NM27	Esperanza Road	497+27	Bridge	1	
NM26	Manzano Street	514+10	Bridge	1	
NM25	Southmost Road	556+40	Box	3	10' x 8'
NM24	30th Street	586+45	Bridge	1	
NM23	International Blvd.	632+43	Box	3	10' x 9'
NM22	14th Street	638+03	Box	3	9' x 9'
NM21	Southern Pacific Railroad	648+53	RR Bridge	1	
NM20	Boca Chica	655+41	Box	3	10' x 7.7'
NM19	Old Port Isabel Road	674+94	Box	1 4	4' x 6' 60"
NM18	Renfro Street	686+26	RCP	3	60"
NM17	Rockwell	696+46	RCP	2	60"
NM16	Paredes Line Road	712+40	Box	1 2	48" 6' x 7'
NM15	Mackintosh	721+85	RCP	1 3	4.5' x 7' 60"
NM14	Southern Pacific Railroad	723+82	RR Bridge	1	
NM13B	Access Road	726+99	Box	2	8' x 7'
NM13A	U.S. 77/83	741+43	Box	2	8' x 7'

TABLE 3-9
HYDRAULIC STRUCTURES
NORTH MAIN DRAIN
(continued)

Structure No.	Street Name	Station	Type	Number	Culvert Size
NM8	West Price Road		Box	2	7' x 7'
NM7	Coria Street	791+86	RCP	3	42"
NM6	Central Blvd.	799+44	Weir Box In Series	1 1 1	 6.5' x 4' 11' x 4'
NM5		817+58	RCP	1	36"
NM4	Honeydale	826+90	RCP	2	36"
NM3	Mopac Railroad	839+65	CMP	1	48"
NM2	El Paso Road	847+71	RCP	2	36"
NM1	Center Drive	857+36	RCP	1	42"

Size: Box - H x V
Pipe - Diameter
Weir - Crest Length

Type: RCP - Reinforced Concrete Pipe
CMP - Corrugated Metal Pipe

TABLE 3-10
HYDRAULIC STRUCTURES
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Structure No.	Street Name	Station	Type	Number	Culvert Size
CC18	Highway 48	79+79	Bridge	1	
CC17	Mopac Railroad	99+93	RR Bridge	1	
CC16	FM 511	109+23	Bridge	1	
CC15	Harbor Road	116+48	Bridge	1	
CC14	FM 802	163+80	Bridge	1	
CC13	Highway 48	182+07	Bridge		
CC12	Railroad	205+46	RR Bridge	1	
CC11	FM 802	228+80	Bridge	1	
CC10	Central Avenue	238+87	Bridge	1	
CC9	Robindale Avenue	279+84	Bridge	1	
CC8	Flume	297+00	Bridge	1	
CC7	Old Port Isabel	299+89	Box	2	9' x 10'
CC6	Dana Road	325+40	Bridge	1	
CC5	Paredes Line Road	393+27	Bridge	1	
CC4	Southern Pacific Railroad	404+96	RR Bridge	1	
CC3	U.S. 77/83	489+55	Box	1	6' x 6'
CC2	Union Pacific Railroad	514+93	Box	1	10' x 8'
CC1	FM 3248	576+50	RCP	1	48"

Size: Box - H x V
Pipe - Diameter
Weir - Crest Length

Type: RCP - Reinforced Concrete Pipe

XP-SWMM was used for the development of the Town Resaca and the Resaca de la Guerra models used in this study. Data for the model input was obtained from limited field surveys, field reconnaissance, construction drawings and previous studies and models as described in Section 2.2.1. The hydraulic analysis for both of the Resacas was carried out in the EXTRAN mode. EXTRAN is able to model adverse or flat slopes and several shapes of conduits (including natural channel sections) as well as specialized hydraulic appurtenances such as pumps and weirs.

EXTRAN nodes for the simulation of the resacas were defined as simple, storage, hydrograph inlet, or outfall nodes. Hydrographs developed in RUNOFF were input at hydrograph inlet nodes in EXTRAN for the 5-, 10-, and 100-year storm events.

One outfall junction was defined at the North Main Drain/Town Resaca confluence. A time-versus-stage hydrograph was used as the boundary condition at this node. One outfall junction was defined for the network model at the North Main Drain/Resaca de la Guerra confluence. A variable stage hydrograph was used as the boundary condition at this node. The hydrograph was estimated from discharges determined in a HEC-1 model of the North Main Drain catchment and was converted to stages with a rating curve developed from HEC-2 output at Section 459+67 of the North Main Drain.

All links in the EXTRAN block are referred to as "conduits", although they can be defined via input parameters as conduits, weirs, pumps, or natural channels. All of these conduit types were used in the Town Resaca model. Conduits, weirs, and natural channels were used in the Resaca de la Guerra model.

Dimensions for natural channel cross-sections were estimated from the Brownsville Urban Waterways Study. The XP-SWMM designations for the Town Resaca natural sections correspond to the numbering from that study, with a prefix "X" added. The Resaca de la Guerra sections were identified with a prefix "HEC_" added. Although the Resacas do not have much vegetation growth within the channels, the natural sections were modeled with a manning's "n" value of 0.04 in the channel in order to be conservative. The overbank areas were modeled with a manning's "n" value of 0.08. Slope paving under bridges was modeled with a manning's "n" of 0 .015, while R.C.P. or box culverts were modeled with an "n" value of 0.013.

Information on conduit inverts and dimensions were taken from Table 3 of the 1987 Master Drainage Plan and from measurements taken during the field investigation phase of this study. These structures are identified in the model using the same structure designations as the 1987 Plan. Tables 3-11 and 3-12 below lists the structures and their various hydraulic parameters for Town Resaca and Resaca de la Guerra, respectively. The location of each of these structures is shown on Exhibits 3-7 and 3-8.

TABLE 3-11
HYDRAULIC STRUCTURES
TOWN RESACA

Structure No.	Street Name	Station	Type	Number	Culvert Size
IM1	Tulipan Drive	43+70	Bridge	1	
IM2	Calle Milpa Verde	56+50	Bridge	1	
IM3	Impala	65+60	Bridge	1	
IM4	East Avenue	64+10	Bridge	1	
TR27	Control Weir	100+00	Weir	1	15'
TR26	WWTP Facility Crossing	150+00	CMP	1 2	80" 36"
TR25	Control Weir	154+80	Weir	1	2'
TR24	22nd Street	155+50	Bridge	1	
TR23	Highway 48	176+70	Box	2	10' x 9'
TR22E	14th	182+90	Box	2	10' x 9'
TR22D	13th	195+58	Box	2	10' x 9'
TR22C	12th	199+18	Box	2	10' x 9'
TR22B	Railroad	202+34	Box	2	10' x 8'
TR22A	Highway 77	206+00	Box	2	10' x 8'
TR22	7th	216+88	Box	2	10' x 8'
TR21	Railroad	219+09	RR Bridge	1	
TR20	6th	220+49	Box	2	9' x 9'
TR19	Ringgold	248+61	Box	2	9' x 3'
TR18	[G. Porter Zoo]	249+50	Weir	1	
TR17	[G. Porter Zoo]	265+30 265+24	Box Box	2 1	9' x 8' 6' x 3'
TR16	Alice	270+64	Box	2	9' x 4'

TABLE 3-11
HYDRAULIC STRUCTURES
TOWN RESACA
(continued)

Structure No.	Street Name	Station	Type	Number	Culvert Size
TR15	Palm Blvd.	290+84 292+10	Box Weir	1 1	10' x 6'
TR14	Railroad	295+26	Box	1	9' x 4'
TR13	Calle Retama	299+59	Box	1	10' x 8'
TR12	Ringold	308+19	Box	1	10' x 10'
TR11	Pedestrian Bridge	325+59	Box	1	12' x 6.5'
TR10	Calle Retama	349+04	Box	1	10' x 8'
TR9A	Control Weir	360+44	Weir	1	
TR9B	Control Weir	360+44	Weir	1	
TR8	Belthair Street	382+44	RCP	1	36"
TR7	Boca Chica	395+49	RCP	1	48"
TR5	Coria	413+04	RCP	1	30"
TR4	Central Blvd.	420+82	RCP	1	36"
TR3	Control Weir	425+00	Weir	1	
TR2	Los Ebanos	435+97	RCP	1	36"
TR1	Honeydale	452+12	RCP	1	18"

Size: Box - H x V
Pipe - Diameter
Weir - Crest Length

Type: RCP - Reinforced Concrete Pipe
CMP - Corrugated Metal Pipe

TABLE 3-12
HYDRAULIC STRUCTURES
RESACA DE LA GUERRA

Structure No.	Street Name	Station	Type	Number	Culvert Size
RG24	Outlet Structure	35+20	RCP Outlet Drop Structure	1 1	.8' x 5.8' 30"
RG23	Morningside Road	39+60	RCP	3	30"
RG22	Morningside Drive	82+80	RCP	1 2	15" 30"
RG21	Lake Acacia	145+40	Bridge	1	
RG20	Billy Mitchell	168+70	RCP	3	42"
RG19	Boca Chica	186+00	Box Weir	2 1	10' x 8'
RG18	14th Street	282+48	RCP Weir	1 1	70"
RG17	Price	308+92	Box	1	10' x 8'
RG16	Railroad	318+36	RR Bridge	1	
RG15	Port Isabel Road	397+96	Box	2	8' x 8'
RG14	Control Weir	406+60	Spillway	1	
RG13	Palo Verde Road	492+15	CMP	1	36"
RG12	Highway 1847	526+41	RCP	1	52"
RG12A	Control Weir	536+03	Weir	1	
RG11	Railroad	541+73	RR Bridge	1	
RG10	Hidden Valley	566+33	RCP	2	30"
RG9	Alice	595+58	RCP	2	52"
RG8	Control Weir	606+72	Spillway	1	
RG7	U.S. 83/77	611+68	Box	1	5' x 5'
RG6	Central Blvd.	632+01	RCP	1	48"

TABLE 3-12
HYDRAULIC STRUCTURES
RESACA DE LA GUERRA
(continued)

Structure No.	Street Name	Station	Type	Number	Culvert Size
RG5	Old Hwy. 21	635+96	Box	1	20' x 8'
RG4F	Private Drive	637+96	RCP	1	42"
RG4E	Private Drive	661+72	CMP	1	24"
RG4D	Country Club	663+82	CMP	1	24"
RG4C	Private Drive	672+82	CMP	1	24"
RG4B	Private Drive	674+87	CMP	2	18"
RG4A	Honeybee Lane	695+07	RCP	1	24"
RG3	Railroad	709+27	Bridge	1	
RG2A	Mercedes Rd.	709+27	Weir	1	
RG2	Laredo	762+67	RCP	1 1	30" 24"
RG1	FM 802	768+05	RCP	1	42"

Size: Box - H x V
Pipe - Diameter
Weir - Crest Length

Type: RCP - Reinforced Concrete Pipe
CMP - Corrugated Metal Pipe
PVC - Plastic PVC Pipe

A long overflow weir was simulated parallel to each level control weir in the model to approximate drowned flow in the simulation. Road crossings for bridges and major conduits were also modeled as weirs with lengths estimated by scaling from aerial photographs and field notes. Tables 3-13 and 3-14 list all of the weir data used in the models for Town Resaca and Resaca de la Guerra, respectively.

TABLE 3-13
WEIR PARAMETERS
TOWN RESACA

Structure Designation	Location	Weir Elev. (ft)	Weir Length (ft)	Discharge Coefficient
TR3	Station 425+00	29.90	200	2.8
TR9A	Station 360+44	26.06	6.3	2.8
TR9B	Station 360+44	26.12	10	2.8
TR15	Palm Boulevard	23.90	10	2.8
TR18	Gladys Porter Zoo	21.47	25	2.8
TR25	Station 154+80	20.23	34.3	2.8
TR27	Station 100+00	19.09	23.6	2.8

TABLE 3-14
WEIR PARAMETERS
RESACA DE LA GUERRA

Structure Designation	Location	Weir Elev. (ft)	Weir Length(ft)	Discharge Coefficient
RG8	Level Control	28.80	19.00	2.75
RG8	Overflow	30.80	150.00	2.65
RG12	Highway 1847	26.25	150.00	3.00
RG12A	Hwy. 1847- Level	27.89	16.00	2.85
RG12A	Hwy. 1847- Overflow	29.89	150.00	2.75
RG14	Level Control	25.25	9.00	2.85
RG14	Overflow	27.25	150.00	2.65
RG17	Price Road	27.22	150.00	3.00
RG18	14th Street - Level	22.65	28.00	2.85
RG18	14th Street - Overflow	28.50	300.00	3.00
RG18_R&C	14th Street	28.53	150.00	3.00
RG_19BOX	Boca Chica Rd	27.66	150.00	2.85
RG19_W	Boca Chica - Level	21.98	52.00	2.85
RG19_W	Boca Chica - Overflow	27.66	250.00	3.00
RG21	Top of Bridge	27.50	150.00	3.00
RG24WEIR	Outfall weir box	20.03	23.20	2.85

Although it discharges flood waters from both the Town Resaca and North Main Drain systems, the Impala Pump Station was modeled within the Town Resaca model and a stage-discharge relationship was imported into the North Main Drain model in order to simulate the interaction of the two systems. The total capacity of the pump station is approximately 160,000 gallons per minute (gpm) and is controlled by the depth of the water in the Impala Ditch. The XP-SWMM data used to model the pump station is shown in Table 3-15. As seen in the table, the four pumps operate independently, with each pump being turned on when the water in the channel reaches a certain depth.

TABLE 3-15
IMPALA PUMP STATION PARAMETERS
TOWN RESACA

Pump Number	Rating(gpm)	Controlling Depth (feet)
1	40,000	2
2	40,000	4
3	40,000	6
4	40,000	8

3.2 Results of Analysis

The hydrologic and hydraulic models were used to evaluate the overall flooding potential of each watershed and to predict the critical locations of out-of-bank flooding for the primary channel systems. Flood indexes identified in the 1987 Master Drainage Plan as minimum critical elevations that generally represent threshold flooding levels for existing buildings or other significant structures were used to indicate possible structural flooding. These flood indices are shown on the water surface profiles developed for each channel by the modeling results. The indices are identified on Table 3-16, which is reproduced from Table 15, Volume I of the 1987 Master Drainage Plan. The following sections summarize the results of the existing conditions for each of the watersheds.

TABLE 3-16
FLOOD INDEX ELEVATIONS FOR THE MAJOR DRAINAGE SYSTEMS
(Reproduced from Table 15, Volume I of the Master Drainage Plan)

Station	Flood Index Water Surface (feet)	Existing 100-Year Elevation* (feet)	Downstream Structure	Description of Adjacent Development
Town Resaca				
150+00	24.0	27.2	TR26	New Subdivision
179+00	26.0	28.0	TR22E	Adjacent Subdivisions
206+00	26.0	28.0	TR22A	Existing Subdivisions
221+10	27.4	28.3	TR20	East 6th Street
249+20	25.0	28.3	TR19	Gladys Porter Zoo
291+00	30.0	30.9	TR15	Palm Boulevard
300+00	29.1	30.9	TR13	Calle Retama
325+60	30.0	30.9	TR11	Ringgold Street
349+50	29.9	30.9	TR10	Calle Retama
370+00	29.5	30.9	TR9	Ebony Lake Residential
455+00	30.5	31.1	TR1	Existing Subdivision
North Main Drain				
126+50	17.0	11.3	NM38	Existing Home
180+00	15.0	15.3	NM36	Mobile Home Park
204+00	19.0	16.3	NM36	Existing Home
362+00	16.0*	22.8	NM33	Airport Runway
441+00	19.0	24.9	NM32	New Subdivision
501+00	24.0	26.7	NM27	Existing Home
575+00	23.5	27.2	NM24	Existing Subdivision
630+00	23.5	27.4	NM24	Existing Subdivision
656+00	23.5	27.8	NM20	Four Corners Comm.
674+94	24.4	27.9	NM19	Existing Subdivision
728+00	28.5	32.5	NM13B	Comm. Development

*Elevation taken directly from 1987 Master Drainage Plan.

TABLE 3-16
FLOOD INDEX ELEVATIONS FOR THE MAJOR DRAINAGE SYSTEMS
(Reproduced from Table 15, Volume I of the Master Drainage Plan)
(continued)

Station	Flood Index Water Surface (feet)	Existing 100-Year Elevation* (feet)	Downstream Structure	Description of Adjacent Development
758+50	28.9	33.7	NM13	Comm. Development
768+13	28.4	33.8	NM9	Existing Subdivision
780+74	28.7	33.8	NM8	Existing Subdivision
824+18	31.3	34.5	NM5	Existing Subdivision
833+28	30.5	34.7	NM4	Existing Subdivision
848+31	32.3	38.0	NM2	Existing Subdivision
Resaca De La Guerra				
73+00	25.5	25.5	RG23	Existing Home
134+00	26.0	26.7	RG22	Res./Comm/ Development
140+00	24.0	26.7	RG22	North Main Drain Embankment
168+70	26.0	27.1	RG20	Four Corners Comm.
284+00	28.0	31.1	RG18	Existing Comm. Development
490+00	28.0	31.1	RG13	Existing Homes
510+00	29.0	31.1	RG13	Existing Homes/School
527+00	26.3	31.1	RG12	Highway 1847
606+00	31.5	31.5	RG3	Existing Apartments
764+00	33.5	33.4	RG2	Existing Subdivision
833+50	34.0	34.5	Y4	Existing Homes

*Elevation taken directly from 1987 Master Drainage Plan.

TABLE 3-16
FLOOD INDEX ELEVATIONS FOR THE MAJOR DRAINAGE SYSTEMS
(Reproduced from Table 15, Volume I of the Master Drainage Plan)
(continued)

Station	Flood Index Water Surface (feet)	Existing 100-Year Elevation* (feet)	Downstream Structure	Description of Adjacent Development
Cameron County Drainage District No. 1 Ditch				
79+79	13.3	12.7	CC18	Hwy. 48 Rdwy. Elevation
113+00	16.6	17.0	CC16	Indus./Comm. Area
200+00	15.4	20.6	CC13	Existing Subdivision
239+00	15.6	21.2	CC10	Valley Comm. Hospital
275+00	16.1	21.4	CC10	Robindale W.W.T.P.
301+00	16.4	22.0	CC7	Existing Subdivision
345+00	17.5	22.5	CC6	Existing Subdivision
415+00	19.9	23.4	CC4	Existing Subdivision
460+50	21.0	24.0	CC4	Existing Homes
490+00	24.0	25.0	CC3	Existing Homes

*Elevation taken directly from 1987 Master Drainage Plan.

3.2.1 North Main Drain

The North Main Drain originates in the western portions of the City of Brownsville and flows through numerous residential and commercial developments until it exits the City past the airport and continues to the Brownsville Ship Channel. The channel has been rectified in the past; however, it currently does not have sufficient capacity to convey even the five-year frequency runoff event without causing significant out-of-bank flooding. Exhibit 3-9 shows the approximate boundaries for the 10- and 100-year flood plains based on the results of the hydraulic analysis of the channel. Approximately 2,300 acres are flooded during the 100-year event. The flood plain boundaries were drawn using the topographic elevations published on the USGS quadrangle maps in conjunction with the water surface elevations produced by the existing conditions HEC-2 model of the North Main Drain. These water surface elevations are shown on Table 3-17 at selected locations along the channel.

The overbank flooding caused by the runoff from the intense rainfalls associated with the three design storm events inundates several road crossings and threatens or has the potential to flood numerous structures located within the flood plain boundaries. Exhibit 3-10 shows the water surface profiles associated with the 5-, 10- and 100-year floods and displays the critical flood indexes as published in the 1987 Master Drainage Plan report. These flood indexes signify elevations where structures will become flooded in a given channel reach.

TABLE 3-17
EXISTING CONDITIONS WATER SURFACE ELEVATIONS
NORTH MAIN DRAIN

Station	Location	Water Surface Elevation		
		5-Year	10-Year	100-Year
1000	South Port Rd.	6.64	8.17	9.24
12688	Oklahoma	9.15	10.14	12.17
15688	Browne	10.20	10.96	13.06
20458	Boca Chica	11.68	12.22	14.49
25688	FM 511	14.41	14.71	16.90
26088	Utah Ave.	14.66	14.94	17.14
41387	Minnesota Ave.	19.10	19.34	21.62
45894	Apollo Drive	20.18	20.57	22.48
46888	Southmost Road	20.66	21.08	22.89
48169	Ramada Drive	21.23	21.69	23.36
48915	La Posada Road	21.43	21.90	23.52
49727	Esperanza Road	21.53	22.03	23.74
51410	Manzano Road	21.75	22.29	24.02
55640	Southmost Road	22.10	22.69	24.48
58645	30th Street	22.32	22.93	24.96
63243	International Blvd.	23.32	23.76	25.17
63803	14th Street	22.90	23.46	25.34

TABLE 3-17
EXISTING CONDITIONS WATER SURFACE ELEVATIONS
NORTH MAIN DRAIN
(continued)

Station	Location	Water Surface Elevation		
		5-Year	10-Year	100-Year
64853	Southern Pacific RR	23.08	23.63	25.60
65541	Boca Chica	23.17	23.76	25.67
67494	Old Port Isabel Road	24.57	24.04	25.82
68626	Renfro Street	24.46	24.93	26.37
69646	Rockwell	25.83	26.02	26.70
71240	Paredes Line Road	29.09	29.92	29.89
72185	Mackintosh	29.34	30.24	30.58
72382	Southern Pacific RR	29.91	30.35	30.71
72699	Access Road	30.30	30.78	31.04
74143	US 77/83	30.28	30.75	30.96
76393	Above 7 x 7 Box	30.64	31.19	31.99

3.2.2 Cameron County Drainage District No.1 Ditch

The CCDD No.1 Ditch is located in the extreme northern portions of the City of Brownsville. Most of the watershed served by the ditch has not been annexed and is still under the jurisdiction of Cameron County. The Drainage District owns the channel and exercises control over channel modifications, maintenance and right-of-way requirements. The watershed is partially developed currently but has the potential for rapid development in the near future.

Although completely rectified along its length, the CCDD No. 1 Ditch does not contain adequate capacity to convey flood waters from the 5-, 10- and 100-year storm events. Out of bank flooding occurs along the majority of the channel for all three design storms. Exhibit 3-11 shows the floodplain boundaries developed from the results of the HEC-2 modeling of the ditch. The water surface elevations predicted by the model were mapped onto the USGS one-foot topographic maps. Approximately 5,400 acres are flooded during the 100-year event. Table 3-18 lists the water surface elevations at selected locations along the ditch.

Numerous road crossings and residential subdivisions are affected by the CCDD No.1 Ditch flooding. Exhibit 3-12 shows the water surface profiles for the ditch and displays the flood indexes from the 1987 Master Drainage Plan which indicate elevations where structural flooding may occur.

TABLE 3-18
EXISTING CONDITIONS WATER SURFACE ELEVATIONS
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Station	Location	Water Surface Elevation		
		5-Year	10-Year	100-Year
7979	Highway 48	7.69	8.40	9.27
9993	Mopac RR	9.60	10.49	11.70
10923	FM 511	10.06	10.99	12.42
11648	Harbor Road	10.56	11.56	13.29
16380	FM 802	12.00	13.11	15.20
18207	Highway 48	12.30	13.42	15.57
20546	Railroad	13.64	14.88	17.39
22880	FM 802	13.97	15.22	17.55
23887	Central Avenue	14.03	15.27	17.57
27984	Robindale Ave.	14.87	16.13	17.95
29700	Flume	15.21	16.45	18.32
29989	Old Port Isabel	15.32	16.56	18.45
32540	Dana Road	16.36	17.65	19.56
39327	Paredes Line Road	17.85	19.05	21.46
40496	Southern Pacific RR	17.98	19.17	21.48
48955	US 77/83	20.10	21.06	22.19
51493	Union Pacific RR	21.28	21.84	23.36
57650	FM 3248	22.17	22.72	24.06

3.2.3 Town Resaca

The XP-SWMM EXTRAN program uses the runoff quantity developed by the RUNOFF program and computes the water surface elevation at each node and the discharge and average velocity in each link of the network at each time step. The EXTRAN output for the Town Resaca model indicates that most of the storm runoff in this watershed is retained within the channel and pond system during the 24-hour 100-year storm event due to the seven water level control weirs within the system and the high tailwater elevation at the outfall to the North Main Drain. The Resaca drains in the days after the storm, when water levels in the North Main Drain recede.

Some key aspects of the dynamic behavior of the drainage system during the 24-hour 100-year storm event as simulated in XP-SWMM include:

- Flow moves upstream on several reaches of the Resaca due to water level control weirs downstream of major storm drain inflow points.
- The Impala Pump station draws off approximately 60% of the 100-year flow in Town Resaca and discharges it to the Rio Grande.
- Discharge from the Town Resaca to the North Main Drain rises at the end of the storm as tailwater levels decline and as the upper portion of the Resaca begins to drain.
- The entire Town Resaca watershed serves as a storm water detention pond, relieving the North Main Drain of substantial inflow during large storm events.
- No out-of-bank flooding occurs along the resaca and no road crossings are flooded during the 100-year design rainfall event simulated by the SWMM program.
- Ebony Lake is an isolated resaca system in the western portion of the Town Resaca watershed which is connected to the Town Resaca under Resaca Boulevard through a 36-inch pipe. The lake levels have risen dramatically during recent flood events and have concerned local residents in adjacent homes. Low areas near the lake have experienced shallow flooding during these events since the higher lake levels prevent internal drainage systems serving these areas from draining into the lake. The Ebony Lake system was included in the Plan with the Town Resaca watershed as discussed in Section 4.3.

Selected maximum water levels in the system are summarized for the 5-, 10-, and 100-year storm in Table 3-19. The floodplain on Town Resaca resulting from this analysis is shown on Exhibit 3-13. The flood profiles for the 5-, 10- and 100-year frequencies are shown on Exhibit 3-14.

TABLE 3-19
EXISTING CONDITIONS WATER SURFACE ELEVATIONS
TOWN RESACA

Structure Designation	Location	Upstream Water Surface Elevation		
		5-Year	10-Year	100-Year
IM1	Tulipan Dr.	23.73	23.73	24.38
IM2	Calle Milpa Verde	20.91	22.74	24.32
IM3	Impala	20.51	22.73	24.38
IM4	East Avenue	19.31	22.90	24.62
TR24	Station 155+50	20.40	23.70	25.69
TR23	Highway 4	20.41	23.79	25.79
TR22E	14th Street	20.70	23.87	25.91
TR22D	13th Street	20.83	23.94	26.07
TR22C	12th Street	20.69	23.95	26.09
TR22A	Highway 77	20.70	23.97	26.13
TR22	7th Street	20.79	23.97	26.14
TR21	Railroad	20.44	23.97	26.15
TR20	6th Street	20.44	23.98	26.16
TR19	Ringgold	20.44	24.03	26.31
TR17	Gladys Porter Zoo	21.60	24.59	26.72
TR15	Palm Boulevard	21.58	24.72	26.89
TR14	Railroad	24.04	26.14	27.11
TR13	Calle Retama (1)	24.04	26.15	27.13
TR12	St. Joseph's	24.04	26.16	27.15
TR10	Calle Retama (2)	24.04	26.18	27.18
TR8	Belthair Street	26.14	27.17	27.83
TR7	Boca Chica	26.16	27.18	27.84
TR4	Central Boulevard	26.16	28.22	30.33

3.2.4 Resaca de la.Guerra

Similar to the Town Resaca, the Resaca de la Guerra system is functioning as a series of runoff detention reservoirs. A review of the SWMM EXTRAN program output indicates that most of the storm runoff in the Resaca de la Guerra watershed is retained within the channel and pond system during the 24-hour 100-year storm event due to the six water level control weirs within the system and the restricted outfall and high tailwater at the North Main Drain. The Resaca drains in the days after the storm, when water levels in the North Main Drain recede.

Some key aspects of the dynamic behavior of the Resaca de la Guerra drainage system during the 24-hour 100-year storm event as simulated in XP-SWMM include:

- The Resaca de la Guerra outfalls into the North Main Drain through a weir/pipe structure. The box weir and the 30-inch outfall pipe to the North Main Drain isolate the Resaca from any downstream influences except as may occur when the water level in the North Main Drain is above the top of the box weir in the Resaca.

- Flow moves upstream on several reaches of the Resaca due to water level control weirs and small culverts downstream of major storm drain inflow points. This leads to several "high spots" in the interior maximum-water-surface profile as inflow moves upstream.

- The entire Resaca de la Guerra watershed serves as a stormwater detention pond, delaying flows from entering the North Main Drain during large storm events.

- Discharge to the North Main Drain is less than 40 cfs during the 24-hour storm event and actually goes negative during the 100-year flood event as water backs up into the resaca. Discharge rises at the end of the storm as tail water levels decline and as the resaca begins to drain.

- The Highway 1847 crossing is over-topped by floodwaters under existing conditions during the 5-, 10-, and 100-year storm event according to top of road elevations used in the model; it is the only out-of-bank flooding predicted in the Resaca de la Guerra watershed.

The flood plain boundaries and maximum water surface elevations along the Resaca de la Guerra are shown for the 5-, 10- and 100-year storms in Exhibit 3-15 and Exhibit 3-16, respectively. The maximum calculated water surface elevations and discharges occurring within 72 hours of the 5-, 10-, and 100-year storm events are tabulated in Table 3-20 below.

TABLE 3-20
EXISTING WATER SURFACE ELEVATION
RESACA DE LA GUERRA

Structure Designation	Location	Upstream Water Surface Elevation		
		5-Year	10-Year	100-Year
Outfall Channel	North Main Drain	19.24	20.22	21.17
RG24BOXWEIR	Outfall Structure	20.64	20.72	21.99
RG23	Morning Side Road	20.64	21.09	22.22
RG22	Morning Side Drive	21.17	21.27	22.69
RG21	Lake Acacia	21.21	21.52	22.77
RG20	Billy Mitchel	21.27	21.51	22.97
RG19	Boca Chica	21.31	21.78	23.31
RG18	14th Street	23.35	23.73	25.13
RG17	Price Road	23.86	24.22	25.38
RG16	Railroad	23.96	24.23	25.39
RG15	Port Isabel Road	25.00	25.02	25.56
RG14	Control Weir	26.59	26.76	27.37
RG13	Palo Verde Road	26.63	27.08	27.73
HWY1847	Hwy 1847	26.95	27.20	27.97
RG12	Control Weir	26.95	29.20	29.58
RG11	Railroad	29.07	29.20	29.59
RG10	Hidden Valley	29.55	29.77	30.29
RG9	Alice	29.80	30.02	30.56
RG8	Control Weir	29.89	30.02	30.56
RG7	U.S. 83/77	29.97	30.03	30.50
RG6	Central Blvd.	30.11	30.13	30.15
RG4	Country Club	30.06	30.43	30.63
RG3	Railroad	30.14	30.51	30.92
RG2	Mercedes Road	30.33	30.89	30.98

3.3 Year 2005 Analysis of the Primary Drainage Systems

The Scope of Services for the Plan project involves the projection of land use 10 years into the future to the year 2005. A consultant currently under contract by the City to analyze existing and future land usage in the City recommended that the year 2000 land use previously developed by the City be used for the 10-year projection because of the current trends of development in the City. The City agreed to the use of the 2000 land use projection for the study's analysis of future development. The projected 2005 land use is shown on Exhibit 2-9.

The increase in developed acreage for each subarea was calculated for the land use patterns shown on Exhibit 2-9. The total increase in development, including water features, for each watershed is estimated as follows:

- North Main Drain
  Existing Development = 1677 acres, 2005 development = 2175 acres
- CCDD No. 1 Ditch
  Existing Development = 387 acres, 2005 development = 758 acres
- Town Resaca
  Existing Development = 2295 acres, 2005 development = 2577 acres
- Resaca de la Guerra
  Existing Development = 1285 acres, 2005 development = 1538 acres

To determine the impact from the increase in development to the year 2005 on the existing drainage system (assuming no further flood protection projects are constructed in that period), the hydrologic and hydraulic models developed for existing conditions were revised. The percent impervious cover for each subarea was adjusted to reflect the development patterns predicted in Exhibit 2-9. The following tables (Tables 3-21 through 3-28) show the increase percent impervious cover for the year 2005 and the resulting changes in flows and water surface elevations for each of the four watersheds:

TABLE 3-21
EXISTING AND YEAR 2005 PERCENT IMPERVIOUS COVER
NORTH MAIN DRAIN

Subarea	Existing % Impervious	Year 2005 % Impervious
NM1-NM11	44.8	57.35
NM12	79.62	79.62
NM13	73.15	73.15
NM14	62.01	62.01
NM15	44.98	85.00

TABLE 3-21
EXISTING AND YEAR 2005 PERCENT IMPERVIOUS COVER
NORTH MAIN DRAIN
(continued)

Subarea	Existing % Impervious	Year 2005 % Impervious
NM16	50.48	57.98
NM17	42.89	53.66
NM18	60.98	60.98
NM19	49.03	49.03
NM20	56.21	57.65
NM21	48.86	66.73
NM22	65.32	71.31
NM23	58.73	71.33
NM24	37.25	51.51
NM25	51.98	55.29
NM26	44.99	44.99
NM27	45.00	45.00
NM28B	33.55	33.55
NM29	47.57	47.52
NM30	14.07	47.52
NM31	40.46	51.47
NM32B	38.44	51.62
NM33	23.96	41.56
NM34	19.55	43.51
NM35	6.21	22.89
NM36	10.67	14.12
NM37	9.78	56.40

TABLE 3-22
EXISTING AND YEAR 2005 100-YEAR PEAK FLOWRATES (CFS) AND WATER SURFACE ELEVATIONS (FEET) NORTH MAIN DRAIN

Station	Location	Existing Peak Flow	Year 2005 Peak Flow	Existing WSEL	Year 2005 WSEL
1000	South Port Road	4050	4120	9.24	9.24
12688	Oklahoma	1180	1220	12.17	12.23
15688	Browne	1120	1160	13.06	13.15
20458	Boca Chica	1020	1060	14.49	14.68
25688	FM 511	1020	1060	16.90	17.10
26088	Utah Avenue	1020	1060	17.14	17.35
41387	Minnesota Avenue	770	830	21.62	21.84
45894	Apollo Drive	770	830	22.48	22.76
46888	Southmost Road	770	830	22.89	23.19
48169	Ramada Drive	770	830	23.36	23.67
48915	La Posada Road	770	800	23.52	23.83
49727	Esperanza Road	770	800	23.74	24.06
51410	Manzano Road	770	800	24.02	24.34
55640	Southmost Road	770	790	24.48	24.80
58645	30th Street	770	790	24.96	25.28
63243	International Blvd.	770	790	25.17	25.55
63803	14th Street	770	790	25.34	25.79
64853	Southern Pacific RR	770	790	25.60	26.03
65541	Boca Chica	770	790	25.67	26.09
67494	Old Port Isabel Road	730	780	25.82	26.17

TABLE 3-22
EXISTING AND YEAR 2005 100-YEAR PEAK FLOWRATES (CFS)
AND WATER SURFACE ELEVATIONS (FEET)
NORTH MAIN DRAIN
(continued)

Station	Location	Existing Peak Flow	Year 2005 Peak Flow	Existing WSEL	Year 2005 WSEL
68626	Renfro Street	730	780	26.37	26.76
69646	Rockwell	730	780	26.70	26.98
71240	Paredes Line Road	730	780	29.89	29.92
72185	Mackintosh	680	720	30.58	30.65
72382	Southern Pacific RR	680	720	30.71	30.79
72699	Access Road	680	720	31.04	31.07
74143	US 77/83	680	720	30.96	30.99
76393	Above 7 x 7 Box	625	650	31.99	32.11

TABLE 3-23
EXISTING AND YEAR 2005 PERCENT IMPERVIOUS COVER
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Subarea	Existing % Impervious	Year 2005 % Impervious
CC1	5.77	5.77
CC2	3.37	49.96
CC3	15.01	51.64
CC4	26.15	51.13
CC5	38.91	44.02
CC6	16.49	38.02
CC7	16.48	59.77
CC8	23.63	52.60
CC9	1.99	27.33
CC10	4.78	32.31
CC11	5.00	5.00
CC12	3.81	39.07
CC13	28.26	41.24
CC14	33.86	33.86
CC15	23.06	24.17
CC16	85.00	85.00
CC17	19.93	85.00
CC18	24.57	20.80
CC19	10.70	14.08

TABLE 3-24
EXISTING AND YEAR 2005 100-YEAR PEAK FLOWRATES IN CFS AND WATER SURFACE ELEVATIONS (WSEL) IN FEET CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Station	Location	Existing Peak Flow	Year 2005 Peak Flow	Existing WSEL	Year 2005 WSEL
7979	Highway 48	2143	2270	9.27	9.39
9993	Mopac RR	2134	2264	11.70	11.76
10923	FM 511	2134	2264	12.42	12.54
11648	Harbor Road	2134	2264	13.29	13.48
16380	FM 802	2079	2211	15.20	15.47
18207	Highway 48	2080	2214	15.57	15.86
20546	Railroad	1541	1642	17.39	17.65
22880	FM 802	1359	1448	17.55	17.81
23887	Central Avenue	1379	1455	17.57	17.83
27984	Robindale Ave.	1311	1394	17.95	18.19
29700	Flume	1311	1394	18.32	18.54
29989	Old Port Isabel	1371	1452	18.45	18.68
32540	Dana Road	1320	1383	19.56	19.68
39327	Paredes Line Road	1040	1084	21.46	21.59
40496	Southern Pacific RR	989	1075	21.48	21.61
48955	US 77/83	141	200	22.55	22.65
51493	Union Pacific RR	174	199	23.03	23.86
57650	FM 3248	173	173	23.96	24.58

TABLE 3-25
EXISTING AND YEAR 2005 PERCENT IMPERVIOUS COVER
TOWN RESACA

Subarea	Existing % Impervious	Year 2005 % Impervious
TR1	27.1	41.8
TR2	46.9	50.4
TR3	56.0	57.3
TR4	45.0	45.0
TR5	48.8	48.8
TR6	46.8	46.8
TR7	45.0	45.0
TR8	45.0	45.0
TR9	62.2	62.2
TR10	44.8	44.8
TR11	45.0	45.0
TR12	45.0	45.0
TR13	45.0	45.0
TR14	43.2	45.0
TR15	60.3	60.3
TR16	59.4	59.4
TR17	71.7	73.7
TR18	57.4	57.4
TR19	49.2	49.2
TR20	51.7	51.7
TR21	59.4	59.4
TR22	45.9	45.9
TR23	58.0	58.8

TABLE 3-25
EXISTING AND YEAR 2005 PERCENT IMPERVIOUS COVER
TOWN RESACA
(continued)

Subarea	Existing % Impervious	Year 2005 % Impervious
TR24	69.9	81.0
TR25	51.5	79.6
TR26	48.3	53.7
TR27	60.0	60.0
TR28	54.4	54.4
TR29	62.5	62.5
TR30	46.1	47.7
TR31	49.8	49.8
TR32 & TR33	69.0	69.0
TR34 & TR35	48.6	52.8
TR36	52.5	52.5
TR37	47.2	47.6
TR38	51.8	51.8
TR39	60.8	60.8
TR40	56.3	56.3
TR41	57.1	57.1
TR42	54.2	54.2
TR43	31.1	32.7
TR44	45.0	45.0
TR45	27.1	45.0
TR46	52.8	55.2
TR47	53.2	53.2
TR48	46.8	47.4

TABLE 3-26
EXISTING AND YEAR 2005 100-YEAR PEAK FLOWRATES IN CFS AND WATER SURFACE ELEVATIONS (WSEL) IN FEET
TOWN RESACA

Structure Designation	Location	Existing Peak Flow	Year 2005 Peak Flow	Existing WSEL	Year 2005 WSEL
IM1	Tulipan Dr.	634	639	24.38	28.28
IM2	Calle Milpa Verde	836	830	24.32	24.34
IM3	Impala	434	437	24.38	24.40
IM4	East Avenue	568	570	24.62	24.64
TR24	22nd Street	381	404	25.69	25.71
TR23	Highway 48	358	358	25.79	25.81
TR22E	14th Street	324	324	25.91	25.93
TR22D	13th Street	305	323	26.07	26.09
TR22C	12th Street	305	323	26.09	26.10
TR22A	Highway 77	298	322	26.13	26.15
TR22	7th Street	291	322	26.14	26.16
TR21	Railroad	289	322	26.15	26.16
TR20	6th Street	286	320	26.16	26.17
TR19	Ringgold	273	303	26.31	26.33
TR17	Gladys Porter Zoo	260	264	24.59	26.73
TR15	Palm Boulevard	231	231	24.72	26.92
TR14	Railroad	242	242	27.11	27.13
TR13	Calle Retama (1)	288	288	27.13	27.15
TR12	Ringgold	316	316	27.15	27.17
TR10	Calle Retama (2)	408	409	27.18	27.20
TR8	Belthair Street	50.5	62	27.83	27.85
TR7	Boca Chica	59.5	61	27.84	27.88
TR4	Central Boulevard	72.5	75	30.33	30.48

TABLE 3-27
EXISTING AND YEAR 2005 PERCENT IMPERVIOUS COVER
RESACA DE LA GUERRA

Subarea	Existing % Impervious	Year 2005 % Impervious
RG41 Upper	20.1	28.0
RG41 Lower	20.1	28.0
RG40	26.7	26.7
RG39	33.8	61.5
RG38	41.0	64.6
RG37	40.5	40.5
RG36	73.2	73.2
RG35 & RG35 A	45.0	45.0
RG34	78.5	78.5
RG33	45.5	45.5
RG32	45.5	63.4
RG31	48.2	64.6
RG30	60.1	60.5
RG29	47.7	47.7
RG28	44.1	45.7
RG25, RG26 &RG27	46.4	50.3
RG21,RG22,RG23&RG24	46.7	57.1
RG20	31.0	52.4
RG19	37.4	64.4
RG15	48.7	57.1
RG8	58.3	71.0

TABLE 3-28
EXISTING AND YEAR 2005 100-YEAR PEAK FLOWRATES IN CFS AND WATER SURFACE ELEVATIONS (WSEL) IN FEET
RESACA DE LA GUERRA

Structure Designation	Location	Existing Peak Flow	Year 2005 Peak Flow	Existing WSEL	Year 2005 WSEL
Outfall Channel	North Main Drain	708	728	21.17	21.35
RG24	Outfall Structure	47	48	21.99	22.13
RG23	Morning Side Road	47	48	22.22	22.35
RG22	Morning Side Drive	58	60	22.69	22.84
RG21	Lake Acacia	152	153	22.77	22.92
RG20	Billy Mitchel	161	167	22.97	23.12
RG19	Boca Chica	199	209	23.31	23.26
RG18	14th Street	154	154	25.13	25.09
RG17	Price Road	161	163	25.38	25.49
RG16	Railroad	160	159	25.39	25.50
RG15	Port Isabel Road	165	165	25.56	25.68
RG14	Control Weir	78	80	27.37	27.38
RG13	Palo Verde Road	38	38	27.73	27.77
HWY1847	Hwy 1847	114	190	27.97	28.27
RG11	Railroad	91	94	29.59	29.63
RG10	Hidden Valley	62	62	30.29	30.36
RG9	Alice	36	37	30.56	30.64
RG7	U.S. 83/77	43	43	30.50	30.56
RG6	Central Blvd.	39	38	30.15	30.47
RG3	--	47	48	30.92	30.98
RG2	Mercedes Road	35	38	30.98	31.02

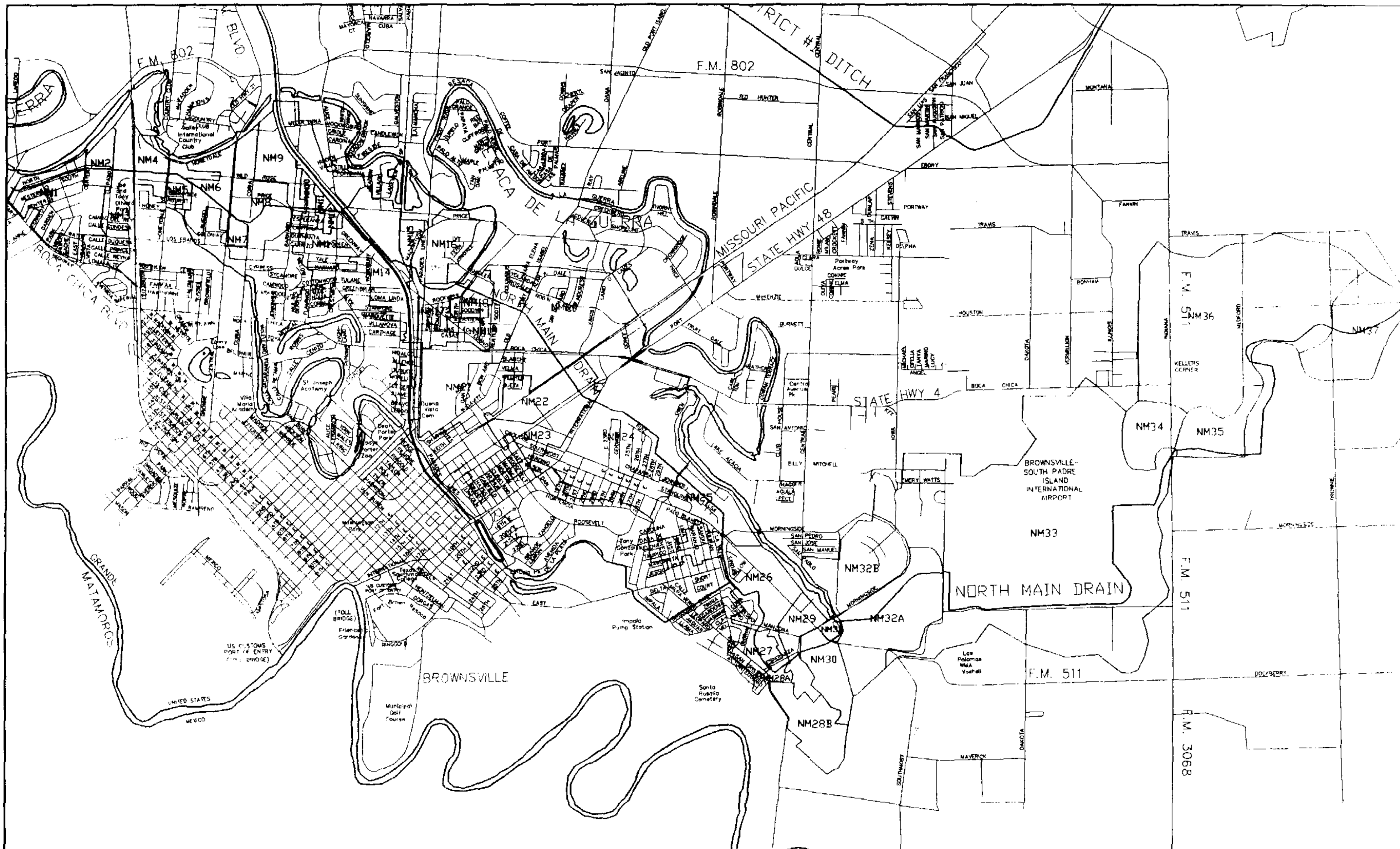
To summarize Tables 3-21, 3-23, 3-25 and 3-27, the total increase in percent impervious cover projected over the next ten years for each of the watersheds is:

- North Main Drain - 14.1%
- CCDD No. 1 Ditch - 21.0%
- Town Resaca - 1.8%
- Resaca de la Guerra - 6.0%

The increases in percentage of impervious cover anticipated in the next ten years are the greatest in the North Main Drain and CCDD No. 1 Ditch watersheds. These watersheds are anticipated to experience continued rapid development in the future. This new development is predicted to increase flows and water surface elevations significantly in both these channels if no additional flood protection policies and projects are implemented.

Specifically, with the addition of approximately 500 acres of new development in the watershed over the next ten years, flows in North Main Drain are predicted to increase by as much as seven percent, with maximum increases in the 100-year water surface elevation of approximately 0.45 feet in critical areas already prone to flooding. Similarly, 100-year flows in CCDD No. 1 Ditch are predicted to increase by as much as 42 percent immediately upstream of US 77, with increases of approximately six percent along the majority of the channel, resulting from the addition of approximately 370 acres of new development in the next ten years. Maximum increases in the resulting water surface elevations are predicted to be approximately 0.25 foot along most of the channel, with an isolated increase of 0.83 foot at the Union Pacific Railroad crossing.

The higher flows in North Main Drain for the year 2005 conditions result in increases to the water surface elevation at the confluences of Town Resaca and Resaca do la Guerra; however, the elevated outfall conditions do not impact upstream water surface elevations in the resacas due to their large storage capacities which act as "shock absorbers" and effectively dampen any downstream impacts. Very little increase in either flows or water surface elevations in the resacas is predicted for the future development condition. No increased out of bank flooding was predicted by the year 2005 hydraulic models ofr the resacas.



LEGEND

———	WATERSHED AND SUBAREA BOUNDARIES
NM14	SUBAREA DESIGNATION

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 1600'
DATE	NOVEMBER 1996

RUST LICHLITER/JAMESON
Environment & Infrastructure
Consulting Engineers, Scientists and Planners

CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

NORTH MAIN DRAIN WATERSHED

EXHIBIT NO. 3-1

PROJECT NO. 68589

LEGEND

———	WATERSHED AND SUBAREA BOUNDARIES
CC4	SUBAREA DESIGNATION

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	1" = 1650'
DATE:	NOVEMBER 1996

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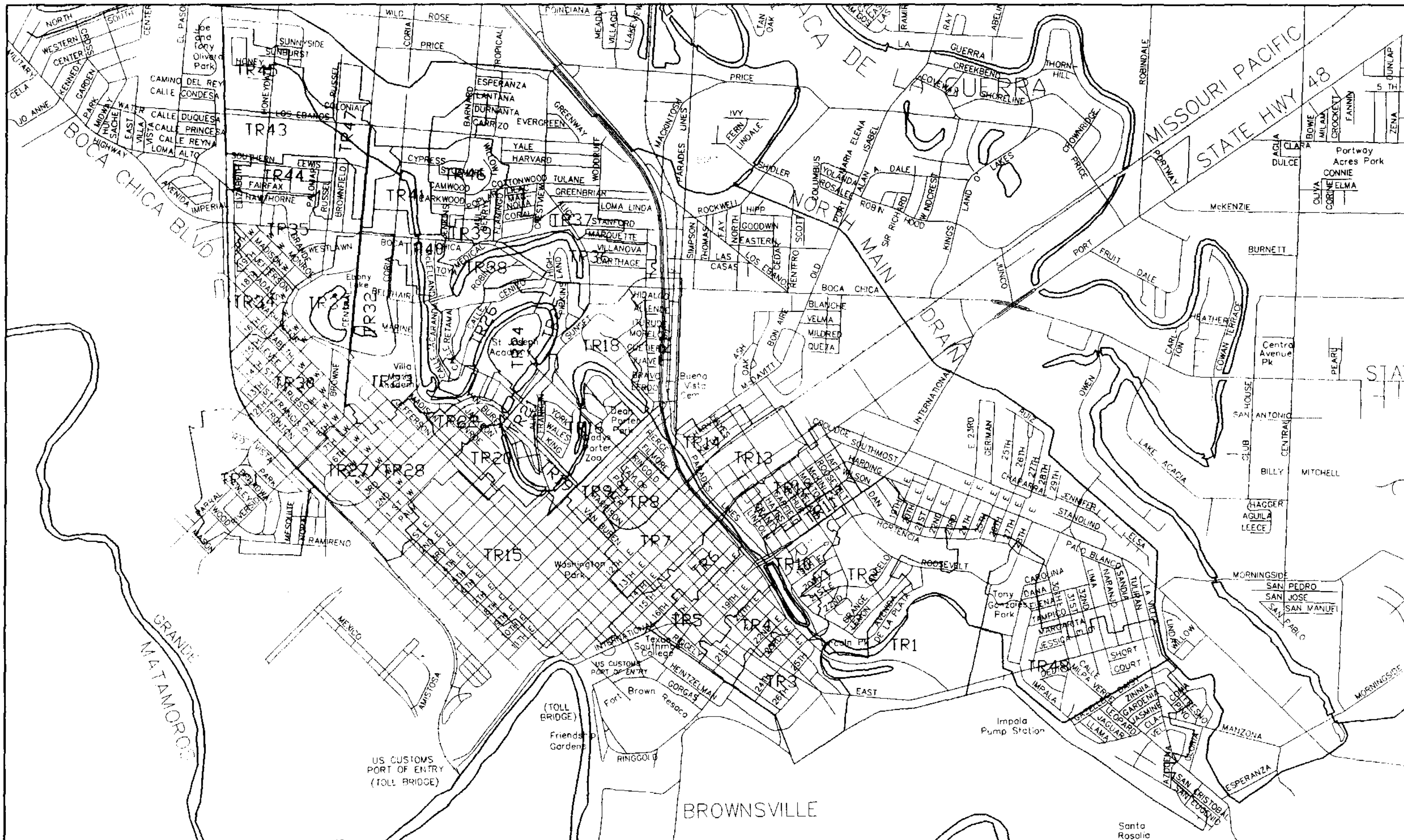
DRAINAGE STUDY

CAMERON COUNTY DRAINAGE DISTRICT #1 DITCH WATERSHED

EXHIBIT NO. 3-2

PROJECT NO. 68589



LEGEND

WATERSHED AND SUBAREA BOUNDARIES

TR5 SUBAREA DESIGNATION

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE: 1" = 1000'	
DATE: NOVEMBER 1996	

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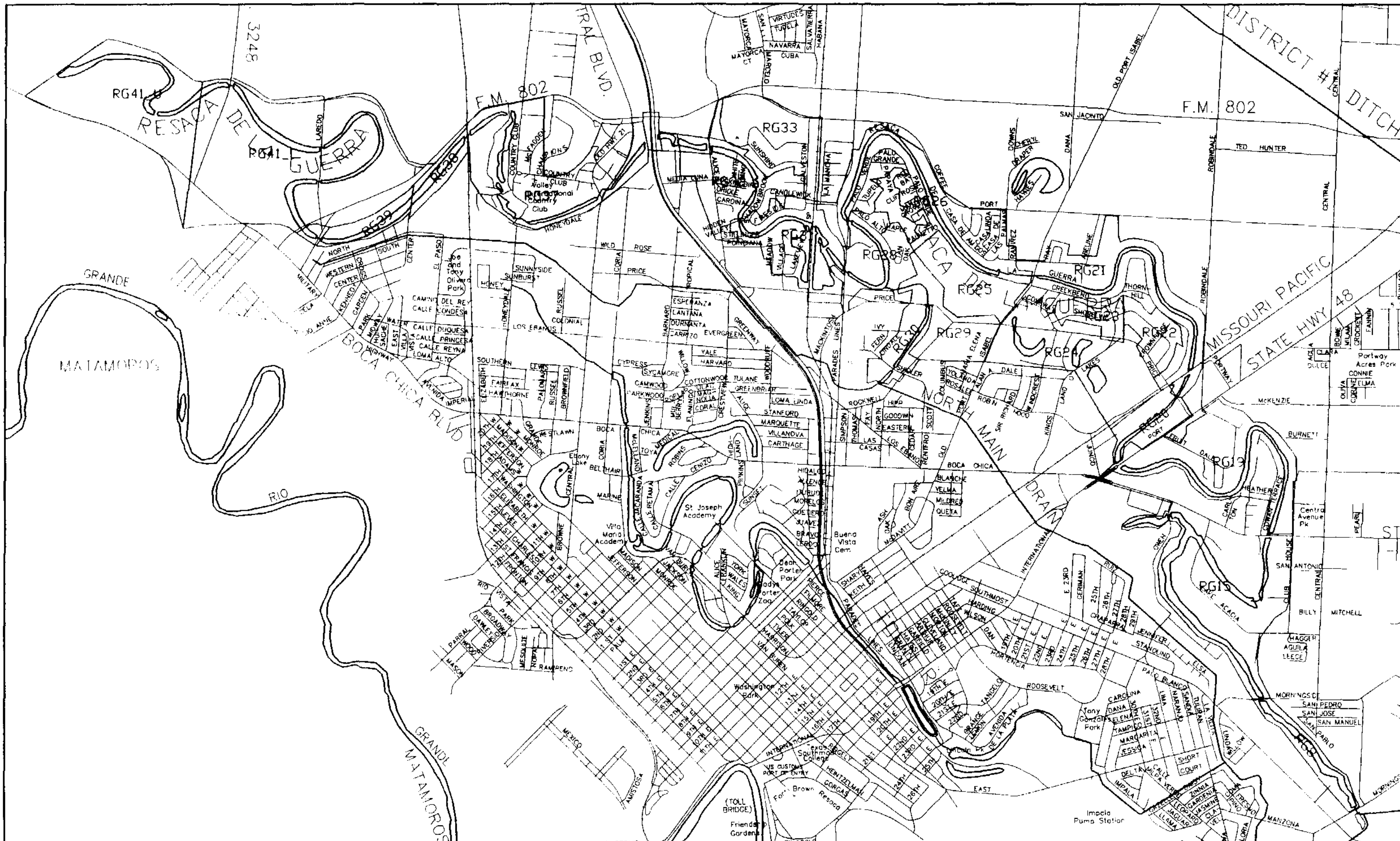
DRAINAGE STUDY

TOWN RESACA WATERSHED

EXHIBIT NO. 3-3

PROJECT NO. 68589



LEGEND

—— WATERSHED AND SUBAREA BOUNDARIES

RG29 SUBAREA DESIGNATION

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 1250'
DATE	NOVEMBER 1996

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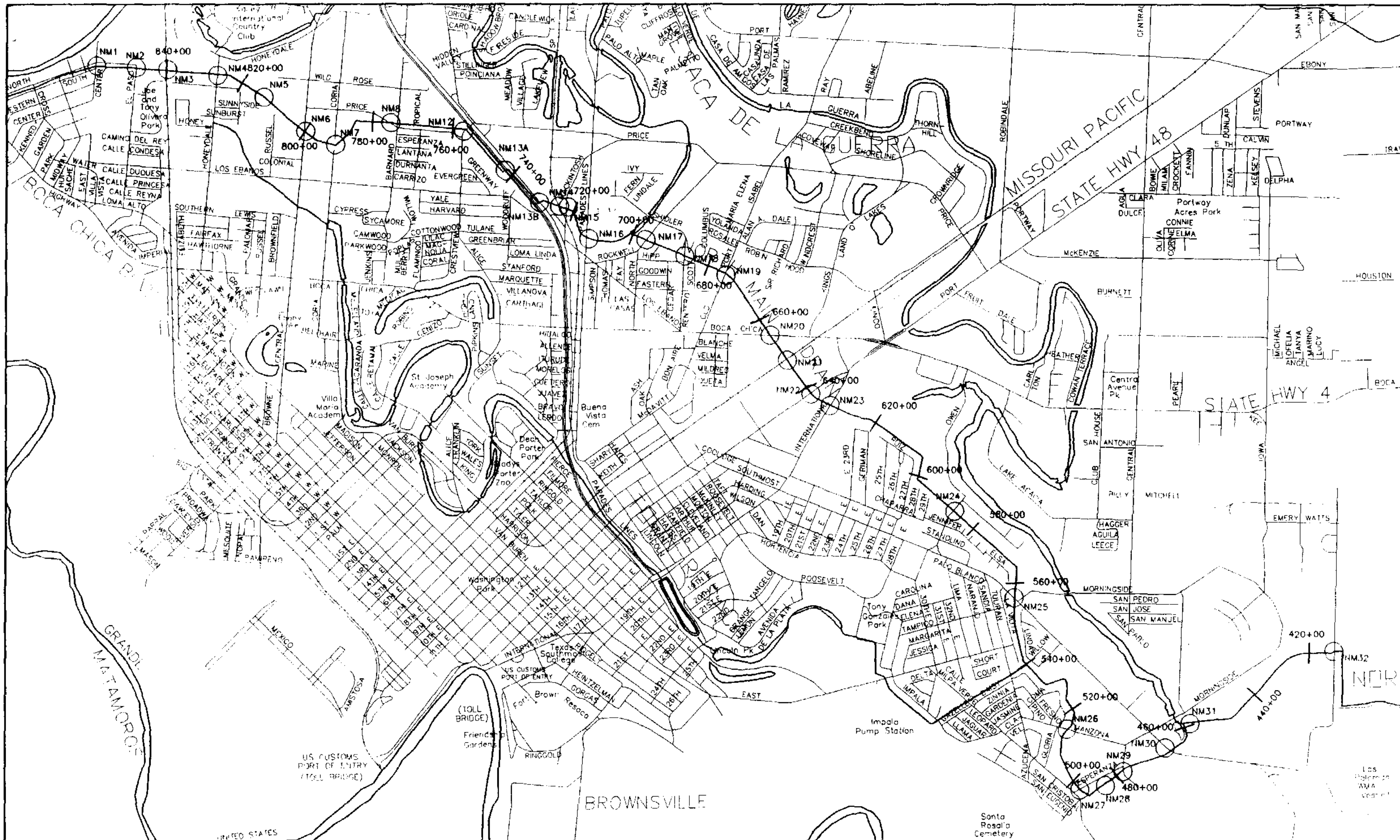
DRAINAGE STUDY

RESACA DE LA GUERRA WATERSHED

EXHIBIT NO. 3-4

PROJECT NO. 68589



LEGEND

○ NM4 HYDRAULIC FEATURE (FROM 1987 MASTER DRAINAGE PLAN)

| 10+00 CROSS SECTION LOCATIONS

DRAWN:	D.V.
DESIGN:	J.C.
CHECKED:	C.W.
PM:	M.J.
SCALE:	1" = 1100'
DATE:	NOVEMBER 1996

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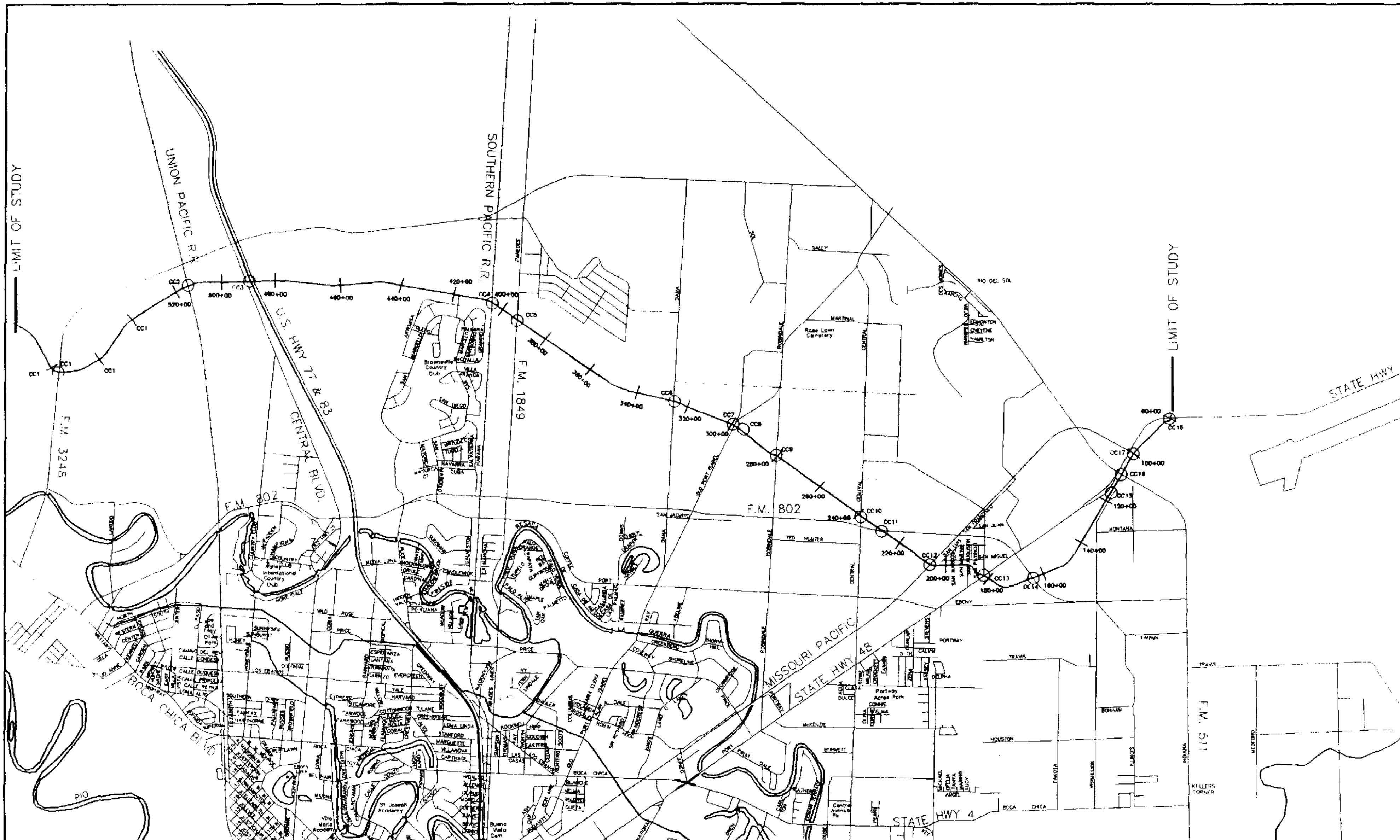
DRAINAGE STUDY

NORTH MAIN DRAIN CHANNEL FEATURES

3-5

PROJECT NO. 68589



LEGEND

CC4 HYDRAULIC FEATURE (FROM 1987 MASTER DRAINAGE PLAN)

10+00 STATION LOCATIONS

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 1700'
DATE	NOVEMBER 1996

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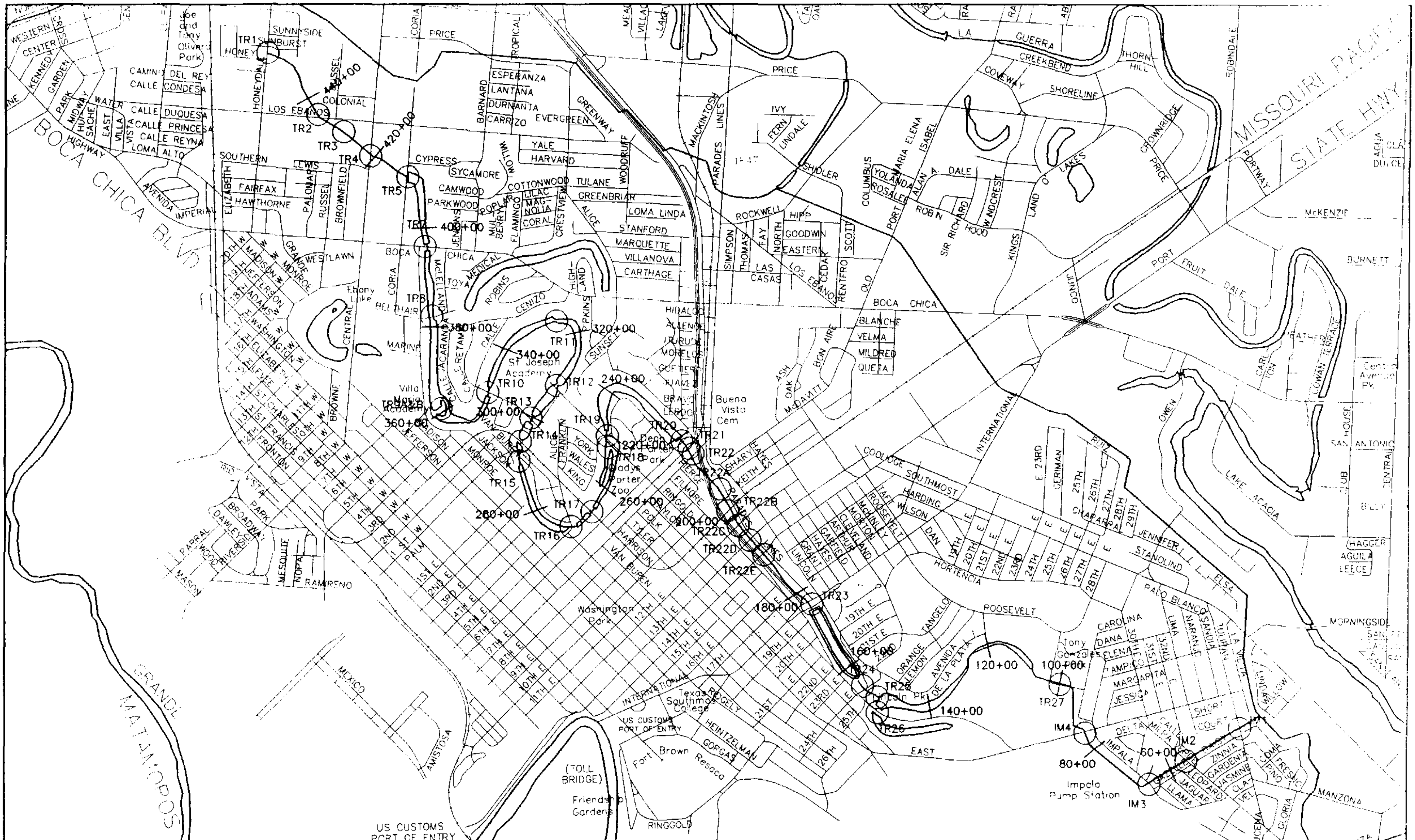
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

CAMERON COUNTY DRAINAGE DISTRICT #1 DITCH
CHANNEL FEATURES

EXHIBIT NO. 3-6

PROJECT NO. 68589



LEGEND

◯TR22B HYDRAULIC FEATURE (FROM 1987 MASTER DRAINAGE PLAN)

| 10+00 CROSS SECTION LOCATIONS

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE: 1" = 1700'	
DATE: NOVEMBER 1996	

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DRAINAGE STUDY

TOWN RESACA CHANNEL FEATURES

EXHIBIT NO. 3-7

PROJECT NO. 68589

LEGEND

◌ RG4 HYDRAULIC FEATURE (FROM 1987 MASTER DRAINAGE PLAN)

| 10+00 CROSS SECTION LOCATIONS

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 1150'
DATE	NOVEMBER 1996

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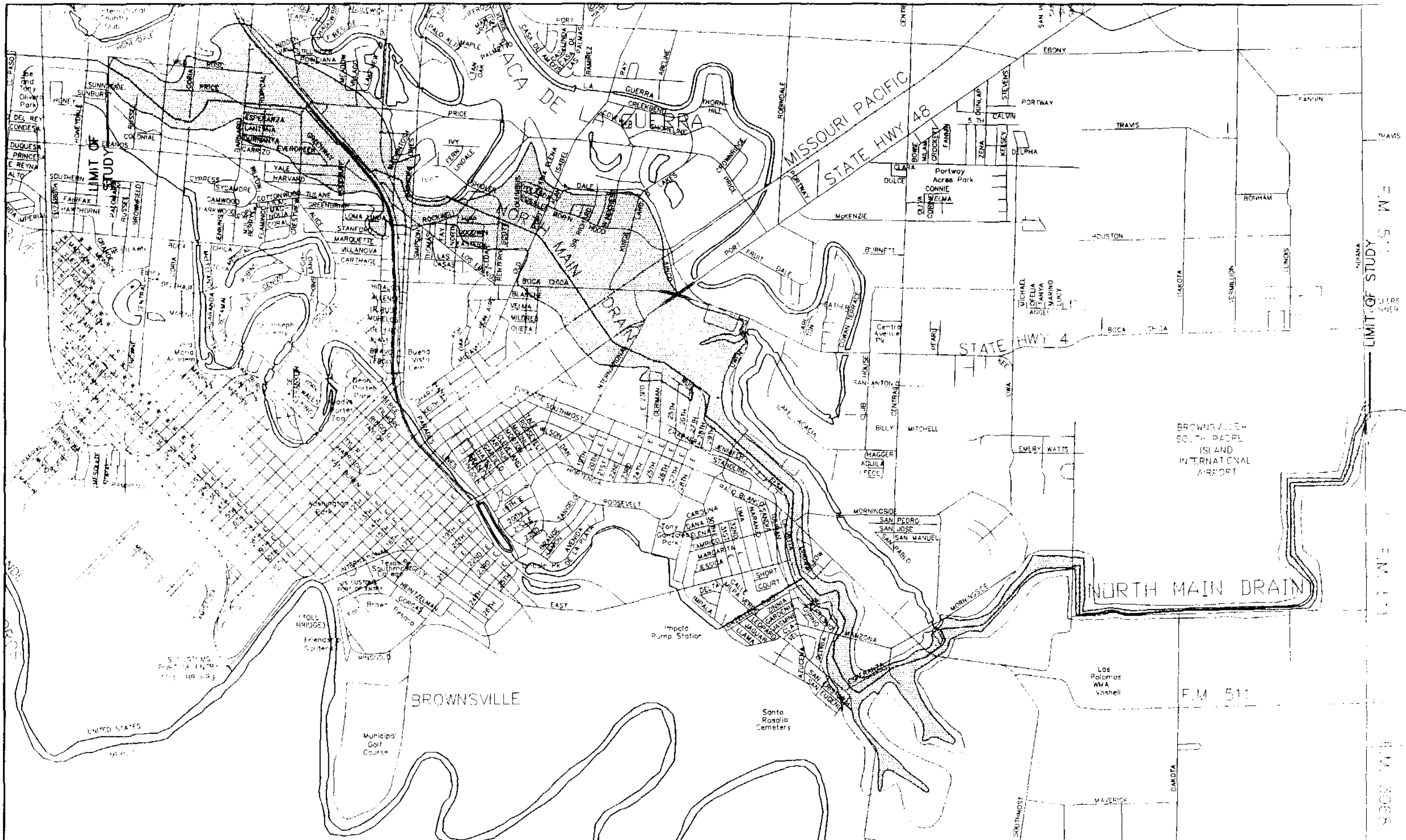
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

RESACA DE LA GUERRA CHANNEL FEATURES

EXHIBIT NO. 3-8

PROJECT NO. 68589



LEGEND

100 YEAR FLOOD PLAIN BOUNDARY

10 YEAR FLOOD PLAIN BOUNDARY

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE: 1" = 1250'	
DATE: NOVEMBER 1996	

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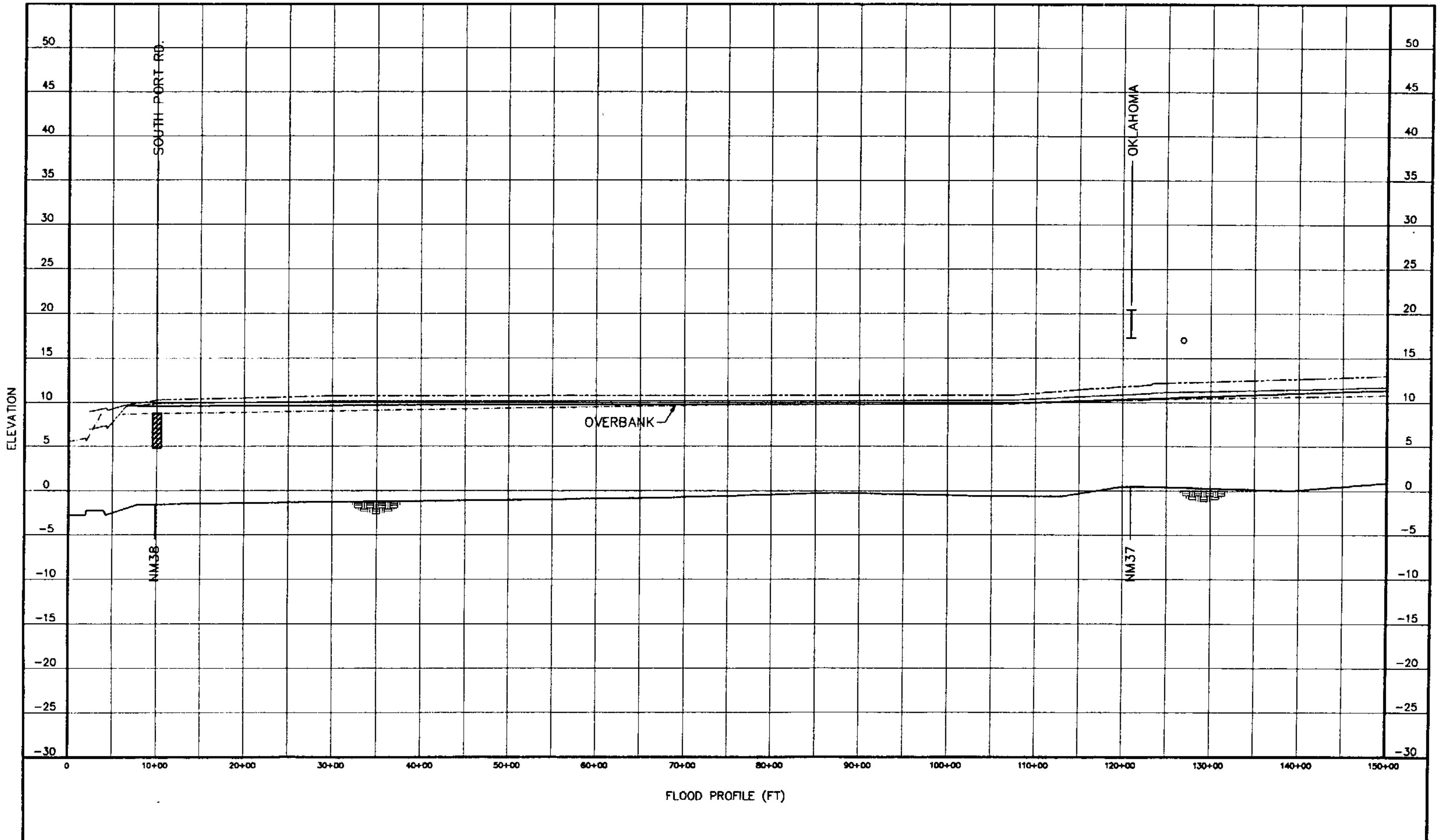
CITY OF BROWNSVILLE, TEXAS
DRAINAGE STUDY

NORTH MAIN DRAIN FLOOD PLAIN MAP

EXHIBIT NO. 3-9

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE	FLOOD INDEX ELEVATIONS
10 YEAR FLOOD PROFILE	CULVERT
100 YEAR FLOOD PROFILE	BRIDGE
TOP OF BANK	FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 10'
DATE:	NOVEMBER 1996

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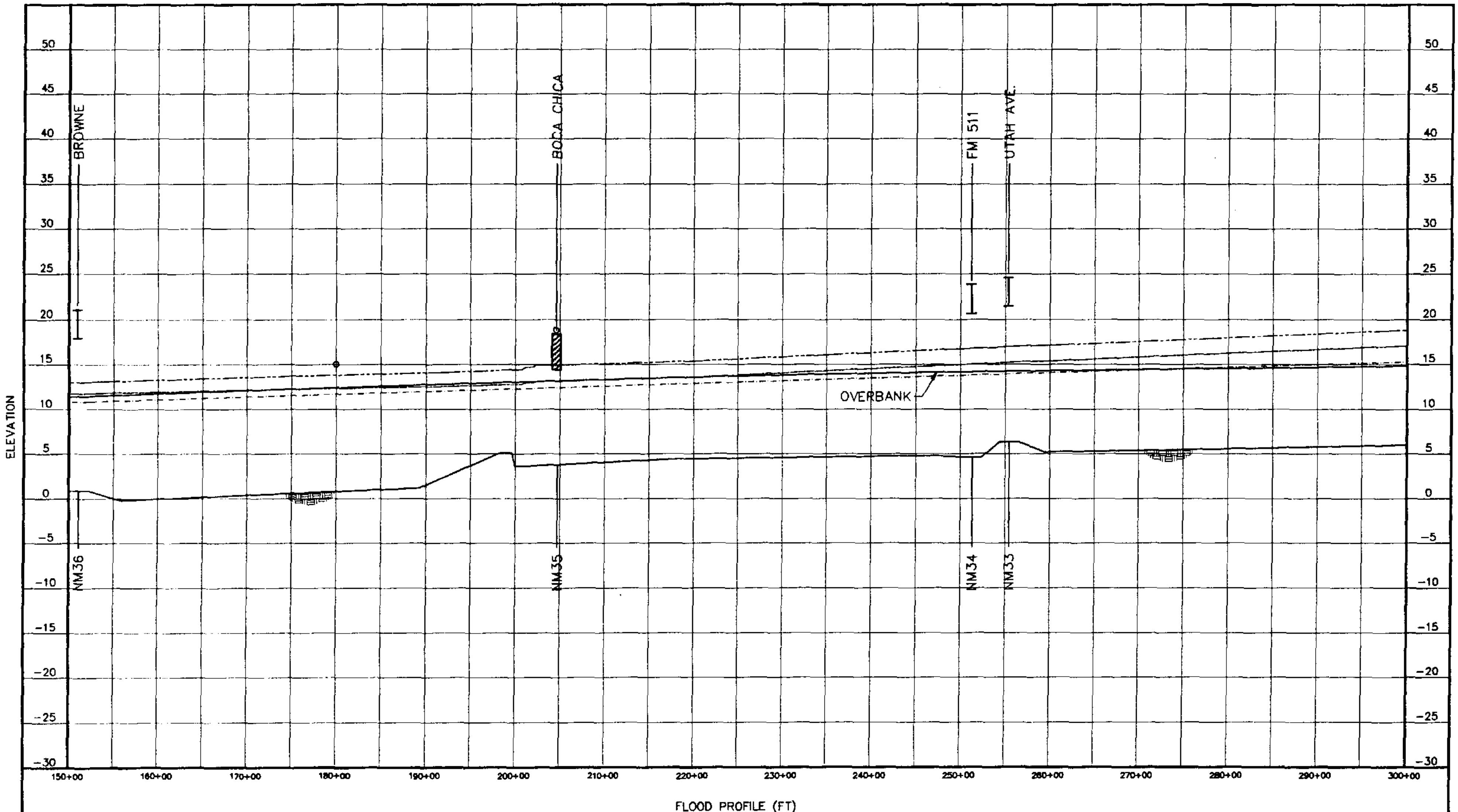
DRAINAGE STUDY

NORTH MAIN DRAIN
FLOOD PROFILE
STA 0+00 TO STA 150+00

EXHIBIT NO. 3-10

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE
10 YEAR FLOOD PROFILE
100 YEAR FLOOD PROFILE
TOP OF BANK

FLOOD INDEX ELEVATIONS
CULVERT
BRIDGE
FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 10'
DATE:	NOVEMBER 1996

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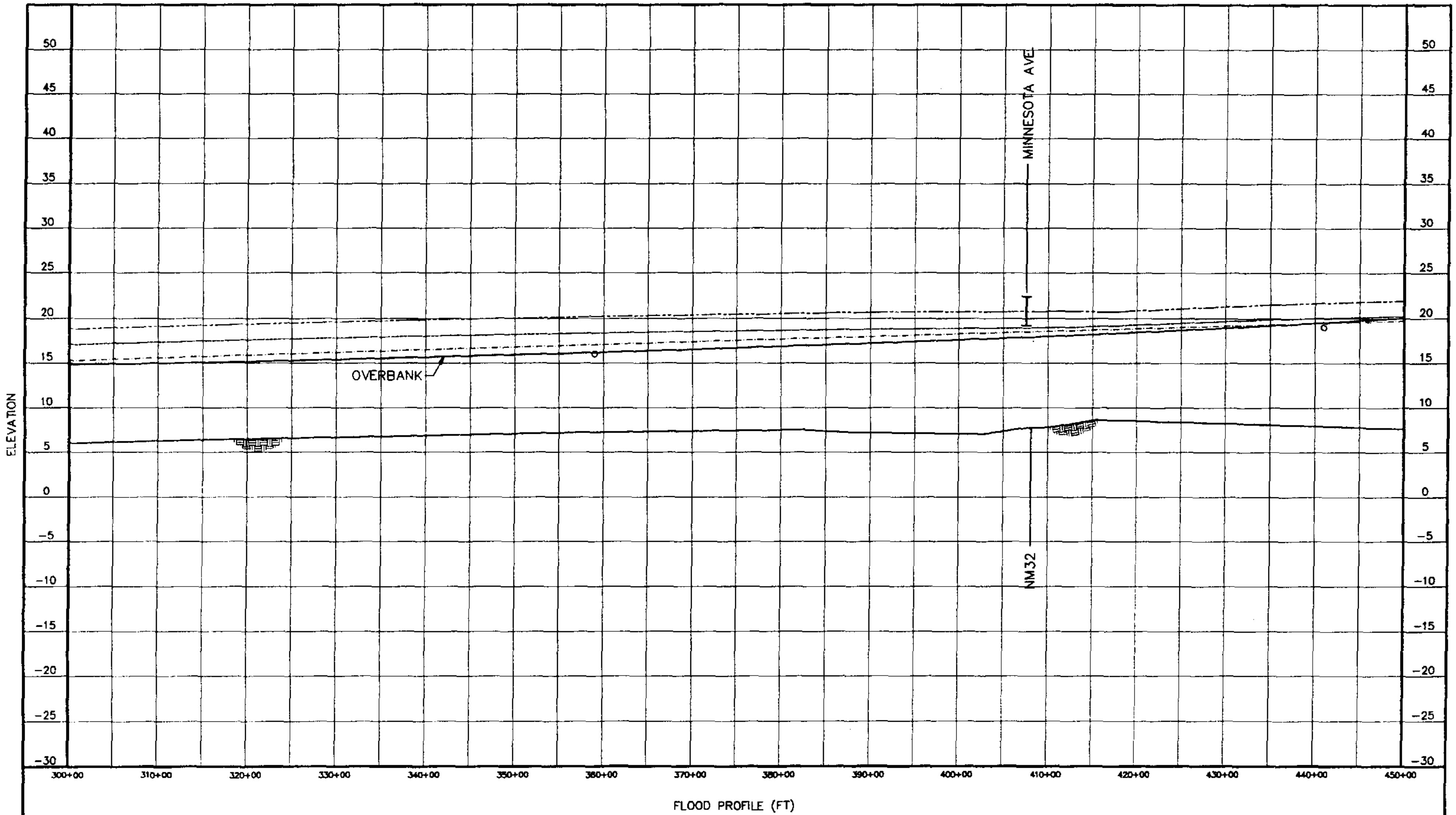
DRAINAGE STUDY

NORTH MAIN DRAIN
FLOOD PROFILE
STA 150+00 TO STA 300+00

EXHIBIT NO. 3-10

PROJECT NO. 68589



LEGEND

- - - - - - -	5 YEAR FLOOD PROFILE	○	FLOOD INDEX ELEVATIONS
————	10 YEAR FLOOD PROFILE		CULVERT
—·—·—·—	100 YEAR FLOOD PROFILE		BRIDGE
————	TOP OF BANK		FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 10'
DATE:	NOVEMBER 1996

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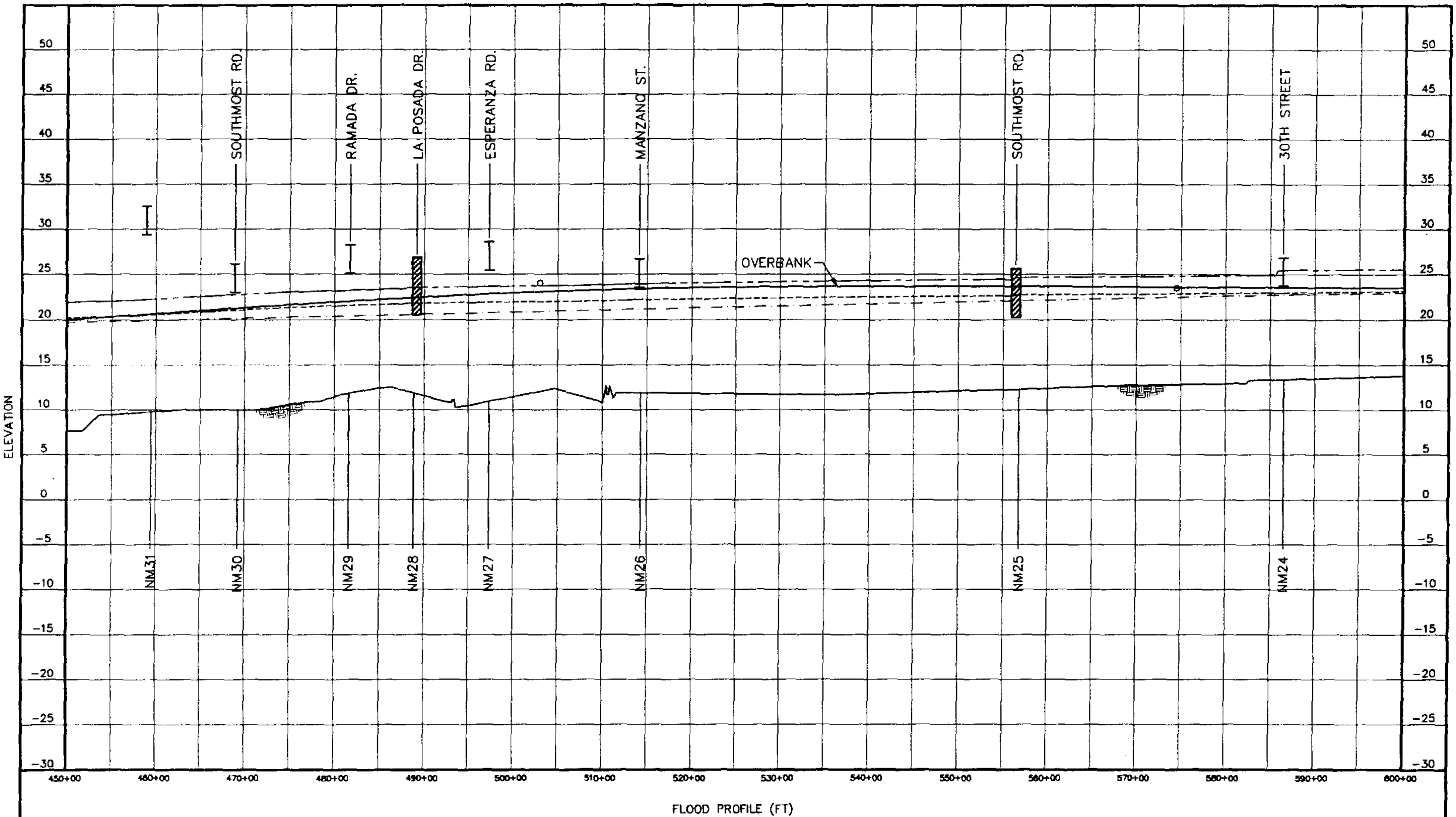
NORTH MAIN DRAIN
FLOOD PROFILE
STA 300+00 TO STA 450+00

EXHIBIT NO. 3-10

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE	FLOOD INDEX ELEVATIONS
10 YEAR FLOOD PROFILE	CULVERT
100 YEAR FLOOD PROFILE	BRIDGE
TOP OF BANK	FLOWLINE

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	H: 1" = 1000' V: 1" = 10'
DATE	NOVEMBER 1996

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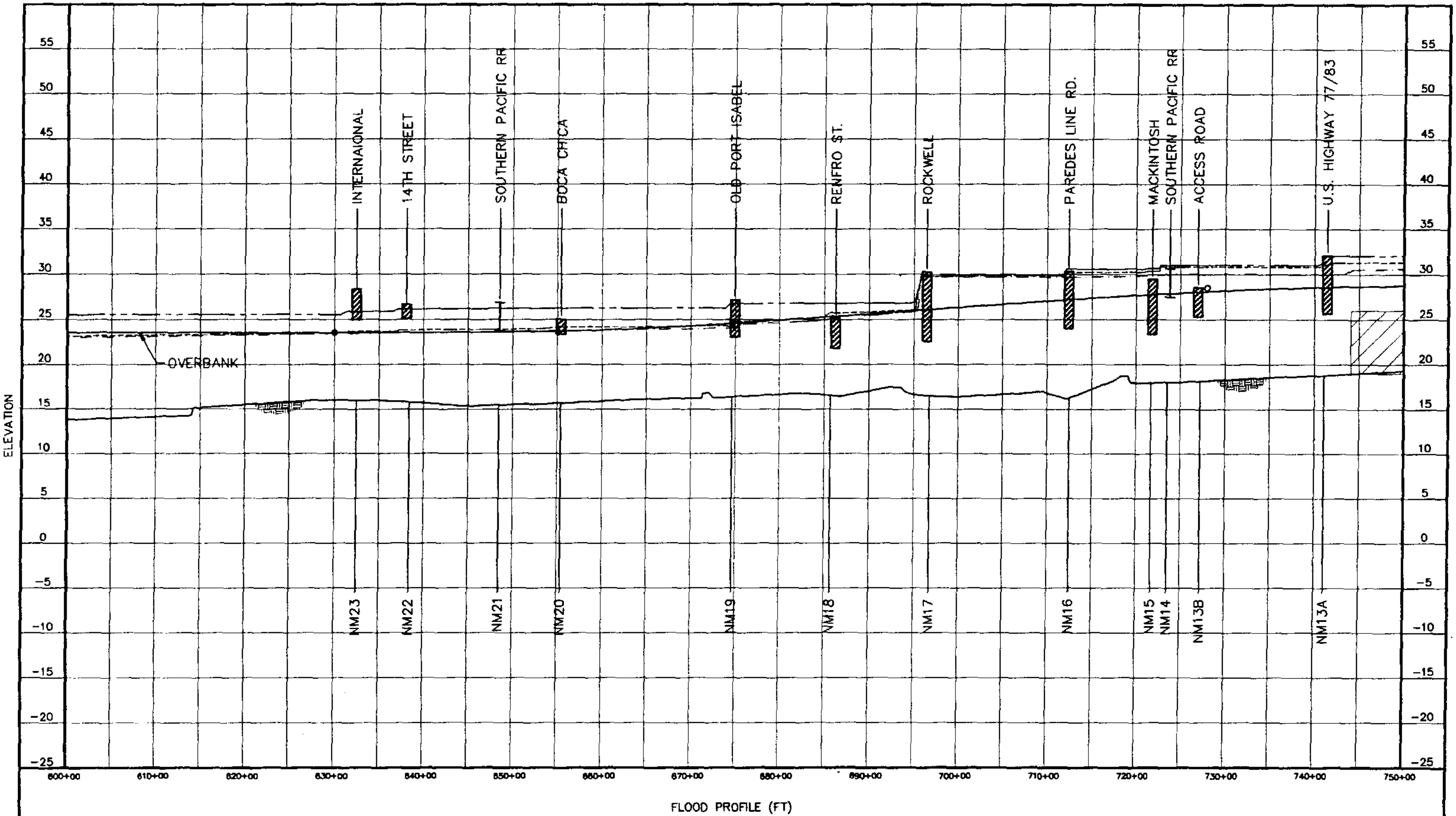
DRAINAGE STUDY

NORTH MAIN DRAIN
FLOOD PROFILE
STA 450+00 TO STA 600+00

EXHIBIT NO. 3-10

PROJECT NO. 68589



LEGEND

— — — — —	5 YEAR FLOOD PROFILE	o	FLOOD INDEX ELEVATIONS
- - - - - - -	10 YEAR FLOOD PROFILE		CULVERT
— - - — - -	100 YEAR FLOOD PROFILE		BRIDGE
———	TOP OF BANK		FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 10'
DATE:	NOVEMBER 1996

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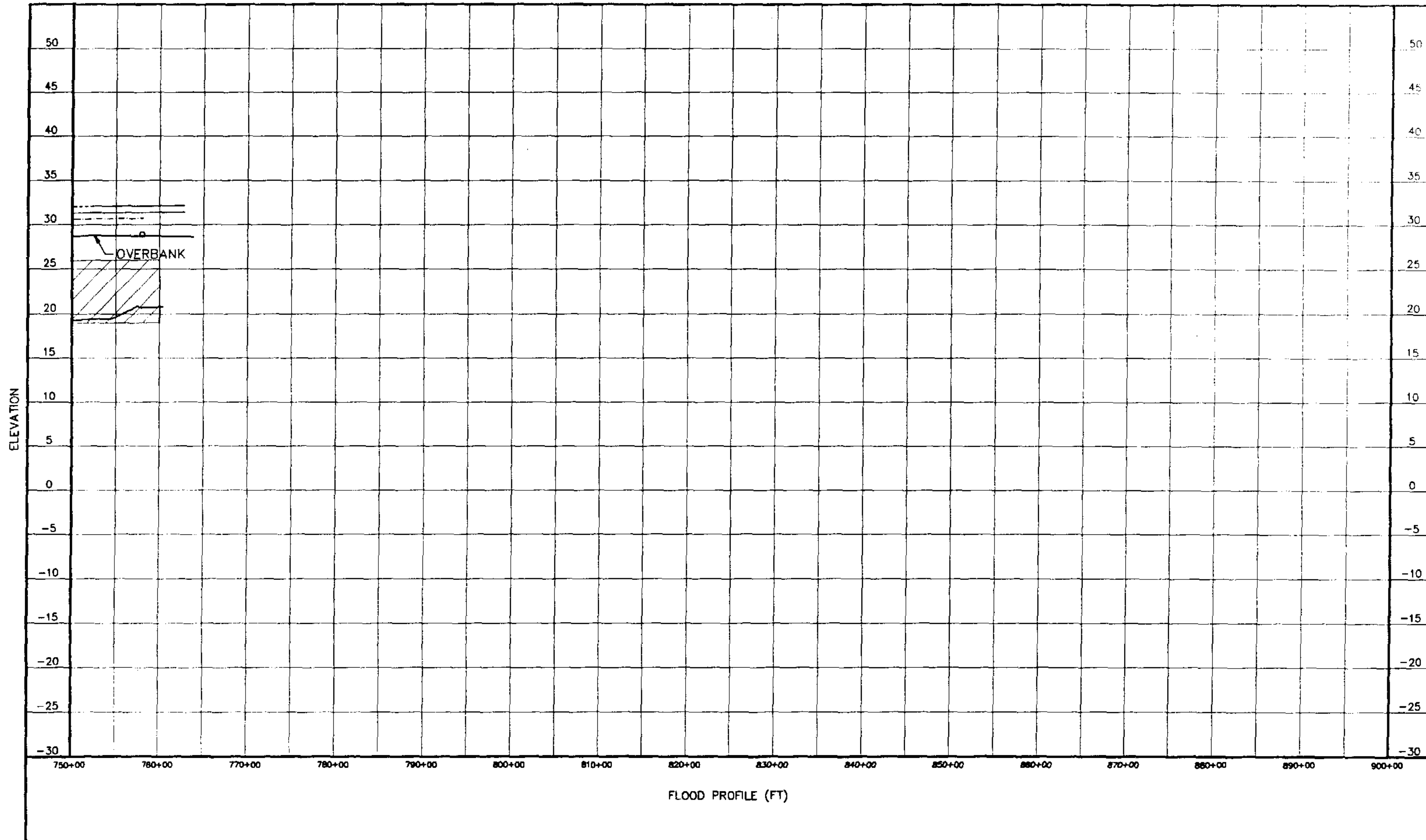
DRAINAGE STUDY

NORTH MAIN DRAIN
FLOOD PROFILE
STA 600+00 TO STA 750+00

EXHIBIT NO. 3-10

PROJECT NO. 68589



LEGEND

- 5 YEAR FLOOD PROFILE
- 10 YEAR FLOOD PROFILE
- 100 YEAR FLOOD PROFILE
- TOP OF BANK
- FLOOD INDEX ELEVATIONS
- CULVERT
- BRIDGE
- FLOWLINE

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	H: 1" = 1000' V: 1" = 10'
DATE	NOVEMBER 1996

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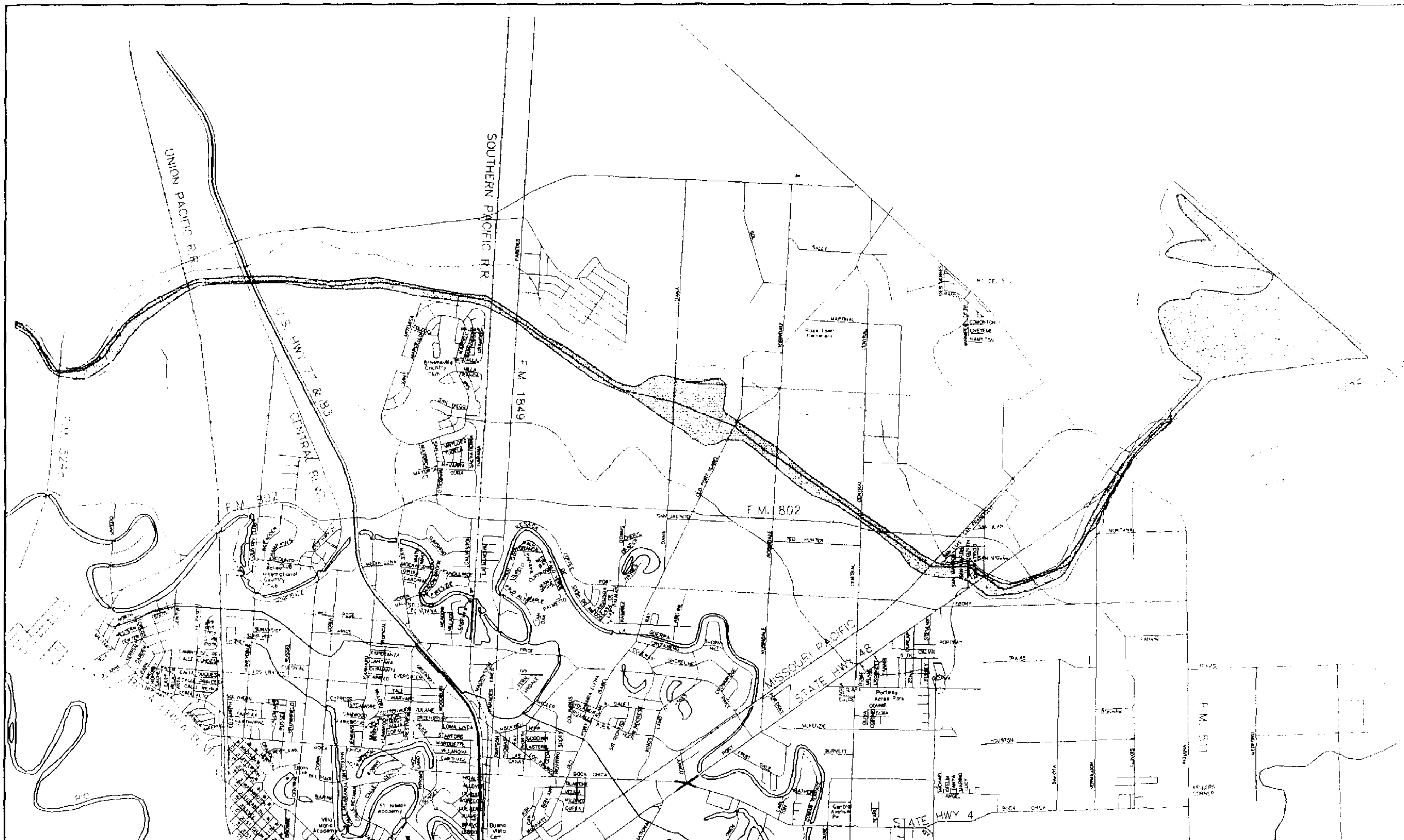
DRAINAGE STUDY

NORTH MAIN DRAIN
FLOOD PROFILE
STA 750+00 TO STA 900+00

EXHIBIT NO. 3-10

PROJECT NO. 68589



LEGEND

100 YEAR FLOOD PLAIN BOUNDARY

10 YEAR FLOOD PLAIN BOUNDARY

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 1700'
DATE	NOVEMBER 1996

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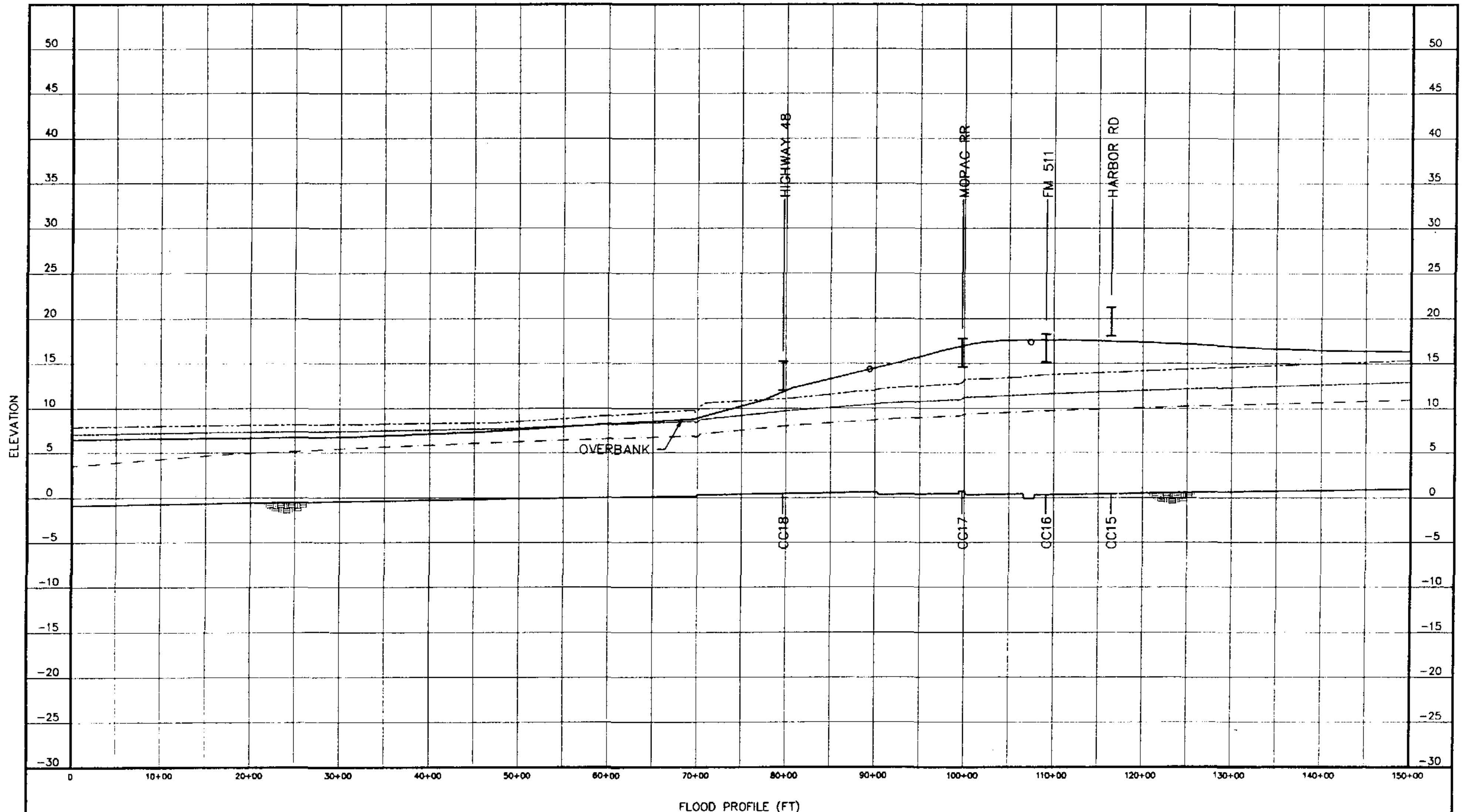
DRAINAGE STUDY

CAMERON COUNTY DRAINAGE DISTRICT #1 DITCH
FLOOD PLAIN MAP

EXHIBIT NO. 3-11

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE
10 YEAR FLOOD PROFILE
100 YEAR FLOOD PROFILE
TOP OF BANK
FLOOD INDEX ELEVATIONS
CULVERT
BRIDGE
FLOWLINE

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	H: 1" = 1000' V: 1" = 10'
DATE	NOVEMBER 1996

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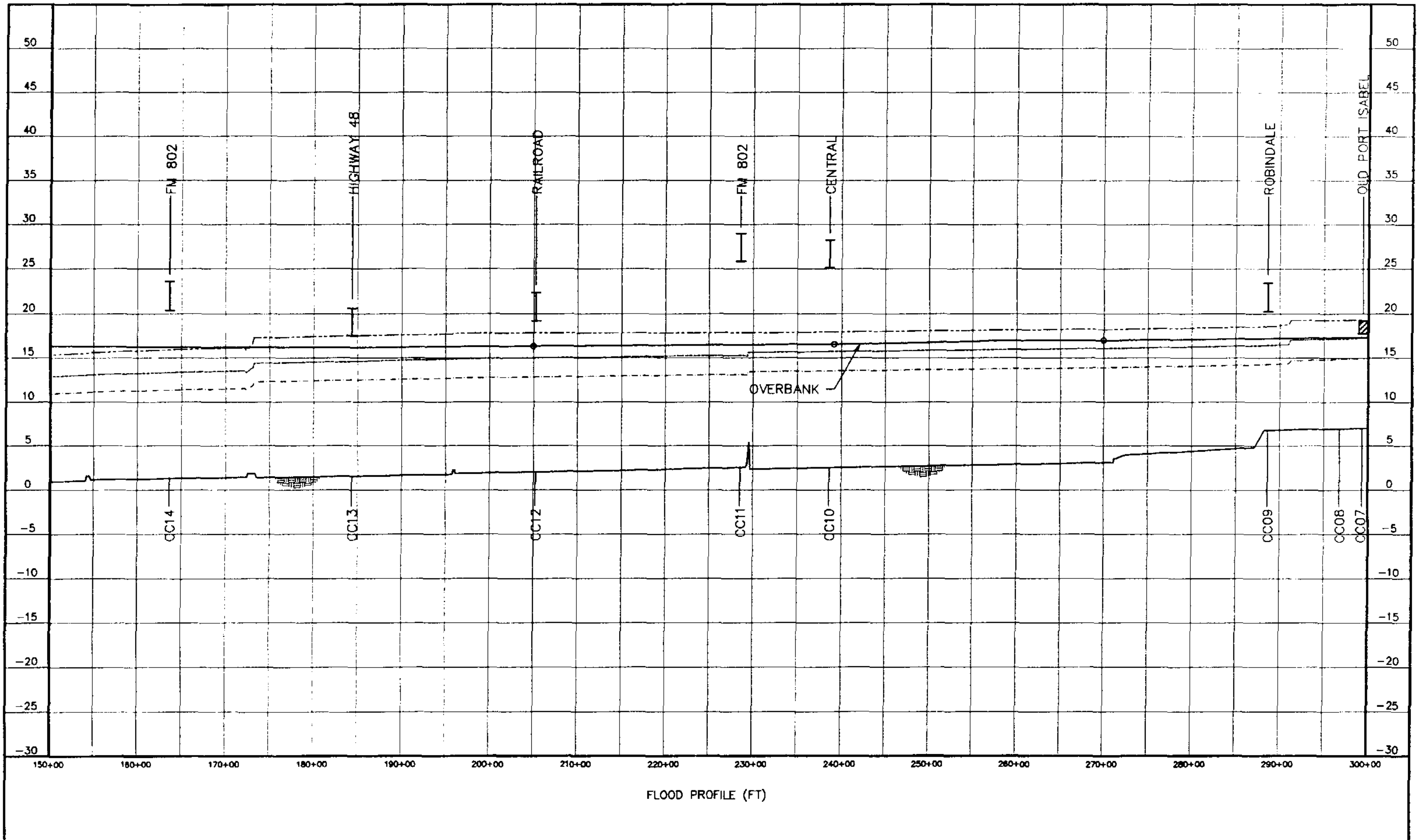
DRAINAGE STUDY

CAMERON COUNTY DRAINAGE DISTRICT No. 1 DITCH
FLOOD PROFILE
STA 0+00 TO STA 150+00

EXHIBIT NO
3-12

PROJECT NO
68589



LEGEND

- - - - - -	5 YEAR FLOOD PROFILE
————————	10 YEAR FLOOD PROFILE
— - — - —	100 YEAR FLOOD PROFILE
————————	TOP OF BANK
O	FLOOD INDEX ELEVATIONS
	CULVERT
	BRIDGE
	FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 10'
DATE:	NOVEMBER 1996

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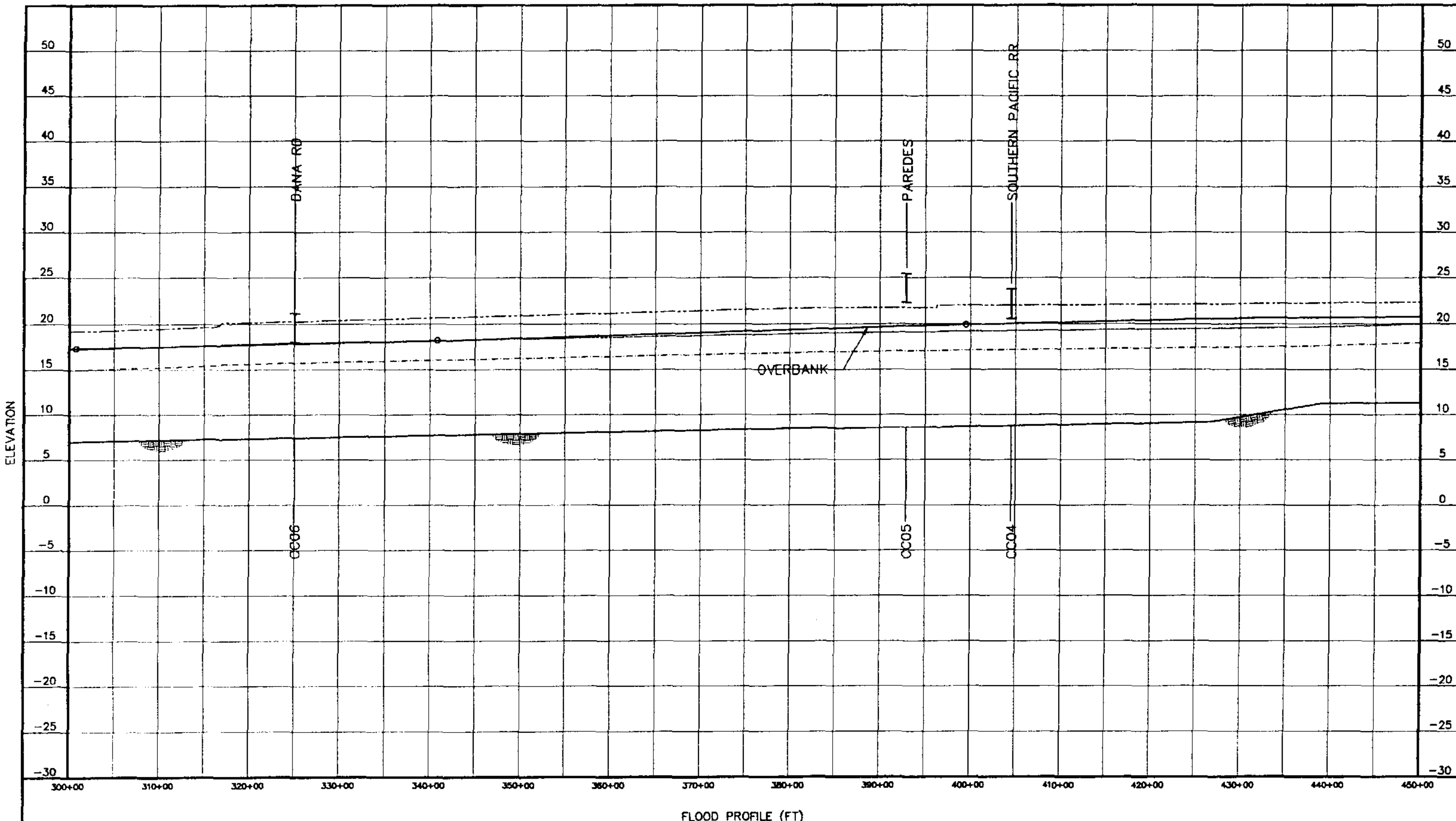
DRAINAGE STUDY

CAMERON COUNTY DRAINAGE DISTRICT No. 1 DITCH
FLOOD PROFILE
STA 150+00 TO STA 300+00

EXHIBIT NO. 3-12

PROJECT NO. 68589



LEGEND

- - - - - - - -	5 YEAR FLOOD PROFILE
————————	10 YEAR FLOOD PROFILE
-·-·-·-·-·-·-	100 YEAR FLOOD PROFILE
————————	TOP OF BANK
o	FLOOD INDEX ELEVATIONS
	CULVERT
	BRIDGE
	FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 10'
DATE:	NOVEMBER 1996

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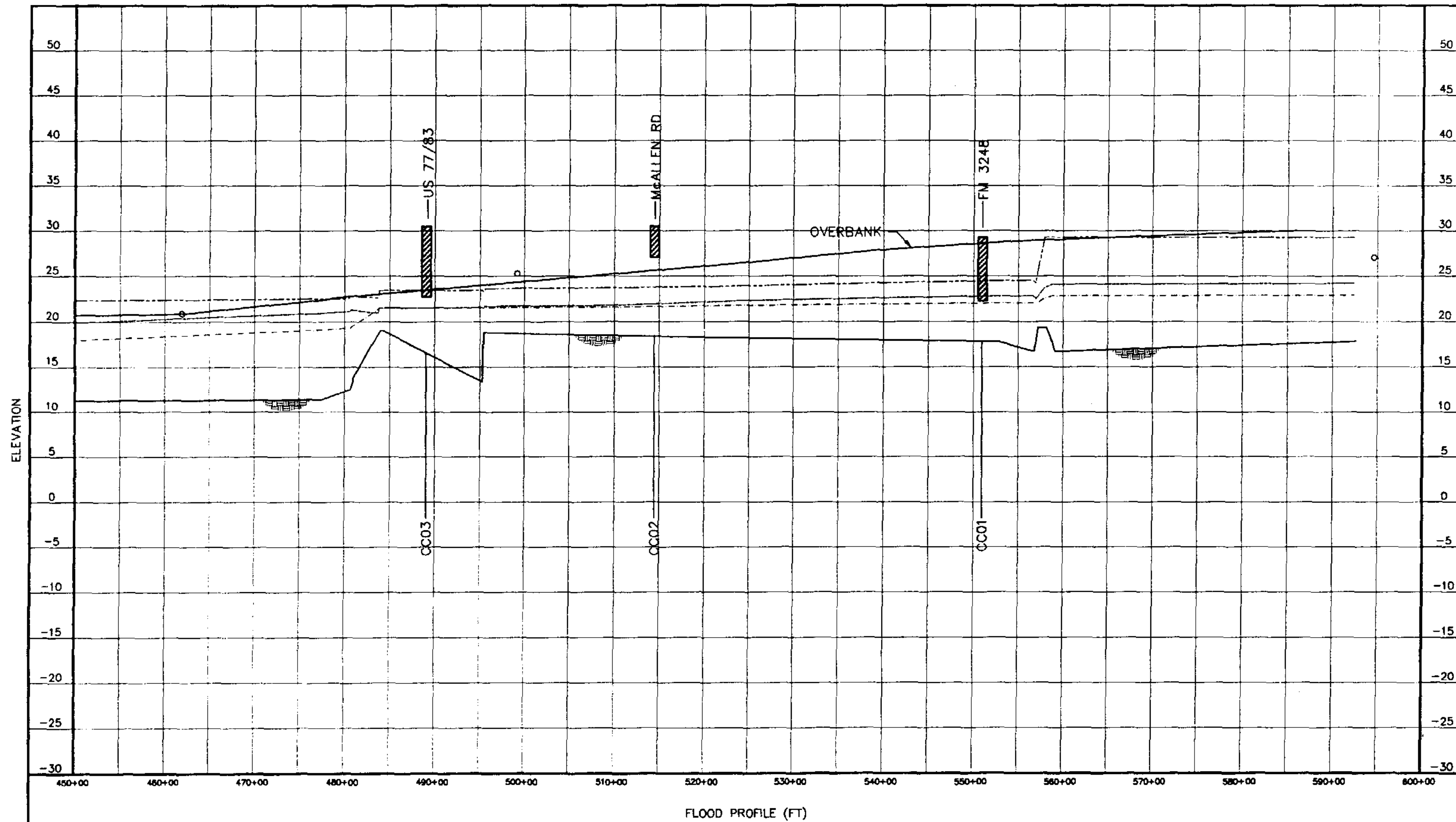
DRAINAGE STUDY

CAMERON COUNTY DRAINAGE DISTRICT No. 1 DITCH
FLOOD PROFILE
STA 300+00 TO STA 450+00

EXHIBIT NO. 3-12

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE	FLOOD INDEX ELEVATIONS
10 YEAR FLOOD PROFILE	CULVERT
100 YEAR FLOOD PROFILE	BRIDGE
TOP OF BANK	FLOWLINE

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE:	H: 1" = 1000' V: 1" = 10'
DATE	NOVEMBER 1996

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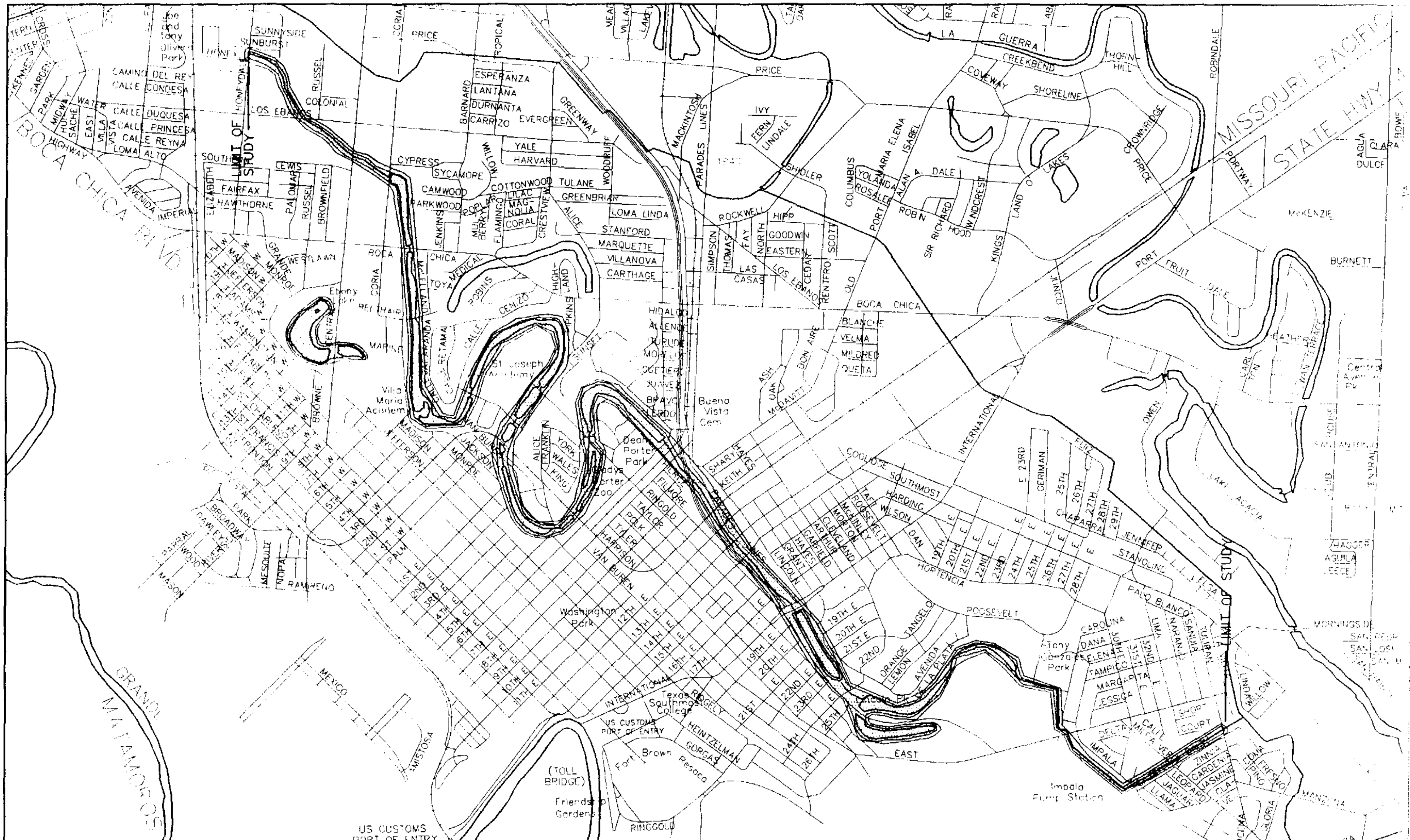
DRAINAGE STUDY

CAMERON COUNTY DRAINAGE DISTRICT No.1 DITCH
FLOOD PROFILE
STA 450+00 TO STA 600+00

EXHIBIT NO. 3-12

PROJECT NO. 68589



LEGEND

	100 YEAR FLOOD PLAIN BOUNDARY
	10 YEAR FLOOD PLAIN BOUNDARY

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	1" = 300'
DATE:	NOVEMBER 1996

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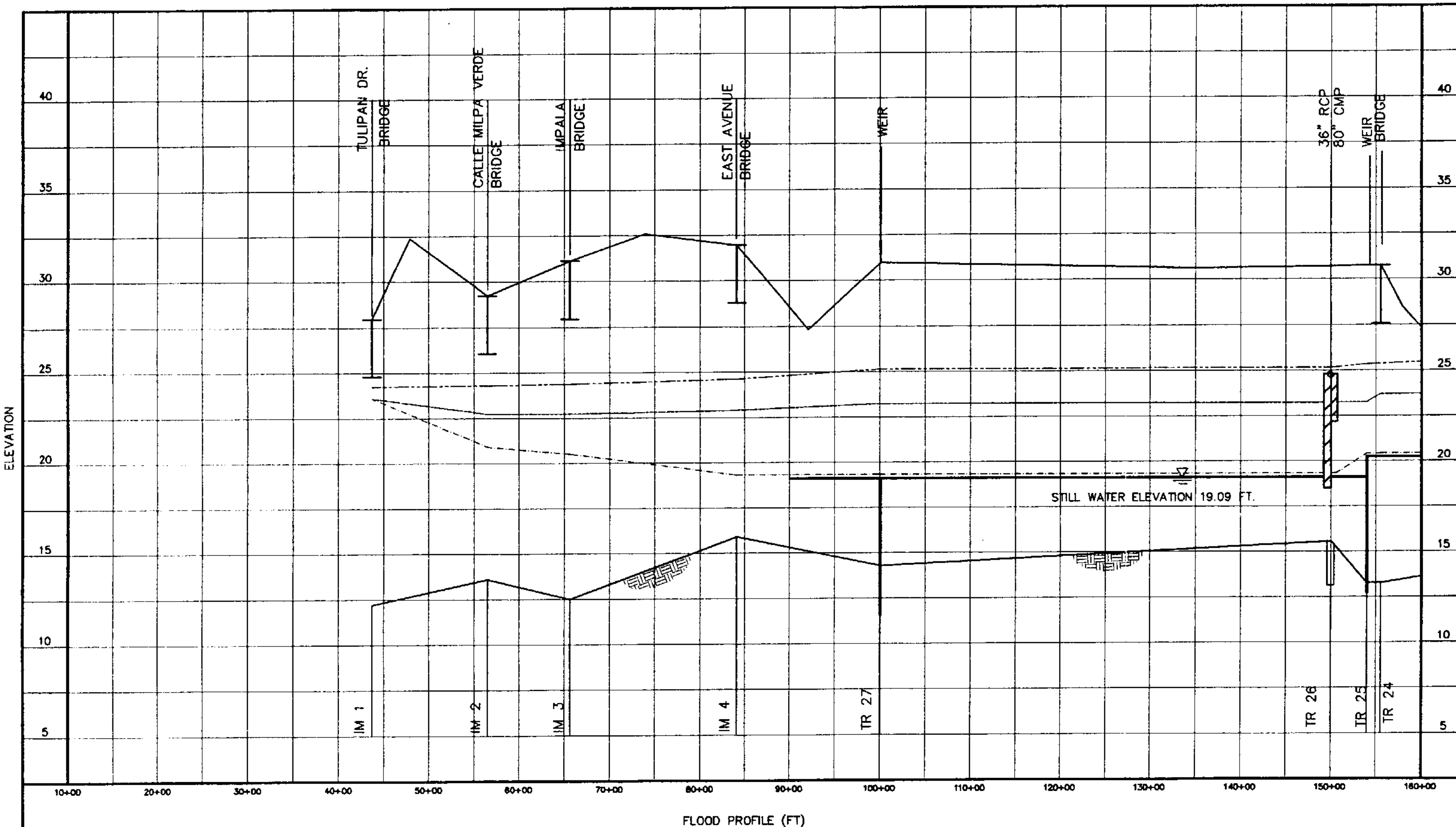
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

TOWN RESACA FLOOD PLAIN MAP

3-13

68589



LEGEND

5 YEAR FLOOD PROFILE
10 YEAR FLOOD PROFILE
100 YEAR FLOOD PROFILE
TOP OF BANK

FLOOD INDEX ELEVATIONS
CULVERT
BRIDGE
FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
FILE:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 5'
DATE:	NOVEMBER 1996

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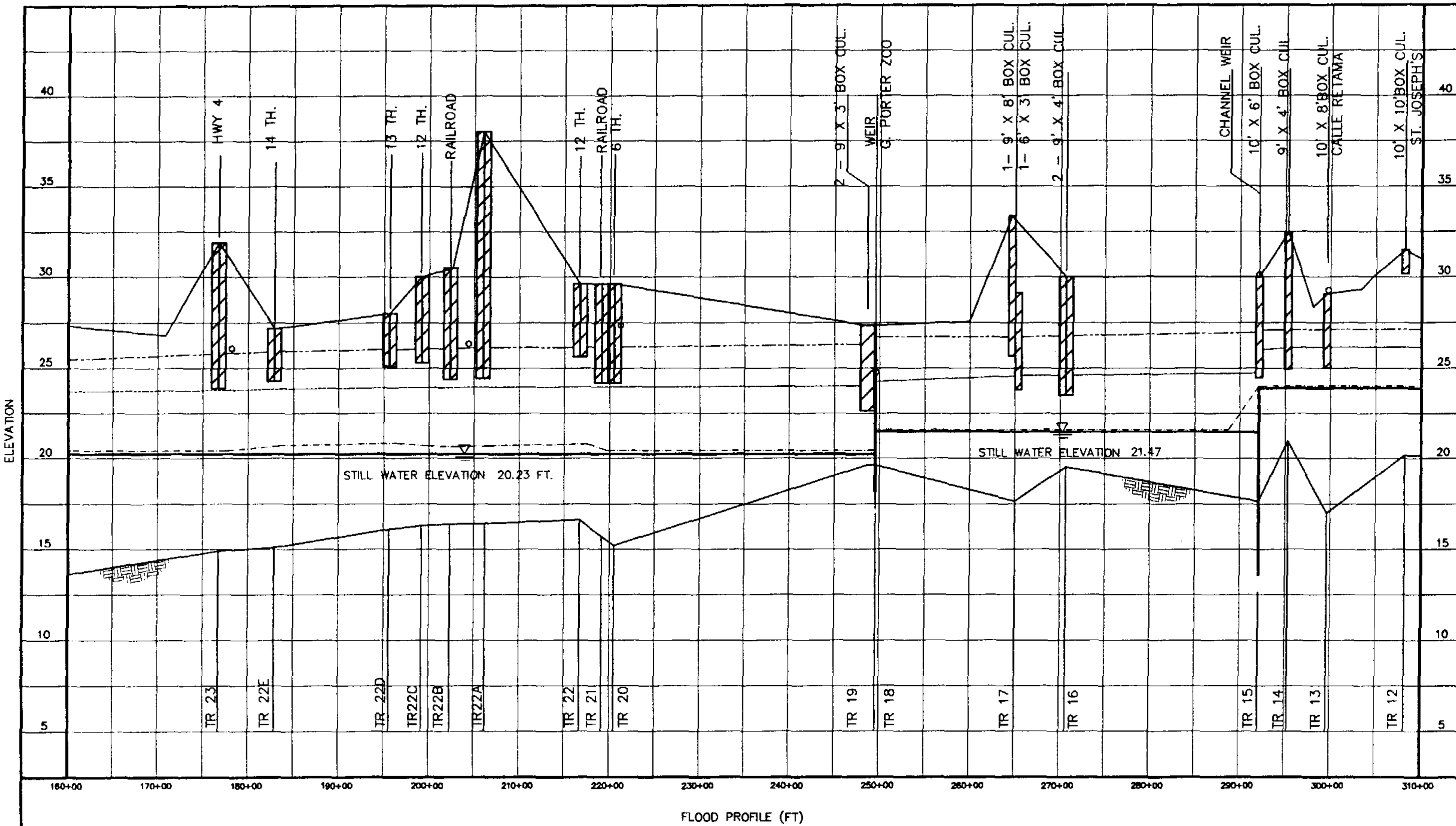
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

TOWN RESACA
FLOOD PROFILE
STA 10+00 TO STA 160+00

EXHIBIT NO. 3-14

PROJECT NO. 68589



LEGEND

- - - - - -	5 YEAR FLOOD PROFILE	○	FLOOD INDEX ELEVATIONS
———	10 YEAR FLOOD PROFILE		CULVERT
-·-·-·-	100 YEAR FLOOD PROFILE		BRIDGE
———	TOP OF BANK		FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 5'
DATE:	NOVEMBER 1996

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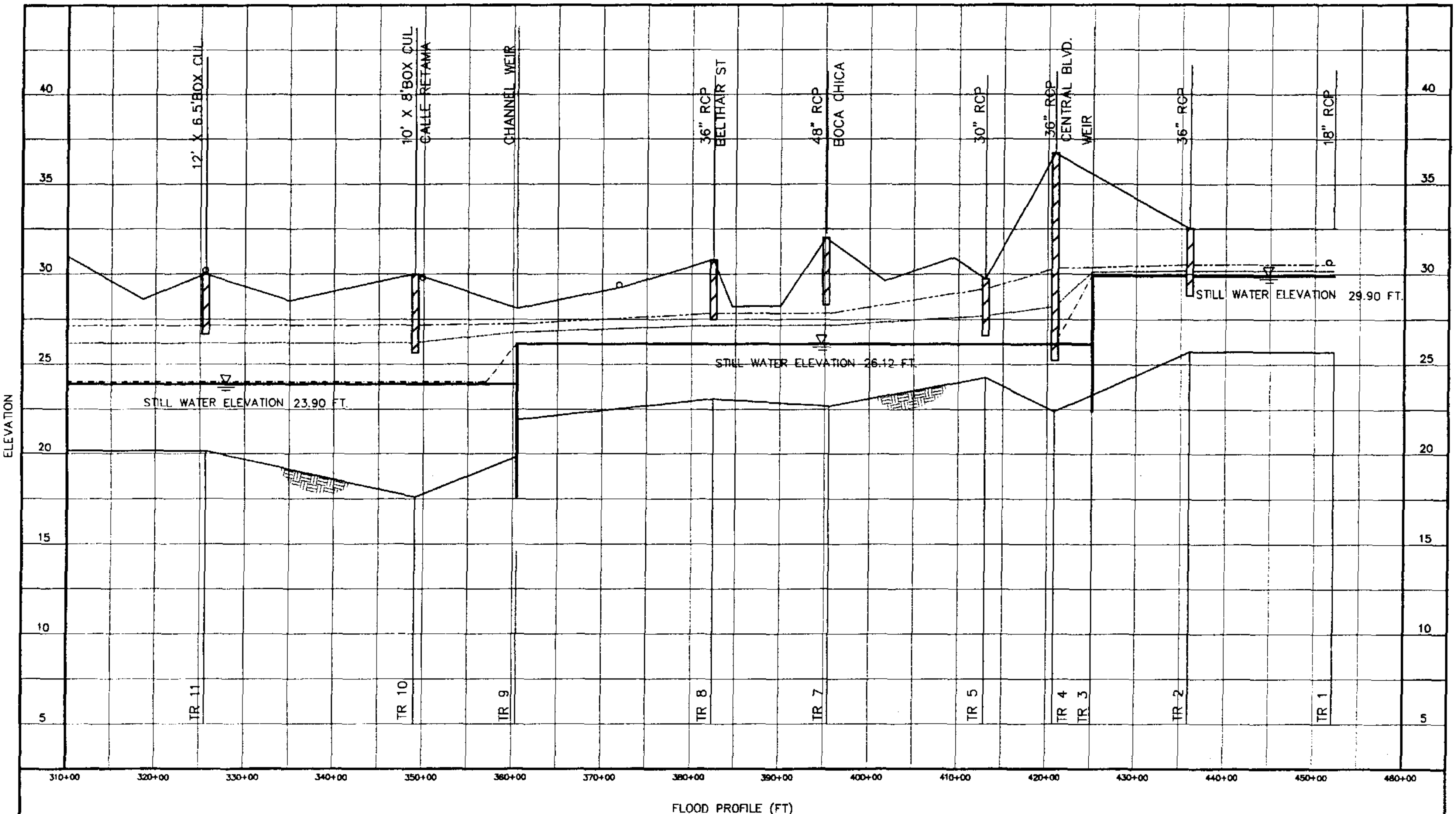
CITY OF BROWNSVILLE, TEXAS
DRAINAGE STUDY
TOWN RESACA
FLOOD PROFILE
STA 160+00 TO STA 310+00

EXHIBIT NO. 3-14
PROJECT NO. 68589



LEGEND			
5 YEAR FLOOD PROFILE		FLOOD INDEX ELEVATIONS	
10 YEAR FLOOD PROFILE		CULVERT	
100 YEAR FLOOD PROFILE		BRIDGE	
TOP OF BANK		FLOWLINE	

DRAWN	D.V.
DESIGN	T.J.
CHECKED:	C.W.
PM	M.J.
SCALE	H: 1" = 1000' V: 1" = 5'
DATE	NOVEMBER 1996

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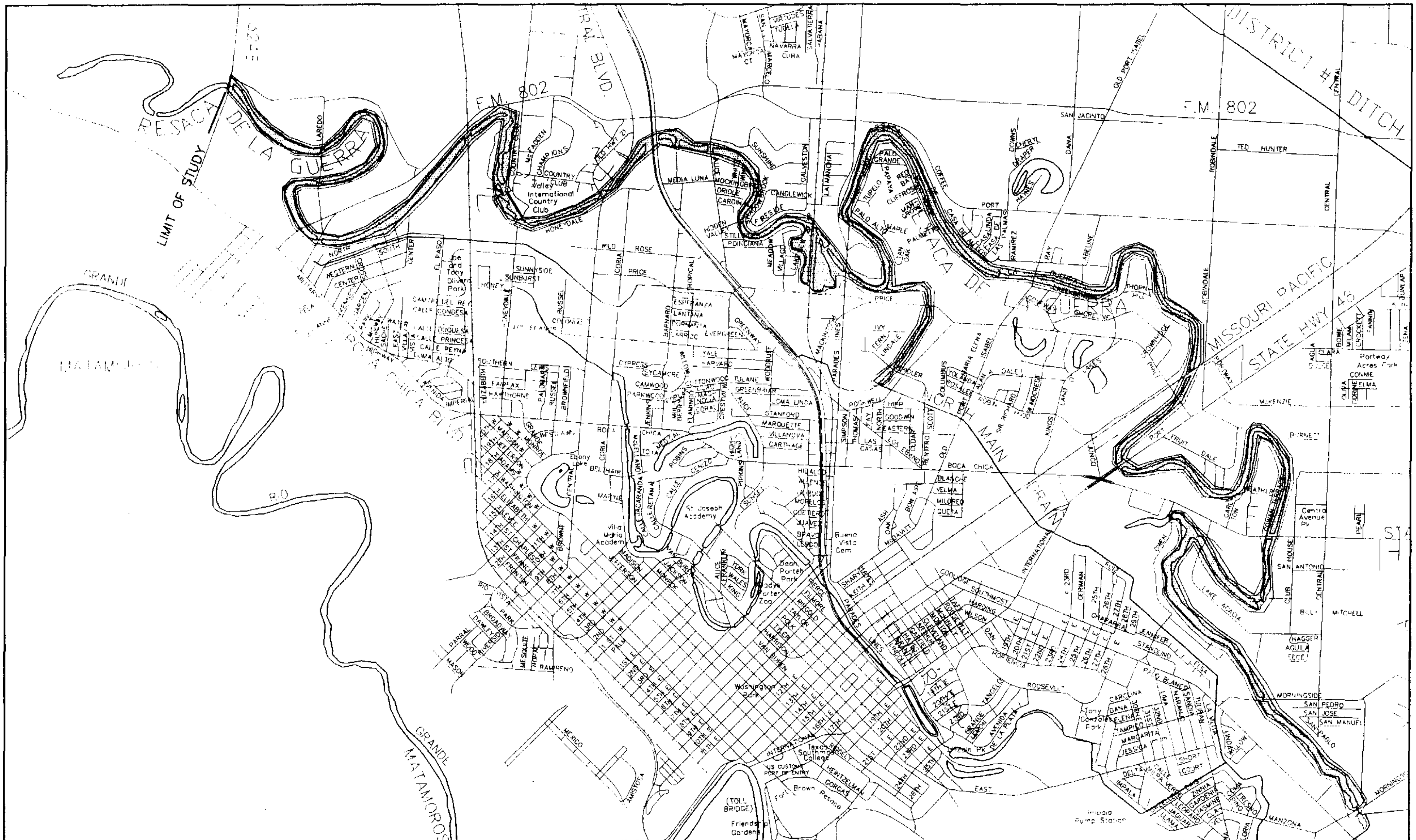
DRAINAGE STUDY

TOWN RESACA
FLOOD PROFILE
STA 310+00 TO STA 460+00

EXHIBIT NO 3-14

PROJECT NO 68589



LEGEND

(blank box)	100 YEAR FLOOD PLAIN BOUNDARY
(shaded box)	10 YEAR FLOOD PLAIN BOUNDARY

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 1250'
DATE	NOVEMBER 1996

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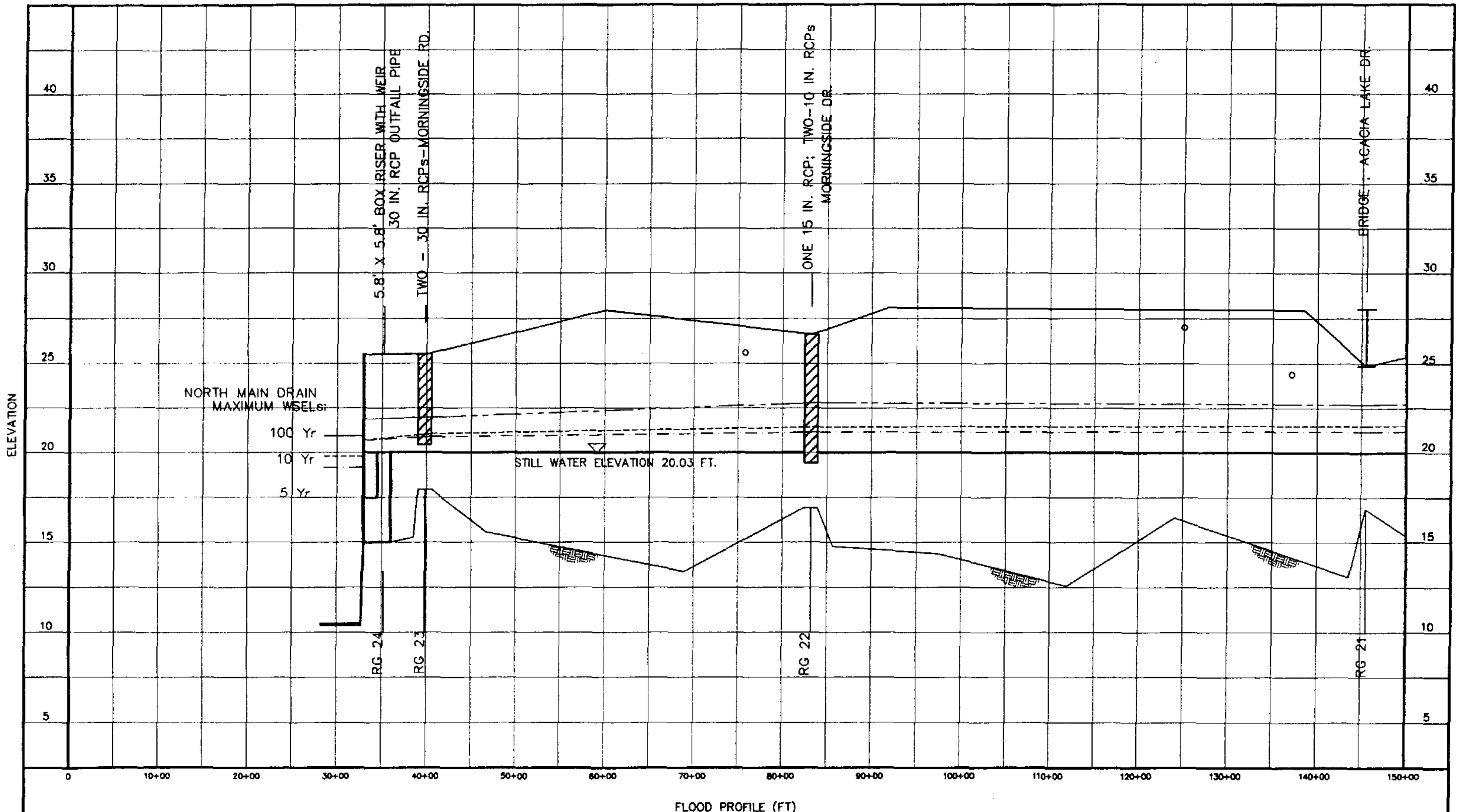
CITY OF BROWNSVILLE, TEXAS
DRAINAGE STUDY

RESACA DE LA GUERRA FLOOD PLAIN MAP

EXHIBIT NO. 3-15

PROJECT NO. 68589



LEGEND

- - - - - -	5 YEAR FLOOD PROFILE
------------	10 YEAR FLOOD PROFILE
—— - —— - ——	100 YEAR FLOOD PROFILE
———————	TOP OF BANK
o	FLOOD INDEX ELEVATIONS
	CULVERT
	BRIDGE
	FLOWLINE

DRAWN	D.V.
DESIGN	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 5'
DATE	NOVEMBER 1996

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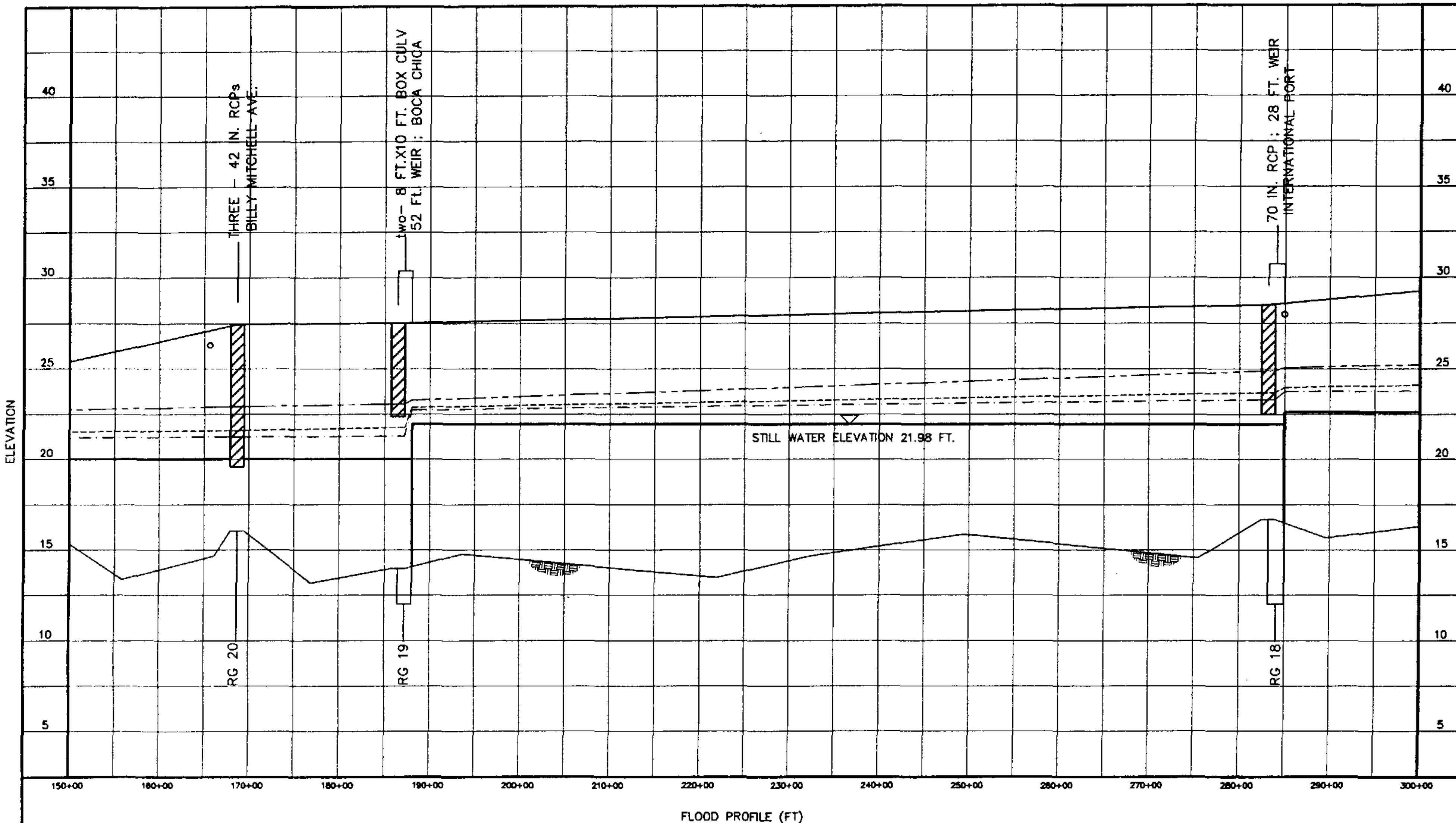
DRAINAGE STUDY

RESACA DE LA GUERRA
FLOOD PROFILE
STA 0+00 TO STA 150+00

EXHIBIT NO. 3-16

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE
10 YEAR FLOOD PROFILE
100 YEAR FLOOD PROFILE
TOP OF BANK
FLOOD INDEX ELEVATIONS
CULVERT
BRIDGE
FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 5'
DATE:	NOVEMBER 1996

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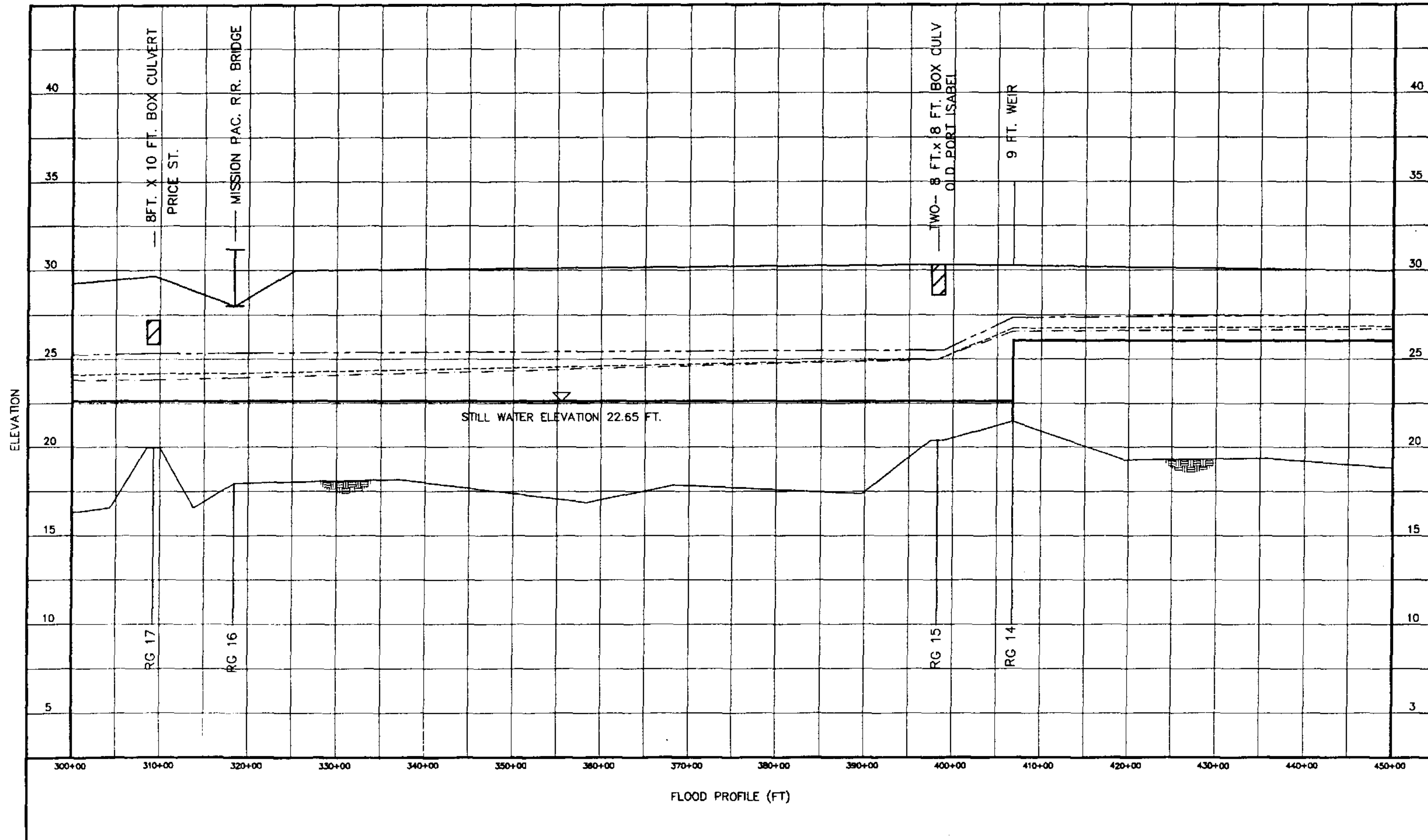
DRAINAGE STUDY
RESACA DE LA GUERRA
FLOOD PROFILE
STA 150+00 TO STA 300+00

EXHIBIT NO. 3-16
PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE	FLOOD INDEX ELEVATIONS
10 YEAR FLOOD PROFILE	CULVERT
100 YEAR FLOOD PROFILE	BRIDGE
TOP OF BANK	FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 5'
DATE:	NOVEMBER 1996

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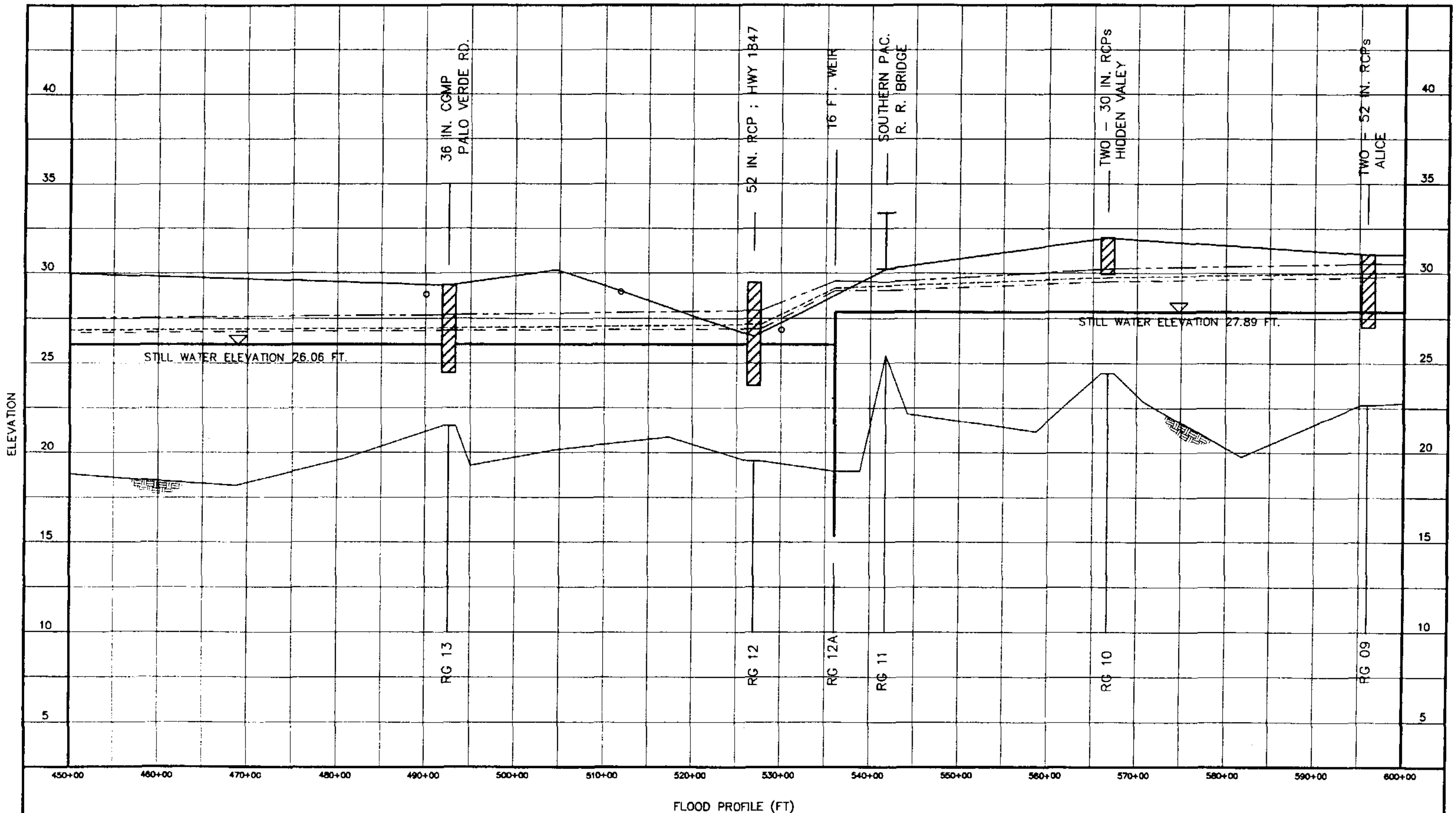
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

RESACA DE LA GUERRA
FLOOD PROFILE
STA 300+00 TO STA 450+00

EXHIBIT NO. 3-16

PROJECT NO. 68589



LEGEND

- 5 YEAR FLOOD PROFILE
- 10 YEAR FLOOD PROFILE
- 100 YEAR FLOOD PROFILE
- TOP OF BANK
- FLOOD INDEX ELEVATIONS
- CULVERT
- BRIDGE
- FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 5'
DATE:	NOVEMBER 1996

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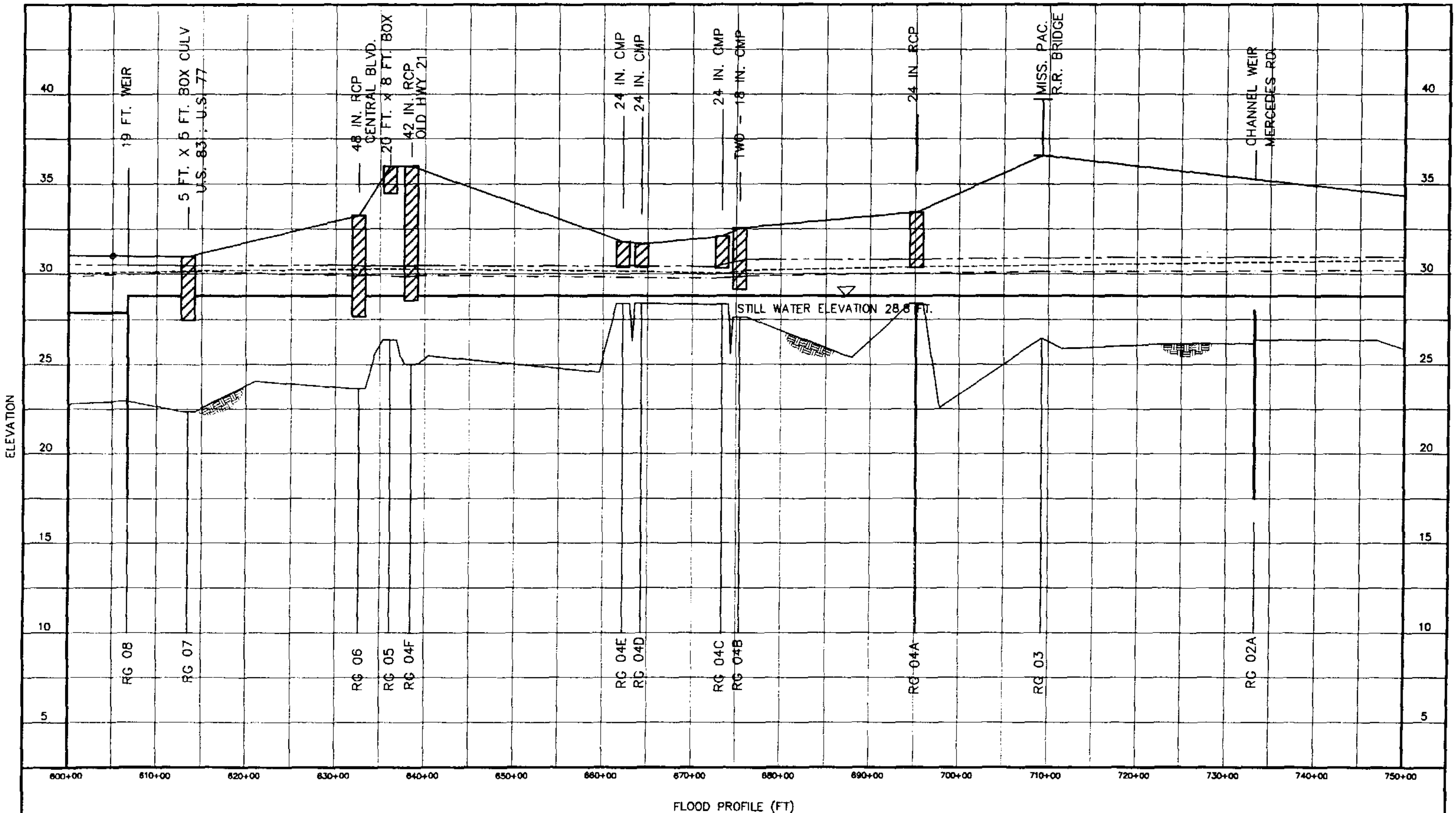
CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

RESACA DE LA GUERRA
FLOOD PROFILE
STA 450+00 TO STA 600+00

EXHIBIT NO. 3-16

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE	O	FLOOD INDEX ELEVATIONS
10 YEAR FLOOD PROFILE		CULVERT
100 YEAR FLOOD PROFILE		BRIDGE
TOP OF BANK		FLOWLINE

DRAWN	D.V.
DESIGN	T.J.
CHECKED	C.W.
PM	M.J.
SCALE	H: 1" = 1000' V: 1" = 5'
DATE	NOVEMBER 1996

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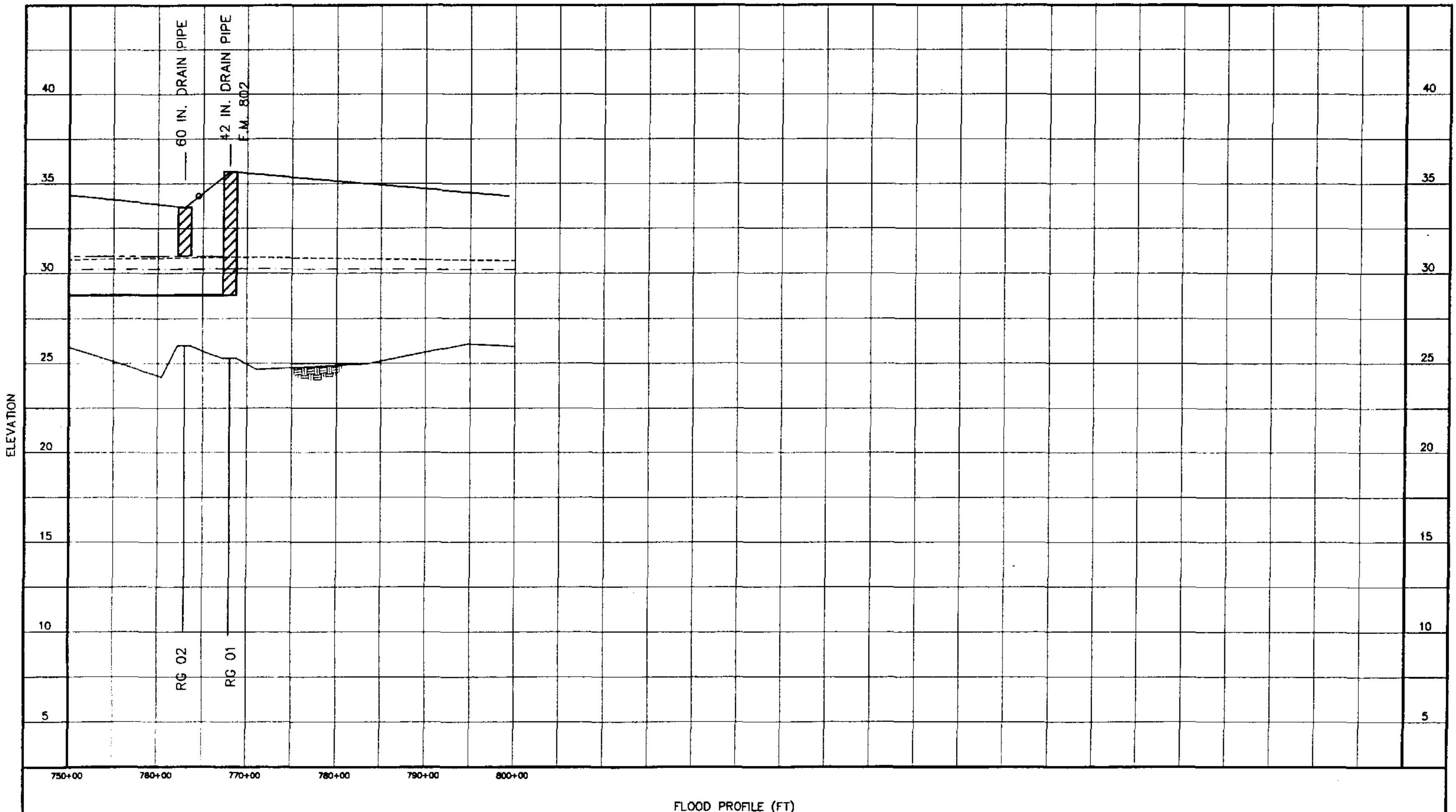
DRAINAGE STUDY

RESACA DE LA GUERRA
FLOOD PROFILE
STA 600+00 TO 750+00

EXHIBIT NO. 3-16

PROJECT NO. 68589



LEGEND

5 YEAR FLOOD PROFILE	FLOOD INDEX ELEVATIONS
10 YEAR FLOOD PROFILE	CULVERT
100 YEAR FLOOD PROFILE	BRIDGE
TOP OF BANK	FLOWLINE

DRAWN:	D.V.
DESIGN:	T.J.
CHECKED:	C.W.
PM:	M.J.
SCALE:	H: 1" = 1000' V: 1" = 5'
DATE	NOVEMBER 1996

RUST LICHLITER/JAMESON

CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

RESACA DE LA GUERRA
FLOOD PROFILE
STA 750+00 TO STA 800+00

EXHIBIT NO
3-16

PROJECT NO
68589

4.0 RECOMMENDED FLOOD PROTECTION PLAN

The primary goal of the Plan project is to develop an implementable drainage plan which will reduce flooding along the major drainage channels in developed areas of the City of Brownsville. While the target level of protection is the 100-year frequency flood event, a lesser level of protection may be recommended due to physical, economical or technical limitations for constructing possible mitigation projects.

In order to develop an implementable Plan, the areas of overbank channel flooding identified by the modeling presented in Section 3.0 were analyzed in conjunction with the localized flooding areas identified by the City on Exhibit 2-2. It should be noted that localized flooding problems in areas away from the channel are probably due to inadequate storm sewer, inlet or street capacity and were not addressed specifically by this plan. However, by lowering water surface elevations and associated flood plains along the major channels, outfall conditions for the secondary drainage system will be improved and the localized flooding may therefore be reduced.

Channel flooding problems were analyzed for the 5-, 10-, and 100-year events on all four channel systems as discussed in Section 3.0. Structural and non-structural methods of reducing flooding were analyzed for applicability to the specific problem areas identified for each watershed.

4.1 North Main Drain

The North Main Drain has significant out-of-bank flooding along most of its length within the planning area. Based on the flood plain maps developed as part of this study, approximately 2,300 acres are flooded by the 100-year rainfall event. Because the ditch drains a heavily urbanized portion of the City, structural flooding and severe street flooding are possible in the watershed during severe storm events. Non-structural methods of reducing the flooding potential along the North Main Drain were considered along with structural methods and are discussed below.

The wide extent of the flood plain in existing residential developments and commercial areas along the North Main Drain will economically preclude any widespread buy-out option. This non-structural option is more applicable to localized, deep flooding of a small number of contiguous residences to be affordable. However, stringent controls on new construction which require on-site detention for new developments over five-acres and require the elevation of structures constructed within the flood plain are recommended for this watershed and are discussed in more detail in Section 5.0. Although these requirements do not address the current flooding problems, they will lessen the potential for the flooding problems to increase in the future.

After considering non-structural flood mitigation methods for the North Main Drain watershed, structural projects were identified which would reduce the existing flood plain and mitigate localized flooding in some areas. Channel improvement projects are not feasible in the short-term due to severe right-of-way constraints in the heavily developed portions of the watershed. Alternative projects which produced the largest positive impact and which are still economically and technically feasible in terms of short-term phasing are:

- **Interconnect to the Resaca de la Guerra watershed**: The diversion of up to 260 cfs of flood water to the Resaca de la Guerra by a gravity system downstream of Hwy. 48. The diversion would occur through an interconnected channel 2,500 feet in length with a six-foot bottom width and 3:1 side slopes. The channel would be graded to flow from the North Main Drain to the Resaca de la Guerra; however, if storm patterns produced heavier flow in the Resaca and the flow in the North Main Drain was low, the very slight grade would allow flows from the Resaca to the North Main Drain. This interconnect does not adversely affect Resaca de la Guerra under 100-year rainfall conditions uniformly applied across the planning area, based on an analysis performed on the Resaca de la Guerra system and described in Section 4.4.

- **Reduction in flow entering North Main Drain from Town Resaca watershed**: The reduction of flow entering North Main Drain from 220 cfs to 40 cfs would be accomplished by the construction of two additional pumps at the Impala Pump Station. Each pump would be a 40,000 gpm pump. Flow from the North Main Drain would flow to the pump station during severe rainfall events. The reduction in flow in North Main Drain decreases the water surface elevation by 1.0 foot upstream of the Airport and 0.30 foot in a critical neighborhood downstream of Hwy. 48 in North Main Drain.

- **Regional Detention Facility**: A 430 acre-feet detention basin in the same location as the Resaca de la Guerra interconnect channel (downstream of Hwy. 48) would be constructed on 40 acres of undeveloped property. The basin would be approximately 11 feet deep with a bottom area of 35 acres. The reservoir would be surrounded by a 30-foot wide maintenance easement. The detention basin would receive flows from the ditch under high-flow conditions via a side-flow weir structure. The basin would then detain the storm waters until the water surface elevation in the channel fell below the elevation of the low-level outfall pipe in the basin. A pumped discharge system may be necessary depending upon the actual location of the reservoir and the elevation of the water table.

- **Bridge Replacement and Detention**: Three bridges will be replaced due to the reduced conveyance through the structures as compared to upstream and downstream channel capacities. The bridges are located at International Blvd., 14th Street and the Southern Pacific Railroad bridge upstream of 14th Street. While headlosses under existing conditions are not large at these three locations, the structures are inundated by the existing 100-year flood. With the implementation of the interconnect, pump station expansion, and regional detention pond, the replacement of these bridges lowers the 100-year profile another six inches.

Exhibit 4-1 shows the locations of the bridge replacements and the pump station as well as the approximate locations of the detention facility and diversion channel. The detention reservoir and the diversion ditch could be implemented separately or combined into a single project. This set of projects is proposed as Phase 1 of the Flood Protection Plan for the North Main Drain. Upon implementation of these projects, the flood plain along the North Main Drain would be reduced by approximately 11 percent. Table 4-1 lists the 5-, 10-, and 100-year water surface elevations for the North Main Drain with the diversion, new pumps, three new bridges and detention pond in place. This initial Phase 1 Plan will provide a 10- to 25-year level of protection along most of the channel downstream of Southmost Road (NM30) and a 100-year level of protection from Southmost Road (NM 30) to Renfro Street (NM18). Upstream of Rockwell Street the improvements have little or no impact.

TABLE 4-1
100-YEAR WATER SURFACE ELEVATIONS
IMPLEMENTATION OF PHASE 1 PROJECTS
NORTH MAIN DRAIN

Station	Location	100-Year Water Surface Elevations (feet)	
		Existing	Phase 1
1000	South Port Rd.	9.24	9.38
12688	Oklahoma	12.17	11.89
15688	Browne	13.06	12.53
20458	Boca Chica	14.49	13.66
25688	FM 511	16.90	15.87
26088	Utah Ave.	17.14	16.10
41387	Minnesota Ave.	21.62	20.59
45894	Apollo Drive	22.48	21.46
46888	Southmost Road	22.89	21.71
48169	Ramada Drive	23.36	22.03
48915	La Posada Road	23.52	22.15
49727	Esperanza Road	23.74	22.25
51410	Manzano Road	24.02	22.42
55640	Southmost Road	24.48	22.71
58645	30th Street	24.96	22.91

TABLE 4-1
100-YEAR WATER SURFACE ELEVATIONS
IMPLEMENTATION OF PHASE 1 PROJECTS
NORTH MAIN DRAIN
(continued)

Station	Location	100-Year Water Surface Elevations (feet)	
		Existing	Phase 1
63243	International Blvd.	25.17	23.28
63803	14th Street	25.34	23.61
64853	Southern Pacific RR	25.60	23.77
65541	Boca Chica	25.67	24.14
67494	Old Port Isabel Road	25.82	24.72
68626	Renfro Street	26.37	25.75
69646	Rockwell	26.70	26.50
71240	Paredes Line Road	29.89	29.90
72185	Mackintosh	30.58	30.64
72382	Southern Pacific RR	30.71	30.76
72699	Access Road	31.04	31.05
74143	US 77/83	30.96	30.97
76393	Above 7 x 7 Box	31.99	32.01

Phase 2 for North Main Drain will involve long-term projects which would provide further flooding protection for the existing and future developments along the channel. The Phase 2 plan for the North Main Drain watershed involves the construction of two additional regional detention facilities to alleviate flood conditions upstream of Rockwell and downstream of Southmost Road.

- A regional detention facility is recommended for construction upstream of the Price Road 7 foot by 7 foot box culverts in order to relieve out-of-bank flooding along the channel. The maximum reservoir which can be implemented on open land in the proximity of Price Road and Coria Street is approximately 160 acre-feet on 18 acres. The reservoir would be an in-line reservoir which would include the North Main Drain channel and would be constructed 10 to 12 feet deep. A pump would be necessary to drain the bottom portion of the reservoir below the flowline of the existing channel and also to control groundwater seepage into the reservoir. All excavated material would be removed from the site.

- A third regional facility is proposed to be located in the lower reaches of the watershed in the general proximity of the intersection of North Main Drain with Southmost or Minnesota Avenue, upstream of the airport. The reservoir would hold approximately 650 acre-feet of runoff and would be constructed approximately 10 feet deep an a 100 acre site. This acreage would allow the disposal of excavated material on-site. The reservoir would alleviate a large portion of the out-of-bank flooding along the channel near the airport and further downstream. The availability of open land in this area would also allow for the expansion of the reservoir if more funding becomes available.

Due to severe limitations on future right-of-way required for channel widening and the relative mild channel slopes, an Ultimate Plan for providing 100-year frequency flood protection along the entire length of the North Main Drain will be very costly. The Scope of Services for the development of the Flood Protection Plan was designed to provide an implementable Plan; therefore, the elements of an ultimate plan were conceptualized only and were not developed into detailed projects for the proposed Capital Improvement Plan.

Generally, some relief from isolated flooding may be obtained in the long-term by replacing most of the road crossings on North Main Drain with higher long-span bridges which create as little obstruction to flow as possible. In addition, all utility crossings which are currently down in the channel should be raised to minimize the obstruction to flow. The airport is another area that should be considered for long-term improvement. The addition of Regional Detention Facility #3 should provide more outfall capacity in the channel at the airport. Obstructions to the North Main Channel, where it crosses the airport property, should be removed or the Channel rerouted outside of the property in order to improve conveyance.

Improvements to the North Main Drain channel itself such as the removal of obstructions (bridges and utility crossings) and channel deepening and concrete lining may provide some relief to areas of out-of-bank flooding; however, these improvements will also increase the flowrate in the channel and may aggravate downstream conditions unless the channel is improved all the way to its outfall, which is not recommended under current funding limitations. The mitigation of 100-year frequency flooding on North Main Drain could approach $40,000,000 in costs and may not provide equivalent benefits. An analysis of conditions in the future at the time such projects are proposed would be required to determine their feasibility and design. Options which should be included in an Ultimate Plan for North Main Drain are:

- Comprehensive Bridge and Utility Crossing Replacements

- Channel Lining

- Channel Relocation at the Airport

- Pump Station in the middle or upper watershed which diverts flows to the Rio Grande

4.2 Cameron County Drainage District No. 1 Ditch

As in the North Main Drain watershed, a wide, shallow flood plain occurs along most of the CCDD No.1 Ditch during severe storm events, encompassing approximately 5,400 acres within the 100-year flood plain. The watershed is characterized by scattered developments and large areas of undeveloped property. Non-structural options such as a widespread buy-out of structures within the 100-year flood plain did not appear to be realistic due to the extensiveness of the flood plain and the economical viability of much simpler structural options such as channel improvements and regional detention. Controls on new developments within the flood plain and within the watershed do appear to have an economical benefit due to the large percentage of undeveloped areas in the watershed. Several alternatives for mitigation of the 100-year flood plain were developed for the CCDD No. 1 Ditch:

- **Channel Improvements and Bridge Replacements**: The first alternative developed to provide 100-year flood protection for the CCDD No. 1 Ditch involves channel improvements along portions of the ditch from Station 80+31 to Station 503+80. Channel improvements are an economical alternative in this area because of the availability of right-of-way along the channel. An earthen channel with 3:1 side slopes and varying bottom widths was developed as follows:

From Station	To Station	Bottom Width (ft)	Top Width (ft)
80+31	229+30	35	125
229+30	447+75	30	100
492+50	503+80	15	70

  Several road crossings are creating large head losses because of undersized culverts or bridges. The abutments for these crossings will encroach into the proposed channel. In order to make these crossings hydraulically efficient with the new channel, new bridges are needed at Old Port Isabel Road, the Union Pacific Railroad and U.S. 77/83. Additional bridges which are in upstream reaches of the watershed where the existing out-of-bank floodplain does not impact any existing developments could be replaced with the cooperation of proposed future developments. The implementation of this alternative reduces the 100-year flood plain be approximately 42 percent.

- **Detention Basin, Channel Improvements and Bridge Replacement**: An alternative to channel improvements on CCDD No. 1 Ditch is the implementation of a regional detention facility upstream of the Brownsville Country Club. The site is undeveloped and would involve a 100-acre reservoir which could store 1000 acre-feet of runoff. The bridge at US 77/83 would be replaced and two additional 9' x 10' box culverts would be constructed under

Old Port Isabel in order to decrease headlosses at these structures. This alternative reduces the 100-year flood plain be approximately 37 percent.

- Construction began in 1996 on the Paseo de la Resaca development downstream of Paredes Line Road. The development includes excavation of a looped channel which will hold a constant water surface elevation at 16 feet. A weir will connect the channel to the CCDD No. 1 Ditch at each end. Assuming that this channel will be designed to detain flood flows, an additional 720 acre-feet of storage was included in each Alternative at the location of the new development.

Table 4-2 compares the resulting 100-year water surface elevations for each alternative to the existing water surface elevation. Alternative 1 includes the channel improvement option and Alternative 2 includes the detention option as described above.

TABLE 4-2
100-YEAR WATER SURFACE ELEVATIONS
IMPLEMENTATION OF ALTERNATIVE 1 AND ALTERNATIVE 2 PROJECTS
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Station	Location	100-Year Water Surface Elevations (feet)		
		Existing	Alternative 1	Alternative 2
7979	Highway 48	9.27	9.58	9.15
9993	Mopac RR	11.70	11.38	11.67
10923	FM 511	12.42	12.04	12.32
11648	Harbor Road	13.29	13.17	13.10
16380	FM 802	15.20	14.52	14.90
18207	Highway 48	15.57	15.25	15.24
20546	Railroad	17.39	16.67	16.97
22880	FM 802	17.55	16.94	17.12
23887	Central Ave.	17.57	17.03	17.18
27984	Robindale Ave.	17.95	17.40	17.59
29700	Flume	18.32	17.84	17.83
29989	Old Port Isabel	18.45	17.94	17.91
32540	Dana Road	19.56	18.27	18.74

TABLE 4-2
100-YEAR WATER SURFACE ELEVATIONS
IMPLEMENTATION OF ALTERNATIVE 1 AND ALTERNATIVE 2 PROJECTS
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH
(continued)

Station	Location	100-Year Water Surface Elevations (feet)		
		Existing	Alternative 1	Alternative 2
39327	Paredes Line Road	21.46	19.56	19.62
40496	Southern Pacific RR	21.48	19.96	19.67
48955	US 77/83	22.19	20.50	21.25
51493	Union Pacific RR	23.36	20.78	23.15
57650	FM 3248	24.06	21.68	23.98

4.3 Town Resaca

The Town Resaca drains one of the most heavily urbanized sections of the City of Brownsville. The series of pools which make up the majority of the resaca system provide one of the most attractive amenities to the City. Although the resaca pools hydraulically have enough capacity to hold the runoff from the 100-year design storm event, historical flooding in localized areas in the watershed shows the results of allowing construction in low-lying areas and the inadequacy of the secondary drainage system (inlets and storm sewers) serving the older urbanized areas. These localized flooding problems must be solved through a more detailed analysis of the particular secondary system in question and are not addressed in this report. More information on many of these areas may be obtained in the 1987 Master Drainage Plan report.

With respect to the City's management of the Town Resaca system as an efficient flood control facility, the series of level pools in the resaca system are effectively detaining floodwater which might otherwise flow into the North Main Drain and aggravate flooding conditions to the east of the City. The City's current practice of lowering the weir structures in the resaca prior to an anticipated storm event may be providing extra capacity in the system; however, caution should be used in allowing more floodwater downstream if high tidal conditions or high water surface elevations in North Main Drain preclude the early flow releases from reaching the Ship Channel outfall before additional runoff reaches the North Main Drain channel system.

Dredging of the resacas to lower the water surface permanently and provide more storage capacity in the resaca pools would possibly allow secondary sewer systems to outfall more efficiently and could eliminate the need for manual lowering and raising of the weir structures; however, the lowering of the permanent pool elevation may have an adverse impact on the perceived amenity value placed on the resaca pools by adjacent homeowners. Dredging of the channel without lowering the weirs (and lowering the resulting permanent pool elevation) will increase the depth of water in the resacas and may increase the water quality in the pools by removing sediment, improving fish habitat, lowering BOD levels, retarding hyacinth growth, and other aesthetic considerations; however, this type of dredging has little or no effect on the system in terms of flood control capacity. The issues associated with the potential dredging of the Town Resaca and Resaca de la Guerra pools are discussed more fully in Section 4.4.

Two short-term flood control projects were identified in the Town Resaca watershed which are economically viable to relieve flooding in adjacent areas:

- **Ebony Lake Outfall**: The existing 36-inch outfall pipe serving the Ebony Lake system should be replaced with three (3) - 8 foot by 5 foot box culverts in order to reduce the headlosses associated with the outfall of the Lake into the Town Resaca system. This increased outfall will allow the 100-year storm event to be handled by the lake and resaca system with less than a one-foot rise in the lake elevations during the event. The outfall box culverts may be reduced in size if a detailed study of the lake and the surrounding topography shows that a larger rise in the lake surface during intense storm events would not cause flooding problems. The Town Resaca system currently has enough freeboard capacity to handle the increased flows from the lake with the three box culverts in place.

- **Expansion of the Impala Pump Station**: Two additional 40,000 gpm pumps are proposed to be added to the Impala Pump Station at the downstream end of the Town Resaca system. These pumps are proposed in order to decrease the contribution of the flows from the Town Resaca outfall to the North Main Drain system during the design storm events. Flows can also enter the Impala Ditch from North Main Drain and be diverted by the Impala Pump Station to the Rio Grande when flows from the Town Resaca recede.

4.4 Resaca de la Guerra

The Resaca de la Guerra functions much like the Town Resaca in that it is comprised of a series of detention pools which contain storm runoff before flows can reach the North Main Drain. The resaca pools serve as amenities to numerous residential neighborhoods, making the resaca system another of Brownsville's attractions for new development. A 36-inch outfall pipe restricts the total flow that can outfall from the Resaca, as do the series of level pool weir structures placed throughout the system. Like the Town Resaca, the Resaca de la Guerra has sufficient hydraulic capacity to detain runoff from the 100-year design storm event; however, pockets of localized flooding problems in the watershed are apparently caused by the inadequate storm sewer system. The only out-of-bank flooding predicted by the models of the system is at the Highway 1847 crossing. This inundation of the low roadway crossing is shallow and occurs only during the most severe flood events, making this a nuisance flooding problem as compared to a life-threatening or damaging problem. Similar to the Town Resaca, the current practice of lowering the weir structures in anticipation of a major storm event may provide some extra flood storage capacity in the pools.

An analysis of recorded sediment levels was made for the Resaca de la Guerra system using cross sectional information surveyed by the City in 1996 at ten locations and information reported in the 1976 Urban Waterways Study. Exhibit 4-2 shows selected cross sections with flowlines estimated in 1976 compared to the 1996 field data. Since the survey performed in 1996 was developed based on estimated locations of the cross sections as determined from published maps in the Urban Waterways Study, the location of the cross section data is approximate and may not match exactly; however, the exhibit does show that while sedimentation has occurred between the original resaca flowline and 1976, very little sedimentation could be measured for the period from 1976 to 1996. Of course, the actual sedimentation in isolated pools may be greater or less than the selected cross sections shown on Exhibit 4-2.

Dredging of the entire system to 1976 reported elevations was modeled for the Resaca de la Guerra to determine the impact of dredging of the backwater areas behind the level control weirs in both resacas (as has been proposed by the City due to current water quality concerns). The potential hydraulic effect of this improvement was modeled for the ten-year and 100-year flood events by deepening the cross sections at all the natural channel sections in the model to approximate the removal of all sediment above the original cross section flowline indicated in the 1976 Urban Waterways Study. The weirs were left as existing conditions in the models.

Comparisons of the maximum water levels simulated for the 10-year and 100-year events with and without dredging indicated reduced peak water surface elevations along some reaches and slightly increased peak levels along other reaches. This result was anticipated due to the slow movement of water through the resaca drainage system. Therefore, if dredging is undertaken to improve water quality in the resacas by increasing the depth of water in the pools while maintaining the current pool surface elevations, the flood protection function of the resaca will not be diminished; however, the dredging will not increase the flood control capacity of the resacas unless the weir elevations and associated pool water surface elevations are lowered as well.

The lowering of the permanent pool elevation may have the same benefits discussed for the Town Resaca system: increased storage capacity, improved outfall conditions for some storm sewer systems and elimination of the need to manually lower the weirs in anticipation of major events. Deepening of the resaca pools will not impact the flood control capacity but may improve the water quality and increase the amenity value by removing sediment, lowering BOD levels, increasing fish populations, retarding hyacinth growth, and improving other associated water amenities.

Only one short-term flood mitigation project is recommended for the Resaca de la Guerra watershed:

- **Interconnect between North Main Drain and Resaca de la Guerra**: A proposal to partially relieve the North Main Drain by allowing up to 260 cfs of flood water to enter Resaca de la Guerra by a gravity system downstream of Hwy. 48 during storm events ("peak shaving") was evaluated by inputting a hydrograph to the Resaca de la Guerra drainage system during the 100-year event. Table 4-3 shows the maximum water surface levels in the resaca for the 100-year storm event under existing and proposed conditions (including the inflow from the North Main Drain). As expected, water surface levels upstream of the intake location are essentially unchanged because the additional inflow does not impact the system above the first upstream water control weir. Downstream of the intake location, increased water levels would still be within banks at all sections of the lower resaca, indicating that the lower resaca has sufficient excess capacity to provide flood control relief for the North Main Drain without any adverse effect on the property adjacent to the resaca.

TABLE 4-3
EXISTING AND PROPOSED CONDITIONS
100-YEAR MAXIMUM WATER SURFACE LEVELS
RESACA DE LA GUERRA

Conduit Name	Location	Existing Max. Elev.	Proposed Max. Elev.	Change in Max. Elev.
RG24BOXWEIR	Outfall Structure	21.99	22.75	0.76
RG23	Morning Side Road	22.22	22.88	0.66
RG22	Morning Side Drive	22.69	23.54	0.85
RG21	Lake Acacia	22.77	23.65	0.88
RG20	Billy Mitchell	22.97	23.84	0.87
RG19	Boca Chica	23.31	23.89	0.58
RG18	14th Street	25.13	25.11	-0.02
RG17	Price Road	25.38	25.35	-0.03
RG16	Railroad	25.39	25.36	-0.03
RG15	Port Isabel Road	25.56	25.53	-0.03
RG14	Control Weir	27.37	27.37	0.00
RG13	Palo Verde Road	27.74	27.72	-0.02
HWY1847	Hwy. 1847	27.97	27.95	-0.02
RG12	Control Weir	29.58	29.55	-0.03
RG11	Railroad	29.59	29.59	0.00
RG10	Hidden Valley	30.29	30.29	0.00
RG9	Alice	30.56	30.60	0.04
RG8	Control Weir	30.56	30.53	-0.03
RG7	U.S. 83/77	30.50	30.62	0.12
RG6	Central Blvd.	30.15	30.63	0.48
RG4	Country Club	30.63	30.63	0.00
RG3	Railroad	30.92	30.92	0.00
RG2	Mercedes Road	30.98	30.99	0.01

4.5 Recommended Flood Protection Plan

The flood mitigation projects identified for each watershed are combined to form the recommended Plan for the City of Brownsville. The projects are listed in Tables 4-4 and 4-5, which shows the project name, project description, and project cost. The costs presented in Tables 4-4 and 4-5 are estimated construction costs in 1996 dollars based on the quantities shown as developed from available data. Detailed field surveying, geotechnical analysis of soil conditions, and environmental investigations of the subject site will need to be performed before more precise cost estimates can be developed. Fees associated with engineering, including surveying and geotechnical analyses, are included in the costs shown on Tables 4-4 and 4-5. Costs associated with environmental investigations and utility adjustments are not included in these estimates.

The costs presented are estimated to allow for a general comparison of the magnitude of the proposed projects. The costs do not include right-of-way land costs for improvement projects along the main channels. Estimated land costs for the regional detention facilities and diversion channel are shown based on data supplied by the City. The excavation costs shown for the construction of the detention facilities assume excavation is performed using scrapers and the excavated material is deposited on a storage site immediately adjacent to the detention reservoir. Land has been included in the total for each reservoir site to allow for the on-site deposition of excavated material. The only exception is the North Main Drain regional detention facility located near Price Road. This facility will utilize all of the available on-site property, so costs have been added for the disposal of the excavated material elsewhere. Legal fees involved with the acquisition of property are not included.

TABLE 4-4
ESTIMATED CONSTRUCTION COSTS FOR FLOOD PROTECTION PLAN PROJECTS

Project Name	Description	Item Cost	Project Cost
1. Impala Pump Station	Add two 40,000 g.p.m. pumps Engineering/Contingencies (25%)	$250,000 $62,500	$312,500
2. North Main Drain - #1 Regional Detention Reservoir downstream of Hwy. 48	Land - 60 ac. @ $12,000 /ac Excavation - 730,000 cu yd @ $1.50/cu yd. Total Est. Construction Cost Engineering/Contingencies (25%)	$720,000 $1,095,000 $1,815,000 $453,750	$2,268,750
3. North Main Drain - Three New Bridges (includes removal of existing structures)	International- 74ft x 65ft x $70/sf 14th Street - 74ft x 65ft x $70/sf Railroad (upstream of 14th) Total Est. Construction Cost Engineering/Contingencies (25%)	$337,000 $337,000 $82,000 $756,000 $189,000	$945,000
4. North Main Drain Interconnect Channel to Resaca de la Guerra	[Length = 2500 feet, 3:1 Side Slopes, Depth = 6 feet, Bottom Width = 6 feet] Structure - Resaca de la Guerra Land = 4 acres @ $12,000/ac Excavation = 13,000 cu yd @ $4.00/cu yd Total Est. Construction Cost Engineering/Contingencies (25%)	 $40,000 $48,000 $52,000 $140,000 $35,000	$175,000
5. North Main Drain - #2 Regional Detention Reservoir upstream of Price Road Culvert	Land - 18 ac. @ $12,000 /ac Excavation/Disposal - 260,000 cu yd @ $5.00/cu yd. Pump Total Est. Construction Cost Engineering/Contingencies (25%)	$216,000 $1,300,000 $5,000 $1,521,000 $380,250	$1,901,250

TABLE 4-4
ESTIMATED CONSTRUCTION COSTS
FOR FLOOD PROTECTION PLAN PROJECTS
(continued)

Project Name	Description	Item Cost	Project Cost
6. North Main Drain - #3 Regional Detention Reservoir upstream of Airport	Land - 100 ac. @ $6,000 /ac Excavation - 1,049,000 cu yd @ $1.50/cu yd. Total Est. Construction Cost Engineering/Contingencies (25%)	$600,000 $1,573,500 $2,173,500 $543,375	$2,716,875
7. Town Resaca - Ebony Lake Outfall Improvements	[Length - 830 feet, three 8' x 5' Box Culverts] 3 Culverts = 830 ft @ $1,400/ft Engineering/Contingencies (25%) (Assumes open cut construction; Road replacement by others; No right of way costs included)	 $1,162,000 $290,000	$1,452,500

TABLE 4-5
ESTIMATED CONSTRUCTION COSTS
FOR FLOOD PROTECTION PLAN PROJECTS
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

Project Name	Description	Item Cost	Project Cost
1. CCDD No. 1 Ditch - Alternative No. 1 Channel Improvements and Bridge Replacements	Channel Excavation = 559,810 cu yd @ $4.00/cu yd	$2,239,240	
	Disposal of material nearby = 559,810 cu yd @ $1.50/cu yd	$839,715	
	Old Port Isabel - 43ft x 80ft @ $70.00 per sq ft	$241,000	
	U.S. 77/83 - 295ft x 65 ft x $70	$1,342,000	
	Union Pacific Railroad	$150,000	
	Total est. Construction Cost	$4,812,000	
	Engineering/Contingencies (25%)	$1,203,000	
			$6,015,000
2. CCDD No. 1 Ditch - Alternative No. 2 Regional Detention Reservoir and Bridge Replacement	Land - 150 ac. @ $2,000 /ac	$300,000	
	Excavation of Reservoir = 1,614,000 cu yd @ $1.50/cu yd.	$2,421,000	
	Upgrade Old Port Isabel road = (Add 2 9'x10' Box Culverts)	$200,000	
	U.S. 77/83 = 14,750 sq ft @ $70.00/sq ft	$1,032,500	
	Total Est. Construction Cost	$3,953,500	
	Engineering/Contingencies (25%)	$988,375	
			$4,941,875

4.6 Implementation Plan

As stated throughout this report, the primary goal of the Plan project is to develop an implementable drainage plan which will reduce existing flooding within the City of Brownsville and allow for the future anticipated growth of Brownsville. The plan identified in Section 4.5 will solve most of the flooding problems along the primary drainage channels in the City and its ETJ within a reasonable Capital Improvement Program (CIP). Current funding mechanisms within the City of Brownsville can provide approximately $6.2 million in bond funds. Of this amount, approximately $4.3 million has been designated for flood control and drainage, with the remainder to be used for resaca beautification and aesthetic improvements. In addition, another $5.7 million is anticipated to be available within the next ten years for flood control and drainage improvements within the City. In order to construct the CIP within a ten year time frame, the implementation schedule was divided into two parts: a five-year CIP and a ten-year CIP.

4.6.1 Five-Year Capital Improvement Program

The five-year CIP was developed to implement the projects from the Plan with the highest priority for flood protection within a $4.3 million budget. Projects identified as part of the Plan for the CCDD No. 1 Ditch would be funded by the Cameron County Drainage District No. 1 and have been separated from the City's CIP. Table 4-6 lists the projects and associated costs for the City's five-year CIP in order of priority for construction. Table 4-7 lists the recommended alternatives for CCDD No. 1 Ditch.

TABLE 4-6
CITY OF BROWNSVILLE FIVE-YEAR
CAPITAL IMPROVEMENT PLAN FOR FLOOD PROTECTION

Priority of Construction	Project	Estimated Project Cost
1	1. Expansion of the Impala Pump Station	$ 313,000
2	4. North Main Drain Interconnect Channel	$ 175,000
3	2. North Main Drain Regional Detention #1	$ 2,269,000
4	7. Ebony Lake Outfall	$ 1,453,000
Total CIP Cost (to the nearest thousand)		**$ 4,210,000**

TABLE 4-7
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH
ALTERNATIVE PROJECTS FOR FLOOD PROTECTION

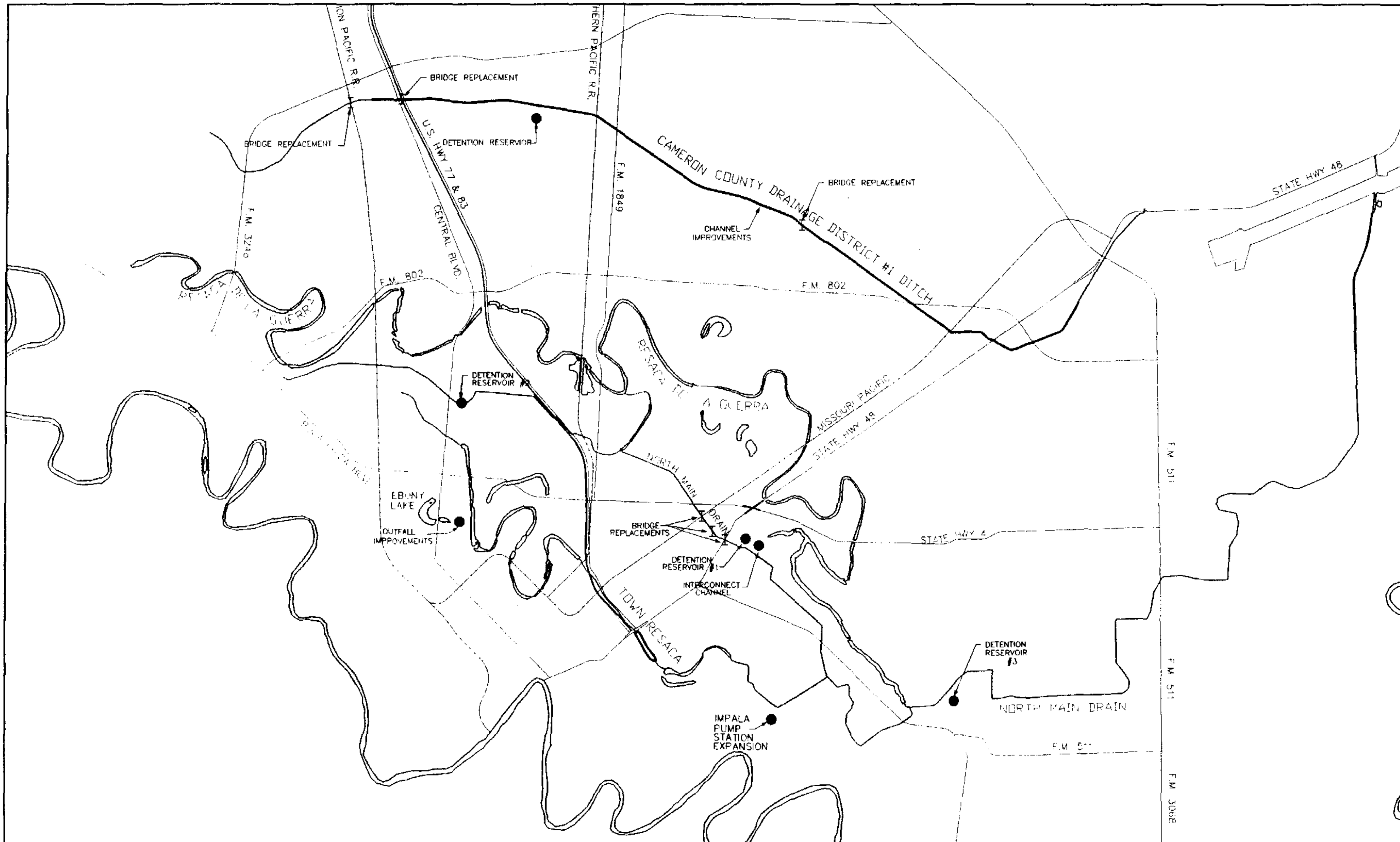
Project	Estimate Project Cost
Alternative 1: Channel Improvements Station 8,083 to 50,380 And Three Bridge Improvements	$ 6,014,000
Alternative 2: Regional Detention Reservoir and Two Bridge Improvements	$ 4,942,000

4.6.2 Ten-Year Capital Improvement Program

The ten-year CIP was developed to implement the remainder of the projects identified in the Plan within the remaining $5.8 million budget. Table 4-8 lists the projects and associated costs for the City's ten-year CIP in order of priority of construction. Expansion of the North Main Drain Regional Detention #3 facility would be possible if more funding became available.

TABLE 4-8
CITY OF BROWNSVILLE TEN-YEAR
CAPITAL IMPROVEMENT PLAN FOR FLOOD PROTECTION

Priority of Construction	Project	Estimated Project Cost
1	3. North Main Drain Bridge Replacements	$ 945,000
2	5. North Main Drain Regional Detention #2	$ 1,901,000
3	6. North Main Drain Regional Detention #3	$ 2,717,000
Total CIP Cost (to the nearest thousand)		**$ 5,563,000**



5-YEAR CIP	10-YEAR CIP	CAMERON COUNTY CIP
● FLOOD PROTECTION MODIFICATIONS	● FLOOD PROTECTION MODIFICATIONS	● FLOOD PROTECTION MODIFICATIONS
I BRIDGE REPLACEMENTS	I BRIDGE REPLACEMENTS	I BRIDGE REPLACEMENTS
		— CHANNEL IMPROVEMENTS

DRAWN	D.V.
DESIGN	C.G.
CHECKED	C.W.
PM	M.J.
SCALE	1" = 2100'
DATE	NOVEMBER 1996

RUST LICHLITER/JAMESON
Environment & Infrastructure
Consulting Engineers, Scientists and Planners
2929 Briarpark Drive, Suite 600, Houston, Texas 77042-3703

CITY OF BROWNSVILLE, TEXAS

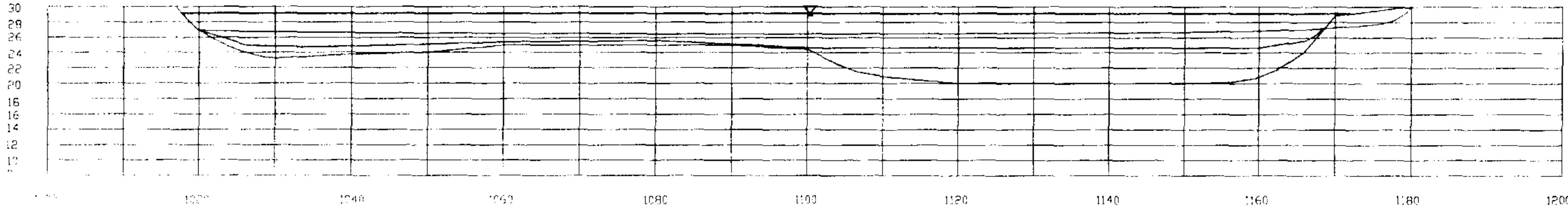
DRAINAGE STUDY

FLOOD PROTECTION PLAN
PROPOSED PROJECTS

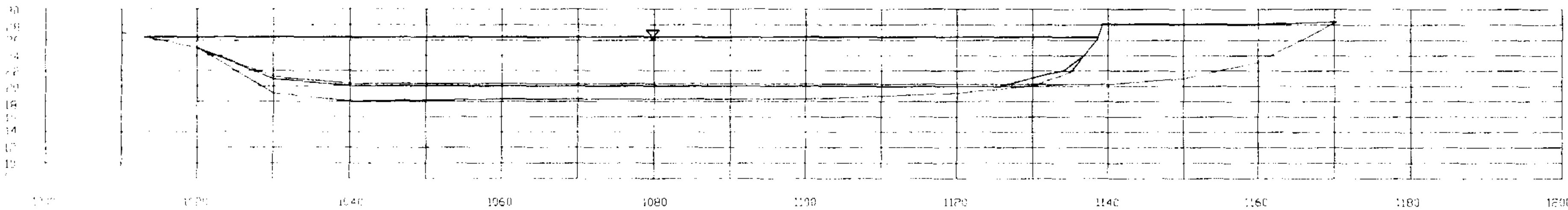
EXHIBIT NO. 4-1

PROJECT NO. 68589

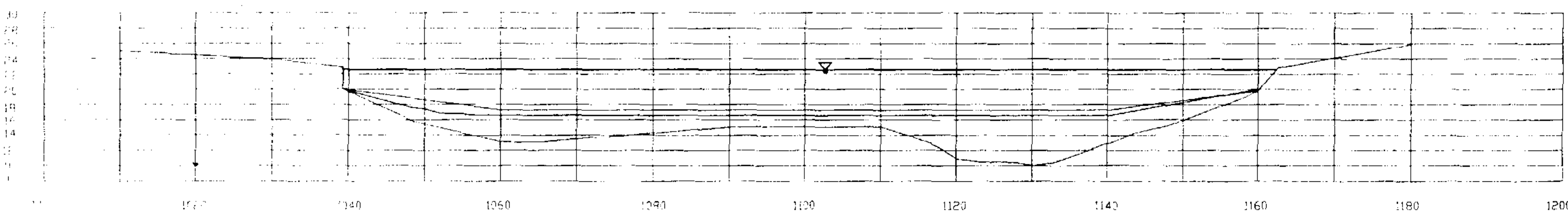
UPSTREAM RESACA DE LA GUERRA



MID-STREAM RESACA DE LA GUERRA



DOWNSTREAM RESACA DE LA GUERRA



LEGEND

- ORIGINAL FLOWLINE
- 1976 SURVEYED FLOWLINE
- 1996 SURVEYED FLOWLINE
- WATER SURFACE ELEVATION

DRAWN	D.V.
DESIGN	C.W.
CHECKED	C.W.
PM	M.J.
SCALE	N.T.S.
DATE	NOVEMBER 1996

RUST LICHLITER/JAMESON

Environment & Infrastructure
Consulting Engineers, Scientists and Planners
2929 Briarpark Drive, Suite 600, Houston, Texas 77042-3703

CITY OF BROWNSVILLE, TEXAS

DRAINAGE STUDY

RESACA DE LA GUERRA
1976,1987, AND 1995 SEDIMENTATION

EXHIBIT NO. 4-2

PROJECT NO. 68589

5.0 FLOOD PLANNING CRITERIA AND FINANCING

5.1 Review of Current Criteria

As part of the Scope of Services for the Plan project, Rust Lichliter/Jameson was asked to review the City's and Cameron County's current flood planning and design criteria and make recommendations regarding potential changes in the criteria. Accordingly, the Engineer obtained copies of the following documents and reviewed them with respect to drainage design and flood plain management:

- City Zoning Ordinance as Amended Through August 20, 1991, City of Brownsville, Texas.
- Subdivision Ordinance as Amended Through December 16, 1992, City of Brownsville, Texas.
- City of Brownsville Manual on Drainage Design, City Engineering Department, undated.
- Article XI of Chapter 26 of the City Code, City of Brownsville, Texas.
- Building Regulations as Required by the National Flood Insurance Act, Title 42, the County of Cameron, August 23, 1994.

Summaries of the current drainage policies and ordinances adopted by the City and the County are given in Sections 5.1.1 and 5.1.2, respectively.

5.1.1 City of Brownsville Flood Planning Criteria

The City of Brownsville's Subdivision Ordinance contains no specific regulations regarding planning or construction in flood prone areas. The Ordinance does reference and adopt Article XI of Chapter 26 of the City Code when addressing building standards in "flood areas". This article describes building standards in "flood areas" as required by participation in the National Flood Insurance Program. "Flood Areas" are defined as "...any property shown on the latest federal Flood Insurance Rate Map (FIRM) as an A, AO, AH, A1-A30, or A99 zone." Generally, Article XI requires City approval and a special permit prior to building in any "flood areas".

Article XI, Floodplain Management specifically addresses construction in flood hazard areas by enforcing the requirements of the National flood Insurance Act. In additions to criteria for building techniques required for construction in a flood hazard area, the article requires new construction or substantial improvement of any residential structure in a designated flood hazard area to have the lowest finished floor elevated to or above the base-flood elevation. Non-residential construction in flood hazard areas must conform to the same requirement or be designed so that below the base-flood elevation the structure is watertight and capable of resisting hydrostatic and hydrodynamic loads and effects of buoyancy.

The City of Brownsville's Manual on Drainage Design has more specific technical requirements for the design of drainage systems within the City limits and the ETJ. Commercial developments less than 0.5 acres are allowed to drain through a green belt on the property. Detention is required for new commercial developments greater that 0.5 acres with the frequency of the basin design dependent on the size of the development. Residential subdivisions must size internal storm sewers based on a five-year return frequency. Small ditches must be sized to contain runoff from a 50-year design storm, while large ditches must be sized to contain runoff from a 100-year design storm. The Rational formula is recommended for design, and specific criteria for C values, time of concentration, velocities, drainage area calculations, and storm sewer pipe sizing are provided. Required easements for access to detention basins, drainage control and maintenance are given, as well as maximum side slope requirements.

5.1.2 Cameron County Flood Planning Criteria

Cameron County has published the Building Regulations as Required by the National Flood Insurance Act Title 42 manual in order to regulate building practices in flood prone areas in unincorporated portions of the County. Generally, the regulations require a development permit for "any structure or land that is being located , altered, or changes use."

The regulations state that the lowest finished floor of any structure constructed in a flood hazard area must be elevated twelve inches above the Base Flood Elevation (BFE) or 24 inches above the highest level of Natural Ground Elevation, whichever is higher. In areas of minimal flood hazard, the lowest finished floor must be at least 18 inches above natural grade. The regulations also set criteria for fill compaction, elevated foundations, structural components, parking and basement design, and manufactured homes located within a flood hazard area. The regulations define a "Coastal High Hazard" area and identify special criteria for construction of structures in these areas.

5.2 Recommendations for New Flood Planning Criteria

The existing drainage and flood plain management criteria published by the City of Brownsville and Cameron County is limited in scope and its ability to properly prevent future flood damages. Based on the review of the documentation provided, Rust Lichliter/Jameson developed proposed criteria changes which will allow the City to more adequately regulate development in flood hazard areas and to prevent existing flooding problems from worsening. These recommendations are categorized into two elements: criteria for new development or redevelopment, and changes in management policy.

5.2.1 Recommended Criteria for New Development

The following criteria have been developed using flood control methods which have been successfully adopted by other municipalities in Texas. They have been adapted and modified to conform to the specific needs of the City of Brownsville and, in some cases, the unique conditions present in a particular watershed. Each of these criteria is recommended for adoption by the City of Brownsville by ordinance or by inclusion in the City's Manual on Drainage Design.

1. The lowest finished floor (including basements) of any structure, being new construction or substantial improvements, within a flood prone area or flood hazard area must be elevated 12 inches above the BFE, the depth number specified in feet on the Community FIRM, or 24 inches above the highest level of Natural Ground Elevation, whichever is higher. Where no depth number is specified on the FIRM and the tract lies in a flood hazard area, the finish floor must be elevated 24 inches above the adjacent grade or the top of curb, whichever is higher. *[This height requirement is to prevent flooding due to input data errors or changing conditions which may effect the accuracy of the published BFE.]*

2. The lowest finished floor (including basements) of any structure not located in a flood prone area must be elevated 18 inches above the adjacent grade or the top of curb, whichever is higher. *[This height requirement is to prevent flooding due to changing flood plain boundaries and due to sheet flow during extreme events.]*

3. Major and arterial streets should be designed to contain the 10-year storm event within the public right-of-way and to have one lane passable during this event. Maximum ponding at the high-point on the lane should be no more than four inches. *[This requirement will allow safe passage of most vehicles and rapid passage of emergency vehicles during extreme events.]*

4. Lot grading must consider sheet flow from adjacent properties and provide a flow path for sheet flow away from proposed or existing structures and to a street or drainage system.

5. Unobstructed access easements of at least 15 feet in width which connect major drainage channels and all resacas with an adjacent street or alley must be provided every 1000 feet in new subdivisions. *[This requirement will allow the City to have guaranteed access to all major channels for maintenance and repairs.]*

6. Drainage easements of 30 feet in width are required along all major drainage channels and resacas. A 15 foot maintenance easement is required along both sides for dry channels greater than 30 feet in width and for all channels and resacas with permanent pools. A 15 foot maintenance easement is required along one side only for dry channels less than 30 feet in width.

7. To maintain the capacity of the existing drainage systems in the North Main Drain and CCDD No. 1 Ditch watersheds, all new development and redevelopment of commercial sites greater than 0.5 acres and residential sites greater than one acre in these watersheds shall reduce the 100-year frequency peak runoff flowrate outfalling from the fully developed site to the flowrate leaving the site prior to development or redevelopment. This reduction may be accomplished through ponding in depressed areas, linear detention along drainage

channels, detention ponds, innovative use of greenspace, detention in parking areas, etc. as approved by the City Engineering Department. The 0.5 acre minimum is based on tract ownership at the time this ordinance is effective and is not affected by subdivision of property or sale of parcels to individual owners. *[This requirement will prevent increases in flows in the main channels.]*

8. Peak flowrates from a site shall consider flows from upstream areas which enter or cross the site. Flows shall be calculated assuming full development (or full development with detention in the North Main Drain and CCDD No. Ditch 1 watersheds) of all areas contributing runoff at the site's outfall into the receiving storm sewer, street or channel.

9. New resacas or channels with a width equal to or greater than 30 feet shall convey the 100-year frequency runoff from full development of upstream areas with 12 inches of freeboard. For resacas and channels less than 30 feet in width, the required freeboard will be recommended by the developer's or owner's engineer and approved by the City Engineering Department with consideration for specific site conditions.

10. Right-of-way must be dedicated to the City of Brownsville, Cameron County Drainage District No. 1, or other applicable public entity, along North Main Drain and CCDD No. 1 Ditch. Existing developments will make acquisition of all of the recommended right-of-way impossible; however, new development and, if possible, redevelopment should be required to provide these widths (assumes 30-foot maintenance ROW on each side of channel):

    - North Main Drain (Existing Channel)
      Station 0 to 10,000: 185 feet centered on channel
      Station 10,000 to 25,000: 160 feet centered on channel
      Station 25,000 to 46,000: 140 feet centered on channel
      Station 46,000 to 77,000: 120 feet centered on channel

    - CCDD No. 1 Ditch (Ultimate Channel)
      Station 0 to 8,000: 160 feet centered on channel
      Station 8,000 to 22,000: 210 feet centered on channel
      Station 22,000 to 30,000: 180 feet centered on channel
      Station 30,000 to 61,000: 160 feet centered on channel

11. Regional Detention facilities serving two or more private developments and subregional detention facilities greater than five acres in surface area serving one or more private developments must be dedicated to the City of Brownsville, Cameron County, Cameron County Drainage District No. 1 or another applicable public entity. A 30 foot maintenance easement must be provided along each side of the detention facility and along the outfall path (including channels and storm sewer outfalls) to the receiving channel or storm sewer. Maintenance of smaller facilities within the City limit or ETJ will be the responsibility of the property owner or neighborhood association. A maintenance schedule which defines

responsibility and frequency of regular maintenance must be filed with the final plat and approved by the City Engineer.

5.2.2 Recommended Changes in Management Policy

The City of Brownsville currently is limited in its ability to proactively manage drainage and flood plains because a mechanism for reviewing subdivision plats for possible drainage problems which may be solved through detention is not in place. The following recommendations are developed to assist the City in defining its internal drainage policies, expanding its information database and providing educational resources to the citizens of the City of Brownsville.

1. The City must establish a clear chain of responsibility for drainage by placing the burden on the development community to manage runoff in order to prevent adverse impacts from new developments on adjacent or downstream property owners.

2. The City should require for all new developments and redevelopment a detailed drainage report describing (in text and tables) the drainage plan and calculations used to size drainage facilities. A site plan should be included which depicts the proposed drainage plan and identifies adjacent structure elevations, sheet flow paths, previously identified flood prone areas, flood plains, etc. This report should be submitted at the time of plat submittal and approval by the City Engineer should be a requirement for final plat approval.

3. The City should establish a goal of reducing or eliminating existing flooding problems, preventing new or expanded flooding and maintaining the natural amenities of its drainage system.

4. The resacas should be publicly promoted as visual and recreational amenities for the City; however, the public should be reminded that their main function is to provide drainage for the City.

5. The City should establish a detailed maintenance schedule for all major drainage systems in the City. The systems must be maintained so that their current flood-carrying capacities are not reduced. The maintenance schedule may be incorporated into the City's response to NPDES permit requirements. The maintenance schedule should be funded on an annual basis and should be distributed to citizens and neighborhood associations to increase public awareness of the activities of the City departments.

6. The City should initiate an aggressive educational campaign aimed at notifying citizens of the flood hazards which exist from being located near the Gulf of Mexico. Recent information on hurricanes and tropical storms should be presented. The availability of low cost Flood Insurance for persons located **in** and **out** of a designated flood hazard area should be promoted. Mortgage companies and real estate agents should be required to participate

in the public awareness campaign by developing brochures or fact sheets to distribute to potential homeowners when purchasing a house.

5.3 Financing Alternatives

The City of Brownsville currently funds major drainage projects through the use of bonds backed by property taxes. Several other types of funding mechanisms have been employed by municipalities in Texas to generate revenues for storm water management, including property taxes, sales tax, state revolving funds, road funding, user fees, bonding, and surcharges on other utility fees. Three of the funding mechanisms which may be applicable to the City of Brownsville are discussed below.

5.3.1 Storm Water Utility Fee

The relatively new concept of storm water utility based funding has been gaining popularity in recent years. In the early 1970's, there were only one or two true storm water utilities in the nation. In the early 1990's there were over 200. This number is expected to more than triple in the next decade as the financial aspects of storm water quality legislation reach small municipalities.

A storm water utility fee is based on the premise that the urban drainage system is a public system, similar to a waste water or water supply system. When a demand is placed on the system by a user paving a previously forested or grassy area, the user is required to pay a fee to compensate the City for the increased demand on the drainage system. The greater the demand (ie., the more the parcel of land is paved), the greater the user fees should be. A comprehensive land use study would be used by the municipality to determine the fee for the different types of land use and impervious cover.

Few, if any, storm water utilities have failed court challenges if: (1) they are fair and reasonable; (2) the costs are related to the services rendered; (3) they are legal by charter or legislation; and (4) the proper procedures are followed in setting up the utility. A storm water utility must be based on a defined storm water management program and not simply a perceived financial need or willingness to pay. In a typical municipality which uses a storm water utility form of financing, a charge of one dollar per residential unit per month (plus equivalent charges for nonresidential properties based on impervious area) will generate between about $25 and $45 per acre per year. [Municipal Storm Water Management, by Thomas Debo and Andrew Reese, published by CRC Press, Inc., 1995]

Following the growing national trend, the City of Brownsville implemented a $2.00 fee on water bills which is referred to as the Federal Unfunded Mandate Compliance Fee. This fee will be used to generate revenue in anticipation of funding landfill federal compliance projects and NPDES program compliance projects. By establishing this user fee, the City has defined a funding structure which could be expanded to include a storm water utility fee which would be earmarked for implementation of the Flood Protection Plan and other major drainage projects.

5.3.2 Development Impact Fee

Development impact fees have been used throughout the state of Texas to fund regional drainage projects to varying degrees of success. In municipalities where a Master Drainage Plan has been formalized, an impact fee system may be implemented on a watershed-by-watershed basis. The Master Plan must define regional projects which alleviate existing flooding problems and differentiate this cost from regional projects which will serve to control drainage from new development. The cost associated with the facilities necessary to control drainage from new developments is then allocated across the watershed based on the anticipated new development in a defined period. Impact fees based on the per acre allocation are collected from developers at the time of platting and are used to construct regional facilities within a time period legislated by the State.

The requirement for construction of regional facilities within a specified time frame (usually three years) from collection of initial fees has been problematic for some municipalities. The time frame limitation essentially requires the municipality to build regional facilities to serve new development prior to the watershed development being completed and, therefore, prior to enough fees being collected to fund the project. This situation forces the municipality to construct the project using public funds and then get reimbursed from new developments as they are built. Inherent problems may occur in funding the projects or repaying loans if new development is not constructed within the anticipated financing period.

A scaled-down version of the impact fee system can be developed for a portion of a watershed with an identified regional project and a defined contributing acreage. For the City of Brownsville, this type of impact fee system may be applicable to the CCDD No. 1 Ditch watershed where regional detention facilities can be designed which have enough storage capacity to control both existing flooding problems and anticipated drainage from new development. The impact fee mechanism of funding does not appear to be applicable to the North Main Drain system since undeveloped property is scarce and all identified sites for regional facilities are required to mitigate existing flooding problems.

5.3.3 Texas Water Development Board - Flood Control Account

The Texas Water Development Board's Flood Control Account provides financing for structural and non-structural flood protection improvements such as construction of storm water retention basins, enlargement of stream channels, modification or reconstruction of bridges, acquisition of floodplain land for use as public open space, acquisition and removal of buildings located in the floodplain, public beach renourishment, flood warning systems, control of coastal erosion and development of floodplain management plans. The purpose of the Flood Control Account is to provide loans to eligible applicants for flood control projects. The repayment period for these types of loans generally ranges from 20 to 25 years.

In order to apply for the TWDB funding, the City must contact the Financial Applications Section Manager. At the time of the application, the following items must be included with the current report:

1. An evaluation of the impacts of the improvements on downstream water surface elevations (i.e. Rio Grande water surface elevation);

2. A review of environmental considerations, and;

3. A consideration of sedimentation and erosion control facilities.

Estimated costs contained in this report will have to be modified based on final design considerations in order to be representative of total project cost. Legal and environmental costs not included in this report, for example, will be incorporated into the total project cost based upon final design details.

TEXAS WATER DEVELOPMENT BOARD

December 11, 1996

RECEIVED
DEC 16 1996
CITY OF BROWNSVILLE
ENGINEERING DEPARTMENT

Mr. P. J. Garcia, P. E.
City Engineer
City of Brownsville
404 E. Washington
Brownsville, Texas 78520

Re: Review Comments for Draft Report Submitted by the City of Brownsville, Texas, TWDB Contract Number 96-483-159

Dear Mr. Garcia:

Staff members of the Texas Water Development Board have completed a review of the draft report under TWDB Contract No. 96-483-159. The comments in Attachment 1 should be considered before the report is finalized.

The Board would like to proceed toward completion of this study as soon as possible.

The Board looks forward to receiving one (1) unbound camera-ready original and nine (9) bound double-sided copies of the Final Report on this planning project. Please contact Mr. Alfredo Rodriguez, the Board's Contract Manager, at (512) 463-7987, if you have any questions about the Board's comments.

Sincerely,

Tommy Knowles

Tommy Knowles
Deputy Executive Administrator
for Planning

cc. Alfredo Rodriguez, TWDB

v:rpp\draft\96483159.ltr

Our Mission
Exercise leadership in the conservation and responsible development of water resources for the benefit of the citizens, economy, and environment of Texas

P.O. Box 13231 • 1700 N. Congress Avenue • Austin, Texas 78711-3231
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ATTACHMENT 1

TWDB REVIEW COMMENTS

The report is well presented and organized, the alternatives and their implementations are explained in detail. The items in the scope of work for the City of Brownsville were completed to satisfaction with the exception of Section 5.3 Financing Alternatives.

Section 5.3 should include information on the the Texas Water Development Board's Flood Control Account as a possible source of financing.

The Flood Control Account provides financing for structural and non-structural flood protection improvements such as construction of stormwater retention basis; enlargement of stream channels; modification or reconstruction of bridges; acquisition of floodplain land for use as public open space; acquisition and removal of buildings located in a floodplain; public beach renourishment; flood warning systems; control of coastal erosion; and development of flood plain management plans.

The purpose of the Flood Control Account is to provide loans to eligible applicants for flood control projects. The repayment period for this types of loans generally range from 20 to 25 years. For additional information, please contact Mr. Ignacio Madera Jr., Financial Applications Section Manager, at (512) 463 - 7509.

The recommendations represent feasible improvements for reducing flood impact and they appear eligible for Texas Water Development Board funding. Study methods appear current and acceptable, and the study will be useful in support of an application for TWDB funding. At time of application and in order to obtain TWDB funding, the following items must be included

1. An evaluation of the impacts of improvements on downstream water surface elevations (i.e. Rio Grande water surface elevation),
2. A review of environmental considerations, and
3. A consideration of sedimentation and erosion control facilities.

Estimated costs presented in the report were not representative of total project cost. Legal and environmental costs were not included, for example. The report does not clearly identify the final disposition of flood waters conveyed in the Resacas and ditches

Additional changes

1.-On page 3-2 the statement: "The North Main Drain watershed was divided into 29 subwatersheds......" should be change to : "The North Main Drain watershed was divided into **39** subwatersheds. "

2.-On page 3-9 the statement: "The Town Resaca watershed was divided into 46 subwatersheds......" should be change to : "The Town Resaca watershed was divided into **48** subwatersheds......"

TNRCC REVIEW COMMENTS

An application for approval of Reclamation Project need not be filed with the Texas Natural Resource Conservation Commission for the referenced proposal. It was determined from our review that the proposed project, since it is in the City of Brownsville, need to be permitted by the city. The City of Brownsville by virtue of its participation in the Nation Flood Insurance Program, and in accordance with Section 16.236 (d)(3&4) of the Texas Water Code, has approval authority for the project. If the City has not already done so, they should insure that the proposed construction is documented and permitted in accordance with their Flood Hazard Prevention Ordinance. This documentation should also be submitted by the City to the Federal Emergency Management Agency to obtain a Letter of Map Revision (LOMR) of Brownsville's Flood Insurance Rate Map.

The technical content of the reference report is based on acceptable hydrological and hydraulic methods and is complete. Therefore, the merits of the proposed project can be evaluated from the report.