VOLUME I

CITY OF BROWNSVILLE, TEXAS

MASTER DRAINAGE PLAN

AUGUST 1987

HOGAN & RASOR, Inc.
Engineers • Planners • Consultants
DALLAS AUSTIN BROWNSVILLE KILLEEN
In Association With

MEJIA, HAMPTON & ROSE, INC.
Engineers-Surveyors
BROWNSVILLE, TEXAS

R. J. BRANDES COMPANY
Consulting Engineers
AUSTIN, TEXAS

HOGAN & RASOR, Inc.
Engineers • Planners • Consultants

August 7, 1987

Honorable Mayor and City Council
City of Brownsville
285 Kings Highway
P.O. Box 911
Brownsville, Texas 78520

Re: Master Drainage Plan

Gentlemen and Mrs. Austin:

We are very pleased to submit herewith our final report on the Master Drainage Plan for the City of Brownsville, which was prepared in accordance with the scope of services outlined in our Engineering Agreement, dated May 7, 1986.

The results of this planning work and the recommendations are presented on the following pages and in Volume II for your consideration and implementation.

It has been a pleasure to perform this study for you, and we look forward to assisting you with the development of the proposed projects.

Respectfully submitted,

HOGAN & RASOR, INC.

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ACKNOWLEDGEMENT

The development of the Master Drainage Plan to correct the major flooding problems within the City of Brownsville, Texas, required the collaboration and assistance of several capable persons. Hogan & Rasor, Inc., in association with Mejia, Hampton & Rose, Inc., and R. J. Brandes Company would like to express their appreciation to Mr. Herbert W. Grubb and Mr. Robert Wear of the Texas Water Development Board, Mr. Ersel G. Lantz of the Resaca & Drainage Conservation Committee, Mr. James R. Webb of the Brownsville Drainage and Irrigation District, Mr. Roy D. Sedwick of the National Flood Insurance Program, and the Departments of Planning and Community Development, Engineering, and Public Works of the City of Brownsville for their assistance in this project.

This study was partially funded by grants from the Texas Water Development Board.

CITY OF BROWNSVILLE, TEXAS

CITY OFFICIALS

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TABLE OF CONTENTS

Page Number

LIST OF FIGURES, TABLES, AND PLATES

VOLUME I

FIGURES

TABLES

VOLUME II

PLATES

CHAPTER I

MASTER DRAINAGE PLAN

CITY OF BROWNSVILLE, TEXAS

I. SUMMARY

This Master Drainage Plan for the City of Brownsville assesses the existing drainage problems of the City and provides a Master Drainage Plan and computer programs for use in the Plan's implementation to correct the major flood problems of the area.

The underlying goal of the drainage plans developed in this study is to provide flood protection for the 100-year storm. This goal is primarily applicable to the major drainage facilities comprised of resacas, ditches and channels. The minor system of storm sewer trunks has not been designed for this level of storm, for economic reasons. This will have the effect of ponding the 100-year flood waters in the streets until the overall system can dissipate it to the receiving water bodies.

The existing drainage system has been analyzed based on a set of criteria and procedures developed in conjunction with the City Engineering and Planning Departments. These criteria were applied to the major structures in the planning area to determine their adequacy with regard to the storm magnitudes and conditions normally used in prudent engineering design.

Components of the Master Drainage Plan that deal with proposed improvements to the major drainage facilities have been developed through an iterative simulation process involving, first, the determination of existing flooding conditions for each of the five principal drainage subsystems, and then, a series of analyses to evaluate the effectiveness of alternative measures for reducing existing flooding levels. A comprehensive set of computer programs has been applied to calculate watershed run-off quantities and associated water levels and discharges along each of the drainage subsystems for the various conditions considered.

The major drainage facilities were analyzed utilizing the HEC-1 Flood Hydrograph Package for hydrologic simulation. This program, originally developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers, has received widespread use throughout the country for solving a wide variety of hydraulic problems.

The minor systems and their drainage areas were analyzed utilizing the Rational Method for determination of discharge. Parameter values and procedures found in the "Hydraulic Manual of the Texas Highway Department" (State Department of Highways and Public Transportation) were applied.

The extremely severe flooding problems of the area result from three principal causes: the natural flatness of the Lower Rio Grande Valley, the large amounts of rainfall, and the development of many flood-prone areas without installation of proper drainage facilities.

The flatness of the area and downstream tailwater conditions cause flow velocities in channels throughout the area to be very slow. This condition requires that the structures and channels conveying the floodwater be very large to carry the flows that are commonly used to design for flood protection.

The analysis portion of this plan has revealed that, generally, the major drainageways and storm sewer trunks in the area do not have sufficient capacities to provide flood protection from even the 5-year storm.

The solution of these extensive and serious problems not only lies in correcting each local problem area with a larger, local system of storm sewer trunks, pipes and inlets, but also with solving the drainage problems of the major systems of the resacas and major ditches.

The solutions proposed, when implemented in the sequence shown, will alleviate the major, and many of the local, flooding problems currently experienced.

To be an effective management and engineering tool for improving the overall drainage system for the City of Brownsville, the Master Drainage Plan should provide an organized procedure for implementing specific structural modifications and flood mitigation measures. It should balance the relative flood protection benefits of specific improvements with the cost of the improvements and the ability of the City to finance the improvements.

The major components of the Master Drainage Plan, when fully implemented, will comprise the ultimate 100-year flood protection plan. For each of the major drainage subsystems, this ultimate plan provides for 100-year water surface profiles that are below all the previously identified flood index elevations.

The proposed recommended Immediate Improvements Program comprises the most essential components of the overall plan. It is considered to be a program that can be implemented within the next few years and can provide immediate solutions to some of the City's more severe flooding problems. This program provides the fundamental basis for the subsequent improvements that are contained in the other components of the Plan.

Generally, implementation of the Immediate Improvements Program will lower 100-year water levels in the lower reaches of the subsystems by several feet and will result in lesser flooding in the upper reaches. Flood protection with the Immediate Improvements Program in place generally will provide for the 25 to 50-year storm on the Town Resaca subsystem and for the 50 to 100-year storm on the Resaca de la Guerra subsystem.

For North Main Drain upstream of Highway 77, at least 2-year flood protection will be provided. In the Four Corners area near Boca Chica Boulevard, 25-year flood protection will be provided, with 100-year flood protection downstream of International Boulevard all the way to the Port Authority Ditch. Flood protection along the Cameron County Drainage District No. 1 Ditch subsystem will be between the 2 and 5- year storm level, although full 100-year protection for the Valley Community Hospital will be provided with a levee and pump system.

The total projected cost of the Immediate Improvements Program, as shown below, is approximately $48,855,000.

Structure	Improvement Measure
NMI-1	Channel Widening from Port Authority Ditch Upstream to Resaca de la Guerra
NMI-2	Channel Realignment East of Airport
NMI-3	Channel Realignment West of Minnesota Avenue
NMI-5	Modifications to Structure NM35 at Boca Chica Blvd.
NMI-6	Modifications to Structure NM32 at Minnesota Avenue
CCI-15	Flood Protection Facilities for Valley Community Hospital
TRI-1	Enhanced Detention Storage near Los Tomates Banco
TRI-4	Modifications to Structure TR26 near 25th Street
RGI-1	Modifications to Structure RG24 at North Main Drain Ditch
RGI-2	Modifications to Structures RG22 and RG23 at Morningside Road Crossings
NMI-4	Channel Lining and Widening from Resaca de la Guerra Confluence Upstream to Impala Ditch Confluence
NMI-20	Modifications to Airport Drainage System
TRI-5	Stormwater Pump Station near Los Tomates Banco
TRI-9	Modifications to Structure TR25 near Lincoln Park
TRI-2	Additional Detention Storage above Belthair Blvd.
TRI-3	Modifications to Structure TR15 at Palm Blvd.
TRI-7	Stormwater Pump Station near Ebony Lake
NMI-23	New Detention Storage Area Downstream of International Boulevard

Structure	Improvement Measure
CCI-11	Additional Detention Storage Area Upstream of Central Avenue
RGI-4	Modifications to Structure RG13 at Palo Verde Drive
RGI-6	Miscellaneous Modifications to Structures Between Billy Mitchell Boulevard and 14th Street
NMI-17	Modifications to Structure NM3 at MOPAC Railroad
NMI-27	New Detention Storage Area Upstream of Paredes Line Road
NMI-32	Additional Detention Storage Area Upstream of MOPAC Railroad
RGI-3	Diversion of Stormwater Flows during High Stage Conditions into Cameron County Drainage Water District No. 1 Ditch near the Paredes Line Road/Highway 802 Intersection
NMI-21	New Detention Storage Area South of Airport
NMI-26	Stormwater Pump Station Upstream of Rockwell Road

Most of the existing storm sewer trunks in the study area are undersized and are not capable of carrying stormwater flows in accordance with the adopted design criteria presented in Chapter IV. Although many of the existing pipes simply are undersized, the hydraulic capacities of most of the storm sewers are severely limited by the existing high tailwater conditions in resaca pools and ditches.

With implementation of the major drainage improvements included in This Master Drainage Plan, these tailwater conditions will be significantly reduced, and storm drains will be able to function more efficiently.

The maintenance plan for existing drainage courses and storm sewers should be one that occupies a high priority in the budgetary, political, and human resource allocations of the City of Brownsville.

The ideal situation for maintenance plans is for sufficient money to be available to cover all the problem areas simultaneously. However, the reality of the situation is, often, only a fraction of the necessary funds are available to perform the many required tasks. The problem then becomes one of assigning priorities to what areas will be maintained first and how the distribution of effort should be allocated.

To most effectively solve the problem, emphasis should always be placed on the downstream, outflow reaches of an area experiencing problems. This is justified because money spent to clean or improve conditions of existing drainage facilities in a local neighborhood or street intersection will not significantly help the problem if the channel or structure downstream will not allow the floodwaters to leave the problem area. This is especially true in Brownsville where the grades are extremely flat and siltation occurs when downstream floods are impeded.

A schedule of maintenance should be evaluated and programmed based on the physical inventory provided in this report and the available resources and funding for the City. This should strive for a frequency of cleanout and repair that approaches at least an annual basis for all streams, ditches and open channels.

The importance of the storm water pump stations, particularly the Impala Pump Station, to the rapid dispersal of flood waters throughout the City is the same as the major outlet channels, resacas, and ditches. Since they are active conveyors of water, and not passive conveyances, they should be inspected and tested weekly to provide for assurance of their operation in the event of a flood.

Each pump station should have a log listing maintenance procedures that have been performed, date, and by whom they were performed. Where diesel or gas standby generators are available, any special procedures necessary to start and operate these engines should be listed. There should be at least two persons that know how to operate each pump and associated equipment to provide continuity in operation in case one person is, for some reason, not available.

CHAPTER II

II. INTRODUCTION

A. Study Authorization

On May 7, 1986, the City of Brownsville, Texas, authorized this study to develop a Master Drainage Plan of the existing storm drainage facilities and future needs within the City Limits and in designated surrounding areas.

B. Study Area

The Master Drainage Plan encompasses a planning area of approximately 117 square miles. Within this area are three major resaca systems; the Town Resaca, Resaca de la Guerra, and Resaca del Rancho Viejo. The area also contains numerous drainage ditches, bridges, drainage structures, culverts, storm water pumping stations and other related drainage facilities. The major ditches studied include North Main Drain, Cameron County Drainage District No. 1 Ditch and a portion of Drainage District No. 6 Ditch.

A location map showing the study area and the watershed boundaries of the principal drainage subsystems is shown in Figure 1, Volume I.

C. Study Purpose and Scope

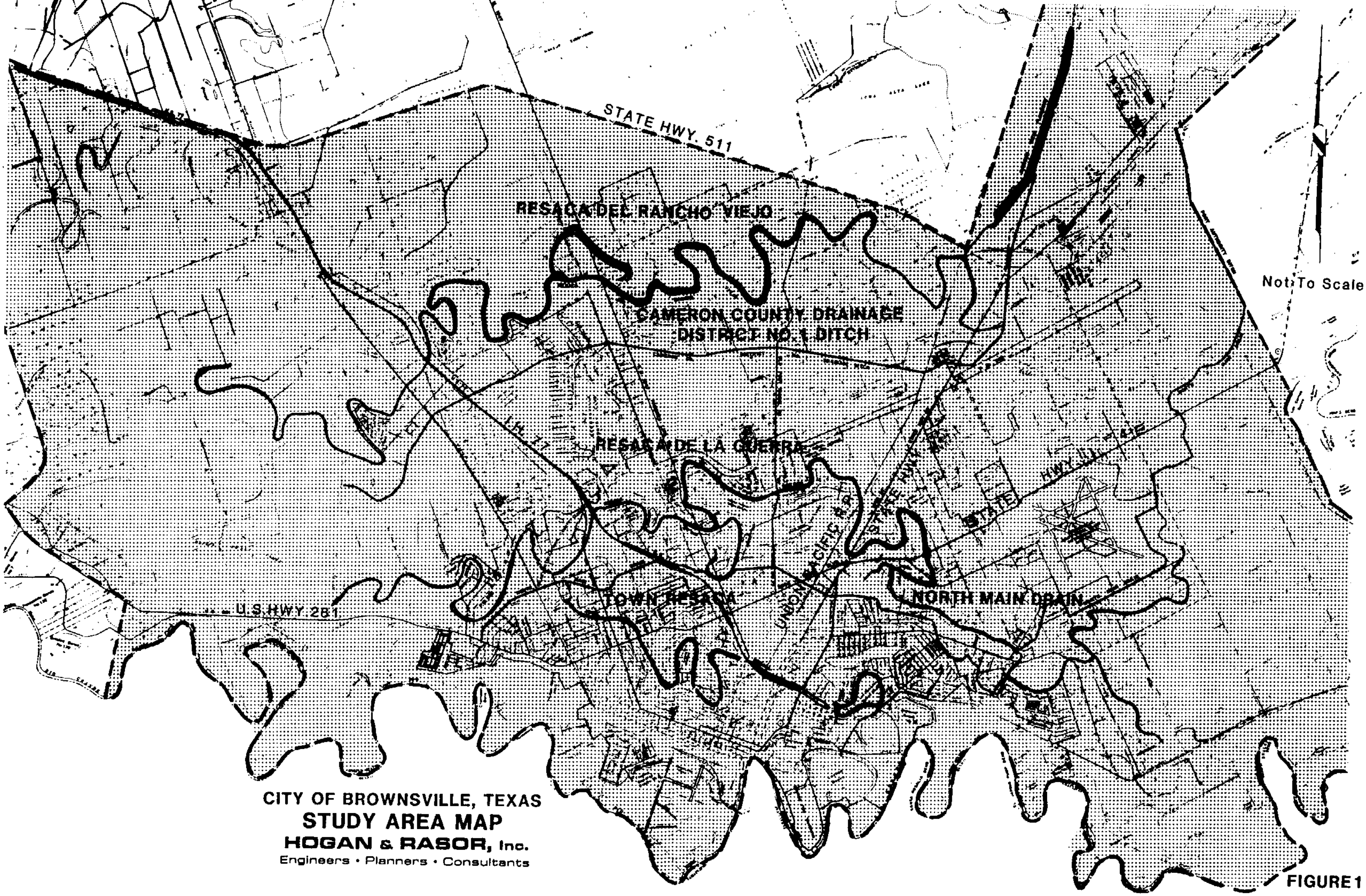
The purpose and scope of this study has been to investigate and analyze the existing drainage facilities, and, based upon the analysis and design criteria agreed upon in conjunction with City Staff, to develop a Master Drainage Plan for a storm drainage system which will provide adequate capacity to handle future growth.

The general scope of work for this study has included:

1. Study Area Reviews, Surveys, and Mapping

   a. Obtain data from prior reports, City files, meetings with other drainage related agencies (U.S. Army Corps of Engineers, Soil Conservation Service, etc.), and public meetings (to incorporate local comments and opinions);

   b. Review all available drainage, zoning, and land-use information furnished by the Owner from previous reports, studies, system layouts, or other data which is pertinent to the planning area;



CITY OF BROWNSVILLE, TEXAS
STUDY AREA MAP
HOGAN & RASOR, Inc.
Engineers • Planners • Consultants

FIGURE 1

c. Conduct an inventory, study, and analysis of the existing drainage conduits, open channels, culvert sizes, storm water pumping stations, and other related drainage systems, excluding inlet lateral lines;

d. Perform field survey work and reviews to determine present condition and adequacy of the major drainage facilities in the planning areas;

e. Review current planning and design criteria for drainage facilities, and prepare recommendations for revisions (This task was not incorporated into the Master Drainage Plan at the direction of the City.); and,

f. Prepare maps at a convenient scale to show existing major facilities (The maps utilized in the report were furnished by the City and were considered to be the best available.).

2. Storm Drainage System Analysis

a. Divide the major watersheds and drainage areas into component areas that will facilitate analysis and later design;

b. Analyze the major drainage facilities and structures and topography for their adequacy to carry present and future flows;

c. Provide a listing and ranking of problem areas discovered; and,

d. Investigate, select, and utilize a computer program model that can be operated on the City Engineering Department Computer.

3. Storm Drainage System Master Plan

a. Develop and utilize a computer program to allow flexible analysis of the storm drainage system for various future land uses for the existing developed areas and the areas anticipated to be developed within each of the major drainage areas; provide these programs with a computer program documentation report for use by the City;

b. Prepare a general plan and layout showing alternatives and proposed major improvements in relation to the existing drainage facilities;

c. Prepare hydraulic gradient profiles to graphically illustrate the problem areas along the major drainage courses, and show the positive effect of the proposed improvements;

d. Prepare a maintenance plan for the existing and proposed flood protection facilities; and,

e. Prepare a recommended plan of implementation, with cost projections and priorities, for the proposed major improvements.

4. Storm Drainage System Planning Report

a. Prepare a report to include the background information and results of the calculations, studies and analysis, summary, conclusions and recommendations, priorities and cost projections for the immediate improvements; and,

b. Address the considerations relating to operation policies and financing the recommendations of the proposed plan.

5. Progress Reports, Report Reviews, Printing and Presentations

a. Attend and participate in quarterly meetings with City Staff and public agencies (The U.S. Army Corps of Engineers and the Soil Conservation Service were invited to these meetings.) to coordinate and develop the Master Drainage Plan;

b. Provide monthly progress reports to the City; and,

c. Provide fifteen (15) draft copies of the report to the City for review and comment; amend, prepare, and present fifty (50) copies of the final report to the City.

D. Prior Studies

Prior studies performed for the study area have included the development of drainage and design plans and reports by the Federal Emergency Management Agency, the Soil Conservation Service, the U.S. Army Corps of Engineers and various engineering companies and other private firms.

These studies and plans provided a portion of the analysis data evaluated. Notes were made of conclusions and recommendations in the prior reports, and these were incorporated into this plan.

CHAPTER III

III. DRAINAGE SYSTEM DESCRIPTION

A. General Overview

The City of Brownsville lies in the Lower Rio Grande Valley, which has experienced the depositional/erosional activity of the Rio Grande for thousands of years. This activity has led to numerous changes in active channel alignments and locations. The evidence of this past activity can be seen in the numerous resacas and bancos (also known as meander scrolls and oxbow bends) that are present throughout the flat deltaic topography of the area. This process is still underway on the present day Rio Grande channel as it continues to slowly erode the banks of its channel and change course. This process of channel movement is a long-term process that occurs over hundreds of years.

Pictures of the typical resaca and ditch drainageways appear in Figures 2 - 7, Volume I.

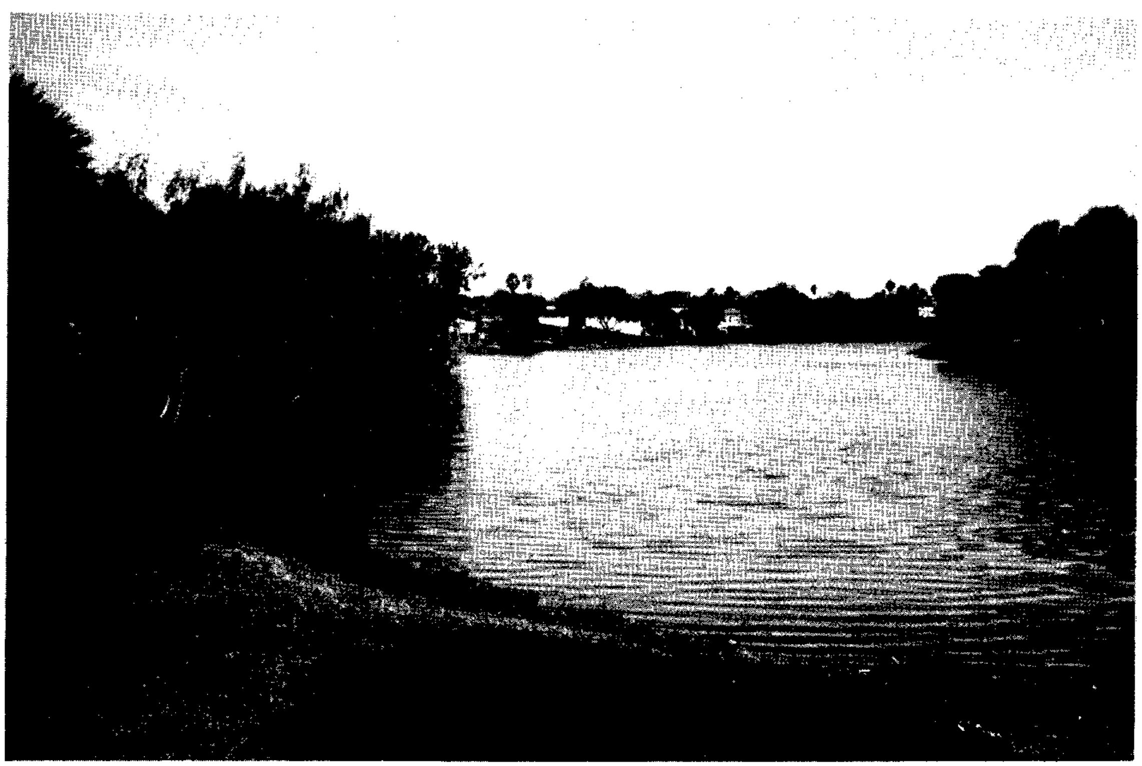
The Rio Grande is a type of river characterized by artificial "levees" or spoil banks that parallel it along the main channel. These "levees" are caused by the deposition of sediment by flood waters when the river leaves its banks during a flood. The water in the main channel has enough velocity and energy to carry the sediment, but when the flood flows leave the channel bank, the water slows down and drops its sediment. This leaves the higher banks surrounding the river.

The resacas in the study area (e.g. Town Resaca, Resaca de la Guerra and Resaca del Rancho Viejo) are the abandoned channel of the Rio Grande and, therefore, also are characterized by high banks. Beyond the high banks, the existing terrain slopes away from the resacas; the high banks cause flood waters that leave the resaca channels to flow to the low areas between the resacas and not readily return to the resacas.

As agriculture developed in the area, drainage ditches were constructed to drain the land between the resacas. These ditches form the basis for the present-day drainage system in the study area. A complex system of canals also has been constructed to convey irrigation water, but these generally do not carry flood flows.

The urbanization and development of the Lower Rio Grande Valley has increased flooding problems along the ditches and resacas through several causes. First, a higher percentage of run-off now occurs due to the increased amount of pavement and less pervious cover. Run-off also occurs more rapidly with less on-ground storage of stormwater due to the installation of storm sewers and drainage ditches. These factors result in peak

TOWN RESACA
Town Resaca Passing Under Wall at Gladys Porter Zoo
Looking Upstream Across Ringgold Street



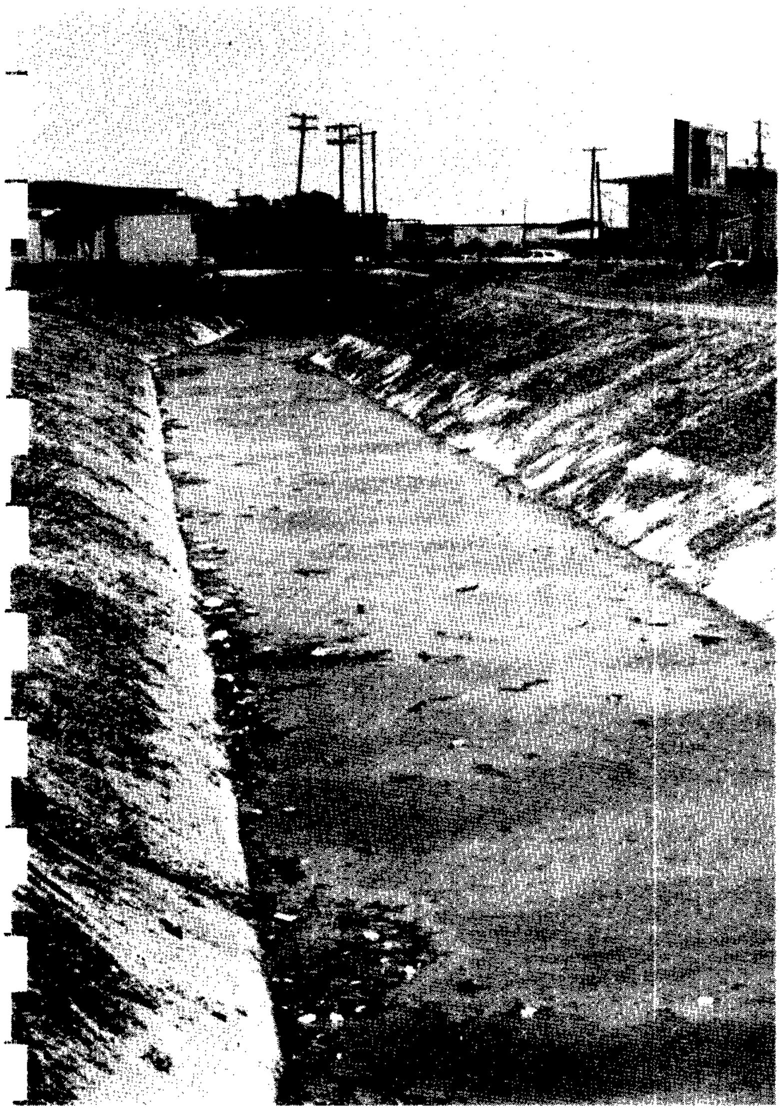
TOWN RESACA
Looking Downstream at Town Resaca From
Ringgold Street at Gladys Porter Zoo

FIGURE 2

TOWN RESACA
Looking Downstream on Town Resaca at 7th Street

TOWN RESACA
Leaving Gladys Porter Zoo

FIGURE 3

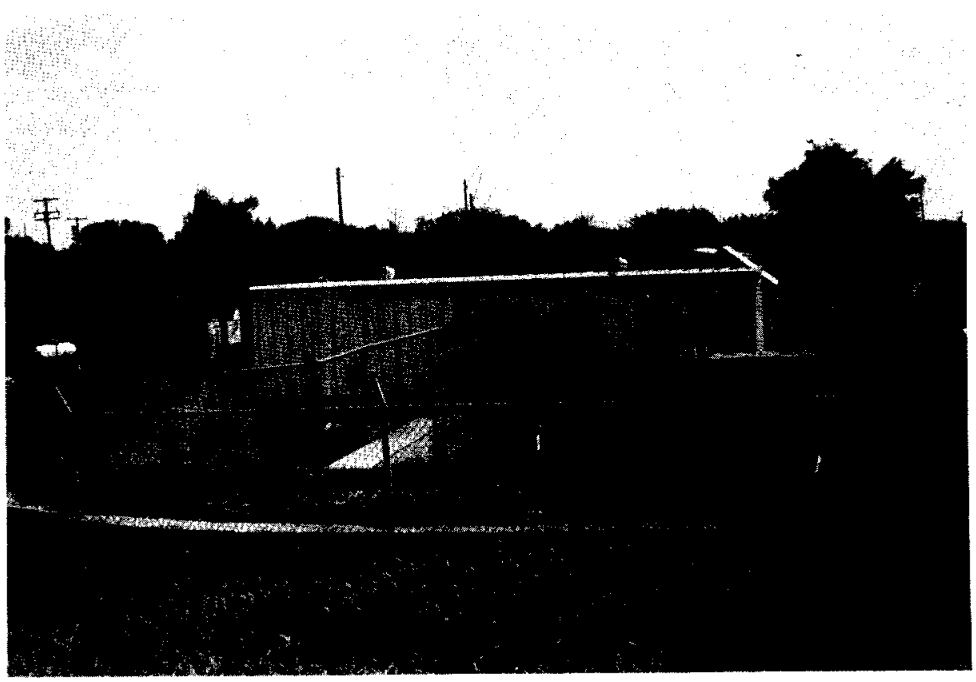


NORTH MAIN DRAIN
North Main Drain After Cleanout, Summer 1986

NORTH MAIN DRAIN
North Main Drain a Few Months After Cleaning, Fall 1986

FIGURE 4

IMPALA PUMP STATION
Outlet Valves at Impala Pump Station to "Jeronimo" Banco,
Leading to Rio Grande



IMPALA PUMP STATION
Impala Storm Water Pump Station on Town Resaca

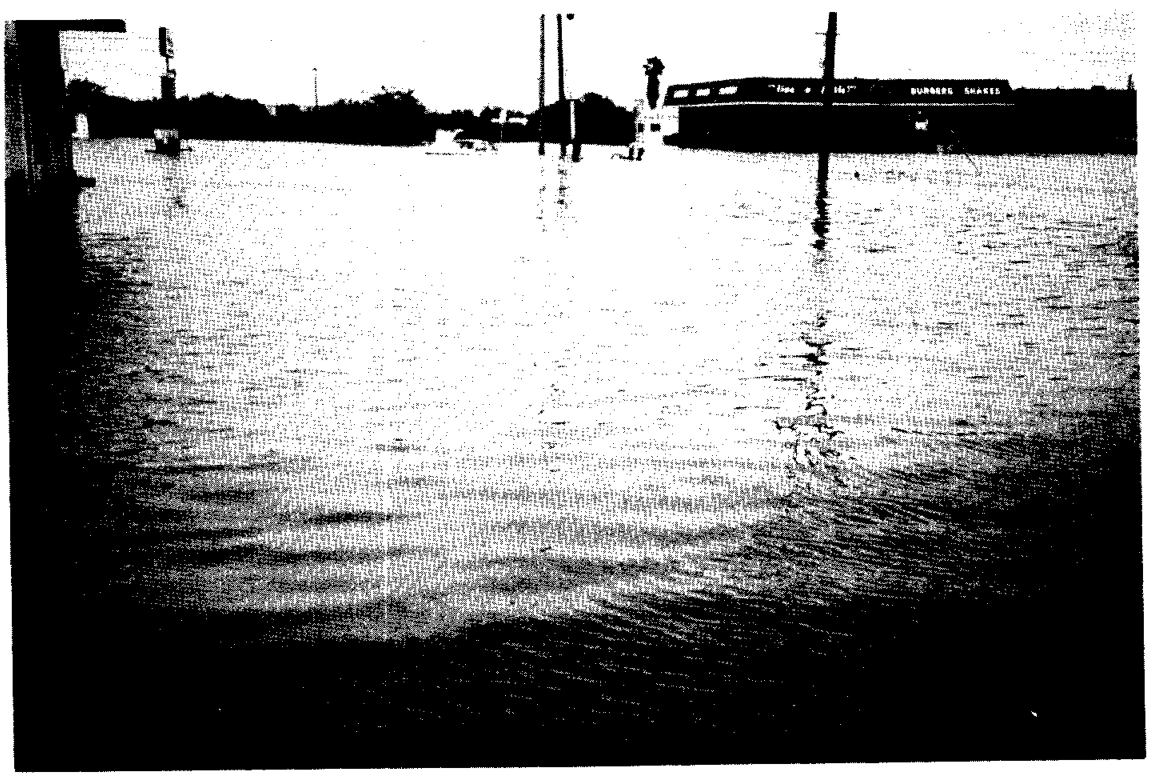
FIGURE 5

AIRPORT DRAINAGE
Airport Drainage Outlet Headwall
Note Sediment Line on Headwall After Recent Ditch Cleanout

NORTH MAIN DRAIN
North Main Drain South of Airport, Looking Downstream

FIGURE 6

RESACA DE LA GUERRA
Flood Conditions on Boca Chica Boulevard, September 1984
Flooding From Main North Drain and Resaca de la Guerra
Looking West From Four Corners Area



RESACA DE LA GUERRA
Looking North Across Boca Chica Boulevard (Highway 48) During
Flood of September, 1984
Near Four Corners Area

FIGURE 7

stormwater flows that are too large for the existing drainage system to carry.

The use of the resacas for water supply storage and aesthetic, constant pool lakes also has contributed to existing flooding problems. The elevated pool levels reduce the available storage volume that could be used to store stormwater during flooding periods.

B. Labeling and Mapping

To facilitate mapping, presentation and identification of structures, a labeling system was developed for use on the Master Drainage Plan.

The major watersheds, other areas, and all the drainage features within them carry a prefix designation that signifies the watershed.

The prefixes used are as follows:
TR - Town Resaca
NM - North Main Drain
RG - Resaca de la Guerra
CC - Cameron County Drainage District No. 1
RV - Resaca del Rancho Viejo
FB - Fort Brown Resaca
RR - Rio Grande

The sub-watershed areas are a two-digit number immediately following the prefix. For example, sub-watershed Number 7 in Town Resaca would be TR07.

The major structures along the drainageways of the resacas and ditches use the same prefix but have the structure number separated by a dash; i.e. TR-8.

The storm sewer trunks are labeled on the detailed drainage sheet based on the sub-watershed where the trunk finally enters the drainageway. The trunk designation for the third trunk in Town Resaca sub-watershed Number 7 would be TR0703.

The drainage areas within these sub-watersheds are further divided into smaller areas for analysis of the capacity of the storm sewer trunks. These labels are placed on the maps with an oval or ellipse placed around them to make them stand out from other markings on the map. An example would be that sub-area 15 of sub-watershed number 4 in Town Resaca would be 4.15 enclosed in an oval in the area of TR-4 on the detail drainage map. The hydrologic characteristics for these sub-areas can be found in the Appendix, Table A1, Volume I.

C. Major Drainage Facilities

Based on an extensive field survey program, as well as a review of City files and plans, previous drainage reports, available construction drawings and other drainage-related data, an inventory has been made of all major drainage facilities in the five principal drainage subsystems within the overall planning area; i.e., Town Resaca, North Main Drain, Resaca de la Guerra, Cameron County Drainage District No. 1 Ditch and Resaca del Ranch Viejo. This inventory includes survey data on 180 structures and 40 stream cross-sections.

The locations of the major structures are indicated on Plates 7a and 7b, Volume II. Tables 1 through 5, Volume I, list the structures and present descriptions and pertinent hydraulic data for each structure.

Maps showing the specific watersheds of the principal drainage subsystems within the planning area are presented in Plates 1 through 6, Volume II. Descriptions of the principal drainage subsystems are presented in the following sections.

1. Town Resaca

The Town Resaca watershed is the most southerly of the five principal drainage subsystems and is bounded on the south by the levee along the Rio Grande. The northern boundary adjoins the drainage divide of the North Main Drain. The upstream western extent of the watershed is near Honeydale Drive. The channel proceeds southeasterly through downtown Brownsville. The downstream end of the watershed is at Tomates Banco, downstream of Lincoln Park. The outlet of the Tomates Banco is a ditch that carries stormwater to the Impala Pump Station and then on to the north to North Main Drain. The watershed covers a total of approximately 3,500 acres and contains 48 sub-watersheds that have been analyzed. Figures 2 and 3, Volume I, show locations on Town Resaca.

2. North Main Drain

This ditch serves to provide drainage in the low area between the Town Resaca and Resaca de la Guerra subsystems.

The North Main Drain encompasses a watershed of approximately 14,892 acres and has a channel length of about 16 miles. This watershed has been analyzed with a total of 43 sub-watersheds. The channel has a top width that ranges from 20 to 70 feet. Figures 4 and 6, Volume I, show two pictures of locations on North Main Drain.

TABLE 1

DESCRIPTION OF OUTLET STRUCTURES IN TOWN RESACA

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
IM1 Tulipan Dr.	43+70 43+90	Bridge	1	LB = 60' WB = 20' HB = 13.3'	12.2	12.2	-	27.96
IM2 Calle Milpa Verde	56+50 56+70	Bridge	1	LB = 60' WB = 20' HB = 13.1'	13.6	13.6	-	29.22
IM3 Impala	65+60 65+80	Bridge	1	LB = 60' WB = 20' HB = 16.2'	12.5	12.5	-	31.12
IM4 East Avenue	64+10 64+30	Bridge	1	LB = 49' WB = 20' HB = 16.0'	15.9	15.9	-	34.45 31.95
TR27	100+00	Weir	1	LW = 23.6'	14.85	19.09	19.09	19.09
TR26	150+00	CMP	1	D = 6' 8"	15.55	14.93	19.09	24.8
		RCP	2	LC = 32' D = 36" LC = 50'	15.95 15.92	16.45 15.61		
TR25	154+80	Weir	1	LW = 34.3'	13.27	20.23	20.23	20.23
TR24	155+50	Bridge	1	LB = 50' WB = 21.3' HB = 14.5'	13.27	13.27	20.23	30.73
TR23 Highway 4	176+70 178+90	Box Culvert	2	10' X 9' LC = 220'	14.90	14.90	20.23	31.90
TR22E	182+90 192+83	Box Culvert	2	10' X 9' LC = 993'	15.10	15.80	20.23	27.19
TR22D	195+58 196+38	Box Culvert	2	10' X 9' LC = 80'	16.10	16.10	20.23	28.00
TR22C	199+18 200+04	Box Culvert	2	10' X 9' LC = 86'	16.30	16.30	20.23	30.00

TABLE 1 (CONT'D)

DESCRIPTION OF OUTLET STRUCTURES IN TOWN RESACA

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
TR22B	202+34 202+66	Box Culvert	2	10' X 8' LC = 32'	16.40	16.40	20.23	30.50
TR22A Highway 77	206+00 210+88	Box Culvert	2	10' X 8' LC = 488'	16.42	16.52	20.23	38.00
TR22	216+68 217+49	Box Culvert	2	10' X 9' LC = 81'	16.63	16.63	20.23	29.62
TR21	219+09	Box Culvert	2	10 X 8' LC = 50'	16.40	16.40	20.23	30.50
TR20	220+49 221+01	Box Culvert	2	9' X 9' LC = 52'	15.20	15.20	20.23	27.35
TR19 Ringgold	248+61 249+24	Box Culvert	2	9' X 3'	19.64	19.64	20.23	24.12
TR18	249+50	Weir	1	LW = 25'	19.64	21.47	21.47	27.47
TR17	265+30 265+64	Box Culvert	2	9' X 8' LC = 34.3'	17.66	17.66	21.47	33.35
	265+24 265+64	Box Culvert	1	6' X 3' LC = 40'	20.84	20.84	21.47	29.11
TR16	270+64 271+24	Box Culvert	1	6' X 4.8' LC = 62.5'	19.52	19.52	21.47	30.00
			2	9' X 4' LC = 60.5'	19.52	19.52		
TR15 Palm Blvd.	290+84 292+06	Box Culvert	1	10' X 6' LC = 122'	19.35	17.65	21.47	30.00
	292+10	Weir	1	LW = 10'	17.65	23.90	23.90	23.90
TR14	295+26 295+59	Box Culvert	1	9' X 4' LC = 33'	20.95	20.95	23.90	32.45
TR13	299+59 300+19	Box Culvert	1	10' X 8' LC = 60'	17.00	17.00	23.90	29.07
TR12	308+19 308+79	Box Culvert	1	10' X 10' LC = 60'	20.17	20.17	23.90	31.50

TABLE 1 (CONT'D)

DESCRIPTION OF OUTLET STRUCTURES IN TOWN RESACA

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
TR11	325+59 325+84	Box Culvert	1	12' X 6.5' LC = 24.5'	20.16	20.16	23.90	30.00
TR10	349+04 349+64	Box Culvert	1	10' X 8' LC = 65'	17.63	17.63	23.90	29.86
TR9A	360+44	Weir	1	LW = 10'	19.82	26.12	26.12	26.12
TR9B	360+44	Weir	1	LW = 6.3'	21.96	26.06	26.12	26.06
TR8 Belthair St.	382+44 383+09	RCP	1	D = 36" LC = 65'	23.09	25.98	26.12	30.80
TR7 Boca Chica	395+49 396+61	RCP	1	D = 48" LC = 112'	22.69	26.00	26.12	32.00
TR5	413+01 413+62	RCP	1	D = 30" LC = 61'	24.29	23.91	26.12	29.74
TR4 Central Blvd.	420+82 421+97	RCP	1	D = 36" LC = 115'	22.46	22.78	26.12	36.72
TR3	425+00	Weir	1	LW = 200'	-	29.90	29.90	29.90
TR2	435+97 437+12	RCP	1	D = 36" LC = 115'	25.70	25.96	29.90	32.52
TR1	452+12 454+92	RCP	1	D = 18" LC = 80'	-	-	-	-

TABLE 2

DESCRIPTION OF CHANNEL STRUCTURES IN NORTH MAIN DRAIN

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	TOP OF STRUCTURE
NM38 South Port Rd.	10+00	RCP	8	D = 60" LC = 208'	-2.04	-1.94	8.80
NM37 Oklahoma	126+88	Bridge	1	WB = 25.5' LB = 100' HB = 17.4'	0.51	0.51	20.41
NM36 Browne	156+88	Bridge	1	WB = 25.4' LB = 101' HB = 17.4'	0.90	0.90	21.07
NM35 Boca Chica	204+58	Box Culvert	3	9' X 8' LC = 35.6'	5.11	5.11	18.40
NM34 FM 511	256+88	Bridge	1	LB = 80' WB = 25.2' HB = 16.7'	4.60	4.60	23.80
NM33 Utah Ave.	260+88	Bridge	1	LB = 100' WB = 25.2' HB = 15.8'	6.30	6.30	24.57
NM32 Minnesota Ave.	413+87	Bridge	1	LB = 80' WB = 27.4' HB = 12.1'	7.71	7.71	22.33
NM31	458+94	Bridge	1	LB = 80' WB = 13.2' HB = 15.8	9.40	9.40	32.50
NM30 Southmost Rd.	468+88	Bridge	1	LB = 60' WB = 25.3' HB = 13.7'	10.04	10.04	26.10
NM29 Ramada Dr.	481+69	Bridge	1	LB = 60' WB = 21.5' HB = 14.9'	10.90	10.90	28.20
NM28 La Posada Dr.	489+15	Box Culvert	4	9' X 8' LC = 49'	12.52	12.52	26.80
NM27 Esperanza Rd.	497+27	Bridge	1	LB = 60' WB = 25' HB = 14.9'	11.15	11.15	28.56

TABLE 2 (CONT'D)

DESCRIPTION OF CHANNEL STRUCTURES IN NORTH MAIN DRAIN

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	TOP OF STRUCTURE
NM26	514+10	Bridge	1	LB = 60'	11.70	11.70	26.67
Manzano St.				WB = 20'			
				HB = 12.5'			
NM25	556+40	Box Culvert	1	10' X 8'	12.20	12.20	25.60
Southmost Rd.				LC = 40'			
			2	10' X 8'	14.40	14.40	
				LC = 40'			
NM24	586+45	Bridge	1	LB = 60'	13.35	13.35	26.85
30th Street				WB = 31.4'			
				HB = 10.8'			
NM23	632+43	Box Culvert	3	10' X 9'	16.00	16.00	28.30
International Blvd.				LC = 74'			
NM22	638+03	Box Culvert	3	9' X 9'	16.00	16.00	26.60
14th Street				LC = 74'			
NM21	648+53	RR Bridge	1	LB = 55'	15.40	15.40	26.85
S. Pac. RR				WB = 14'			
				HB = 9.0'			
NM20	655+41	Box Culvert	3	10' X 7.7'	15.57	15.57	25.00
Boca Chica				LC = 118'			
NM19	674+94	Box Culvert	1	6' X 4'	16.26	17.45	27.08
Old Port Isabel Rd.				LC = 73'			
		RCP	2	D = 60"	17.40	17.43	
				LC = 73'	17.51	17.48	
NM18	686+26	RCP	3	D = 60"	16.77	16.80	25.15
Rentfro St.				LC = 68'	16.77	16.74	
					16.81	16.69	
NM17	696+46	RCP	2	D = 60"	17.50	17.54	30.21
Rockwell				LC= 69'	17.63	17.60	
			1	D = 48"	17.58	17.58	
				LC = 69'			
NM16	712+40	Box Culvert	2	7' X 6'	17.00	17.00	30.27
Paredes Line Rd.				LC = 109'			
				LC = 114'			
			1	7' X 4.5'	17.00	17.00	
				LC = 118'			

TABLE 2 (CONT'D)

DESCRIPTION OF CHANNEL STRUCTURES IN NORTH MAIN DRAIN

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	TOP OF STRUCTURE
NM15 Mackintosh	721+85	RCP	3	D = 60" LC = 71'	18.91 18.71 18.65	17.64 17.48 17.58	29.44
NM14 S. Pac. RR	723+82	RR Bridge	1	LB = 80' WB = 17' HB = 10.0'	18.20	18.20	30.63
NM13B Access Road	726+99	Box Culvert	2	8' X 7' LC = 100'	18.30	18.34	28.50
NM13A U. S. 77/83	741+43	Box Culvert	2	8' X 7' LC = 194'	18.67	18.77	32.08
NM12 Old Alice Road	755+80	Box Culvert	2	8' X 7' LC = 160'	19.37 19.32	19.50 19.50	28.90
NM11 Driveway	761+03	RCP	2	D = 72" LC = 33.3'	20.86 20.93	20.76 20.68	28.24
NM10 Driveway	764+03	RCP	2	D = 72" LC = 33'	20.83 20.85	20.84 20.98	28.40
NM9 Driveway	768+03	RCP	2	D = 72" LC = 32.5'	20.89 21.12	20.96 20.78	28.43
NM8 West Price Road	773+50	RCP	2	D = 60" LC =254'	21.28 21.30	21.17 21.31	28.72
NM7 Coria Street	791+86	RCP	3	D = 24" LC = 15.5'	20.51 20.65 20.69	20.30 20.40 20.24	25.41
		Weir	1	LW = 26'	-	25.41	
NM6 Central Blvd.	799+44	Box Culvert (In Series)	1	6.5' X 4' LC = 110'	24.15	-	32.70
			1	11' X 4' LC = 109'	-	24.21	
NM5	817+58	RCP	1	D = 36" LC = 72'	23.44	23.42	32.40
NM4 Honeydale	826+90	RCP	2	D = 36" LC = 49'	23.49 23.49	24.14 23.89	30.52

TABLE 2 (CONT'D)

DESCRIPTION OF CHANNEL STRUCTURES IN NORTH MAIN DRAIN

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	TOP OF STRUCTURE
NM3 Mopac RR	839+65	CMP	1	D = 48" LC = 57'	25.64	25.74	37.34
NM2 El Paso Road	847+71	RCP	2	D = 36" LC = 65'	25.46 25.41	25.45 25.51	32.28
NM1 Center Drive	857+36	RCP	1	D = 42"	24.43	-	33.15

TABLE 3

DESCRIPTION OF OUTLET STRUCTURES IN RESACA DE LA GUERRA

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
RG24	35+20	RCP Outlet	1	5.8' X 5.8'	-	20.03	20.03	20.03
		Drop Structure	1	D = 30"	15.70	15.91	-	26.00
				LC = 42'				
RG23	39+60	RCP	3	D = 30"	17.98	18.35	20.03	25.55
Morningside Rd.		40+00		LC = 60'				
RG22	82+ 80	RCP	1	D = 15"	20.55	-	20.30	26.64
	83+60		2	D = 30"	16.95	16.95		
				LC = 75'				
RG21	145+40	Bridge	1	LB = 21'	16.90	17.80	20.30	27.50
	145+70			WB = 34'				
				HB = 8'				
RG20	168+70	RCP	3	D = 42"	16.09	16.91	20.03	27.50
Billy Mitchell	170+10			LC = 146'				
RG19	186+00	Box Culvert	2	10' X 8'	14.44	14.44	20.03	27.66
Boca Chica	186+88			LC = 88.75'				
		Weir	1	LW = 52'	14.44	21.98	21.98	21.98
RG18	282+48	RCP	1	D = 70"	16.72	13.76	21.98	28.53
14th St.	283+92			LC = 144'				
		Weir	1	LW = 28'	13.76	22.65	22.65	22.65
RG17	308+92	Box Culvert	1	10' X 8'	20.35	19.92	22.65	27.22
	309+56			LC = 64'				
RG16	318+36	RR Bridge		LB = 84'	17.84	17.84	22.65	29.72
				WB = 9.0'				
				HB = 8.9'				
RG15	397+ 96	Box Culvert	2	8' X 8'	20.63	20.63	22.65	30.34
	398+60			LC = 64'				
RG14	406+60	Spillway	1	LW = 9'	19.40	25.25	26.06	25.25
	406+95							
RG13	492+15	CGMP	1	D = 36"	21.51	21.24	26.06	29.34
Palo Verde Rd.	493+01			LC = 86'				

TABLE 3 (CONT'D)

DESCRIPTION OF OUTLET STRUCTURES IN RESACA DE LA GUERRA

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
RG12 Hwy 1847	526+41 527+53	RCP	1	D = 52" LC = 112'	19.56	19.48	26.06	26.25
RG12A	536+03	Weir	1	LW = 16'	-	27.89	27.89	27.89
RG11	541+73	RR Bridge	1	LB = 43' WB = 9' HB = 5.5'	23.35	23.35	27.89	31.90
RG10	566+33 566+98	RCP	2	D = 30" LC = 64.7'	24.47 24.23	24.49 23.88	27.89	29.76
RG9	595+58 596+32	RCP	2	D = 52" LC = 73.5'	22.71 22.66	23.56 23.28	27.89	31.08
RG8	606+72	Spillway	1	LW = 19'	25.33	28.80	28.80	28.80
RG7 U.S. 83 & 77	611+68 615+21	Box Culvert	1	5' X 5' LC = 353'	22.50	22.50	28.80	-
RG6 Central Blvd.	632+01 633+16	RCP	1	D = 48" LC = 115'	23.69	23.09	28.80	33.29
RG5	635+96 636+23	Box Culvert	1	20' X 8' LC = 27'	26.51	26.51	28.80	36.02
RG4F	637+96 638+92	RCP	1	D = 42" LC = 96'	25.04	24.15	28.80	36.02
RG4E	661+72 662+72	CGMP	1	D = 24" LC = 100'	28.39	28.66	28.80	31.82
RG4D	663+82 664+82	CGMP	1	D = 24" LC = 100'	28.69	28.85	28.80	31.70
RG4C	672+82 673+87	CGMP	1	D = 24" LC = 105'	28.34	28.34	28.80	32.12
RG4B	674+87 675+87	CGMP	2	D = 18" LC = 100'	27.67 26.79	28.39 28.99	28.80	32.57
RG4A	695+07 695+27	RCP	1	D = 24" LC = 20'	28.40	27.77	28.80	33.46

TABLE 3 (CONT'D)

DESCRIPTION OF OUTLET STRUCTURES IN RESACA DE LA GUERRA

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
RG3	709+27	Bridge	1	LB = 105' WB = 9' HB = 12.26'	26.87	26.87	28.80	42.13
RG2A Mercedes Rd.	733+27	Weir	1	LW = 6'	28.00	28.00	28.80	28.00
RG2	762+67 763+25	RCP	2	D = 30" LC = 58' D = 24" LC = 45'	26.10 25.93	26.25 27.09	28.80	33.77
RG1 F. M. 802	768+05 769+10	RCP	1	D = 42" LC = 105'	25.30	25.30	28.80	35.70
Y6	787+10 787+45	RCP	2	D = 18" LC = 35'	26.94	26.94	28.80	32.54
Y4	832+90 833+20	Road (No Pipes)			-	32.33	32.323	32.33
Y3	869+20 870+10	RCP With Gate	1	D = 36" LC = 90'	24.52	27.41	32.33	34.85
Y2	896+10 896+95		1	D = 18" LC = 85'	32.28	32.24	32.33	34.40
Y1	933+60 933+80	PVC	2	D = 12" LC = 20'	31.86	32.02	32.33	34.40

TABLE 4
DESCRIPTION OF CHANNEL STRUCTURES IN
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	TOP OF STRUCTURE
CC18 Highway 48	79+79	Bridge	1	LB = 68' WB = 42' HB = 13'	-0.76	-0.76	13.33
CC17 Mopac RR	99+93	RR Bridge	1	LB = 59' WB = 14' HB = 13.6'	0.26	0.26	16.33
CC16 FM 511	109+23	Bridge	1	LB = 67' WB = 54' HB = 6.5'	-0.70	-0.70	16.79
CC15 Harbor Road	116+48	Bridge	1	LB = 129' WB = 105' HB = 17.5'	1.59	1.59	20.15
CC14 FM802	163+80	Bridge	1	LB = 100' WB = 43' HB = 20'	1.14	1.14	22.34
CC13 Highway 48	182+07	Bridge	1	LB = 86' WB = 38' HB = 14'	2.96	2.96	18.56
CC12	205+46	RR Bridge	1	LB = 70' WB = 9' HB = 14.2'	4.16	4.16	20.85
CC11 FM 802	228+80	Bridge	1	LB = 119.6' WB = 40' HB = 11'	4.37	4.37	18.89
CC10 Central Avenue	238+87	Bridge	1	LB = 32' WB = 27' HB = 10.5'	5.40	5.00	17.10
CC9 Robindale Ave.	279+84	Bridge	1	LB = 77' WB = 32.2' HB = 14.6'	5.27	5.27	21.62
CC8 Flume	297+00	Bridge	1	LB = 75' WB = 7.5' HB = 10.9'	4.41	4.41	20.86

TABLE 4 (CONT'D)
DESCRIPTION OF CHANNEL STRUCTURES IN
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	TOP OF STRUCTURE
CC7 Old Port Isabel	299+89	Box Culvert	2	10' X 9' LC = 20'	6.50	6.50	19.00
CC6 Dana Road	325+40	Bridge	1	LB = 30.5' WB = 20' HB = 11.9'	6.40	6.80	19.90
CC5 Paredes Line Rd.	393+27	Bridge	1	LB = 74.5' WB = 46' HB = 14.1'	8.23	8.23	24.02
CC4 S. Pac. RR	404+96	RR Bridge	1	LB = 45.5' WB = 19.5' HB = 11.0'	8.67	8.67	21.65
CC3 U.S. 77/83	489+55	Box Culvert	1	6' X 6' LC = 295'	13.46	18.65	29.76
CC2	514+93	Box Culvert	1	10' X 8' LC = 15'	18.38	18.38	29.76
CC1 FM 3248	576+50	RCP	1	D = 48" LC = 99'	16.18	18.95	28.58

TABLE 5

DESCRIPTION OF OUTLET STRUCTURES IN RESACA DEL RANCHO VIEJO

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE		NORMAL WATER SURFACE	TOP OF STRUCTURE
					D/S	U/S		
RY41	10+00	Box Culvert	2	5' X 5' LC = 40'	5.78	6.83	6.83	14.57
RY37	91+00	Steel	1	D = 18" LC= 29'	10.79	11.60	11.60	13.30
RY36 FM 511	115+50	Bridge	1	LB = 168' WB = 46' HB = 13.5'	6.10	-	11.60	23.16
RY35B	121+50	RCP	1	D = 30" LC = 50'	9.38	-	11.60	19.90
RY35A	122+05	Drop Structure	1	D = 3.5" LW = 11.0'	-	17.16		
RY34	153+50	Structure Removed						
RY33	160+50	CGMP	1	D = 60" LC = 59'	9.68	11.18	17.17	19.80
RY32B	275+50	Structure Removed						
RY32A Old Port Isabel	308+50	Wooden Bridge	1	L B= 17' WB = 20' HB = 11.6'	10.00	-	17.17	23.58
RY31B	350+50	RCP	1	D = 52" LC = 32'	10.63	11.27	17.17	20.22
RY31A	350+87	Lift Gate	1	LW = 7'	11.27	16.11	17.17	16.11
RY30B	370+50	RCP	1	D = 60" LC = 33'	11.40	11.70	17.17	20.51
RY30A	371+15	Lift Gate	1	LW = 7'	11.70	17.50	17.50	17.50
RY29 Dana Road	457+50	RCP With Gate Open	1	D = 60" LC = 86'	10.83	10.95	17.50	20.36
RY28B	506+50	RCP	1	D = 60" LC = 35'	18.86	11.45	15.38	18.42

TABLE 5 (CONT'D)

DESCRIPTION OF OUTLET STRUCTURES IN RESACA DEL RANCHO VIEJO

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
RV28A	506+95	Lift Gate	1	LW = 8.0'	11.45	18.95	15.38	18.95
RV27 Paredes Rd.	584+50	RCP	2	D = 36" LC = 306'	11.51 12.02	15.11 19.73	15.38	27.12
RV26	591+50	RR Bridge	1	LB = 193' WB = 9' HB = 10.1'	15.29	-	16.41	28.92
RV2B	595+50	Box Culvert	3	5' X 2' LC = 65'	14.03	14.05	16.41	20.48
RV25A	596+23	Drop Structure With Lift Gates	1	28' X 8'	14.05	17.50	17.50	17.50
RV24	613+50	RCP	2	D = 72" LC = 81'	13.37 13.39	12.81 13.23	17.50	25.53
RV23 Trail North Drive	650+50	RCP	2	D = 72" LC = 38'	13.20 13.08	12.80 12.63	17.50	25.89
RV22	688+50	RCP	2	D = 72" LC = 80'	13.53	13.32	17.50	24.72
RV21 Duncan Road	732+50	RCP	2	D = 36" LC = 25'	15.67 15.40	15.52 15.55	17.50	22.47
RV20	747+50	RCP	1	D = 24" LC = 24'	16.81	17.00	17.50	22.91
RV19 Highway 77	859+00	RCP	2	D = 72" LC = 270'	16.81	16.91	20.50	30.58
RV18 Access Road	862+00	Bridge	1	LB = 146' WB = 35' HB = 12.7'	17.90	-	20.50	31.58
RV17	881+00	RR Bridge	1	LB = 151' WB = 10' HB = 13.0'	20.11	-	-	34.13
RV16B Sandy Hill Dr.	907+00	Box Culvert	1	6' X 5' LC = 63'	18.47	18.51	24.50	25.97

TABLE 5 (CONT'D)

DESCRIPTION OF OUTLET STRUCTURES IN RESACA DEL RANCHO VIEJO

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
RV16A	907+75	Drop Structure	1	5' X 5'	18.51	24.50	24.50	24.50
RV15	969+00	RCP	1	D = 60" LC = 110'	20.01	20.66	24.50	31.85
RV14	981+00	RCP	1	D = 60" LC = 103'	21.14	21.50	24.50	32.25
RV13	1001+00	CGMP	1	D = 48" LC = 21'	22.40	24.25	24.50	27.60
RV12	1002+50	RCP	1	D = 24" LC = 33'	24.13	24.40	24.50	27.95
RV11	1096+50	CGMP	1	D = 72" LC = 23'	22.94	23.00	24.50	29.59
RV10	1120+50	RCP	1	D = 36" LC = 64'	21.44	21.32	24.50	30.47
RV8	1176+50	CGMP	1	54" X 37" Arch Pipe LC = 23'	27.74	27.38	27.75	32.08
RV7B	1281+50	CGMP	2	D = 30" LC = 25'	27.62 27.24	25.98 26.12	27.75	32.19
RV7A	1284+50	CGMP	2 1	D = 36" D = 30"	21.80 -	21.80 -	27.75	26.80
RV6B FM 1732	1364+50	RCP	1	-	-	-	27.75	30.70
RV6A	1370+00	RCP	1	-	-	-	27.75	26.80
RV5 Casa Grande	1463+00	Bridge	1	L B = 23' HB = 14.3' WB = 25'	19.2	-	27.75	-
RV4C Balboa		Bridge	1	L B = 23' HB = 14.3' WB = 25'	19.2	-	27.75	-

TABLE 5 (CONT'D)

DESCRIPTION OF OUTLET STRUCTURES IN RESACA DEL RANCHO VIEJO

STRUCTURE NO.	STATION	TYPE	NUMBER	SIZE	FLOW LINE D/S	FLOW LINE U/S	NORMAL WATER SURFACE	TOP OF STRUCTURE
RV4B Pizorro		Bridge	1	LB = 23' HB = 14.3' WB = 25'	19.2	-	27.75	-
RV4A		Bridge	1	LB = 23' HB = 14.3' WB = 25'	18.3	-	27.75	30.5
RV3 Carmen	1603+00	Bridge	1	LB = 23' HB = 14.3' WB = 25'	19.1	-	27.75	33.0
RV2I		Bridge	1	LB = 23' HB = 14.3' WB = 25'	19.1	-	27.75	32.9
RV2H		Bridge	1	LB = 23' HB = 14.3' WB = 25'	18.3	-	27.75	32.8
RV 2G Escondon		Bridge	1	LB = 23' HB = 14.3' WB = 25'	19.6	-	27.75	33.1
RV2F	1739+00	Embankment			-	-	-	-
RV2E		No Structure			-	-	-	-
RV2D		CGMP	1	D = 4' LC = 20'	-	-	-	-
RV2C								
RV2B		Embankment						
RV2A		CGMP	1	D = 30" LC = 40'	-	-	-	-
RV1	1829+00	RCP	2	D = 6' LC = 80'	-	-	-	-

The upstream end of the watershed starts at U.S. Highway 281 on the west and extends southeasterly through the City to join Resaca de la Guerra. From this point, the North Main Drain channel continues eastward past the airport and then north to the Brownsville Ship Channel. The extent of this watershed is illustrated on the map in Plate 3 in Volume II.

3. Resaca de la Guerra

The Resaca de la Guerra watershed covers approximately 3,100 acres and is almost 15 miles along. Its western end is near F.M. 3248, and it extends to near F.M. 1419 (Southmost Road) on the east. It has been subdivided and analyzed in 40 sub-watersheds. The drainage area for this resaca subsystem is shown on Plate 4, Volume II.

Resaca de la Guerra, North Main Drain, and Town Resaca are highly interrelated hydraulically for large storm events. Tailwater or water surface elevation conditions at the downstream confluence along North Main Drain affect the performance of each of the three subsystems. The North Main Ditch and Resaca de la Guerra watershed divide is overtopped in several areas during large floods, and stormwater flows are exchanged between the two subsystems depending on their relative stages.

4. Cameron County Drainage District No. 1 Ditch

This ditch lies to the north of the City of Brownsville and drains a watershed of approximately 13,268 acres. It is north of the Resaca de la Guerra watershed and south of Resaca del Rancho Viejo. The length of this ditch is about 11.5 miles, and it extends from F.M. 3248 on the west to the Rancho Viejo floodway on the east.

The area covered by this subsystem is identified on the map in Plate 5, Volume II. This watershed has been divided into 19 sub-watersheds for run-off analyses.

5. Resaca del Rancho Viejo

This is the most northerly of the five principal drainage subsystems in the study area. This watershed has a drainage area of approximately 13,824 acres, which has been analyzed in 37 sub-watersheds. This drainage system, as analyzed, extends from its upstream end west of Olmito and continues easterly for a distance of about 32.6 miles until it reaches Cameron County Drainage District No. 1 Ditch.

D. Stormwater Pumping Stations

Four major stormwater pumping stations exist within the City Limits of Brownsville. These are:

1. The Amigoland Pump Station, which is located on the Rio Grande levee south of Amigoland Mall, has a rated capacity of 36,000 gallons per minute (g.p.m.) [80 cubic feet per second (c.f.s.)] and drains the areas south of the old levee. This is an automatic pump with two auxiliary diesel engines;

2. The 12th and Mexico Street Pump Station, located near the B&M Railroad bridge into Mexico, drains the sag point area of these streets and has a rated capacity of 15,000 g.p.m. (33.5 c.f.s.). It is automatically operated. This station has three pumps, two of which have auxiliary diesel engines;

3. The 12th and Fronton Street Pump Station is located across the Rio Grande levee from this intersection. This pump station has a capacity of 12,000 g.p.m. (26.8 c.f.s.), produced by two electric pumps and is manually operated. This pump station serves the bus depot area and the southeast corner of the downtown area; and,

4. The Impala Pump Station is the major pump station in the City's drainage system. It is located at the end of Impala Street at the Rio Grande levee. It has a total capacity of 162,000 g.p.m. (362 c.f.s.) and is automatically operated. This pump discharges floodwaters from the Town Resaca and the North Main Drain subsystems. Pictures of this pump station can be seen in Figure 5, Volume I.

The locations of these four stormwater pump stations are shown on Plate 7a, Volume II.

Other pumping facilities exist throughout the City on many of the smaller, isolated lakes, ponds, and resacas. These smaller pumps were not analyzed as a part of the major watershed systems because their capacities are very small when compared to the large volumes of floodwater generated by the major storms used in this study.

E. Storm Sewer Facilities

An extensive storm sewer inventory has been made to locate and determine pertinent hydraulic data on main storm sewer trunks within the City Limits.

This inventory included data on 275 trunks throughout the City. These data are presented in Table 6, Volume I.

TABLE 6
STORM SEWER TRUNK INVENTORY AND ANALYSIS SUMMARY

TRUNK NO.	PLNG. DIST. NO.	TOTAL DRAINAGE AREA (acres)	ANALYSIS STORM FREQUENCY (years)	DESIGN DISCHARGE (cfs)	REQUIRED PIPE SIZE AT OUTLET	ACTUAL PIPE SIZE AT OUTLET	ACTUAL DISCHARGE CAPACITY (cfs)	ACTUAL PIPE PERCENT OF REQUIRED CAPACITY (%)
TR0301	1	5.30	5	17	1 @ 33"	1 @ 24"	8	47%
TR0302	1	21.50	5	45	2 @ 54"	1 @ 42"	14	31%
TR0401	1	31.42	5	81	1 @ 54"	1 @ 24"	12	15%
TR0402	1	11.16	5	36	1 @ 42"	1 @ 24"	10	28%
TR0501	1	56.30	25	305	3 @ 60"	1 @ 24"	9	3%
TR0601	1	58.96	25	324	3 @ 60"	1 @ 42"	54	17%
TR0701	1	68.82	25	236	5 @ 60"	1 @ 18"	2	1%
TR0801	1	35.72	5	90	1 @ 60"	1 @ 30"	17	19%
TR0901	1	22.17	5	61	2 @ 54"	1 @ 20"	3	5%
FB01	2	23.41	25	193	2 @ 54"	1 @ 18"	5	3%
RRS0201	2	6.57	25	60	1 @ 27"	1 @ 18"	21	35%
RRS0202	2	20.84	25	129	1 @ 60"	1 @ 36"	42	33%
RRS0203	2	105.32	25	447	3 @ 60"	1 @ 42"	79	18%
TR2001A	2	107.32	25	621	4 @ 72"	1 @ 36"	42	7%
TR2001B	2	17.01	25	101	1 @ 54"	1 @ 36"	49	49%
TR2001D	2	5.72	25	50	1 @ 42"	1 @ 12"	2	4%
TR2002	2	54.74	25	414	2 @ 60"	1 @ 38"	108	26%
NM0101	3	101.38	25	359	2 @ 60"	1 @ 36"	71	20%
NM0102	3	46.33	10	135	2 @ 54"	1 @ 24"	9	7%
RRS0301	3	25.78	5	73	1 @ 54"	1 @ 36"	32	44%
NM0103	3	28.86	5	79	1 @ 48"	1 @ 24"	18	23%
CC0441	4	21.59	5	73	1 @ 42"	1 @ 42"	118	162%
CC0442	4	28.96	5	88	1 @ 48"	1 @ 42"	139	158%
NM1401	5	34.96	25	134	1 @ 60"	1 @ 60"	199	149%
NM1402	5	86.51	10	199	3 @ 54"	1 @ 30"	21	11%
NM1403	5	22.76	5	69	1 @ 42"	1 @ 18"	10	14%
NM1404	5	79.19	10	298	1 @ 60"	1 @ 30"	53	18%
NM1405	5	3.43	25	31	1 @ 33"	1 @ 18"	8	26%
NM1406	5	7.35	25	68	1 @ 39"	1 @ 18"	10	15%
NM1407	5	41.28	25	294	8 @ 60"	1 @ 36"	13	4%
NM1408	5	21.58	25	176	2 @ 60"	1 @ 36"	42	24%
TR3601	5	10.45	5	32	1 @ 42"	1 @ 12"	1	3%
TR3602	5	31.16	5	77	1 @ 42"	2 @ 21"	36	47%
TR4101A	5	4.41	5	13	1 @ 42"	1 @ 24"	4	31%
TR4101B	5	6.17	5	20	1 @ 36"	1 @ 24"	8	40%
TR4601	5	11.94	5	36	1 @ 33"	1 @ 18"	8	22%
TR1601	6	5.01	5	11	1 @ 27"	1 @ 10"	1	9%
TR1602	6	28.47	5	64	1 @ 54"	1 @ 10"	1	2%
TR1701A	6	30.57	5	79	2 @ 54"	1 @ 42"	45	57%
TR1701B	6	6.15	5	20	1 @ 33"	1 @ 12"	1	5%
TR1701C	6	14.80	5	46	1 @ 33"	1 @ 12"	3	7%
TR1801	6	61.49	10	218	3 @ 54"	1 @ 12"	2	1%

TABLE 6 (CONT'D)
STORM SEWER TRUNK INVENTORY AND ANALYSIS SUMMARY

TRUNK NO.	PLNG. DIST. NO.	TOTAL DRAINAGE AREA (acres)	ANALYSIS STORM FREQUENCY (years)	DESIGN DISCHARGE (cfs)	REQUIRED PIPE SIZE AT OUTLET	ACTUAL PIPE SIZE AT OUTLET	ACTUAL DISCHARGE CAPACITY (cfs)	ACTUAL PIPE PERCENT OF REQUIRED CAPACITY (%)
TR2004	6	6.83	25	50	1 @ 33"	1 @ 18"	11	22%
TR2005	6	6.04	25	39	1 @ 42"	1 @ 18"	4	10%
TR2006	6	3.13	25	24	1 @ 36"	1 @ 12"	2	8%
TR2201	6	20.13	5	68	1 @ 33"	1 @ 18"	14	21%
TR2202	6	32.14	5	96	1 @ 60"	1 @ 14"	2	2%
TR2601	6	8.11	5	26	1 @ 36"	1 @ 18"	4	15%
TR2602	6	5.64	5	18	1 @ 33"	1 @ 18"	4	22%
TR2901A	6	193.42	25	864	11 @ 60"	1 @ 48"	45	5%
TR2901E	6	17.31	25	65	1 @ 48"	1 @ 18"	5	8%
TR2901F	6	22.92	5	56	1 @ 42"	1 @ 12"	2	4%
TR2901H	6	30.80	5	133	2 @ 48"	1 @ 18"	6	5%
TR2902	6	49.03	10	135	2 @ 60"	1 @ 30"	12	9%
NM2101	7	92.14	10	260	3 @ 54"	1 @ 36"	31	12%
NM2102	7	48.03	10	187	2 @ 60"	1 @ 24"	10	5%
NM2301A	7	47.03	10	222	3 @ 54"	1 @ 54"	85	38%
TR1101	7	25.71	25	126	2 @ 54"	1 @ 24"	14	11%
TR1201	7	71.45	25	433	3 @ 60"	1 @ 24"	15	3%
TR1301	7	14.92	25	86	1 @ 48"	1 @ 24"	26	30%
TR1302	7	40.84	25	218	2 @ 54"	1 @ 24"	22	10%
TR1401	7	17.42	25	96	3 @ 60"	1 @ 14"	1	1%
TR1402	7	6.83	25	60	1 @ 60"	1 @ 14"	2	3%
TR2901B	8	16.82	25	95	1 @ 60"	1 @ 18"	4	4%
TR2901C	8	14.26	25	67	2 @ 42"	1 @ 20"	5	7%
TR2901D	8	10.20	5	32	1 @ 42"	1 @ 18"	7	22%
TR3301A	8	223.05	25	608	6 @ 60"	1 @ 42"	42	7%
TR3303	8	15.86	25	54	1 @ 42"	1 @ 36"	38	70%
TR3304A	8	85.12	25	351	2 @ 60"	1 @ 15"	5	1%
TR3304B	8	22.97	25	90	1 @ 48"	1 @ 14"	5	6%
TR3304C	8	11.93	25	84	1 @ 48"	1 @ 14"	4	5%
NM0501	9	16.28	5	53	2 @ 48"	1 @ 18"	2	4%
NM0601	9	14.29	5	46	1 @ 36"	1 @ 24"	18	39%
NM0602	9	4.04	5	12	1 @ 27"	1 @ 24"	9	75%
NM0603	9	7.49	5	22	1 @ 36"	1 @ 24"	9	41%
TR4301	9	61.87	10	207	3 @ 60"	1 @ 24"	9	4%
TR4401	9	23.45	5	61	1 @ 54"	1 @ 36"	28	46%
TR4402	9	27.44	5	83	2 @ 60"	1 @ 18"	2	2%
TR4501	9	8.89	5	29	1 @ 42"	1 @ 14"	2	7%
CC1305	10	31.81	25	215	2 @ 60"	1 @ 42"	54	25%
CC1306	10	53.9	25	319	3 @ 60"	2 @ 39"	84	26%
CC1307	10	60.28	25	316	4 @ 60"	2 @ 24"	16	5%
CC1308	10	60.6	25	358	4 @ 60"	1 @ 42"	42	12%
CC1310	10	29.72	25	191	3 @ 54"	1 @ 24"	10	5%

TABLE 6 (CONT'D)
STORM SEWER TRUNK INVENTORY AND ANALYSIS SUMMARY

TRUNK NO.	PLNG. DIST. NO.	TOTAL DRAINAGE AREA (acres)	ANALYSIS STORM FREQUENCY (years)	DESIGN DISCHARGE (cfs)	REQUIRED PIPE SIZE AT OUTLET	ACTUAL PIPE SIZE AT OUTLET	ACTUAL DISCHARGE CAPACITY (cfs)	ACTUAL PIPE PERCENT OF REQUIRED CAPACITY (%)
CC1311	10	148.31	25	443	10 @ 60"	1 @ 60"	47	11%
CC1312	10	16.68	25	111	1 @ 60"	1 @ 24"	11	10%
CC1313	10	32.76	5	97	1 @ 60"	1 @ 30"	25	26%
CC1314	10	30.73	25	162	2 @ 54"	1 @ 24"	10	6%
CC1315	10	29.66	25	211	3 @ 60"	1 @ 30"	14	7%
CC1316	10	27.84	25	181	3 @ 54"	1 @ 18"	4	2%
CC1317	10	8.52	25	51	1 @ 48"	1 @ 24"	25	49%
CC1318	10	5.44	25	42	1 @ 42"	1 @ 18"	4	10%
CC1319	10	7.05	25	54	1 @ 48"	1 @ 18"	4	7%
MN3306	10	50.83	25	277	3 @ 60"	1 @ 42"	38	14%
NM3302	10	29.89	25	190	2 @ 60"	1 @ 30"	17	9%
NM3303	10	24.9	25	168	2 @ 60"	1 @ 24"	9	5%
NM3304	10	10.58	25	69	1 @ 54"	1 @ 36"	28	41%
NM3305	10	58.45	25	321	3 @ 60"	1 @ 42"	42	13%
NM3307	10	47.39	25	244	3 @ 60"	1 @ 48"	60	25%
NM3308	10	78.9	25	480	4 @ 60"	1 @ 48"	69	14%
NM3309	10	145.72	25	635	11 @ 60"	1 @ 48"	34	5%
NM3310	10	13.15	25	94	1 @ 54"	1 @ 24"	12	13%
NM3311	10	26.30	25	164	2 @ 60"	1 @ 42"	42	26%
NM3312	10	35.00	25	215	1 @ 60"	1 @ 24"	22	10%
NM3313	10	133.41	25	760	11 @ 60"	1 @ 36"	19	3%
NM1301A	11	85.25	25	539	5 @ 60"	1 @ 48"	60	11%
NM1301B	11	17.67	25	160	1 @ 54"	1 @ 24"	19	12%
NM1402	11	31.25	25	287	3 @ 60"	1 @ 30"	19	7%
RG3101	11	2.91	5	9	1 @ 27"	1 @ 12"	1	11%
RG3102	11	25.19	5	81	3 @ 60"	1 @ 18"	1	1%
RG3103	11	7.71	25	71	1 @ 54"	1 @ 24"	9	13%
CC0701	12	6.78	5	21	1 @ 36"	1 @ 18"	4	19%
CC0702	12	3.47	5	11	1 @ 27"	1 @ 24"	9	82%
CC0703	12	32.99	5	86	1 @ 60"	1 @ 30"	18	21%
NM1601	12	14.29	5	45	1 @ 48"	1 @ 30"	13	29%
NM1801A	12	71.45	10	38	2 @ 54"	1 @ 36"	33	87%
NM1801B	12	46.62	10	149	3 @ 60"	1 @ 18"	2	1%
NM1802	12	12.04	5	35	1 @ 48"	1 @ 36"	54	154%
NM1901A	12	20.02	5	49	1 @ 48"	1 @ 30"	17	35%
NM1901B	12	3.88	5	13	1 @ 27"	1 @ 18"	6	46%
NM1902	12	3.36	5	11	1 @ 30"	1 @ 18"	3	27%
RG2101	12	4.86	5	16	1 @ 42"	1 @ 24"	5	31%
RG2601	12	29.44	5	51	4 @ 60"	1 @ 24"	1	2%
RG2602	12	20.78	5	65	2 @ 60"	1 @ 36"	9	14%
RG2603	12	7.27	5	24	1 @ 36"	1 @ 24"	10	42%
RG2604	12	21.34	5	69	1 @ 54"	1 @ 24"	9	13%

TABLE 6 (CONT'D)

STORM SEWER TRUNK INVENTORY AND ANALYSIS SUMMARY

TRUNK NO.	PLNG. DIST. NO.	TOTAL DRAINAGE AREA (acres)	ANALYSIS STORM FREQUENCY (years)	DESIGN DISCHARGE (cfs)	REQUIRED PIPE SIZE AT OUTLET	ACTUAL PIPE SIZE AT OUTLET	ACTUAL DISCHARGE CAPACITY (cfs)	ACTUAL PIPE PERCENT OF REQUIRED CAPACITY (%)
RG2605	12	20.41	5	66	1 @ 48"	1 @ 24"	12	18%
RG2901	12	86.91	10	283	6 @ 60"	1 @ 36"	15	5%
RG2902	12	3.93	5	13	1 @ 27"	1 @ 18"	5	38%
RG2903	12	5.80	5	19	1 @ 33"	1 @ 18"	4	21%
RG3001	12	33.59	5	109	1 @ 48"	1 @ 18"	9	8%
NM2401	13	11.79	5	38	1 @ 42"	1 @ 24"	10	26%
NM2402	13	24.21	5	78	1 @ 48"	1 @ 36"	38	49%
NM2403	13	25.49	5	82	2 @ 48"	1 @ 18"	3	4%
NM2404	13	49.29	10	169	2 @ 54"	1 @ 24"	13	8%
NM2405	13	23.00	5	69	1 @ 54"	1 @ 24"	8	12%
NM2406	13	38.04	25	280	2 @ 60"	1 @ 42"	62	22%
NM2407	13	5.43	5	23	1 @ 30"	1 @ 24"	15	65%
NM2409	13	45.77	10	138	10 @ 60"	1 @ 36"	4	3%
NM2410	13	13.99	5	60	1 @ 42"	1 @ 24"	14	23%
NM2411	13	14.10	5	46	1 @ 42"	1 @ 24"	14	30%
NM2501	13	63.15	10	216	2 @ 60"	1 @ 30"	21	10%
NM2601	13	109.40	25	370	4 @ 60"	1 @ 24"	10	3%
TR0101	13	54.51	10	145	3 @ 54"	1 @ 48"	45	31%
TR0102	13	14.29	25	110	2 @ 48"	1 @ 18"	4	4%
TR0103	13	4.85	25	37	1 @ 42"	1 @ 18"	4	11%
TR0104	13	6.35	25	49	1 @ 48"	1 @ 18"	4	8%
TR0106	13	1.98	25	14	1 @ 36"	1 @ 36"	112	800%
TR0107	13	26.59	25	213	3 @ 54"	1 @ 24"	9	4%
TR0201	13	97.63	10	262	3 @ 60"	1 @ 36"	25	10%
TR0202	13	8.37	5	27	1 @ 36"	1 @ 12"	1	4%
TR1001	13	1.95	25	14	1 @ 24"	1 @ 24"	39	279%
TR1002	13	2.98	25	28	1 @ 24"	1 @ 24"	32	114%
TR1003	13	6.02	25	55	1 @ 30"	1 @ 24"	33	60%
TR1004	13	19.14	25	176	1 @ 48"	1 @ 18"	15	9%
TR4801	13	14.50	5	42	1 @ 48"	1 @ 30"	13	31%
TR4802	13	41.17	5	78	2 @ 60"	1 @ 24"	4	5%
TR4803	13	6.65	5	20	1 @ 39"	1 @ 24"	6	30%
TR4804	13	28.57	5	88	1 @ 54"	1 @ 30"	23	26%
TR4805	13	27.59	5	85	1 @ 48"	1 @ 24"	16	19%
TR4806	13	18.44	5	60	6 @ 60"	1 @ 24"	1	2%
NM2501	14	4.39	5	14	1 @ 30"	1 @ 24"	8	57%
NM2502	14	4.50	5	15	1 @ 27"	1 @ 24"	12	80%
NM32A01	14	36.67	5	110	1 @ 60"	1 @ 24"	11	10%
NM32A02	14	3.42	5	11	1 @ 18"	1 @ 18"	19	173%
NM32A03	14	5.18	5	17	1 @ 18"	1 @ 18"	19	112%
NM32B01	14	9.77	5	31	1 @ 30"	1 @ 18"	8	26%
NM32B02	14	3.27	5	11	1 @ 24"	1 @ 24"	24	218%

TABLE 6 (CONT'D)
STORM SEWER TRUNK INVENTORY AND ANALYSIS SUMMARY

TRUNK NO.	PLNG. DIST. NO.	TOTAL DRAINAGE AREA (acres)	ANALYSIS STORM FREQUENCY (years)	DESIGN DISCHARGE (cfs)	REQUIRED PIPE SIZE AT OUTLET	ACTUAL PIPE SIZE AT OUTLET	ACTUAL DISCHARGE CAPACITY (cfs)	ACTUAL PIPE PERCENT OF REQUIRED CAPACITY (%)
RG1501	14	3.70	5	12	1 @ 33"	1 @ 24"	6	50%
CC0704A	15	40.35	10	124	3 @ 48"	1 @ 42"	30	24%
CC0704B	15	22.90	5	73	1 @ 54"	1 @ 30"	18	25%
NM2001	15	6.65	25	43	1 @ 48"	1 @ 24"	9	21%
NM2003	15	7.16	25	51	2 @ 48"	1 @ 30"	10	20%
NM2004	15	16.08	25	122	1 @ 54"	1 @ 36"	55	45%
NM2005	15	63.75	25	535	7 @ 60"	1 @ 30"	14	3%
NM2006	15	89.99	10	341	4 @ 60"	1 @ 30"	17	5%
RG2101	15	14.23	5	45	1 @ 54"	1 @ 30"	13	29%
RG2102	15	30.26	5	83	1 @ 60"	1 @ 30"	17	20%
RG2103	15	12.53	5	40	1 @ 42"	1 @ 24"	9	23%
RG2104	15	5.51	5	18	1 @ 24"	1 @ 24"	28	50%
RG2105A	15	6.10	5	56	2 @ 54"	1 @ 24"	4	22%
RG2105B	15	6.10	5	20	1 @ 42"	1 @ 30"	8	40%
RG2105C	15	6.10	5	20	1 @ 48"	1 @ 24"	4	20%
RG2201	15	37.06	5	119	1 @ 48"	1 @ 24"	10	8%
RG2401	15	198.35	25	531	5 @ 60"	1 @ 42"	47	9%
CC0403	17	3.86	5	13	1 @ 27"	1 @ 24"	10	77%
CC0404	17	4.78	5	15	1 @ 30"	1 @ 24"	11	73%
CC0405	17	3.16	5	10	1 @ 24"	1 @ 18"	5	50%
CC0406	17	2.83	5	9	1 @ 24"	1 @ 18"	5	56%
CC0407	17	2.02	5	7	1 @ 24"	1 @ 18"	5	71%
CC0408	17	52.77	10	152	4 @ 60"	1 @ 36"	13	9%
CC0409	17	21.05	5	68	1 @ 60"	1 @ 30"	13	19%
CC0410	17	19.50	5	63	1 @ 48"	1 @ 36"	31	49%
CC0411	17	13.21	5	43	1 @ 42"	1 @ 24"	11	26%
CC0412	17	6.98	5	19	1 @ 33"	1 @ 24"	11	58%
CC0413	17	14.69	5	47	1 @ 48"	1 @ 30"	19	40%
CC0414	17	5.41	5	18	1 @ 30"	1 @ 24"	11	61%
CC0415	17	6.43	5	21	1 @ 36"	1 @ 24"	9	43%
CC0416	17	4.08	5	13	1 @ 27"	1 @ 18"	5	38%
CC0417	17	19.69	5	64	1 @ 48"	1 @ 36"	40	63%
CC0418	17	4.26	5	14	1 @ 27"	1 @ 24"	11	79%
CC0419	17	4.66	5	15	1 @ 30"	1 @ 24"	11	73%
CC0420	17	15.53	5	50	1 @ 48"	1 @ 30"	19	38%
CC0421	17	4.70	5	15	1 @ 30"	1 @ 18"	4	27%
CC0422	17	23.91	5	77	1 @ 60"	1 @ 24"	8	10%
CC0423	17	3.78	5	12	1 @ 36"	1 @ 18"	2	17%
CC0424	17	25.42	5	82	1 @ 60"	1 @ 24"	8	10%
CC0425	17	3.74	5	12	1 @ 27"	1 @ 18"	4	33%
CC0426	17	19.17	5	62	1 @ 48"	1 @ 18"	5	8%
CC0427	17	5.95	5	19	1 @ 33"	1 @ 18"	4	21%

TABLE 6 (CONT'D)
STORM SEWER TRUNK INVENTORY AND ANALYSIS SUMMARY

TRUNK NO.	PLNG. DIST. NO.	TOTAL DRAINAGE AREA (acres)	ANALYSIS STORM FREQUENCY (years)	DESIGN DISCHARGE (cfs)	REQUIRED PIPE SIZE AT OUTLET	ACTUAL PIPE SIZE AT OUTLET	ACTUAL DISCHARGE CAPACITY (cfs)	ACTUAL PIPE PERCENT OF REQUIRED CAPACITY (%)
CC0428	17	7.05	5	23	1 @ 36"	1 @ 24"	9	39%
CC0429	17	1.20	5	22	1 @ 24"	1 @ 24"	11	50%
CC0430	17	28.98	5	94	2 @ 60"	1 @ 30"	8	9%
CC0431	17	16.08	5	52	1 @ 48"	1 @ 24"	10	19%
CC0432	17	69.60	10	264	4 @ 60"	1 @ 36"	18	7%
CC0433	17	17.70	5	57	1 @ 48"	1 @ 36"	31	54%
CC0434	17	29.75	5	96	1 @ 60"	1 @ 30"	19	20%
CC0435	17	50.61	10	192	2 @ 60"	1 @ 30"	19	10%
CC0436	17	5.33	5	17	1 @ 30"	1 @ 24"	11	65%
CC0437	17	5.40	5	17	1 @ 30"	1 @ 24"	11	65%
CC0438	17	1.69	5	6	1 @ 21"	1 @ 18"	5	83%
CC0439	17	18.95	5	61	1 @ 54"	1 @ 54"	143	234%
CC0440	17	18.21	5	59	1 @ 42"	1 @ 42"	91	154%
RR0201	18	32.62	25	289	3 @ 60"	1 @ 48"	63	22%
RR0202	18	28.28	25	252	6 @ 54"	1 @ 48"	35	14%
RR0203	18	7.82	25	70	1 @ 54"	1 @ 15"	3	4%
RR0204	18	20.86	25	164	3 @ 54"	1 @ 48"	42	26%
CC1301	20	20.05	5	57	2 @ 54"	1 @ 24"	4	7%
CC1302	20	7.16	5	23	1 @ 27"	1 @ 24"	17	74%
CC1303	20	4.66	5	15	1 @ 30"	1 @ 30"	23	153%
CC1304	20	4.29	5	14	1 @ 30"	1 @ 30"	27	193%
RG1501	20	12.67	5	37	1 @ 42"	1 @ 24"	11	30%
RG1502	20	9.22	5	29	1 @ 48"	1 @ 24"	9	31%
RG1901	20	7.78	5	25	1 @ 36"	1 @ 18"	4	16%
RG1902	20	8.50	5	28	1 @ 36"	1 @ 18"	4	14%
RG1903	20	7.19	5	23	1 @ 36"	1 @ 18"	4	17%
RG1904	20	26.75	5	81	1 @ 54"	1 @ 24"	9	11%
RG1905	20	9.14	5	30	1 @ 42"	1 @ 18"	4	13%
RG1906	20	10.06	5	33	1 @ 36"	1 @ 18"	6	18%
RG1907	20	17.70	5	56	1 @ 48"	1 @ 30"	17	30%
CC0401A	21	60.70	25	214	5 @ 60"	1 @ 36"	12	6%
CC0401B	21	36.73	25	251	3 @ 60"	1 @ 24"	9	4%
NM2602	22	4.29	5	13	1 @ 36"	1 @ 36"	25	192%
NM2605	22	6.65	5	21	1 @ 36"	1 @ 24"	9	43%
NM2606	22	10.57	5	32	1 @ 42"	1 @ 18"	11	34%
NM2701	22	2.31	5	7	1 @ 24"	1 @ 24"	9	129%
NM2702	22	21.34	5	67	1 @ 54"	1 @ 24"	9	13%
NM2703	22	4.11	5	13	1 @ 30"	1 @ 24"	9	69%
NM2704	22	4.88	5	15	1 @ 33"	1 @ 24"	8	53%
NM2705	22	6.02	5	19	1 @ 36"	1 @ 18"	4	21%
NM28A01	22	7.82	5	25	1 @ 30"	1 @ 18"	7	28%
NM28A02	22	8.70	5	28	1 @ 36"	1 @ 18"	5	18%

TABLE 6 (CONT'D)
STORM SEWER TRUNK INVENTORY AND ANALYSIS SUMMARY

TRUNK NO.	PLNG. DIST. NO.	TOTAL DRAINAGE AREA (acres)	ANALYSIS STORM FREQUENCY (years)	DESIGN DISCHARGE (cfs)	REQUIRED PIPE SIZE AT OUTLET	ACTUAL PIPE SIZE AT OUTLET	ACTUAL DISCHARGE CAPACITY (cfs)	ACTUAL PIPE PERCENT OF REQUIRED CAPACITY (%)
NM28B01	22	18.25	5	55	1 @ 48"	1 @ 30"	18	33%
NM28B02	22	21.23	5	61	1 @ 48"	1 @ 30"	21	34%
NM28B03	22	17.55	5	52	1 @ 36"	1 @ 36"	68	131%
NM2901	22	24.72	5	71	1 @ 60"	1 @ 36"	20	28%
TR4807	22	38.12	5	89	1 @ 60"	1 @ 30"	36	40%
TR4809	22	3.41	5	11	1 @ 27"	1 @ 18"	4	36%
TR4808	22	48.48	10	164	2 @ 60"	1 @ 48"	60	37%
RR2301	23	45.98	10	115	1 @ 60"	1 @ 24"	60	52%
RV2301	27	5.29	5	17	1 @ 24"	1 @ 24"	21	123%
RV2302	27	4.70	5	15	1 @ 24"	1 @ 24"	21	138%
RV2303	27	2.35	5	8	1 @ 18"	1 @ 18"	10	132%
RV2304	27	2.37	5	8	1 @ 24"	1 @ 24"	21	273%
RV2305	27	5.40	5	17	1 @ 27"	1 @ 24"	16	94%
NM32A04	31	14.18	5	46	1 @ 30"	1 @ 30"	53	115%

CHAPTER IV

IV. PLANNING AND DESIGN CRITERIA

A. Analysis Criteria

The existing drainage system has been analyzed based on a set of criteria and procedures developed in conjunction with the City Engineering and Planning Departments. These criteria were applied to the major structures in the planning area to determine their adequacy with regard to the storm magnitudes and conditions normally used in prudent engineering design.

The existing system has been analyzed in two portions--the major facilities (resacas and ditches) and the minor facilities (storm sewer trunks).

1. Major Facilities

The major drainage facilities have been analyzed for their ability to convey stormwater run-off for rainfall events with recurrence intervals of 2, 5, 25, and 100 years. These storm magnitudes have provided sufficient spread of results to allow interpolation for other intermediate frequency storms for elevations or flows at various points throughout the drainage subsystems.

The existing major facilities have been analyzed for run-off characteristics as they exist now for present soil conditions and land development. The analysis of future run-off conditions in developing areas have been based on land-use projections obtained from the City of Brownsville Planning Department. The increased land-use density has been represented by an increased value of imperviousness for the sub-watersheds affected.

2. Minor Facilities

The minor system, consisting of the main storm sewer trunks and their contributing drainage areas, has been analyzed as follows:

The Rational Method was used for determination of discharge, and parameter values and procedures found in the "Hydraulic Manual of the Texas Highway Department" (State Department of Highways and Public Transportation) were applied.

Run-off coefficients that were used in analysis of the drainage areas contributing to the existing trunk lines are listed in Table 7 shown below.

TABLE 7
RUN-OFF COEFFICIENTS

TYPE OF AREA OR LAND USE	RUN-OFF COEFFICIENT "C"
Parks or Open Areas	0.35
Residential	0.50
Industrial	0.70
Apartments	0.75
Commercial	0.90
Central Business District	0.90

Initial inlet time was set at 15 minutes for analyses of all the storm sewer trunks except in commercial and industrial areas, where the initial inlet time was set at 10 minutes. This provided for a more conservative (higher intensity) storm flow.

This aided in consistency with future design criteria procedures to require more inlets throughout the City.

More inlets will help to drain the streets and to reduce flooding, as well as paving failure problems.

Storm frequency is the frequency with which a given storm is equaled or exceeded, on the average, once in a period of years. Thus, a 5-year storm would be expected to be equaled or exceeded 20 times in 100 years.

Storm frequencies used for analysis of the storm sewer trunks are shown in Table 8, Volume I.

The existing system has been assumed to be comprised of concrete pipe with a Manning's "n" value of 0.014, unless other material is noted in the field inventory. The values for Manning's "n" for concrete pipe can range from 0.013 to 0.017. The existing system pipes that have been analyzed are older and have more debris and rough joints inside than new pipes. The value of 0.014 was selected to represent this condition and allow rapid comparison with new pipes being designed and evaluated.

TABLE 8
STORM FREQUENCIES USED FOR ANALYSIS

TYPE OF DRAINAGE FACILITIES	DESCRIPTION OF AREA TO BE DRAINED	ADOPTED MINIMUM YEAR DESIGN FREQUENCY
Storm Sewer	Residential-less than 40 acres	5
Storm Sewer	Residential-less than 100 acres and more than 40 acres	10
Storm Sewer	Residential more than 100 acres, or Commercial and Industrial	25
Culverts, Bridges, Channels, Resacas, and Ditches	Any type of area less than 100 acres	25
Culverts, Bridges, Channels, Resacas, and Ditches	Any type of area more than 100 acres and less than 1,000 acres	50
Culverts, Bridges, Channels, Resacas, and Ditches	Any type of area greater than 1,000 acres	100

Analyses have been made for each pipe trunk for three tailwater conditions:

a. No tailwater in the channel; the tailwater elevation has been set at the top of the outlet pipe for analysis of the hydraulic gradient;

b. Tailwater elevation in the receiving major resaca or ditch has been assumed to have the same storm frequency as that used with the pipe trunk; and,

c. The 100-year storm tailwater elevation in the receiving ditch or resaca has been used to assess its effect on the hydraulic gradient.

B. Design Criteria

The underlying goal of the drainage plans developed in this study is to provide flood protection for the 100-year storm. This goal is primarily applicable to the major drainage facilities comprised of resacas, ditches and channels. The minor system of storm sewer trunks has not been designed for this level of storm, for economic reasons, and this will have the effect of ponding the 100-year flood waters in the streets until the overall system can dissipate it to the receiving water bodies.

The goal of designing the major system improvements to eliminate flooding during the 100-year storm will have to be balanced against economic, right-of-way and feasibility considerations and may not always be practicable.

1. Major Facilities

a. Channels

Earthen channels have been designed to have side slopes of 3 to 1 (horizontal to vertical) and to be grass-lined to minimize slope stability problems and maintenance. The Manning's "n" value utilized for the design of these channels is 0.035.

Concrete channels have been designed with side slopes of 1.5 to 1 (horizontal to vertical), and they have incorporated a lateral slope to the centerline of one-half inch per foot to aid passage of low flows. The Manning's "n" value used for these channels is 0.015.

Velocities have been kept in the acceptable region as outlined in the City criteria.

b. Detention/Retention Structures and Areas

These structures have been designed, to the extent practical, with the goal of providing flood protection for the 100-year storm.

c. Pump Stations

Pump stations have been designed to account for the storage effects of the system and to provide protection to the level stated previously.

2. Minor Facilities

The storm sewer trunks have been designed to the frequency values and hydraulic parameters as stated previously. The slopes of the new pipes have been considered to be equal to those in existence. The recommended pipe sizes are highlighted to show where deficiencies exist and can be corrected.

C. Recommendations

It is recommended that the design criteria utilized in this report and the criteria being informally used by the City Engineering Department be formalized and adopted by the City in an official drainage ordinance.

The flow values computed for drainage facilities in new development should allow for the ultimate development of the drainage areas upstream and provide for conveyance of that flow through the area being developed.

CHAPTER V

V. DRAINAGE SYSTEM ANALYSIS

A. Major Drainage Facilities

Conveyance of stormwater run-off through the planning area, for ultimate discharge into either the Gulf of Mexico or the Rio Grande, is provided by a complex system of interconnected resacas, ditches, conduits, channels, floodways and other watercourses, supplemented with pumping. These principal conveyance facilities not only drain the major watersheds and transport the stormwater downstream, but they also provide a substantial amount of storage volume that is particularly effective in reducing peak flow rates and water levels during flooding periods. For the proper analysis of existing flooding conditions and the evaluation of proposed drainage improvements, it is essential that both the hydraulic characteristics and the storage capacity of the major drainage facilities be appropriately described and accounted for.

For purposes of these analyses, the major drainage facilities within the planning area have been considered in terms of five principal subsystems, with each providing drainage for a major portion of the overall planning area watershed. The five subsystems are identified as Town Resaca, North Main Drain, Resaca de la Guerra, Resaca del Rancho Viejo, and Cameron County Drainage District No. 1 Ditch. The watershed boundaries of these principal drainage subsystems are delineated on the map of the planning area on Plate 1, Volume II.

Stormwater discharges from the Town Resaca, North Main Drain, and Resaca de la Guerra subsystems ultimately combine and flow into the Brownsville Ship Channel, with a portion of the outflows from Town Resaca and North Main Drain pumped into the Rio Grande by the Impala Pump Station (maximum discharge rate of 162,000 g.p.m. or 362 c.f.s.). Since the hydraulics of these three subsystems are interdependent and controlled, to a large extent, by their combined outflows and the resultant downstream tailwater elevation, the analyses of these subsystems with regard to flooding have been undertaken simultaneously and collectively. The Cameron County Drainage District No. 1 Ditch and Resaca del Rancho Viejo subsystems also have required coordinated analyses since stormwater flows can be exchanged between these two subsystems through a connecting ditch, depending on their relative stage levels during flooding periods. Outflows from the downstream ends of both of these subsystems are discharged into San Martin Lake, then to the Brownsville Ship Channel, and, ultimately into the tidal flats near lower Laguna Madre.

1. Technical Approach

Components of the Master Drainage Plan that deal with proposed improvements to the major drainage facilities have been developed through an iterative simulation process involving, first, the determination of existing flooding conditions for each of the five principal drainage subsystems, and then, a series of analyses to evaluate the effectiveness of alternative measures for reducing existing flooding levels. A comprehensive set of computer programs has been applied to calculate watershed run-off quantities and associated water levels and discharges along each of the drainage subsystems for the various conditions considered.

The independent variable used as the driving mechanism for all the storm analyses has been rainfall depth as it occurs over a specified period of time (duration). Based on historical data, the U.S. Weather Bureau has developed statistical information describing rainfall frequencies for the United States [References 2 and 8], and this information has been used in this study to establish specific rainfall parameters for the Brownsville area. Table 9 below presents a summary of the rainfall depths, for a range of durations and frequencies of occurrence, that have been considered in this study. These quantities were extracted directly from the U.S. Weather Bureau publications. For purposes of comparison with major historical storm events, previous 24-hour rainfall amounts recorded at Brownsville by the National Weather Service include 8.15 inches during the September, 1984, flood (approximately the 15-year storm) and 12.09 inches during Hurricane Beulah on September, 20, 1967 (slightly greater than the 100-year storm).

TABLE 9
STATISTICAL RAINFALL DATA FOR BROWNSVILLE, TEXAS

STORM DURATION (Hours)	RAINFALL DEPTH FOR INDICATED RECURRENCE INTERVALS (Inches) 2-YR	5-YR	10-YR	25-YR	50-YR	100-YR
1	2.2	2.8	3.3	3.8	4.2	4.7
2	2.7	3.5	4.2	4.8	5.3	5.9
3	2.9	3.8	4.5	5.2	5.9	6.5
6	3.3	4.6	5.4	6.3	7.3	8.0
12	3.9	5.4	6.5	7.5	8.8	10.0
24	4.6	6.4	7.5	9.0	10.2	11.7
48	5.3	7.2	8.6	10.9	11.6	13.4
72	5.8	7.8	9.2	11.4	12.6	14.4
96	6.1	8.3	9.7	11.9	13.5	15.3
240	7.8	10.2	12.0	14.7	17.0	19.0

As noted previously in the Planning and Design Criteria section of this report, the fundamental goal of the overall Master Drainage Plan with regard to the major drainage facilities is to provide sufficient capacity for the conveyance of 100-year stormwater flows without causing flooding of developed areas. Ultimately, implementation of the overall Master Drainage Plan should provide 100-year flood protection for the entire developed portion of the planning area. Although this goal may not be practical at this time, given the magnitude of the problem and the costs involved in constructing the required flood control facilities, the 100-year rainfall depths in Table 9 have been used to establish existing flooding conditions along each of the major drainage subsystems and to test the effectiveness of all the proposed flood control measures. The lesser magnitude rainfall depths have been used to determine the levels of flooding protection that are provided by the existing drainage system and by various combinations of improvements, or subplans, within the context of the overall Master Drainage Plan.

The duration of the rainfall is important because individual drainage systems respond differently to various amounts of rainfall depending on the hydrologic characteristics of their respective watersheds. The time that it takes for a particle of water to travel through a watershed, i.e., the time of concentration, is determined by a variety of factors such as the size and areal configuration of the drainage area, the extent to which it is developed and its associated degree of impervious cover, the general slope of the terrain, soil conditions and hydraulic conveyance characteristics. In the Brownsville area, times of concentration vary from a few minutes for individual storm sewer pipes to several hours or even days for the major resaca systems.

In order to properly analyze these facilities for flooding, appropriate rainfall amounts and durations must be considered that are consistent with actual times of concentration. For the five principal drainage subsystems, stormwater run-off simulations have been made for rainfall durations varying from six hours to three days, taking into account the respective hydrologic characteristics of each major watershed. These simulated run-off hydrographs have been hydraulically routed through the individual components (resacas, ditches, channels, conduits, etc.) of the drainage subsystems with specified downstream tailwater levels corresponding to the combined outflows from the subsystems.

Based on the resulting peak flood stages, the 24-hour rainfall duration has been established as the critical area-wide storm that generally produces near-maximum water levels in the Town Resaca, North Main Drain, Resaca de la Guerra and Cameron County Drainage District No. 1 Ditch subsystems. Because of the extensive volume of storage available in the upper portion of the Resaca del Rancho Viejo subsystem west of U.S. Highway 77 and the considerable length of the flow path through the connected resaca pools, the 72-hour storm duration has been determined to be critical for this subsystem. In this study, all subsequent analyses of existing flooding conditions for the major drainage facilities and the analyses of the effectiveness of proposed drainage improvements have been based on either the 24-hour or the 72-hour storms depending on the subsystem being considered.

The general procedure that has been applied for analyzing flooding conditions and for determining flood levels within the principal drainage subsystems for a particular rainfall event (i.e., frequency of occurrence) is illustrated by the diagram in Figure 8, Volume I. As shown, the overall process involves two types of simulations. First, the Hydrologic Simulation translates rainfall to run-off for an interrelated system of sub-watersheds with specified hydrologic characteristics. The basic output from the Hydrologic Simulation is the temporal distribution of run-off quantity expressed as a discharge rate, i.e., in units of cubic feet per second (c.f.s.), over the period of the storm being analyzed. These run-off hydrographs, simulated for all the sub-watersheds that comprise a single drainage subsystem, are then used as the inputs to the Hydraulic Simulation.

Basically, the Hydraulic Simulation provides a description of the water surface profile along the drainage subsystem in response to specified run-off hydrographs, taking into account both the storage capacity and the hydraulic characteristics of the individual components that comprise the subsystem, i.e., resacas, ditches, pipe conduits, box culverts, overflow weirs, etc. Peak water surface elevations corresponding to a specified set of run-off hydrographs are determined either by dynamic routing of the flood flows through the resaca pools or by steady-state backwater computations along the channel and ditch segments.

2. Hydrologic Simulation

The HEC-1, Flood Hydrograph Package, computer program (Reference 4) has been used for all the Hydrologic

PROCEDURE FOR ANALYSIS OF MAJOR DRAINAGE FACILITIES

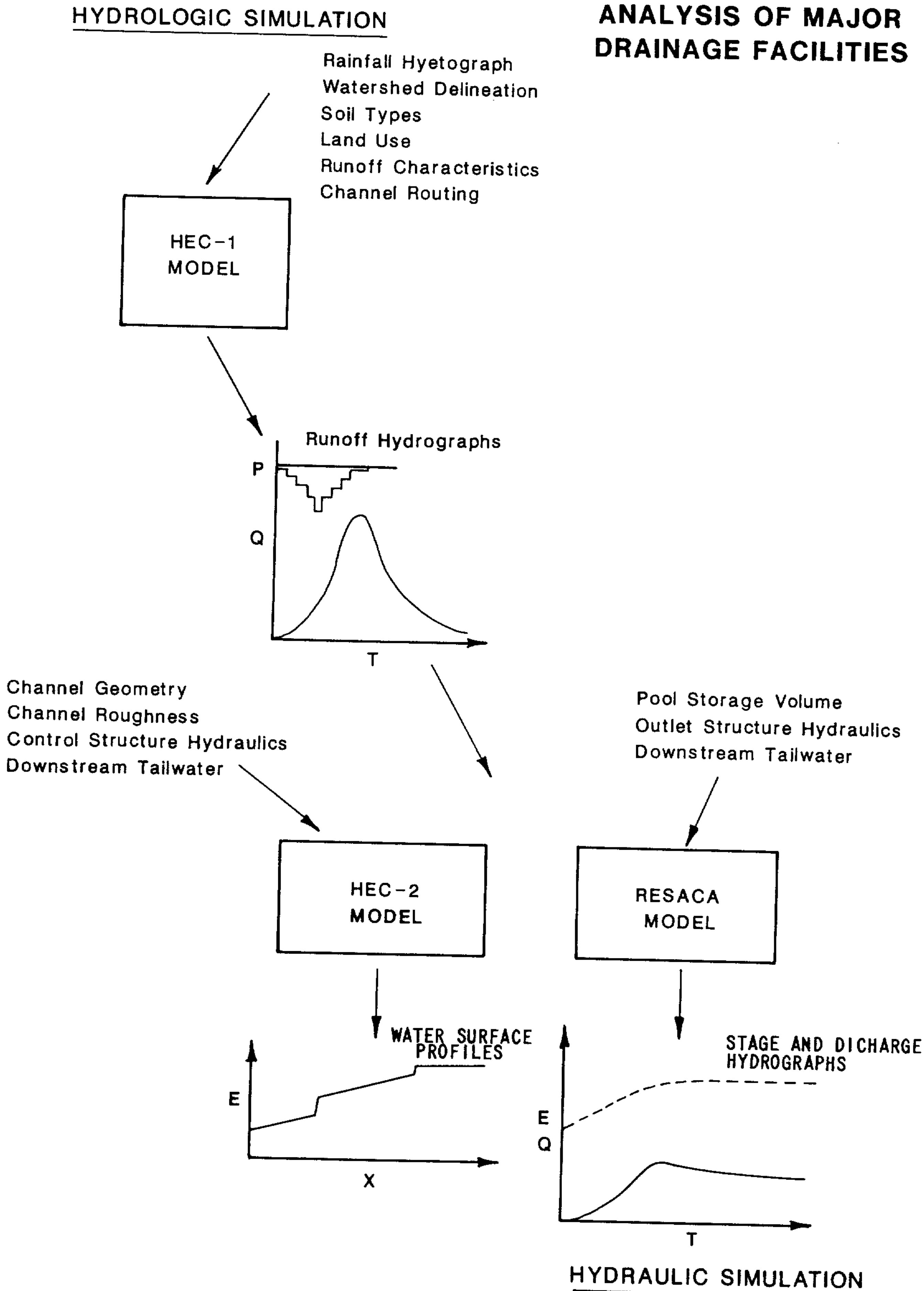


FIGURE 8

Simulation analyses. This program was originally developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers, and it has received widespread use throughout the country for solving a variety of hydrologic problems. The HEC-1 model is designed to simulate the surface run-off response of a basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components.

Each component models an aspect of the overall precipitation-run-off process within a portion of the basin, commonly referred to as a sub-basin or sub-watershed. A component may represent a surface run-off entity, a stream channel or a reservoir pool. Representation of a component requires a set of parameters which specify the particular hydraulic and hydrologic characteristics of the component and the mathematical relations which describe associated physical processes. The result of the modeling process is the computation of run-off or streamflow hydrographs at desired locations in the basin. The HEC-1 program has various options for modeling the different aspects of the overall precipitation-run-off process. For the Brownsville area applications, the following have been used:

a. Soil Conservation Service (SCS) synthetic temporal rainfall distribution for design storms;
b. SCS infiltration loss function based on soil types and natural run-off curve numbers;
c. Percent impervious cover parameter to modify run-off for urbanization;
d. SCS dimensionless unit hydrograph run-off generation method; and,
e. Modified Puls storage routing method for accounting for storage effects in channel reaches.

The application of the HEC-1 program to each of the major drainage subsystems has involved compilation and coding of the following information:

a. Delineation of sub-watersheds corresponding to the contributing drainage areas for each major resaca pool and/or ditch segment, based on existing topography and field surveys of existing drainage facilities;
b. Time of concentration (SCS lag time) for each sub-watershed, based on flow distances and velocities corresponding to overland run-off, street flow and channel and pipe hydraulics;

c. Acreage of each sub-watershed, based on existing maps of the area;
d. SCS curve numbers for each sub-watershed, based on SCS Cameron County soils report and SCS hydrologic manuals and reports [References 6, 7, and 9];
e. Impervious cover percentage for each sub-watershed, based on 1983 and 1986 aerial photographs and ground surveys; and,
f. Storage-discharge relationships for major ditch segments, based on results of iterative flood routing and backwater simulations.

3. Hydraulic Simulation Analysis

Following the generation of run-off hydrographs through the Hydrologic Simulation process, the Hydraulic Simulation analyses for each of the principal drainage subsystems have been performed using one of two different computer programs depending on whether flooding levels in resaca pools or along ditches were being determined. For the drainage subsystems comprised primarily of interconnected resaca pools, a type of reservoir routing computer program, referred to as RESACA, that has been developed specifically for this study, has been applied. For the ditch subsystems, the Corps of Engineers' HEC-2, Water Surface Profiles, computer program [Reference 5] has been used to simulate backwater conditions.

The diverse and complex hydraulic behavior of the resaca drainage subsystems has necessitated the development of the special RESACA computer program. The conveyance of stormwater run-off through a series of connected resaca pools is influenced by the available storage volume within the pools, by the hydraulic characteristics of the outlet structures at the ends of the pools and by the water levels in downstream pools that determine tailwater conditions for the individual pool outlet structures. The RESACA computer program takes into account these interrelationships as it performs a mass balance on the volume of stormwater entering and leaving the individual resaca pools along the length of a resaca drainage subsystem, and it simulates the resulting water levels in the individual pools as they vary over time during the occurrence of a storm event. The peak water surface elevations simulated by the RESACA computer program during a storm event indicate maximum levels of flooding, and these can occur in the pools at different times during a storm depending on the relative storage capacities and outlet controls of individual pools and the size of their contributing drainage areas.

The complexities involved in analyzing resaca hydraulics are illustrated by the two sets of plots shown in Figure 9, Volume I, which are based on results from the RESACA computer program applied to the Town Resaca subsystem. The lower set of plots indicates the variation of the water level (stage) over an 18-hour period in three resaca pools that are connected in series, with Pool 1 being the most upstream. The corresponding outflow and inflow hydrographs for Pools 1 and 2 are shown in the upper set of plots over the same time period. All these results are based on the 25-year, 24-hour storm simulation. Many of the complicating hydraulic factors associated with the resaca drainage subsystems are illustrated by these curves, including the following:

a. Pool 1 has a weir structure for its outlet control with the normal water surface elevation maintained at the crest of the weir, thus limiting the pool's available storage volume for flood flows. Consequently, its outflow hydrograph is similar to the run-off inflow hydrograph, with only a small reduction in the peak outflow rate due to storage effects;

b. Pool 2 has a 36-inch outlet pipe and an overlying weir structure for its outlet control with the normal water surface elevation maintained near the pipe flowline by the outlet structure downstream in Pool 3. During flooding periods, the water level in Pool 2 can rise almost five feet before the weir crest at its outlet structure is overtopped. The effectiveness of the associated storage volume for reducing the outflows from Pool 2 is apparent in the plot of the outflow hydrograph, which is considerably lower at the peak of the storm than the sum of the corresponding inflows into Pool 2, i.e., the Pool 2 run-off plus the Pool 1 outflow;

c. During the initial hours of the storm, the water level in Pool 2 is below that of Pool 1 because of their different normal water surface elevations, but gradually, the level of Pool 2 rises above the weir crest of Pool 1 as inflows increase. Eventually, Pool 1 and Pool 2 become a single pool (at 11.5 hours), with the Pool 2 outlet structure controlling their combined water level;

d. In the latter part of the storm, the stage of the combined Pools 1 and 2 stabilizes just above the weir crest elevation of the Pool 2 outlet structure, and the magnitude of the Pool 2 outflow, which is comprised of the sum of the 36-inch pipe flow and the

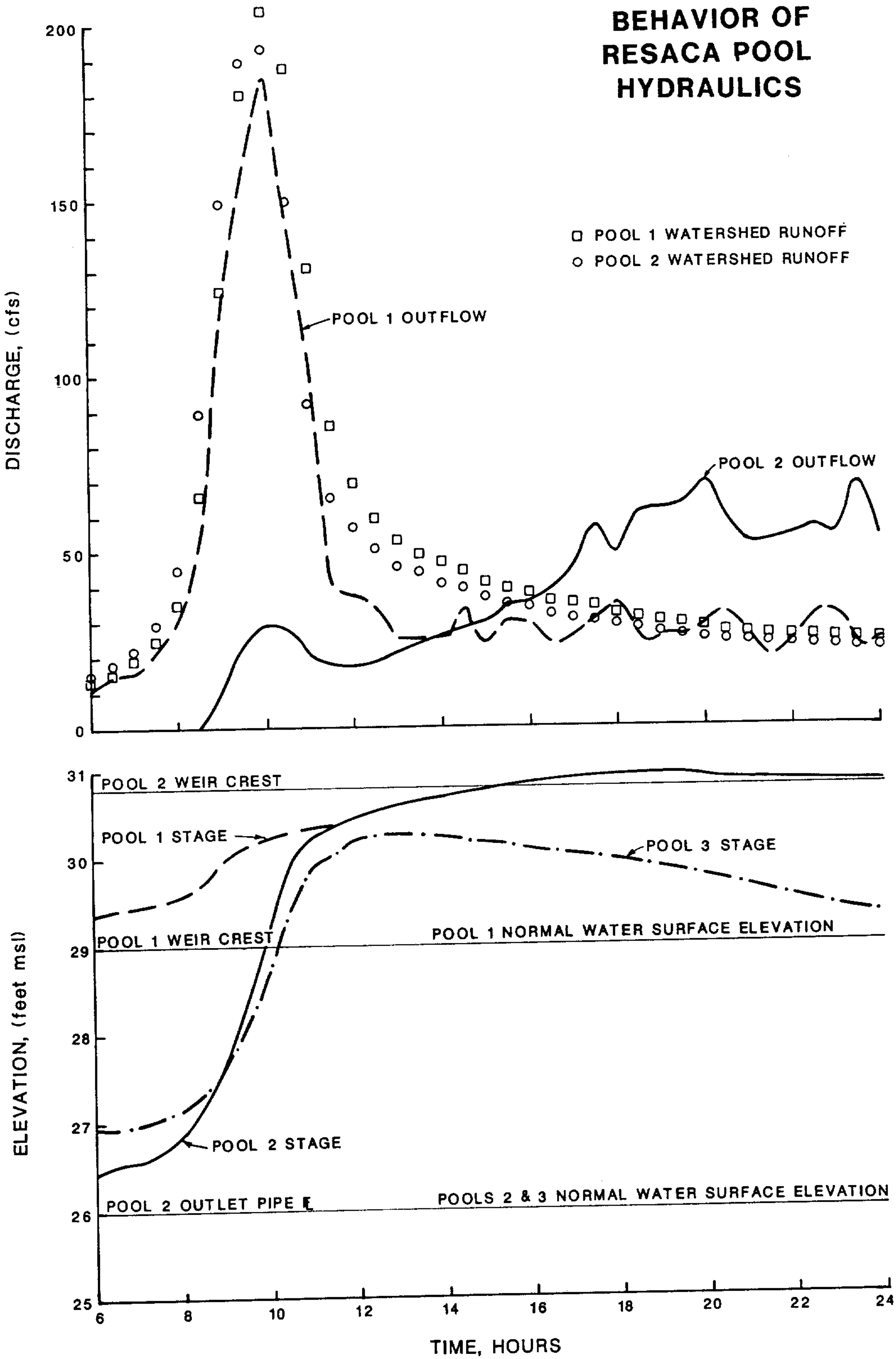

BEHAVIOR OF
RESACA POOL
HYDRAULICS
POOL 1 WATERSHED RUNOFF
POOL 2 WATERSHED RUNOFF
POOL 1 OUTFLOW
POOL 2 OUTFLOW
DISCHARGE, (cfs)
0
50
100
150
200
POOL 2 WEIR CREST
POOL 1 STAGE
POOL 3 STAGE
POOL 1 WEIR CREST
POOL 1 NORMAL WATER SURFACE ELEVATION
POOL 2 STAGE
POOL 2 OUTLET PIPE ℄
POOLS 2 & 3 NORMAL WATER SURFACE ELEVATION
ELEVATION, (feet msl)
25
26
27
28
29
30
31
6
8
10
12
14
16
18
20
22
24
TIME, HOURS

FIGURE 9

weir overflow, is approximately equal to the total inflow to Pool 2, i.e., the sum of the Pool 2 watershed run-off and the Pool 1 outflow; and,

e. The effect of downstream tailwater on the outflow from resaca pools is illustrated by the irregular behavior of the Pool 1 and Pool 2 outflow hydrographs after the outlet structures become submerged and the water levels in adjoining pools approach the same elevation.

Simulation of the hydraulic behavior of resaca pools, as depicted by these plots, requires that all the pools in a particular subsystem be analyzed simultaneously to assure the proper consideration of tailwater effects. The RESACA computer program has been specifically designed to perform these analyses. In applying the RESACA model to the Town Resaca, Resaca de la Guerra and Resaca del Rancho Viejo subsystems, the following information has been compiled and coded as input data to the computer program:

a. Detailed descriptions of the outlet structures for all resaca pools, including the number, sizes, dimensions, lengths, upstream and downstream flowline elevations, material types and head loss coefficients for pipe and box culverts and the cross-section (stations and elevations), breadth and discharge parameters for overflow weirs, based on field surveys made during this study, supplemented with data from existing plans and previous reports;
b. Storage volume versus elevation relationships (or data points) for all resaca pools, based on field surveys made in this study, supplemented with topographic information from current U.S. Geological Survey quad sheets and 1929 - 1930 series one-foot contour maps; and,
c. A description of the variation of the tailwater elevation during the period of a particular storm event for the receiving water body at the downstream end of each resaca drainage system, based on iterative analyses of the outflows from the individual drainage subsystems and the hydraulics of the downstream receiving water bodies

Peak flood levels along the ditch subsystems, i.e., North Main Drain and Cameron County Drainage District No. 1 Ditch, are influenced primarily by the conveyance capacity of the channel sections and the hydraulic characteristics of control structures such as bridges and culverts, although the downstream tailwater conditions also can be a key factor. Storage volume is important for reducing peak discharges along the ditches, and, unlike the resaca subsystems which are predominantly controlled by the pool outlet structures, ditch storage usually can be related to the flow rate in the ditches. Generally, for a given storm event, peak discharge rates along the ditch subsystems increase or remain relatively constant in the downstream direction as run-off enters the channels from tributary watersheds.

The HEC-2 computer program is intended for calculating water surface profiles for steady, gradually varied flow in natural or man-made channels and ditches. Both subcritical and supercritical flow profiles can be calculated. The effects of various obstructions such as bridges, culverts, weirs and structures in the flood plain may be considered in the computations. The computational procedure is based on the solution of the one-dimensional energy equation with energy loss due to friction evaluated with Manning's equation. The computational procedure is generally known as the Standard Step Method. The computer program is also designed for application in flood plain management and flood insurance studies to evaluate floodway encroachments and to designate flood hazard zones. Also, capabilities are available for assessing the effects of channel improvements and levees on water surface profiles.

In applying the HEC-2 model to the North Main Drain and Cameron County Drainage District No. 1 Ditch drainage subsystems, the following information has been compiled and coded as input data to the program:

a. Segmentation networks comprised of computational sections and channel reaches identified in accordance with the hydraulic characteristics of each subsystem;
b. Descriptions of channel and overbank cross-section/geometry (stations and elevations) at representative locations (computational sections) throughout the length of the subsystems, based on field surveys made during this study;
c. Descriptions of control structures such as bridges and culverts, including their cross-section descriptions, dimensions, flowline elevations and head loss parameters, based on field surveys made during this study and existing plans and previous reports; and,
d. Descriptions of channel and overbank roughness conditions in terms of Manning's "n" values.

4. Town Resaca Drainage Subsystem

For simulating run-off for the Town Resaca subsystem the overall drainage area has been divided into 48 sub-watersheds based on existing drainage patterns and individual resaca pools. These sub-watersheds are delineated on the map in Plate 2, Volume II. Each of these sub-watersheds contributes run-off into an individual pool of the Town Resaca subsystem, and each of these pools is associated with a specific outlet control structure. These structures have been previously identified on the map in Plate 7A, Volume II, and they have been described in terms of their physical features in Table 1, Volume I.

The correspondence between sub-watersheds and outlet control structures for the Town Resaca subsystem is indicated in Table 10, Volume I. Also listed in this table for each sub-watershed are the drainage area size, the time of concentration, the SCS curve number and impervious cover percentages for existing and future (year 2000) land use conditions. These data have been used as the primary inputs to the HEC-1 program for purposes of simulating run-off hydrographs for specific storm events.

Using the inflow hydrographs generated with the HEC-1 model, the RESACA computer program has been operated to route the flood flows through the entire subsystem for the purpose of determining peak flood levels. Through successive operations of the model, the following outlet control structures have been determined to be the most important with regard to their effects on resaca water levels:

Structure TR3	36-Inch Waterline
Structure TR8	At Belthair Street
Structure TR9	Near W. Monroe Street
Structure TR15 & 15A	At Palm Blvd.
Structure TR19A	Near Gladys Porter Zoo
Structure TR19	At Ringgold Street
Structure TR22A	At Pierce Street
Structure TR22E	At 14th Street
Structure TR23	At International Blvd.
Structure TR25	Near 24th Street
Structure TR26	Near Los Tomates Banco
Structure TR27	Near Wastewater Treatment Plant.

RESACA simulations have been made for the 2, 5, 25 and 100-year storm events based on existing land-use and run-off conditions. The resulting water surface profiles along the Town Resaca subsystem are plotted on Plate 8,

TABLE 10

SUB-WATERSHED HYDROLOGIC CHARACTERISTICS FOR TOWN RESACA

SUB-WATERSHED DESIGNATION	ASSOCIATED CONTROL STRUCTURE	DRAINAGE AREA (acres)	TIME OF CONCENTRATION (hours)	SCS CURVE NUMBER	PERCENTAGE IMPERVIOUS COVER EXISTING	FUTURE
TR1	TR27	247.2	.94	74	12	36
TR2	TR26	148.0	1.53	73	32	34
TR3	TR27	5.0	.31	69	48	48
TR4	TR25	54.2	.83	78	45	45
TR5	TR25	65.6	1.08	69	47	47
TR6	TR23	60.0	.94	69	45	45
TR7	TR22E	73.1	1.11	69	45	45
TR8	TR22C	40.3	.86	69	45	45
TR9	TR22A	45.7	.79	69	51	51
TR10	TR25	56.7	.55	75	28	30
TR11	TR25	27.4	.88	69	39	39
TR12	TR23	71.6	.88	70	38	38
TR13	TR22E	72.0	.76	71	36	36
TR14	TR22C	29.8	.95	69	39	39
TR15	TR16	248.3	1.06	69	61	61
TR16	TR19	76.1	.76	74	18	18
TR17	TR22	75.6	1.14	74	41	41
TR18	TR20	93.5	.76	74	31	31
TR19	TR17	22.3	.41	72	62	62
TR20	TR16	39.9	.43	74	39	39
TR21	TR15	19.8	.71	69	48	48
TR22	TR15	31.8	.75	70	32	32
TR23	TR14	10.8	.31	78	30	34
TR24	TR13	34.2	.33	72	17	17
TR25	TR12	260.8	.60	79	20	20
TR26	TR11	53.2	.32	73	21	21
TR27	TR10	8.9	.08	80	3	3
TR28	TR9AB	170.0	1.63	72	44	44
TR29	TR9AB	97.7	.72	74	39	39
TR30	TR9AB	141.4	1.50	70	40	41
TR31	TR9AB	140.7	1.18	74	31	38
TR32	TR9AB	53.6	.74	76	22	36
TR33	TR9AB	54.7	.59	74	28	34
TR34	TR9AB	51.1	1.07	69	40	41
TR35	TR9AB	112.6	.92	69	40	41
TR36	TR8	95.1	.75	75	39	39
TR37	TR8	38.8	.57	69	33	35
TR38	TR8	67.0	.57	74	36	38
TR39	TR8	20.2	.61	74	30	30
TR40	TR8	50.0	.43	74	26	30

TABLE 10 (CONT'D)

SUB-WATERSHED HYDROLOGIC CHARACTERISTICS FOR TOWN RESACA

SUB-WATERSHED DESIGNATION	ASSOCIATED CONTROL STRUCTURE	DRAINAGE AREA (acres)	TIME OF CONCENTRATION (hours)	SCS CURVE NUMBER	PERCENTAGE IMPERVIOUS COVER EXISTING	FUTURE
TR41	TR7	37.9	.26	75	24	25
TR42	TR5	18.9	.59	73	45	45
TR43	TR3	41.0	.71	73	11	30
TR44	TR3	46.6	.83	69	35	35
TR45	TR2	75.8	.69	73	21	33
TR46	TR7	77.1	.53	72	26	29
TR47	TR4	38.2	.46	72	28	36
TR48	TR28	279.7	1.42	79	32	32

Volume II. The peak outflow rates from Town Resaca (at Structure TR27) corresponding to these four storm events as simulated with the RESACA model are 339, 373, 671 and 850 c.f.s., respectively.

5. North Main Drain Drainage Subsystem

The sub-watersheds that have been used in simulating run-off within the North Main Drain subsystem with the HEC-1 model are shown on the map in Plate 3, Volume II. The hydrologic characteristics of these sub-watersheds are listed in Table 11, Volume I, along with their associated pool outlet control structures.

Using the peak flow rates along the North Main Drain system as simulated with HEC-1 for the 2, 5, 25 and 100-year storm events, the HEC-2 program has been operated to determine corresponding water surface profiles. These results are plotted on Plate 9, Volume II, along the entire length of North Main Drain from near State Highway 4 east of the Airport upstream to near F.M. Road 802. Also, shown on these plots are the minimum channel bank elevations along the ditch. The peak discharges in the North Main Drain channel just upstream of its confluence with Impala Ditch for the four storm events analyzed have been determined to be 532, 645, 815 and 996 c.f.s., respectively. Downstream of the point where Resaca de la Guerra discharges into North Main Drain in the vicinity of the Airport, the peak discharges in the North Main Drain channel have been determined to be 608, 787, 1,125 and 1,545 c.f.s., respectively, for the 2, 5, 25 and 100-year storms.

6. Resaca de la Guerra Drainage Subsystem

Plate 4, Volume II, shows the sub-watersheds used in the HEC-1 model for simulating run-off within the Resaca de la Guerra subsystem. The associated pool outlet structures and the hydrologic characteristics of these sub-watersheds are listed in Table 12, Volume I.

From successive analyses of the hydraulic behavior of the overall subsystem, the following outlet structures have been determined to be the principal controls with regard to water surface elevations:

TABLE 11

SUB-WATERSHED HYDROLOGIC CHARACTERISTICS FOR NORTH MAIN DRAIN

SUB-WATERSHED DESIGNATION	ASSOCIATED CONTROL STRUCTURE	DRAINAGE AREA (acres)	TIME OF CONCENTRATION (hours)	SCS CURVE NUMBER	PERCENTAGE IMPERVIOUS COVER EXISTING	FUTURE
NM1	NM1	183.3	1.56	77	31	32
NM2	NM2	34.7	0.40	81	0	11
NM3	NM3	126.3	1.30	78	11	24
NM4	NM4	5.3	.15	78	0	11
NM5	NM5	44.6	.54	73	11	25
NM6	NM6	81.5	1.20	78	41	51
NM7	NM7	18.9	.40	74	41	51
NM8	NM8	144.0	1.10	78	30	48
NM9	NM9	80.8	1.20	82	30	48
NM10	NM10	23.2	.44	84	31	48
NM11	NM11	11.7	.29	84	56	56
NM12	NM12	11.2	.29	84	60	60
NM13	NM13	174.5	1.61	82	43	53
NM14	NM14	233.6	1.36	75	33	45
NM15	NM15	22.9	.62	73	24	60
NM16	NM16	99.9	.64	75	33	43
NM17	NM17	31.9	.44	74	25	28
NM18	NM18	27.2	.40	76	53	53
NM19	NM19	157.0	1.38	80	27	41
NM20	NM20	199.0	1.75	83	35	51
NM21	NM21	256.7	1.93	81	35	47
NM22	NM22	100.0	1.43	84	49	70
NM23	NM23	97.2	1.41	78	42	56
NM24	NM24	513.1	1.32	78	34	40
NM25	NM25	131.2	.94	74	28	35
NM26	NM26	237.7	.94	77	18	28
NM27	NM27	45.5	.48	77	35	35
NM28A	NM28	28.4	.33	74	35	35
NM28B	NM28	108.2	.57	70	35	35
NM29	NM29	60.1	.49	73	23	23
NM30	NM30	82.6	.59	74	0	0
NM31	NM31	6.2	.25	74	0	60
NM32	NM32	251.0	1.01	76	0	0
NM33A	NM33	584.9	1.17	81	12	19
NM33B	NM33	256.2	2.44	78	3	3
NM33C	NM33	634.8	1.61	80	12	12
NM34	NM34	89.7	.57	77	3	3
NM35	NM35	113.9	1.04	72	0	0
NM36	NM36	847.0	1.32	74	0	0
NM37	NM37	187.9	.65	71	0	0
NM38A	NM38	7,732.0	6.74	78	0	0
NM38B	NM38	817.3	2.00	79	0	0

TABLE 12

SUB-WATERSHED HYDROLOGIC CHARACTERISTICS FOR RESACA DE LA GUERRA

SUB-WATERSHED DESIGNATION	ASSOCIATED CONTROL STRUCTURE	DRAINAGE AREA (acres)	TIME OF CONCENTRATION (hours)	SCS CURVE NUMBER	PERCENTAGE IMPERVIOUS COVER EXISTING	PERCENTAGE IMPERVIOUS COVER FUTURE
RG1	RG24A	6.4	.25	85	0	10
RG5	RG23	62.1	.25	85	3	15
RG15	RG22	328.7	.62	75	20	33
RG16	RG20	35.2	.62	75	34	43
RG19	RG19A	237.5	.59	73	16	28
RG20	RG18	49.4	.15	72	8	29
RG21	RG16-17	201.7	.49	74	24	29
RG22	RG18	54.0	.42	73	26	26
RG23	RG18	21.7	.17	75	23	23
RG24	RG18	245.4	.59	74	23	34
RG25	RG18	84.5	1.14	79	12	28
RG26	RG14-15	213.6	.53	77	25	29
RG27	RG13	26.2	.20	83	0	0
RG28	RG13	96.6	.47	73	9	29
RG29	RG13	87.0	1.00	77	15	42
RG30	RG13	53.1	.35	74	29	35
RG31	RG12	135.1	.37	75	18	24
RG32	RG18	135.0	.67	73	22	32
RG33	RG18	80.6	.73	80	13	13
RG34	RG9	8.1	.09	85	18	18
RG35	RG8	7.8	.05	80	9	37
RG36	RG7	28.0	.44	75	33	49
RG37A	RG4	98.8	.35	74	23	23
RG37B	RG6	96.6	.35	74	17	20
RG38	RG4	49.0	.09	78	9	23
RG39	RG2A	37.3	.09	75	0	39
RG40	RG2	10.0	.12	77	0	42
RG41	RG1	276.8	2.22	78	0	21
RG42-43	RG1	101.1	.15	73	8	24
RG44	RG1	91.8	.51	72	5	24
RG45	RG1	41.3	.15	81	0	0
RG46	RG1	96.8	.56	76	0	0
RG47	RG1	49.8	.25	72	0	0

Structure RGY3	At F.M. 3248
Structure RGY4	At Laredo Rd. near Quail Hollow Dr.
Structure RG2	At Laredo Rd.
Structure RG4E	Near Honeydale Rd.
Structure RG8	Between U.S. 83 and Old Alice Rd.
Structure RG10	At Hidden Valley Dr.
Structure RG12A	At Paredes Line Rd.
Structure RG13	At Palo Verde St.
Structure RG14	Near Port Isabel Rd.
Structure RG18A &18B	At 14th St.
Structure RG19A	At Boca Chica Blvd.
Structure RG20	At Billy Mitchell Blvd.
Structure RG22 & 23	At Morningside Road
Structure RG24A &B	At North Main Drain

Considering these structures in the RESACA model, the peak water surface elevations have been determined for the 2, 5, 25 and 100-year storm events. These are plotted on Plate 10, Volume II. Because the outlet structure at the downstream end of Resaca de la Guerra at its confluence with North Main Drain consists of only a single 30-inch pipe, peak outflows into North Main Drain are relatively small. For the four storms simulated, peak outflows have been determined to be on the order of 50 c.f.s..

7. Cameron County Drainage District No. 1 Ditch Drainage Subsystem

This subsystem covers an extensive area immediately north of Resaca de la Guerra, and it drains much of the planning area that is projected to develop by the year 2000. Plate 5, Volume II, identifies the sub-watersheds used in the HEC-1 analyses of run-off. Their hydrologic characteristics and associated outlet control structures are listed in Table 13, Volume I.

Based on the results of HEC-1 run-off simulations, considerable quantities of stormwater flow through this subsystem. Peak discharge rates in the channel for the 2, 5, 25 and 100-year storms have been determined to be 755, 841, 990 and 1,200 c.f.s., respectively, at the Southern Pacific Railroad crossing near the middle of the subsystem and 1,450, 1,772, 2,450 and 3,260 c.f.s., respectively, at State Highway 48 near the downstream end. The corresponding water surface profiles, as simulated with the HEC-2 backwater model, are plotted on Plate 11, Volume II. As illustrated, flood levels along the channel generally exceed the minimum bank elevations.

TABLE 13

SUB-WATERSHED HYDROLOGIC CHARACTERISTICS FOR CAMERON COUNTY DRAINAGE DISTRICT #1 DITCH

SUB-WATERSHED DESIGNATION	ASSOCIATED CONTROL STRUCTURE	DRAINAGE AREA (acres)	TIME OF CONCENTRATION (hours)	SCS CURVE NUMBER	PERCENTAGE IMPERVIOUS COVER EXISTING	FUTURE
CC1	CC1	505.3	4.22	75	0	0
CC2	CC2	439.8	2.20	83	0	0
CC3	CC3	259.0	1.48	77	3	18
CC4	CC4	3,449.0	13.37	80	17	31
CC5	CC5	318.8	6.06	80	4	26
CC6	CC6	1,234.0	5.08	81	9	31
CC7	CC7	1,075.0	5.63	79	15	30
CC8	CC8	111.0	4.68	84	15	30
CC9	CC9	175.0	4.16	89	0	30
CC10	CC10	833.0	4.67	81	4	27
CC11	CC11	8.6	.30	89	0	35
CC12	CC12	800.0	4.94	83	4	30
CC13	CC13	2,525.0	8.83	79	23	39
CC14	CC14	166.5	2.98	74	18	35
CC15	CC15	593.5	5.27	76	6	39
CC16	CC16	11.4	.13	82	60	60
CC17	CC17	31.3	1.26	84	30	60
CC18	CC18	336.0	4.68	79	14	67
CC19	CC19	396.0	2.76	84	6	30

8. Resaca del Rancho Viejo Drainage Subsystem

The areal extent of this subsystem is shown on the map in Plate 6, Volume II. As illustrated, most of its contributing drainage area is located west of U.S. Highway 77. In addition, a substantial amount of storage volume is available in Sub-watershed RV9. As this sub-watershed fills with run-off during an extended storm, it functions as a large reservoir with a continuous discharge of stormwater into Resaca del Rancho Viejo. As noted previously, results of hydraulic simulations with the RESACA model and related calculations indicate that maximum water levels along this resaca subsystem generally are achieved after about three days of run-off. Conditions tend to stabilize for longer storm durations as the water surface elevations of the Sub-watershed RV9 storage volume reaches its maximum and as outflows from the overall subsystem become steady. Storms with shorter durations do not allow adequate time for the discharges from Sub-watershed RV9 to reach the downstream end of the subsystem while intermediate run-off is still occurring.

Based on HEC-1 run-off simulations for the sub-watersheds delineated on the map in Plate 6, Volume II, and listed in Table 14, Volume I, and from steady-state RESACA model hydraulic results, the peak discharges in the Rancho Viejo subsystem at Structure RV27 near F.M. Road 1849 have been determined to be 220, 281, 326 and 367 c.f.s., respectively, for the 2, 5, 25 and 100-year storms. The corresponding water surface elevations are illustrated on the profile plots in Plate 12, Volume II.

B. Storm Sewer Trunk System

1. Technical Approach

The storm sewers located throughout the City are closely interconnected to the hydraulic performance of the receiving ditches and resacas. The flatness of the topography in the area causes every storm sewer pipe to operate in outlet control. This means that the controlling factor for allowing rapid removal of water from an area is the downstream hydraulic condition of the open channel and the main storm sewer trunks emptying into the channel.

This condition means that to effectively improve the drainage conditions on a local basis, the main storm sewer pipes must be improved first within the system before the system will work more effectively. For this reason, and to effectively delineate areas that need improvement, only the main storm sewer trunks have been analyzed.

TABLE 14

SUB-WATERSHED HYDROLOGIC CHARACTERISTICS FOR RESACA DEL RANCHO VIEJO

SUB-WATERSHED DESIGNATION	ASSOCIATED CONTROL STRUCTURE	DRAINAGE AREA (acres)	TIME OF CONCENTRATION (hours)	SCS CURVE NUMBER	PERCENTAGE IMPERVIOUS COVER EXISTING	FUTURE
RV2	RV2	286.1	.83	74	0	0
RV3	RV3	384.3	.93	76	9	15
RV5	RV5	523.3	1.39	74	12	18
RV6	RV6	1,232.5	1.85	74	5	8
RV7	RV7	128.1	.37	79	2	2
RV8	RV8	121.0	.46	83	0	8
RV9	RV9	5,017.0	8.33	72	0	3
RV10	RV10	2,865.0	9.44	80	0	0
RV11	RV11	125.2	1.30	77	0	0
RV12	RV12	189.3	.56	78	0	0
RV13-14	RV14	68.2	.56	79	0	0
RV15	RV15	18.5	.37	74	0	0
RV16	RV16	168.0	.60	75	0	0
RV17	RV17	51.2	.56	74	0	0
RV18-19	RV19	37.6	.60	71	2	2
RV20	RV20	286.1	.83	73	2	2
RV21	RV21	103.9	.56	73	0	0
RV22-23	RV23	253.3	1.20	72	5	7
RV24-25	RV25	251.8	1.67	72	7	7
RV26-27	RV27	19.8	.33	74	0	0
RV28	RV28	476.6	1.11	75	0	5
RV29	RV29	176.5	.46	78	0	0
RV30	RV30	254.8	1.11	78	0	0
RV31	RV31	47.0	.74	81	0	0
RV32A	RV32A	113.9	1.39	77	0	0
RV32B	RV32B	109.6	.74	74	0	0
RV33	RV33	279.1	.65	77	0	0
RV34-35	RV35	116.7	1.30	77	0	0
RV36-37	RV37	52.0	2.32	86	15	62
RV41	RV41	103.9	.17	86	0	0

The main trunk on each storm sewer was determined by starting at the outlet end of the pipe and running back upstream along the pipes to the furtnest reach of the largest pipes. The effective hydraulic capacity of this pipe determines the effective pipe capacity of all the laterals and inlets attached to it.

Analysis criteria and methodology to analyze the existing storm sewer trunks were developed in conjunction with the City Staff during early phases of the project.

The methods and criterion used are identical to those used in the later design stages of the plan. This provides for evaluation of the performance of the existing system with that of proposed or desired future system.

The tailwater conditions were analyzed on the existing storm sewer trunks initially for tailwater equal to the top of pipe. In most cases, the small size of the pipes present in the existing system already produced hydraulic grade lines far above the street grades.

The designs, grades, hydraulic grade lines, sizes and types of storm sewer have been calculated based on existing locations and present grades and have not been optimized to provide the final, most efficient design for that drainage area. They have been calculated to give a conservative projection of the costs and the size of structures needed. A summary of the upgraded storm sewer requirements is shown in Table 6, Volume I.

The tailwater effects of the receiving ditch and resacas were initially input on the storm sewer trunks from the full 24-hour storms that were used to analyze the major drainage systems. The discrepancy of this 24-hour storm timing versus the ten- to twenty-minute storms used in pipe designs was immediately apparent. The peak water elevations of the 24-hour storms in the receiving drainageway would occur some 10 to 12 hours after the pipe discharges had occurred.

Evaluation of various duration storms used on the large watersheds revealed that the 1-hour storm duration produced rainfall intensities that closely approximated those used in the Rational Method for pipe flows. These 1-hour duration storms were input into the major system computer models to predict the water surface elevations for the 5, 10, 25-year 1-hour duration storms.

These analyses, showed the water surface rise to range from about 0.5 foot to just under 1.0 foot. On the resacas it was found that the maximum water surface rise above normal pool was a maximum of just under 1 foot. This seemed to hold true regardless of storm frequency due to the large storage capacity of the resaca systems. To be conservative, one foot above normal pool was adopted as the standard tailwater elevations for all trunks emptying into the resacas.

The ditch systems were analyzed for their respective water surface profile elevations using the HEC-1 and HEC-2 models for the 5-year, 10-year, and 25-year 1-hour duration storms. These values were then utilized for the tailwater conditions for the storm sewer trunk and storm frequency indicated. The values for these two runs are contained with the Computer Documentation Report.

2. Pipe Template

The analysis of the existing pipe trunks and subsequent adequate pipe design of sizes followed the procedure format used in the Texas State Highway Department Hydraulics Manual. This layout of computations and pipe size calculations is widely used throughout the engineering profession for design computations of storm sewer trunks.

The analysis of the storm sewer trunks was accomplished with a computer spreadsheet template written to make use of Lotus 1-2-3 Version 1A, an electronic spreadsheet, designed for use on IBM PC and IBM compatible machines.

The creation of this spreadsheet template allows very rapid computation of alternate pipe sizes by changing the values of pipe slope, number of barrels and design storm desired.

This spreadsheet template has been supplied to the City of Brownsville Engineering Department and runs on their HP Vectra computer. Data disks containing the data for the existing storm sewers and the proposed sizes have also been provided to the Engineering Department. These can be used for future analysis and design of storm sewers in the City. A detailed discussion of the principles and techniques for use is available in the Computer Documentation Report.

Three (3) copies of this Computer Documentation Report are available at the City.

3. Existing Capacity

The capacities of the existing storm sewer trunks are presented in Table 15, Volume I. The values shown generally indicate that the storm sewers in the older and more heavily urbanized areas of the City have less of the required flow capacity than those in the outlying reaches. These outlying reaches of the Study Area show improvement, but only a small percentage (less than 10%) can carry the storm flows that were analyzed.

CHAPTER VI

VI. SUMMARY OF PROBLEMS

A. General

The study area has five major watersheds that flow to the east and exit through two main drainage outlets. The southern three systems, Town Resaca, North Main Drain and Resaca de la Guerra all combine into one channel just west of the Brownsville/South Padre Island International Airport and flow east past the airport and then north to the Brownsville Ship Channel.

The two northern watersheds, Cameron County Drainage District No. 1 Ditch and Resaca del Rancho Viejo, confluence at Hwy. 511 and flow to the Rancho Viejo Floodway just north of the Brownsville Ship Channel.

These outlet channels present a problem for efficient removal of water due to their elevation relative to the water level of the Gulf of Mexico. The most critical rainfall events that cause flooding in the Study Area will be associated with hurricanes. This is due to the fact that a hurricane carries a storm surge with it that will raise the water level in the Gulf of Mexico and, hence, the water levels in these major outlet channels for the area. This will restrict the timely discharge of floodwater from the area.

The general flatness of the area contributes to the flooding problem by allowing only relatively slow water velocities in the resacas, channels, ditches and storm drains of the area. These low velocities produce a slow removal of floodwater unless the conveying channel or conduit is large or the water is aided in removal by pumping.

The natural drainage problems of the area have been compounded by the past misuse (development) of the flood-prone areas of the region. Areas that consistently flood have been developed to contain residences, industry or service locations. The lack of planning has resulted in the increase in physical damage to property and persons located in or near these flood-prone areas.

Public agency control and regulation of the waterways must be improved to prevent further misuse of problem areas.

B. Specific Problem Areas

The following problem areas have been identified through various contacts with the City, the various agencies and the general public. These areas were examined in the hydrologic and hydraulic modeling and, in virtually every case, found to show the indications of the observed problems.

The areas shown to have problems include the following:

1. Central Boulevard has overflow flooding problems due to the channel restriction of the Town Resaca caused by the 36-inch raw water line crossing the resaca at this point.

2. The Town Resaca drainage basin upstream of Central Boulevard has been completely developed and experiences flooding due to the location of occupied structures within the low area of the resaca bed.

3. The Town Resaca watershed is the most heavily urbanized and developed of the five major watersheds. Many of the areas at the upstream end and to each side of the channel have filled and no longer contain water. These areas have been developed, and various structures occupy these low lying areas. Specific examples are: A) the resaca bed west of Central Boulevard and north of Los Ebanos Boulevard; and, B) the old Town Resaca bed north of Roosevelt Street. These areas will be prone to flooding in the future and should not have been allowed to be developed.

4. Another problem that has occurred in the Town Resaca watershed is the development of the Gladys Porter Zoo in the resaca. The hydraulic structures and placement of the walls at the zoo effectively block off much of the channel capacity at Ringgold Street and at the railroad tracks just upstream of the zoo on the southwest corner of the zoo property.

5. The areas around Ebony Lake contribute drainage to this Lake which, in turn, drains to Town Resaca through a 36-inch diameter pipe. Principally, the backwater effects of the Town Resaca compounded by this small outlet pipe do not allow this Lake to drain adequately in the 100-year storm.

6. The Los Tomates Banco and Lincoln Park areas have flooding problems due to poor placement of buildings in flood-prone areas. The old resaca bed from Los Tomates Banco heading northeast past the Harry L. Faulk Junior High School has had subdivisions and streets placed in it. This area appears on Flood Insurance Maps and other sources as a flood hazard area.

7. The North Main Drain has several problem areas that generally are due to insufficient water-carrying capacity for the watershed. This is caused by undersized structures (bridges and culverts), small channel cross-sections or poor channel alignment.

The Brownsville/South Padre Island International Airport experiences flooding from the North Main Drain due to the relatively low elevation of the airfield topography in relation to the surrounding area. The North Main Drain does not generally have sufficient capacity in this area to convey the 100-year flood flows past the Airport. The floodwater in excess of the channel capacity flows over the channel banks and covers the southern portion of the Airport.

The northwestern portion of the Airport experiences flooding due to the backup of water in the Chicago drain which heads northward to Cameron County Drainage District No. 1 Ditch. The flood elevations on the Ditch are high enough that backwater flooding will occur at the Airport.

8. The Southmost area along Santa Elena and Ruiz Streets will experience flooding due to downstream backwater effects and inadequate capacity in the channel. This area as well as the Four Corners area experiences flooding from both the North Main Drain and Resaca de la Guerra. This area has the main channels of each watershed in close proximity to each other, and the peak elevations from each watershed system will flood into the other.

9. The Four Corners Area and Strawberry Square Area experience flooding due to interconnection and close proximity between the two systems and inability of the water control structures at Highway 48 to convey water from Resaca de la Guerra downstream. The waters flow south and cross the Four Corners area toward the downstream portions of North Main Drain. This problem area can be seen on the existing water surface profile Plate 9, Volume II, at Station 656+00 and Plate 10, Volume II, at Station 186+00 and in the pictures depicting flooding in this area during the September 1984 flood. (See Figure 7, Volume I.)

   This interconnection phenomenon also occurs in the area of Rockwell Drive and Paredes Line Road.

10. The Downtown Area will experience heavy flooding in the 100-year storm due to several factors. These include inadequate number and spacing of inlets, small pipes under the streets, and high tailwater conditions in Town Resaca under full storm conditions.

11. In the watershed of Cameron County Drainage District No. 1 Ditch, the most troublesome flooding area is that of the Valley Community Hospital. This is primarily due to the location of the Hospital in a low, flood-prone area of the Ditch's floodplain. This area has been largely

agricultural in character, and, as urbanization occurs within the watershed, the amount of water carried by the Ditch will increase, thereby, flooding the Hospital.

12. The Resaca del Rancho Viejo watershed has the fewest problems of all the watershed areas due to several factors. One factor is that the area of the contributing watershed is small when compared to the storage the resaca contains. The high degree of urbanization and consequent increase in run-off has not yet occurred to the degree that has occurred in Resaca de la Guerra and Town Resaca.

    The Cameron County Drainage District No. 1 Ditch and Resaca del Rancho Viejo present an opportunity to properly manage and plan the growth occurring to minimize the problems experienced in the three southern watersheds.

CHAPTER VII

VII. DRAINAGE IMPROVEMENT ALTERNATIVES

The improvements to the existing drainage system that are required to provide adequate flood protection within the overall Study Area have been considered with regard to both nonstructural, procedural measures and physical, structural modifications. From the results of the various analyses of existing flooding conditions associated with the major drainage facilities such as resacas and ditches and with the storm sewer facilities, it is apparent that there are certain specific components of the overall drainage system that require improvements. These improvements range from increased pipe capacities for more effective drainage in localized areas to large-scale ditch realignments and enlargements for better hydraulic conveyance through the major drainage subsystems. Also, as new areas begin to develop primarily in the Cameron County Drainage District No. 1 Ditch and Resaca del Rancho Viejo subsystems, additional drainage facilities will be required.

Presented in this chapter are the specific drainage improvement alternatives that have been identified and considered in this study for purposes of developing the overall Master Drainage Plan. Specific structural improvements are discussed and listed for the major drainage subsystems and for the existing storm sewer facilities. Plates 42 and 42A, Volume II, present maps of the Study Area showing all the alternatives that have been identified.

A. Major Drainage Structural Improvements

In determining the specific improvements required for the major drainage subsystems, the underlying goal generally has been to provide flood protection for the 100-year storm. This is consistent with the design criteria adopted for this study as outlined in Chapter IV. Basically, achieving this goal requires that the existing major drainage subsystems, comprised of resacas, ditches and various control structures, be modified and expanded in order to lower projected 100-year water levels below prescribed flood index elevations.

These flood index elevations have been established by reviewing available topographic maps and field survey data and then selecting, at key locations along each of the drainage subsystems, minimum critical elevations that generally represent threshold flooding levels for existing buildings or other significant structures. Detailed survey data describing the exact finished floor elevations of existing buildings and structures in flood-prone areas are not available; therefore, in order to facilitate the drainage planning process, the various flood index elevations listed in Table 15, Volume I, have been determined using the best available information. For example, in the Four Corners area near Station 656+00 on North Main Drain, a flood index elevation of 23.5 feet has been established. An elevation of 23.0 feet is noted on the

TABLE 15

FLOOD INDEX ELEVATIONS FOR THE MAJOR DRAINAGE SUBSYSTEMS

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 Subdivision
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
758+60	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

*21.0 if special Airport drainage improvements are implemented.

TABLE 15 (CONT'D.)
FLOOD INDEX ELEVATIONS FOR THE MAJOR DRAINAGE SUBSYSTEMS

RESACA DE LA GUERRA				
73+00	25.5	25.5	RG23	Existing Homes
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. Dev.
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	RG8	Existing Apartments
764+00	33.5	33.4	RG2	Existing Subdivision
833+50	34.0	34.5	Y4	Existing Homes
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH				
79+79	13.3	12.7	CC18	Hwy. 48 Rdwy. Elev.
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
RESACA DEL RANCHO VIEJO				
92+00	16.0	15.3	RV37	Port Auth. Water Plant
107+00	17.0	15.3	RV37	Industrial Development
214+00	22.0	21.8	RV33	Existing Homes
465+00	22.5	22.0	RV29	Existing Homes
517+00	23.0	22.0	RV28	Existing Homes
600+00	27.6	26.7	RV25	New Subdivision
750+00	27.0	26.7	RV20	Existing Homes
950+00	30.0	27.2	RV16	New Subdivision
1170+00	33.4	32.9	RV8	Ranch Headquarters
1250+00	33.0	32.9	RV7	Existing Subdivision

U.S.G.S. topographic map of the area on Boca Chica Boulevard at its crossing of the North Main Drain channel. Also, the original construction plans for improving and concrete-lining the channel show a natural ground elevation between 23.0 and 23.5 feet. Based on these specific values, the flood index elevation of 23.5 feet at Station 656+00 was selected, and it is considered to be generally representative of minimum finished floor elevations in the area. Similarly, at Station 249+20 on Town Resaca near the Gladys Porter Zoo, survey data for Structure TR-19 indicated roadway elevations between 24.3 and 25.0 feet. Therefore, a flood index elevation of 25.0 feet was adopted to represent the threshold flooding level for adjacent houses.

For purposes of this planning study, these indices have been used as the standard for measuring the effectiveness of the various drainage improvement alternatives. The adopted flood index elevations are denoted on the existing water surface profile plots in Plates 8 through 12, Volume II, for the major drainage subsystems, and comparison of these index elevations with the existing flood levels indicates the magnitude of present flooding problems along each of the subsystems.

Because of the extremely flat terrain in the Brownsville area, the undersized capacity of most of the existing major drainage facilities and the present level of development that already exists in flood-prone areas, the improvements that are required in the major drainage subsystems to fully provide 100-year flood protection are very extensive and costly. Implementation of these improvements undoubtedly will have to be phased over many years in the future in order for the goal of 100-year flood protection ultimately to be achieved.

Included in the following sections are discussions and descriptions of the various drainage improvements that have been determined to be effective and, in most cases, essential for lowering existing flood levels and ultimately achieving 100-year flood protection in each of the major drainage subsystems.

1. Town Resaca

Flooding problems along Town Resaca are the result of: (a) the extensive development and urbanization of the drainage area, which contributes large quantities of stormwater run-off; (b) the limited conveyance capacity of the resaca pools because of undersized and restricted outlet structures; (c) the limited volume of flood storage available in the resaca pools because of the relatively high normal water surface elevations that presently are maintained; and (d) the high tailwater conditions that can occur at the downstream end of the subsystem in the vicinity of the Impala Ditch where outflows from Town Resaca and North Main Drain combine. Improvements in the North Main Drain subsystem downstream of Impala Ditch, i.e. channel widening, are essential for solving existing flooding problems in Town Resaca because of the high tailwater conditions.

With more stormwater conveyed through the North Main Drain subsystem to the Brownsville Ship Channel or the Rio Grande, tailwater levels in the Impala Ditch will be lowered, thus allowing more outflow from Town Resaca.

To provide increased conveyance of stormwater through the Town Resaca subsystem to the Impala Ditch, existing outlet structures for many of the individual pools must be expanded and modified, without affecting normal pool levels. Also, additional stormwater ponding areas must be created to provide detention storage, and additional pumping facilities and drainage diversions are required to remove a portion of the existing stormwater from the system, i.e. discharged into the Rio Grande.

The recommended drainage improvements for the Town Resaca subsystem are listed and conceptually described in Table 16, Volume I. With the exception of alternative schemes involving pump station sizes and locations and drainage diversions into the Rio Grande, all the recommended improvements are essential for achieving the goal of 100-year flood protection.

2. North Main Drain

Reducing present flooding problems along the North Main Drain subsystem requires major modifications of the existing channel to increase its conveyance capacity, as well as the construction of new facilities for diverting run-off and for providing detention storage in the middle and upper reaches of the subsystem in order to reduce stormwater flows and volumes.

The lower reach of the North Main Drain from its outlet at the Port Authority Ditch near the Brownsville Ship Channel to its confluence with Impala Ditch, a distance of over seven miles, is considerably undersized and will require extensive widening to provide adequate capacity for conveyance of the combined outflows from the Town Resaca, North Main Drain and Resaca de la Guerra drainage subsystems.

With these channel modifications ultimately in place, together with other major upstream improvements, existing flooding problems at the Brownsville/South Padre Island

TABLE 16

RECOMMENDED IMPROVEMENTS FOR THE TOWN RESACA DRAINAGE SUBSYSTEM

TRI-1 Enhanced Detention Storage near Los Tomates Banco
- -Excavate on-channel and off-channel areas within the existing floodplain
- -Create 315 acre-feet of new storage volume covering 90 acres (existing & new storage)
- -Use 50 acres of Los Tomates Banco area for spoil disposal, filled to a height of six feet
- -Remove existing overflow weir at Structure TR27
- -Install 1,600 feet of 48" drain pipe from off-channel storage area to existing Los Tomates Banco storage area

TRI-2 Additional Detention Storage above Belthair Blvd.
- -Eliminate flow obstruction caused by 36" water line at Structure TR3
- -Install one 5' X 2' box culvert under water line (L = 20')
- -Provide 60 acre-feet of additional on-channel storage volume

TRI-3 Modifications to Structure TR15 at Palm Blvd.
- -Lengthen existing overflow weir to 40 feet
- -Lower crest elevation of existing overflow weir to 23.50'
- -Add two 10' X 10' box culverts (L = 122')

TRI-4 Modifications to Structure TR26 near 25th Street
- -Replace existing pipe culverts with four 10' X 8' box culverts (L = 100')

TRI-5 Stormwater Pump Station near Los Tomates Banco
- -Construct stage-activated, multi-pump facility near levee
- -Discharge stormwater over levee to Rio Grande
- -Pumping capacity of 600,000 g.p.m.

TRI-6 Drainage Diversion to Rio Grande for Portions of Sub-watersheds 8, 9, 15, 20, 22, 28, 30 & 31 in the Downtown Area
- -Modify drainage system for 747 acres to divert stormwater from Town Resaca watershed to the Rio Grande
- -Construct new 300,000-g.p.m. pump station at levee with 185 acre-feet of sump storage
- -Increase pumping capacity of the existing 12th and Fronton Street Pump Station to 350,000 g.p.m.

TRI-7 Stormwater Pump Station near Ebony Lake
- -Construct stage-activated, multi-pump facility
- -Discharge stormwater over levee into Rio Grande
- -Pumping capacity of 70,000 g.p.m.
- -Install 6,000 feet of 60-inch discharge line from pump station to outlet structure at levee
- -Replace existing 36-inch pipe between Ebony Lake and Town Resaca with two 10' X 8' box culverts (L = 600')
- -Replace existing 48-inch pipe and associated 5' X 5' box under Central Boulevard with two 10' X 8' box culverts (L = 130')

TABLE 16 (CONT'D.)

RECOMMENDED IMPROVEMENTS FOR THE TOWN RESACA DRAINAGE SUBSYSTEM

TRI-8 Modifications to Structures TR18 & 19 near Gladys Porter Zoo
- -Lengthen existing overflow weir to 80 feet
- -Lower crest elevation of existing weir to 21.00'
- -Replace existing box culverts with three 10' X 8' boxes (L = 65')

TRI-9 Modification to Structure TR25 near Lincoln Park
- -Lengthen existing overflow weir to 100 feet
- -Lower crest elevation of existing weir to 17.80'
- -Excavate 35 acre-feet of normal pool storage upstream of structure
- -Concrete line channel bottom and sides up to 8 ft. depth over a distance of 600 feet immediately downstream of Lincoln Park

TRI-10 Miscellaneous Modifications to Other Structures
- -Lengthen existing overflow weir at Structure TR9 to 35 feet
- -Add two 10' X 10' box culverts at Structure TR14 (L = 33')
- -Add two 9' X 9' box culverts at Structure TR20 (L = 52')
- -Add two 10' X 9' box culverts at Structure TR22 (L = 81')

International Airport and in the Four Corners area can be significantly reduced.

The various recommended drainage improvements for the entire North Main Drain subsystem are listed and described in Table 17, Volume I. Implementation of all these improvements will provide 100-year flood protection along the entire length of the North Main Drain subsystem, including the Four Corners area. The 100-year flood levels near Four Corners will be lowered by a total of almost 4.0 feet with the overall Master Drainage Plan ultimately implemented; however, this level of protection requires that major improvements and modifications be made to the existing drainage facilities along North Main Drain in the immediate vicinity of Four Corners.

One of the principal causes of the existing flooding in the Four Corners area is the significant quantity of run-off that drains into the North Main Drain channel from local sub-watersheds in the immediate area, i.e. Sub-watersheds 19, 20, 21, 22, and 23 (see Plate No. 3, Volume II). The combined peak 100-year run-off rate for these sub-watersheds, taking into account all available detention storage areas that can be reasonably utilized, is 1,510 c.f.s., which is greater than the available capacity (950 c.f.s.) of the existing concrete-lined North Main Drain channel through this reach, even with the proposed downstream channel widening and other upstream improvements in place.

It appears that the solution to this problem must include: (a) the diversion of most of the upstream flood flows in the North Main Drain channel at Rockwell Road into Resaca de la Guerra with a 300,000-g.p.m. pumping station (NMI-26); (b) concrete lining and widening of the existing channel to a bottom width of 100 feet from south of International Boulevard (Station 627+00) upstream to Old Port Isabel Road (Station 674+00) (NMI-25); and (c) the diversion of a substantial portion of the flood flows in the North Main Drain channel downstream of International Boulevard into Resaca de la Guerra with a 500,000-g.p.m. pumping station (NMI-24).

Without these specific improvements included in the overall Master Drainage Plan, the projected 100-year water surface elevation in the North Main Drain channel at Boca Chica Boulevard will be 23.92 feet, which is only 0.4 feet above the flood index elevation at this location.

Without the additional improvements in the Four Corners section of the North Main Drain, the implementation of the remaining improvements listed in Table 17, Volume I, will

TABLE 17

RECOMMENDED IMPROVEMENTS FOR THE NORTH MAIN DRAIN DRAINAGE SUBSYSTEM

NMI-1 Channel Widening from Port Authority Ditch Upstream to Resaca de la Guerra
- Widen channel bottom to 80 feet from Station 111+00 to Station 458+34
- Modify existing channel to trapezoidal section with 3:1 side slopes

NMI-2 Channel Realignment East of Airport
- Replace sharp bends with straight channel between Stations 281+00 and 341+00
- Construct 4,200 feet of 80' wide bottom trapezoidal channel section

NMI-3 Channel Realignment West of Minnesota Avenue
- Replace sharp bends with straight channel between Stations 400+00 and 449+00
- Construct 2,500 feet of 80' wide bottom trapezoidal channel section

NMI-4 Channel Lining and Widening from Resaca de la Guerra Confluence Upstream to Impala Ditch Confluence
- Concrete line and widen channel from Station 456+50 to Station 539+90
- Concrete line channel bottom and sides up to depth of 4.0 feet
- Widen channel bottom to 40 feet between Stations 458+34 and 468+88
- Widen channel bottom to 60 feet between Stations 469+73 and 481+69
- Widen channel bottom to variable 40 - 48 feet between Stations 482+51 and 514+10
- Widen channel bottom to 50 feet between Stations 514+80 and 539+40

NMI-5 Modifications to Structure NM35 at Boca Chica Blvd.
- Replace existing structure with bridge to span 80' wide (bottom) improved channel
- Length of new bridge to be approximately 100 feet
- New bridge centerline at Station 205+00
- Minimum low beam elevation at 13.50'
- Flowline elevation of channel at Station 205+00 is 2.66'

NMI-6 Modifications to Structure NM32 at Minnesota Avenue
- Replace existing structure with bridge to span 80' wide (bottom) improved channel
- Length of new bridge to be approximately 100 feet
- New bridge centerline at Station 400+00
- Minimum low beam elevation at 16.70 feet
- Flowline elevation of channel at Station 400+00 is 8.50'

TABLE 17 (CONT'D.)

RECOMMENDED IMPROVEMENTS FOR THE NORTH MAIN DRAIN DRAINAGE SUBSYSTEM

NMI-7 Channel Lining and Widening from Old Port Isabel Road Upstream to above Rockwell Road
- Concrete line and widen channel from Station 675+30 to Station 701+80
- Modify existing channel to trapezoidal section with bottom width of 20 feet
- Concrete line bottom and sides up to depth of 4.0 feet
- Construct overbank flow section 10.0 feet wide and 3.0 feet deep along right (south) bank of channel

NMI-8 Modifications to Structure NM19 at Old Port Isabel Road
- Replace existing structure with bridge to span 20' wide (bottom) improved channel
- Length of new bridge to be approximately 70 feet
- New bridge centerline at Station 675+30
- Minimum low beam elevation at 27.00'
- Flowline elevation of channel at Station 675+30 is 16.30'

NMI-9 Modifications to Structure NM18 at Rentfro Street
- Replace existing structure with bridge to span 20' wide (bottom) improved channel
- Length of new bridge to be approximately 70 feet
- New bridge centerline at Station 686+60
- Minimum low beam elevation at 27.50'
- Flowline elevation of channel at Station 686+60 is 16.90'

NMI-10 Modifications to Structure NM17 at Rockwell Road
- Replace existing structure with bridge to span 20' wide (bottom) improved channel
- Length of new bridge to be approximately 70 feet
- New bridge centerline at Station 696+80
- Minimum low chord elevation at 28.00'
- Flowline elevation of channel at Station 696+80 is 17.50'

NMI-11 Channel Widening from above Rockwell Road Upstream to Mackintosh Road
- Widen channel from Station 701+80 to Station 721+ 85
- Modify existing channel to trapezoidal section with 2:1 side slopes and bottom width of 100 feet

NMI-12 Modifications to Structure NM15 at Mackintosh Road
- Replace existing pipes with four 10' X 8' box culverts (L = 65')

NMI-13 Channel Lining and Widening from Mackintosh Road Upstream to Highway 77
- Concrete line and widen channel from Station 721+85 to Station 726+99
- Modify existing channel to trapezoidal section with bottom width of 20 feet
- Concrete line bottom and sides up to depth of 4.0 feet

TABLE 17 (CONT'D.)
RECOMMENDED IMPROVEMENTS FOR THE NORTH MAIN DRAIN DRAINAGE SUBSYSTEM

NMI-14 Modifications to Structure NM6 at Central Boulevard
- Replace existing boxes with two 10' X 5' box culverts (L = 230')

NMI-15 Modifications to Structure NM5 Between Central Boulevard and Honeydale Road
- Replace existing pipe with two 8' X 6' box culverts (L = 72')

NMI-16 Modifications to Structure NM4 at Honeydale Road
- Replace existing pipes with two 8' X 6' box culverts (L = 49')

NMI-17 Modifications to Structure NM3 at Union Pacific Railroad
- Replace existing pipe with two 8' X 6' box culverts (L = 57')

NMI-18 Modifications to Structure NM2 at El Paso Road
- Replace existing pipes with two 8' X 6' box culverts (L = 65')

NMI-19 Modifications to Structure NM16 at Paredes Line Road
- Add three 7' X 6' box culverts (L = 120')

NMI-20 Modifications to Airport Drainage System
- Construct levee embankment around Airport site
- Excavate sump storage area inside the proposed levee system to provide a volume of 450 acre-feet with a bottom elevation of 12.00' and a maximum water surface elevation of 17.30'
- Modify existing Airport stormwater drainage system to discharge into sump storage area, including 300 acres from Cameron County Drainage District No. 1 Ditch watershed
- Install 240,000-g.p.m. pump station to discharge stormwater from Airport site into North Main Drain at Station 281+00

NMI-21 New Detention Storage Area South of Airport
- Excavate off-channel stormwater detention pond between Main Drain and Airport at Station 362+00
- Create 330 acre-feet of storage volume with a bottom elevation 9.00' and a maximum water surface elevation of 17.50'
- Construct a side channel spillway with a crest elevation of 16.00' to connect North Main Drain channel to the proposed storage area

NMI-22 Stormwater Pump Station near Nogales School
- Construct stage-activated, multi-pump facility upstream of Structure NM28 at La Posada Drive
- Discharge stormwater over levee into Rio Grande
- Pumping capacity of 500,000 g.p.m.

TABLE 17 (CONT'D.)
RECOMMENDED IMPROVEMENTS FOR THE NORTH MAIN DRAIN DRAINAGE SUBSYSTEM

NMI-23 New Detention Storage Area Downstream of International Boulevard
- Excavate off-channel stormwater detention pond between Main Drain and Resaca de la Guerra at Station 627+00 upstream of Structure NM24
- Create 510 acre-feet of storage volume with a bottom elevation of 15.20' and a maximum water surface elevation of 23.00'
- Construct a side channel spillway with a crest elevation of 19.00' to connect North Main Drain channel to the proposed storage area

NMI-24 Stormwater Pump Station Downstream of International Boulevard
- Construct stage-activated, multi-pump facility upstream of Structure NM24
- Discharge stormwater over existing embankment into Resaca de la Guerra upstream of Structure RG22
- Pumping capacity of 500,000 g.p.m.
- Add three 10' X 10' boxes to each of the improved culverts (RGI-2) at Structures RG22 and RG23 on Resaca de la Guerra at Morningside Road (L = 75')

NMI-25 Channel Lining and Widening and Structure Modifications from Downstream of International Boulevard to Old Port Isabel Road
- Concrete line and widen channel from Station 627+00 to Station 674+00
- Modify existing channel to trapezoidal section with bottom width of 100 feet
- Concrete line channel bottom and sides up to depth of 6.0 feet
- Replace existing culverts at Structures NM20, NM22 and NM23 with bridges to span the widened channel (L = 130')
- Replace existing railroad trestle at Structure NM21 with bridge to span the widened channel (L = 130')
- Install 1,400 feet of concrete retaining wall (10' high) along modified channel reaches where full trapezoidal channel sections cannot be constructed due to existing right-of-way restrictions

NMI-26 Stormwater Pump Station Upstream of Rockwell Road
- Construct stage-activated, multi-pump facility upstream of Structure NM17
- Discharge stormwater over existing embankment into Resaca de la Guerra upstream of Structure RG13
- Pumping capacity of 300,000 g.p.m.
- Add two 10' X 8' boxes to the improved culverts (RGI-4) at Structure RG13 on Resaca de la Guerra at Palo Verde Road (L = 64') and two 10' X 10' boxes at each of the other existing structures on the side arm of Resaca de la Guerra at Shidler Drive, Price Road and Eagle Drive (L = 100')

TABLE 17 (CONT'D.)

RECOMMENDED IMPROVEMENTS FOR THE NORTH MAIN DRAIN DRAINAGE SUBSYSTEM

- Expand storage volume of proposed stormwater detention pond to 400 acre-feet for diversions from Resaca de la Guerra into Cameron County Drainage District No. 1 Ditch subsystem (RGI-3)

NMI-27 New Detention Storage Area Upstream of Paredes Line Road
- Excavate and drain existing off-channel resaca pool north of North Main Drain channel and adjacent to Paredes Line Road
- Create 78 acre-feet of storage volume with a bottom elevation of 17.00' and a maximum water surface elevation of 30.00'
- Construct a side channel spillway with a crest elevation of 24.00' at Station 720+00 to connect North Main Drain channel to the proposed storage area

NMI-28 Modifications to Structure NMI3B at Highway 77 East Access Road
- Add two 8' X 7' box culverts to existing structure (L = 100')

NMI-29 Additional Detention Storage Area Upstream of West Price Road
- Excavate on-channel stormwater detention pond between Station 776+00 and Station 795+00 upstream of Structure NM8
- Create 50 acre-feet of storage volume with a bottom elevation of 21.30' and a maximum water surface elevation of 30.00'

NMI-30 Additional Detention Storage Area Upstream of Central Boulevard
- Excavate on-channel stormwater detention pond between Station 809+00 and Station 818+00 upstream of Structure NM6
- Create 89 acre-feet of storage volume with a bottom elevation of 24.00' and a maximum water surface elevation of 30.00'

NMI-31 Stormwater Pump Station Upstream of Central Boulevard
- Construct stage-activated, multi-pump facility upstream of Structure NM6
- Discharge stormwater over existing embankment into Resaca de la Guerra upstream of Structure RG4F
- Pumping capacity of 100,000 g.p.m.

NMI-32 Additional Detention Storage Area Upstream of MOPAC Railroad
- Excavate on-channel stormwater detention pond between Station 840+00 and Station 856+00 upstream of Structure NM3
- Create 260 acre-feet of storage volume with a bottom elevation of 26.50' and a maximum water surface elevation of 32.00'

NMI-33 Modifications to Structures NM8 through NM12 from West Price Road to Old Alice Road
- Replace existing channel and structures between Stations 755+80 and 776+04 with three 10' X 6' box culverts (L = 2,024')
- Integrate design of proposed box culverts with proposed widening of West Price Road in accordance with current Street and Drainage Capital Improvements Program

TABLE 17 (CONT'D.)
RECOMMENDED IMPROVEMENTS FOR THE NORTH MAIN DRAIN DRAINAGE SUBSYSTEM

NMI-34 Modifications to Structure NM38 at South Port Road and Associated Channel Improvements

- Widen channel to 300 feet from Station 0+00 to Station 111+00
- Modify existing channel to trapezoidal section with 3:1 side slopes
- Replace existing pipe culverts with bridge to span widened channel
- Length of new bridge to be approximately 320 feet
- New bridge centerline at Station 11+00
- Minimum low beam elevation of new bridge at 27.00 feet
- Flowline elevation of channel at Station 11+00 is 6.00 feet

provide flood protection in the Four Corners area for only the 25-year storm.

3. Resaca de la Guerra

The causes of the existing flooding problems along the length of this subsystem are similar to those for Town Resaca. Undersized and restricted outlet structures on the resaca pools, particularly the most downstream structure, and limited pool storage volumes are principal concerns, and the high tailwater levels that can occur in the North Main Drain near the downstream outlet of the Resaca de la Guerra subsystem significantly limit outflows. As with Town Resaca, the proposed channel modifications in the lower portion of the North Main Drain subsystem are essential for reducing flooding conditions in Resaca de la Guerra.

Because of the proximity of Resaca de la Guerra to the Cameron County Drainage District No. 1 Ditch drainage subsystem, it is feasible to consider diverting by gravity a portion of the stormwater flows from Resaca de la Guerra into a detention storage area within the Ditch watershed. These flows then could be discharged gradually into the Ditch as flood levels subside. This flood control measure would be effective in significantly reducing stormwater flows in the downstream pools of Resaca de la Guerra.

The recommended drainage improvements for the Resaca de la Guerra subsystem are listed and described in Table 18, Volume I. Basically, these include structure modifications, provisions for increased on-line detention storage and the diversion of a portion of the flows into the Cameron County Drainage District No. 1 Ditch subsystem.

4. Cameron County Drainage District No. 1 Ditch

Extensive flooding along the main channel through this subsystem results from the undersized capacity of the existing ditch sections and associated restrictions at road crossings and other structures. Major flooding problems exist in the vicinity of the Valley Community Hospital (Station 239+00) and near several subdivisions located along the main channel upstream of Highway 48 (Stations 200+00, 301+00 and 345+00). Existing 100-year water levels are as much as six feet above the flood index elevations at several points along the subsystem.

Recommended improvement measures for achieving full 100-year flood protection along the entire length of the subsystem are listed and described in Table 19, Volume I.

TABLE 18

RECOMMENDED IMPROVEMENTS FOR THE RESACA DE LA GUERRA DRAINAGE SUBSYSTEM

RGI-1 Modifications to Structure RG24 at North Main Drain Ditch
- -Construct new 10' X 50' drop inlet structure with crest elevations set at 20.03' for the 50' main section and at 22.00' for the 10' end sections
- -Install two 4' X 4' box culverts as outlets for the new drop inlet with flowline elevations set at 12.00'
- -Construct overflow spillway section 200 feet long with a crest elevation set at 22.40'

RGI-2 Modifications to Structures RG22 and RG23 at Morningside Road Crossings
- -Add three 10' X 10' box culverts to each structure
- -Length of RG22 boxes is 75 feet
- -Length of RG23 boxes is 63 feet

RGI-3 Diversion of Stormwater Flows during High Stage Conditions into Cameron County Drainage District No. 1 Ditch near the Paredes Line Road/Highway 802 Intersection
- -Construct overflow weir section near Station 463+00, 100 feet long, with a crest elevation set at 26.80'
- -Construct adjacent detention storage pond between Resaca de la Guerra and Cameron County Drainage District No. 1 Ditch to provide 225 acre-feet of storage with a low capacity outlet structure
- -Improve existing channels between detention pond and Cameron County Drainage District No. 1 Ditch

RGI-4 Modifications to Structure RG13 at Palo Verde Drive
- -Add two 10' X 8' box culverts (L = 64')

RGI-5 Upstream Detention Storage above Highway 802
- -Utilize resaca bed and low area within existing 100-year floodplain for detention storage
- -Replace existing pipes at Structures RGY1 & Y2 with 36-inch pipes with flowline elevations set at 29.10' and 29.00', respectively (L = 50')
- -Install one 48-inch pipe at Structure RGY4 with a flowline elevation set at 25.10' (L = 60')
- -Install one 48-inch pipe at Structure RGY6 with a flowline elevation set at 25.00' (L = 50')
- -Add one 42-inch pipe to Structure RG1 with a flowline elevation set at 25.30' (L = 105')
- -Replace existing pipes at Structure RG2 with two 48-inch pipes with flowline elevations set at 25.00' (L = 60')

TABLE 18
RECOMMENDED IMPROVEMENTS FOR THE RESACA DE LA GUERRA DRAINAGE SUBSYSTEM

RGI-6 Miscellaneous Modifications to Structures Between Billy Mitchell Boulevard and 14th Street
- Replace existing pipes at Structure RG20 with two 9' X 8' box culverts (L = 144')
- Lengthen existing overflow weir at Structure RG19 to 80 feet
- Replace existing pipe at Structure RG18 with two 10' X 10' box culverts (L = 144')
- Lengthen existing overflow weir at Structure RG18 to 80 feet

RGI-7 Miscellaneous Modifications to Structures Between Old Port Isabel Road and F.M. 802
- Lengthen existing overflow weir at Structure RG12A to 70 feet
- Replace existing pipes at Structure RG10 with two 72-inch pipes (L = 70')
- Lengthen existing overflow weir at Structure RG8 to 140 feet
- Add two 42-inch pipes to Structure RG4F (L = 100')
- Replace existing pipes at Structures RG4A through RG4E with two 48-inch pipes at each structure (L = 96', 100', 100', 105', 100' and 20', respectively)

RGI-8 Modifications to Structure RG12 at Paredes Line Road
- Replace existing pipe culvert with two 10' X 10' box culverts (L=112 feet)
- Raise road profile to a minimum low point elevation of 29.00 feet

TABLE 19
RECOMMENDED IMPROVEMENTS FOR CAMERON COUNTY DRAINAGE
DISTRICT DITCH NO. 1 DRAINAGE SUBSYSTEM

CCI-1 Channel Widening Downstream of Union Pacific Railroad
- -Widen existing channel bottom to trapezoidal section with 300 foot bottom width from Station 10+00 upstream to Station 98+77

CCI-2 Modifications to Structure CC18 at Highway 48
- -Replace existing structure with bridge to span 300' wide (bottom) improved channel
- -Length of new bridge to be approximately 330 feet
- -New bridge centerline at Station 80+00
- -Minimum low beam elevation at 10.00'
- -Flowline elevation of channel at Station 80+00 is -0.76'

CCI-3 Channel Lining and Widening from Union Pacific Railroad to Harbor Road
- -Concrete line and widen channel from Station 98+77 upstream to Station 117+53
- -Concrete line channel bottom and sides up to depth of 4.0 feet
- -Widen channel bottom to 100 feet

CCI-4 Modifications to Structure CC17 at MOPAC Railroad
- -Replace existing structure with bridge to span 100' wide (bottom) improved channel
- -Length of new bridge to be approximately 120 feet
- -New bridge centerline at Station 100+00
- -Minimum low beam elevation at 13.80'
- -Flowline elevation of channel at Station 100+00 is 0.25'

CCI-5 Modifications to Structure CC16 at F.M. 511
- -Replace existing structure with bridge to span 100' wide (bottom) improved channel
- -Length of new bridge to be approximately 120 feet
- -New bridge centerline at Station 109+50
- -Minimum low beam elevation at 10.00'
- -Flowline elevation of channel at Station 109+50 is -0.70'

CCI-6 Channel Widening from Harbor Road to Highway 48
- -Widen existing channel bottom to trapezoidal section with 200 foot bottom width 200 feet from Station 117+53 upstream to Station 182+07

CCI-7 Channel Lining and Widening from Highway 48 to Old Railroad Grade
- -Concrete line and widen channel from Station 182+07 upstream to Station 206+25
- -Concrete line channel bottom and sides up to depth of 4.0 feet
- -Widen channel bottom to 80 feet

TABLE 19 (Cont'd.)
RECOMMENDED IMPROVEMENTS FOR CAMERON COUNTY DRAINAGE
DISTRICT DITCH NO. 1 DRAINAGE SUBSYSTEM

CCI-8 Modifications to Structure CC13 at Highway 48
- Replace existing structure with bridge to span 80' wide (bottom) improved channel
- Length of new bridge to be approximately 100 feet
- New bridge centerline at Station 182+50
- Minimum low beam elevation at 12.00'
- Flowline elevation of channel at Station 182+50 is 2.96'

CCI-9 Channel Widening from Old Railroad Grade to the Southern Pacific Railroad
- Widen existing channel bottom to 200 feet from Station 206+25 upstream to Station 404+96

CI-10 Modifications to Structure CC10 at Central Avenue
- Replace existing structure with bridge to span 200' wide (bottom) improved channel
- Length of new bridge to be approximately 220 feet
- New bridge centerline at Station 239+00
- Minimum low beam elevation at 14.50'
- Flowline elevation of channel at Station 239+00 is 5.00'

CCI-11 Additional Detention Storage Area Upstream of Central Avenue
- Excavate on-channel stormwater detention pond between Station 239+19 and Station 264+19
- Create 1,593 acre-feet of storage volume with a surface area of 140 acres , a bottom elevation of 5.00' and a maximum water surface elevation of 17.10'
- Remove 2.3 million cubic yards of material

CCI-12 Modifications to Structure CC7 at Old Port Isabel Road
- Add four 10' X 10' box culverts to existing structure (L = 20')

CCI-13 Additional Detention Storage Area Upstream of Dana Road
- Excavate on-channel stormwater detention pond between Station 325+60 and Station 393+27
- Create 2,790 acre-feet of storage volume with a surface area of 235 acres , a bottom elevation of 6.40' and a maximum water surface elevation of 18.80'
- Remove 4.1 million cubic yards of material

TABLE 19 (Cont'd.)
RECOMMENDED IMPROVEMENTS FOR CAMERON COUNTY DRAINAGE
DISTRICT DITCH NO. 1 DRAINAGE SUBSYSTEM

CCI-14 Channel Widening from the Southern Pacific Railroad to F.M. 3248
- -Widen existing channel bottom to 100 feet from Station 405+05 upstream to Station 421+00
- -Widen existing channel bottom to 80 feet from Station 421+00 upstream to Station 489+44
- -Widen existing channel bottom to 50 feet from Station 492+65 upstream to Station 514+83
- -Widen existing channel bottom to 50 feet from Station 515+18 upstream to Station 576+50

CCI-15 Local Drainage Problem Solution at Valley Community Hospital
- -Encircle property with 2,900 feet of levee
- -Excavate 7.9 acre-feet of detention storage
- -Install automatic 3,000 g.p.m. pump facility with backup engine
- -Install 5,000 feet of road at elevation 22.0 for access

These include widening and concrete lining of the main channel, replacement or enlargement of existing structures, and excavation of extensive stormwater detention storage areas in the middle reach of the subsystem.

5. Resaca del Rancho Viejo

   As illustrated by the flood index elevations plotted on the existing 100-year water surface profiles in Plate 12, Volume II, flooding problems generally are minimal along the Resaca del Rancho Viejo subsystem. The extensive volume of existing storage in the upper portion of the overall watershed, i.e., above Structure RV11 at Station 996+50, and the narrow contributing drainage area along the watercourse downstream, limit the magnitude of flood flows along the length of the subsystem. The principal improvements proposed for the subsystem include enhancement of the primary outlet structure near the head of the Resaca del Rancho Viejo Floodway and installation of a flood gate structure on the ditch that connects Resaca del Rancho Viejo to the Cameron County Drainage District No. 1 Ditch to control the exchange of stormwater flows between the two subsystems. The recommended improvements for the Resaca del Rancho Viejo subsystem are listed in Table 20, Volume I.

Considerations were also given to the potential use of additional gravity drains to the Rio Grande and Cameron County Drainage District No. 2 Ditch as alternatives to help dissipate the stormwaters.

Cameron County Drainage District No. 2 Ditch was determined to be an infeasible alternative due to the following:

1. The length of the Cameron County Drainage District No. 2 Ditch is longer than the North Main Drain;

2. The Cameron County Drainage District No. 2 Ditch would require extensive rehabilitation; and,

3. Upon completion of the rehabilitation of the Cameron County Drainage District No. 2 Ditch, the new capacity would not be adequate to convey the 100-year stormwater.

The gravity drains were found to be infeasible due to the high tailwaters realized by the Rio Grande during flood conditions which would compound the flooding problems experienced in the City.

TABLE 20

RECOMMENDED IMPROVEMENTS FOR THE RESACA DEL RANCHO VIEJO DRAINAGE SUBSYSTEM

RVI-1 Modifications to Structure RV37 at Port Authority Water Intake
- Replace existing pipe with two 6' X 1.5' box culverts (L = 30')
- Install concrete cap spillway embankment protection with a minimum crest elevation of 13.30' (L = 200')

RVI-2 Modifications to Structure RV35 near head of Rancho Viejo Floodway
- Construct emergency overflow concrete spillway within the existing embankment with a uniform crest elevation of 18.90' (L = 200')
- Refurbish two existing and abandoned concrete drop inlets (4.5' and 3.5' diameters)

RVI-3 Modifications to Structure RV31 at Robindale Road
- Install mechanism for raising existing 7.5' X 7.5' lift gate

RVI-4 Modifications to Structure RV28 Downstream of Paredes Line Road
- Construct emergency overflow spillway within the existing embankment with a uniform crest elevation of 18.20' (L = 200')
- Install flood gate structure (crest elevation at 24.50') to control stormwater flows through the existing ditch between Resaca del Rancho Viejo and Cameron County Drainage District No. 1 Ditch (two 5' X 5' sluice gates with lift mechanisms.)

B. Local Drainage Structural Improvements

Although the primary purpose of this Master Drainage Plan is to provide a plan to correct the widespread flooding problems of the area, several local problem areas were evaluated, and localized solutions analyzed.

1. The Brownsville/South Padre Island International Airport experiences flooding as discussed in the Chapter VI Summary of Problems. The problems can be alleviated if all the North Main Drain solutions downstream of the airport are implemented and if Cameron County Drainage District No. 1 Ditch is improved to prevent backwater flooding into the northwest corners of the Airport.

   However, the implementation of these major improvements may be on a longer term basis than the City and Airport administration wish to tolerate.

   A local solution was conceptually planned and evaluated. This solution was to encircle the Airport property with a levee and reroute the internal drainage system along the inner edge of the levee to drain to a sump and pump facility on the east side of the Airport. The pump facility would pump stormwater run-off over the Airport levee into North Main Drain.

   The description of this alternative is presented as North Main Drain Improvement (NMI-20) in Table 17, Volume I. The projected cost for this installation is shown in Table 21, Volume I, and totals approximately $4,725,000.

2. The Valley Community Hospital experiences flooding in the watershed of Cameron County Drainage District No. 1 Ditch. It is located in a low area of the floodplain and can benefit from a local solution similar to the solution proposed at the Airport.

   An encircling levee, internal drainage systems, detention sump and stormwater pump would serve to keep the Hospital unflooded. The projected cost for this improvement would be approximately $255,000.

   The access to the Hospital should be maintained during flood events, and a roadway high enough to avoid flooding should be incorporated in the Hospital drainage solutions. The projected cost for approximately 5,000 feet of roadway to provide access would be approximately $685,000.

TABLE 21
COSTS OF RECOMMENDED IMPROVEMENTS

IMPROVEMENT NUMBER	R.O.W. COST	CONSTRUCTION COST*	TOTAL COST
TOWN RESACA			
TRI- 1	$2,100,000	$1,440,000	$3,540,000
TRI- 2	$180,000	$254,000	$434,000
TRI- 3		$150,000	$150,000
TRI- 4		$148,000	$148,000
TRI- 5		$5,625,000	$5,625,000
TRI- 6	$675,000	$20,325,000	$21,000,000
TRI- 7	$75,000	$2,270,000	$2,345,000
TRI- 8		$131,000	$131,000
TRI- 9		$256,000	$256,000
TRI- 10	$30,000	$146,000	$176,000
NORTH MAIN DRAIN			
NMI- 1	$543,900	$996,500	$1,540,400
NMI- 2	$242,000	$226,500	$468,500
NMI- 3	$30,000	$212,000	$242,000
NMI- 4	$300,000	$2,000,000	$2,300,000
NMI- 5		$572,000	$572,000
NMI- 6		$322,000	$322,000
NMI- 7	$128,000	$367,000	$495,000
NMI- 8	$15,000	$325,000	$340,000
NMI- 9	$15,000	$325,000	$340,000
NMI- 10	$15,000	$325,000	$340,000
NMI- 11	$138,000	$81,500	$219,500
NMI- 12		$123,600	$123,600
NMI- 13	$12,400	$24,800	$37,200
NMI- 14		$167,000	$167,000
NMI- 15		$47,900	$47,900
NMI- 16		$39,800	$39,800
NMI- 17		$54,400	$54,400
NMI- 18		$48,200	$48,200
NMI- 19		$93,200	$93,200
NMI- 20		$4,725,000	$4,725,000
NMI- 21	$582,000	$2,200,000	$2,782,000
NMI- 22	$150,000	$5,200,000	$5,350,000
NMI- 23	$975,000	$3,300,000	$4,275,000
NMI- 24	$60,000	$5,400,000	$5,460,000
NMI- 25	$255,000	$5,146,000	$5,401,000
NMI- 26	$330,000	$4,200,000	$4,530,000
NMI- 27	$165,000	$418,000	$583,000
NMI- 28		$69,600	$69,600
NMI- 29	$150,000	$105,000	$255,000
NMI- 30	$300,000	$187,000	$487,000
NMI- 31	$30,000	$1,000,000	$1,030,000
NMI- 32	$765,000	$1,640,000	$2,405,000
NMI- 33	$100,000	$2,800,000	$2,900,000
NMI- 34	$1,032,000	$2,392,000	$3,424,000

TABLE 21 (Cont'd.)
COSTS OF RECOMMENDED IMPROVEMENTS

IMPROVEMENT NUMBER	R.O.W. COST	CONSTRUCTION COST *	TOTAL COST
RESACA DE LA GUERRA			
RGI- 1		$204,000	$204,000
RGI- 2		$94,750	$94,750
RGI- 3	$480,000	$1,545,000	$2,025,000
RGI- 4		$89,700	$89,700
RGI- 5		$43,000	$43,000
RGI- 6	$30,000	$282,000	$312,000
RGI- 7		$291,600	$291,600
RGI- 8	$30,000	$210,000	$240,000
CAMERON COUNTY DRAINAGE DISTRICT NO. 1 DITCH			
CCI- 1	$764,000	$1,620,000	$2,384,000
CCI- 2		$1,415,000	$1,415,000
CCI- 3	$42,000	$942,000	$984,000
CCI- 4		$234,000	$234,000
CCI- 5		$514,800	$514,800
CCI- 6	$356,000	$905,900	$1,261,900
CCI- 7	$66,600	$993,600	$1,060,200
CCI- 8		$429,000	$429,000
CCI- 9	$1,026,400	$2,247,600	$3,274,000
CCI- 10		$943,800	$943,800
CCI- 11	$1,980,000	$6,168,000	$8,148,000
CCI- 12		$49,000	$49,000
CCI- 13	$3,525,000	$10,800,000	$14,325,000
CCI- 14	$86,400	$435,300	$521,700
CCI- 15		$684,655	$684,655
RESACA DEL RANCHO VIEJO			
RVI- 1		$105,600	$105,600
RVI- 2		$95,000	$95,000
RVI- 3		$65,000	$65,000
RVI- 4		$208,000	$208,000

* Construction costs shown include allowances for technical services and contingencies.

The projected cost of the local system and the roadway would total approximately $940,000 and is shown in Table 21, Volume I, and described in more detail in Table 19, Volume I.

C. Storm Sewer Structural Improvements

The improvement of flooding conditions in most parts of the City and surrounding area will be dependent on implementation of the improvements on the major resacas and ditches as presented in the Master Drainage Plan in Chapter IX.

The analysis and design of upgraded storm sewer trunks within the City have been based on the premise that the existing local tailwater conditions will remain for a long period as the portions of the Master Drainage Plan are implemented over a period of years. A summary of the upgraded storm sewer requirements is shown in Table 6, Volume I.

The implementation of the storm sewer upgrades should not be placed on hold pending implementation of the improvements to the major systems of resacas and ditches. Where street paving improvements or reconstruction occur, the design criteria used in this study and the storm sewer analysis computer template should be used to correctly design the necessary storm sewer trunks.

The philosophy of installing only the limited capacity of the existing pipes or structures will only serve to perpetuate the flooding problems the City experiences. This philosophy will also negate the positive effects of preventing flooding that the improvements to the major system accomplish.

D. Nonstructural Measures

The costs of structural and capital improvements for drainage and flood control become a burden that the City must bear at some point in time, particularly if the development of a city has been relatively unregulated from a drainage engineering standpoint.

The policies, procedures and ordinances that a city enacts and follows and enforces can serve as a low cost solution to many of the drainage problems that are experienced. The proper management of currently developed and developing areas of the City can reduce future flooding problems and costs and litigation costs by giving a consistent, long-term approach to solving the problems.

Several key elements should be considered for implementation in the City of Brownsville.

1. Public Ownership and Access

The major drainageways of the area fall in two categories, the resacas and the drainage ditches.

The resacas and their banks have been developed as privately-owned bodies of water and are treated as private lakes. The resacas are, in many instances, also being used as storage for irrigation water and raw drinking water storage.

These uses do not have the primary goal of flood control in their operation and, therefore, often aggravate flooding problems.

The drainage ditches are treated as public drainageways, but maintenance access clearance is narrow or non-existent in many areas.

The drainageways of the City of Brownsville must be placed under closer control and maintenance of a unified agency that will balance the need for pool elevations for beauty and water storage as well as flood control.

As a minimum, a maintenance access easement should be obtained on both sides of all resacas, and each control structure that controls the outflow of each resaca pool should be accessible for public maintenance. The structures that can be adjusted to give varying pool elevations and greatly affect the flood levels should be under the control of a public entity. As new structures are built in the resacas, they should be analyzed in light of the Master Drainage Plan with the computer models provided and approved by the City prior to construction.

The resacas will be watched more closely now by the U.S. Army Corps of Engineers under their Section 404 permit program for dredge and fill in navigable waters and wetlands.

The resacas can also be considered Waters of State when structures are placed in the resaca bed to impound water. This statute can be found in Volume I of the Texas State Water Code, Section II, Subsection D, Permits to use State Water. Impounding structures placed in any waterway over 30 feet in width will fall under this statute. This permitting process will give the City of Brownsville the review and approval opportunity to preserve its drainage plans.

The City should obtain a right-of-way (R.O.W.) easement with all new ditch construction that allows access from both sides of the channel if the channel top width is greater than 50 feet. The more narrow channel sections can be maintained with a 20- to 30-foot maintenance easement on one side.

Concrete-lined sections can be maintained from within the channel bottom itself, but access to and from the channel must be maintained. A small drainage maintenance access easement on both sides is still desirable to keep fences, outbuildings, and other flow obstructions from being constructed too close to the channel and obstructing flood waters and, potentially, washing downstream and forming debris clogs in bridges and culverts and causing higher flood levels.

There seem to be four (4) maintenance options available to the City:

a. Maintain the floodplains using City funds and crews. The City retains control of the areas (by easement, ownership, etc.) but must also assume the financial burden associated with ownership;

b. Fund maintenance by assessment of adjacent property owners based on floodplain frontage. City crews are still used but are funded on an assessment basis. City control is retained, and the financial burden is lifted, but the lag time in the assessment collection may require the City to temporarily front the funding;

c. Form a Drainage District or Floodplain Management Agency to manage and maintain the floodplains. This creates a separate level of government that is specifically designed to address the management of these areas. The City is relieved of any financial burden, but also cedes control of the areas; and,

d. Require adjacent property owners to be responsible for maintenance along their property "frontage". The financial problems and additional bureaucracy are resolved, but the City has only minimal control of the areas, and enforcement of regular maintenance and other requirements may be difficult.

It is recommended that a Drainage District or Floodplain Management Agency be formed to manage and maintain the floodplains (the third alternative).

Public control and maintenance of the drainageways and structures that influence flood levels must be implemented or the expenditure of funds to improve the drainage problems will not be effective.

2. Design Standards

The newly developing areas and newly reconstructed areas of the City of Brownsville should follow a consistent set of design criteria for drainage. This will provide a uniform basis for flood protection throughout the City.

The design and analysis section of this report, in conjunction with the guidelines being informally used by the City Engineering Department, should be formalized and enacted as a drainage ordinance to be applied to all construction.

Several factors should be considered in developing these ordinances:

a. The flow values used for designing structure sizes should be based on the run-off characteristics for the drainage area when it is fully developed. Drainageways passing through a site should be designed to provide conveyance for run-off from upstream areas when they are fully developed.

b. Design storm criteria for the main storm sewer trunks should be kept at the levels shown in the design criteria section of this report. Reducing the design storm does not significantly reduce the cost of the installed system since most of the cost is involved in placing these storm sewers is incorporated in the cost of opening the street, purchasing R.O.W., moving utilities, placing the structures and covering and refinishing the streets. The small decrease in pipe or culvert size obtained by going to a lesser design will save only a small fraction of the cost and multiply the risk of flooding several fold.

c. The time frame required to implement the full Master Drainage Plan will be over a period of years. In the interim period, new building construction should be initiated to prevent flooding from the existing conditions. On new developments, and, to the extent practicable, on building permits within developed areas, several items should be required.

    1) A grading plan should be required that shows where all drainage and flows will drain.

    2) Finished floors of structures should be placed a minimum of 2 feet above the curb elevation on

the street elevation at the lowest point on the lot. Where the development occurs within a flood-prone area as defined on the existing FEMA maps, guidelines for construction should place the minimum finished floor 2 feet above the elevations shown in those reports.

The water surface profiles of this report should be used to help determine the flooding potential of a developing area. The elevations of the water surface on the drainageway in question should be compared to the lot and floor elevations, and a determination of finished floor requirements should be made.

3) Detention of flood waters on developing land should be considered. This can be implemented on a site-by-site basis (on-site) or on a regional basis. The use of detention will reduce the effect of development of increasing run-off from areas as they change from undeveloped to developed land uses.

These items can be funded by the developer in two ways, each tied into the detention style utilized.

The on-site detention regulation would require that a developer design his grading and drainage plan to prevent the rate and volume of discharge from increasing. This can be relatively inexpensive when incorporated into a larger area of development under a well-designed, internal drainage plan. The developer pays for this directly as a part of his on-site drainage plan.

The regional detention ordinance can develop a regional basin to catch the floods and release them at a rate no greater than the downstream channels and structures can handle.

The cost of the regional detention structure should be spread over the drainage area above the regional detention structure and should be adjusted by the impact the development has on run-off. Large paved areas will increase run-off more than large, grassy areas. Therefore, the areas with large amounts of impervious cover should pay a higher portion of the cost of the regional detention structure.

3. Planning and Zoning

a. Zoning

The areas that have been designated as new detention, channel and/or pump station areas should be protected from future development. Since these areas are, for the most part, located in the 100-year floodplains and other flood-prone areas, it would be desirable to discourage development because of the potential for flood damage.

The Federal Emergency Management Administration (FEMA) requires adherence to very strict standards for floodplain development and the reclamation of floodplain lands. (Development in the actual floodway is not permitted.) Development in the floodplain in accordance with FEMA guidelines is usually financially unattractive and affords protection from flooding in only a 100-year storm. The development is not guaranteed against flood damage. For these reasons, it is not desirable to develop these natural areas.

There is also a qualitative benefit to protecting these natural settings in urbanized areas. They provide a greenbelt effect and can be cultivated as linear parks with hiking/biking trails, as is the case with the 18-mile Trinity Trail in Fort Worth, Texas. The preservation of these natural areas is an amenity that cannot be quantified but does serve to enhance the "quality of life" of the area.

b. Enforcement of Zoning and Protection of Floodplains

It is recommended that these areas be preserved from further development utilizing the City's existing Floodplain Ordinance until such time as all drainage improvements are completed.

These areas may be reserved in the same fashion as thoroughfare rights-of-way. At the time of subdivision platting/replatting, the dedication of a floodplain easement would be required to assure that development does not take place in these zones.

There may be some legal concern raised over the recent U.S. Supreme Court decision regarding zoning and "taking" of land. (In that case, a church camp in Glendale, California was located in a floodplain and was a "non-conforming use". It was subsequently destroyed by a flood. As a "non-conforming use", the City did not allow the church camp to be rebuilt. The church claimed a taking of the land without just compensation, and judgment was ruled in their favor.)

This case hinges upon the ability of the property owner to show total loss of the use of the land. As of this writing, a test case under this ruling has not yet been tried in the State of Texas. The City should be aware of any potential legal implications relating to the rezoning of land.

c. Alternative Uses of Floodplains

As stated in Section 3a. above, there are several alternative uses for the floodplain areas:

1) The floodplains can be left in their natural state and be promoted as linear parks and greenbelts;

2) Residential properties can be allowed to develop adjacent to the floodplains, provided that no permanent structures are located within the floodplain; and,

3) Commercial/office/retail properties can be allowed to develop adjacent to the floodplains, provided that no permanent structures or paved surfaces are located within the floodplain.

Because of the potential for increased pollution due to urban surface storm water run-off, as well as the increase in storm water run-off alone, development in these areas is not recommended. The floodplains should be maintained in the natural state as park-like settings.

d. Flood-Proofing

There is no doubt that some areas can be "flood-proofed" in accordance with FEMA and City guidelines. However, the ability to do so can be a financial disincentive. Economics aside, allowing the development in these areas through either flood-proofing, reclamation or channelization will increase the run-off coefficients of adjacent areas. This development can result in an increase in the size of the floodplains, an increase the size of the structures required to channelize the waterways, an increase in the pollution of the waterways, or an increase the potential of inundating downstream properties.

These areas should be protected from development because of their value as an urban amenity and their potential to increase pollution and storm water run-off.

e. Consistency

It is imperative that the City review all pertinent ordinances, regulations, guidelines, etc., to assure consistency in the policies regarding the floodplains. All regulatory instruments should be in agreement. Those not in compliance should be amended as soon as practicable.

4. Jurisdictional Considerations

The Study and Planning Area of this Plan encompassed an area of 117 square miles, five (5) major watersheds and at least seven (7) jurisdictional entities in some way related to flood control, drainage, irrigation or water supply.

These entities and jurisdictions included the City of Brownsville, the City of Brownsville PUB, the Brownsville Irrigation and Drainage District, the County of Cameron, the Cameron County Drainage District No. 1, and the Valley Municipal Utility Districts Nos. 1 and 2.

These different entities make coordination of plans, permits, etc., very difficult as each entity may have slightly different goals, and a consistent, central forum for cooperation and communication does not exist.

A county-wide forum or committee should be formed that incorporates input from all the above entities. This committee should develop a unified set of ordinances and review procedures that best fulfill their needs and complies with state and federal laws.

This committee or commission should have power by law to enforce its findings; therefore, some type of empowering legislation is necessary. This legislation should come from either the County or State level to give the necessary legal authority.

CHAPTER VIII

VIII. CAPITAL IMPROVEMENTS AND COST PROJECTIONS

Each of the options proposed to correct a portion of the flooding problems was evaluated for cost of construction and cost of potential right-of-way purchase.

The costs of construction were projected based on the quantity calculations for the major system improvements and the storm sewer trunk system.

Unit prices are based on local prices for 1986. These prices included earthwork, concrete lining, reinforced concrete culverts, pipe installation, pavement repair, and stormwater pump station costs.

The construction costs projected include allowances for construction contingencies and technical services.

To give a more accurate picture of the total costs of the capital improvements, a cost for right-of-way acquisition was also projected. This was based on the full recommended sections required for proper maintenance and a cost per acre supplied by the City of Brownsville Planning Department.

This cost of $15,000 per acre was used where a high degree of development does not exist. In very congested areas where the major improvements impact a large number of landowners, the cost per acre was doubled to allow for the complexities of acquiring the right-of-way and easements.

The summary of each major improvement and its associated right-of-way and construction cost is presented in Table 21, Volume I.

CHAPTER IX

IX. MASTER DRAINAGE PLAN IMPLEMENTATION

A. Recommended Improvements

To be an effective management and engineering tool for improving the overall drainage system for the City of Brownsville, the Master Drainage Plan must provide an organized procedure for implementing specific structural modifications and flood mitigation measures. It must balance the relative and absolute flood protection benefits of specific improvements with the cost of the improvements and the ability of the City to finance the improvements. In this regard, the Master Drainage Plan proposed herein is organized into two components: an Immediate Improvements Program and a Long Range Improvements Program. Each of these is comprised of a group of specific improvement measures that collectively provide for the required levels of flood protection. Each individual improvement measure within each of the programs also has been assigned a priority number which indicates the relative importance of implementing the measure with regard to its overall flood protection benefits and its cost. Priority numbers range from "one" for the most needed and effective improvements up to a maximum value of "twenty-nine" for those improvements that provide marginal flood protection benefits relative to their costs.

The recommended Master Drainage Plan consists of the two improvements programs which together, when fully implemented, comprise the ultimate 100-year flood protection plan. The Immediate Improvements Program is the most essential component of the overall plan. It is considered to be a program that can be implemented over the next five (5) years and can provide immediate solutions to some of the City's more severe flooding problems. This program provides the fundamental basis for the subsequent improvements that are contained in the Long Range Improvements Program, which cannot be effectively implemented until critical portions of the Immediate Improvements Program are in place. The Long Range Improvements Program might be expected to be implemented over the next 25 years.

The specific improvement measures that comprise the Immediate Improvements Program are listed in Table 22, Volume I, in the order of their relative implementation priorities, and they are identified on the map of the Study Area in Plate 42, Volume II. These improvement measures are a subset of the alternatives listed and described in Chapter VII. The implementation priorities were developed through a complex iterative process involving successive operations of the HEC-1, HEC-2 and RESACA computer models. These models were modified to reflect the proposed improvements in the Town Resaca, North Main Drain, Resaca de la Guerra, and Cameron County Drainage District No. 1 Ditch.

TABLE 22

RECOMMENDED IMMEDIATE IMPROVEMENTS PROGRAM

Priority		Improvement Measure	Project Cost
1	NMI-1	Channel Widening from Port Authority Ditch Upstream to Resaca de la Guerra	$1,540,000
1	NMI-2	Channel Realignment East of Airport	$468,500
1	NMI-3	Channel Realignment West of Minnesota Avenue	$242,000
1	NMI-5	Modifications to Structure NM35 at Boca Chica Blvd.	$572,000
1	NMI-6	Modifications to Structure NM32 at Minnesota Avenue	$322,000
1	CCI-15	Flood Protection Facilities for Valley Community Hospital	$684,655
2	TRI-1	Enhanced Detention Storage near Los Tomates Banco	$3,540,000
2	TRI-4	Modifications to Structure TR26 near 25th Street	$148,000
3	RGI-1	Modifications to Structure RG24 at North Main Drain Ditch	$204,000
3	RGI-2	Modifications to Structures RG22 and RG23 at Morningside Road Crossings	$94,750
4	NMI-4	Channel Lining and Widening from Resaca de la Guerra Confluence Upstream to Impala Ditch Confluence	$2,300,000
4	NMI-20	Modifications to Airport Drainage System	$4,725,000
5	TRI-5	Stormwater Pump Station near Los Tomates Banco	$5,625,000
5	TRI-9	Modifications to Structure TR25 near Lincoln Park	$256,000
6	TRI-2	Additional Detention Storage above Belthair Blvd.	$434,000
6	TRI-3	Modifications to Structure TR15 at Palm Blvd.	$150,000
6	TRI-7	Stormwater Pump Station near Ebony Lake	$2,345,000
7	NMI-23	New Detention Storage Area Downstream of International Boulevard	$4,275,000

TABLE 22

RECOMMENDED IMMEDIATE IMPROVEMENTS PROGRAM

Priority		Improvement Measure	Project Cost
8	CCI-11	Additional Detention Storage Area Upstream of Central Avenue	$8,148,000
9	RGI-4	Modifications to Structure RG13 at Palo Verde Drive	$89,700
9	RGI-6	Miscellaneous Modifications to Structures Between Billy Mitchell Boulevard and 14th Street	$312,000
10	NMI-17	Modifications to Structure NM3 at MOPAC Railroad	$54,400
10	NMI-27	New Detention Storage Area Upstream of Paredes Line Road	$583,000
10	NMI-32	Additional Detention Storage Area Upstream of MOPAC Railroad	$2,405,000
11	RGI-3	Diversion of Stormwater Flows during High Stage Conditions into Cameron County Drainage District No. Ditch near the Paredes Line Road/Highway 802 Intersection	$2,025,000
12	NMI-21	New Detention Storage Area South of Airport	$2,782,000
13	NMI-26	Stormwater Pump Station Upstream of Rockwell Road	$4,530,000

With various combinations and sizes of the improvement alternatives incorporated in the models, simulations of stormwater run-off and the resulting flood levels have been made for each of the drainage subsystems, with the overall process systematically repeated until satisfactory water surface elevations were achieved. Cost considerations were factored into this process by continuously tracking the total program costs and striving to maintain an equitable balance between the projected financial burden to the City and the flood protection benefits derived for each combination of improvement alternatives.

The Immediate Improvements Program focuses primarily on reducing existing critical flooding problems in the Town Resaca, North Main Drain and Resaca de la Guerra drainage subsystems. Since outflows from all these subsystems presently combine downstream of Impala Ditch and then flow from the area through the North Main Drain channel to the Port Authority Ditch, it is essential that this section of channel be significantly enlarged to handle greater volumes and rates of stormwater run-off. Stormwater flows in the middle and upper reaches of the North Main Drain subsystem also significantly exceed the existing channel capacity, and widening and concrete lining, along with corresponding improvements to existing bridges and culverts, are required to increase the available conveyance through this reach. Even with these improvements, several stormwater detention ponds and a pumping station are necessary to achieve acceptable flood protection.

As an alternative to major improvements to the North Main Drain Channel from Resaca de la Guerra to the Port Authority Ditch, the stormwater pump station and detention pond (NMI-22) might be increased in capacity near the intersection of Esperanza Road and the levee. This pump station would pump stormwater from the North Main Drain Ditch and Resaca de la Guerra into the Rio Grande. In order to accomplish this, the North Main Drain Ditch will need to be rechanneled to flow westward from the Resaca de la Guerra to the proposed new pump station. This Esperanza pump station alternative would be in lieu of channel improvements NMI-1, NMI-2, NMI-3, NMI-5, NMI-6, and NMI-21. The additional costs associated with this alternative plan is projected to be approximately $2,500,000. If the pump station were to be located further southeast on Esperanza Road (see Plate 76, Volume II), the additional cost would be approximately $3,000,000.

In the two resaca subsystems, modifications to existing outlet structures on individual pools are necessary at several locations to improve conveyance. A new, major pump station and associated detention basin are required near Los Tomates Banco on Town Resaca to reduce the outflows from this subsystem into

Impala Ditch. Another smaller pump station near Ebony Lake is necessary to lower flood levels and to divert stormwater from the Town Resaca subsystem into the Rio Grande.

A gravity diversion facility on Resaca de la Guerra that discharges stormwater flows into a detention pond in the Cameron County Drainage District No. 1 Ditch subsystem near the Paredes Line Road/Highway 802 intersection is required to reduce downstream flooding. The recommended immediate improvements for the Cameron County Drainage District No. 1 Ditch subsystem include a large detention storage area upstream of Central Avenue and a levee system and pumping station at the Valley Community Hospital.

Since no significant flooding problems have been projected for the Resaca del Rancho Viejo subsystem, no drainage improvements are included in the Immediate Improvements Program for this subsystem.

The simulated water surface profiles along the Town Resaca, North Main Drain, Resaca de la Guerra, and Cameron County Drainage District No. 1 Ditch subsystems, with all the Immediate Improvements Program in place, are plotted in Plates 43 through 46, Volume II, respectively. Profiles for the 2, 5, 25 and 100-year storm events are indicated, along with the existing 100-year profile and the projected 100-year profile with the overall Master Drainage Plan fully implemented.

Generally, implementation of the recommended Immediate Improvements Program will lower 100-year water levels in the lower reaches of the subsystems by several feet and will result in lesser flooding in the upper reaches. Flood protection with this Program in place generally will be provided for the 25 to 50-year storm on the Town Resaca subsystem and for the 50 to 100-year storm on the Resaca de la Guerra subsystem.

For North Main Drain upstream of Highway 77, a two-year flood protection generally can be expected. In the Four Corners area near Boca Chica Boulevard, 25-year flood protection can be expected, with 100-year flood protection downstream of International Boulevard all the way to the Port Authority Ditch. Flood protection along the Cameron County Drainage District No. 1 Ditch subsystem will be between the 2 and 5-year storm level, although full 100-year protection for the Valley Community Hospital will be provided with a levee and pump system.

The total projected cost of the recommended **Immediate Improvements Program is approximately $48,855,000.** This figure is the sum of the individual costs of the specific improvement measures included in this Program as itemized in Chapter VIII.

If the Esperanza pump station is constructed in lieu of the downstream channel improvements on North Main Drain Ditch, the total project cost for the recommended Immediate Improvements Program is approximately $50,428,100.

The recommended improvements for the Long Range Program are listed in Table 23, Volume I, along with their respective implementation priorities, and they are identified on the map in Plate 42A, Volume II. These improvements are of lesser importance than those in recommended Immediate Improvements Program, but they are essential for ultimately achieving 100-year flood protection throughout all the major drainage subsystems. Improvements in all five subsystems are included in this program. With complete implementation of the Long Range Program, the level of flood protection provided throughout all of the subsystems is expected to be at least the 100-year storm.

The 100-year water surface profiles corresponding to complete implementation of the overall Master Drainage Plan, i.e., the recommended Immediate Improvements Program and the Long Range Improvements Program, are shown on Plates 43 through 46 for the Town Resaca, North Main Drain, Resaca de la Guerra, and Cameron County Drainage District No. 1 Ditch subsystems, respectively, and in Plate 47 for the Resaca del Rancho Viejo subsystem.

As discussed in Chapter V, most of the existing storm sewer trunks in the study area are undersized and are not capable of carrying stormwater flows in accordance with the adopted design criteria presented in Chapter IV. Although many of the existing pipes simply are under-sized, the hydraulic capacities of most of the storm sewers are severely limited by the existing high tailwater conditions in resaca pools and ditches.

With implementation of the major drainage improvements included in the Master Drainage Plan, these tailwater conditions will be significantly reduced, and storm drains will be able to function more efficiently.

It is most desirable for improvements in the major drainage subsystems to be implemented first, before any significant expenditures are invested in upgrading the capacity of the storm sewer system. For this reason, improvements to the storm sewer system are considered to have an implementation priority similar to those in the Long Range Improvements Program, i.e., greater than about 20 in the priority numbering system. Most of these improvements simply will not be effective until a large portion of the improvements programs are in place. In general, the installation of additional storm sewer trunks in existing developments probably should not be undertaken in the next few years unless other associated street improvements are

TABLE 23

LONG RANGE IMPROVEMENTS PROGRAM

Priority		Improvement Measure
14	CCI-3	Channel Lining and Widening from MOPAC Railroad to Harbor Road
14	CCI-6	Channel Widening from Harbor Road to Highway 48
14	CCI-7	Channel Lining and Widening from Highway 48 to Old Railroad Grade
14	CCI-9	Channel Widening from Old Railroad Grade to the Southern Pacific Railroad
15	CCI-4	Modifications to Structure CC17 at MOPAC Railroad
15	CCI-5	Modifications to Structure CC16 at F.M. 511
15	CCI-8	Modifications to Structure CC13 at Highway 48
15	CCI-10	Modifications to Structure CC10 at Central Avenue
16	NMI-29	Additional Detention Storage Area Upstream of West Price Road
16	NMI-30	Additional Detention Storage Area Upstream of Central Boulevard
16	NMI-33	Modifications to Structures NM8 through NM12 from West Price Road to Old Alice Road
17	NMI-7	Channel Lining and Widening from Old Port Isabel Road Upstream to above Rockwell Road
17	NMI-8	Modifications to Structure NM19 at Old Port Isabel Road
17	NMI-9	Modifications to Structure NM18 at Rentfro Street
17	NMI-10	Modifications to Structure NM17 at Rockwell Road
17	NMI-11	Channel Widening from above Rockwell Road Upstream to Mackintosh Road
17	NMI-12	Modifications to Structure NM15 at Mackintosh Road
17	NMI-13	Channel Lining and Widening from Mackintosh Road Upstream to Highway 77
17	CCI-12	Modifications to Structure CC7 at Old Port Isabel Road
17	CCI-13	Additional Detention Storage Area Upstream of Dana Road
18	RVI-1	Modifications to Structure RV37 at Port Authority Water Intake
18	RVI-2	Modifications to Structure RV35 near head of Rancho Viejo Floodway
18	RVI-3	Modifications to Structure RV31 at Robindale Road
18	RVI-4	Modifications to Structure RV28 Downstream of Paredes Line Road

TABLE 23 (CONT'D.)

LONG RANGE IMPROVEMENTS PROGRAM

Priority		Improvement Measure
19	TRI-8	Modifications to Structures TR18 & 19 near Gladys Porter Zoo
19	TRI-10	Miscellaneous Modifications to Other Structures
20	TRI-6	Drainage Diversion to Rio Grande for Portions of Subwatersheds 8, 9, 15, 20, 22, 28, 30 & 31
21	RGI-5	Upstream Detention Storage above Highway 802
21	RGI-7	Miscellaneous Modifications to Structures Between Old Port Isabel Road and F.M. 802
22	CCI-1	Channel Widening Downstream of MOPAC Railroad
22	CCI-2	Modifications to Structure CC18 at Highway 48
23	NMI-14	Modifications to Structure NM6 at Central Boulevard
23	NMI-15	Modifications to Structure NM5 Between Central Boulevard and Honeydale Road
23	NMI-16	Modifications to Structure NM4 at Honeydale Road
23	NMI-18	Modifications to Structure NM2 at El Paso Road
23	NMI-19	Modifications to Structure NM16 at Paredes Line Road
23	NMI-28	Modifications to Structure NM13B at Highway 77 East Access Road
24	CCI-14	Channel Widening from the Southern Pacific Railroad to F.M. 3248
25	NMI-22	Stormwater Pump Station near Nogales School
26	NMI-34	Modifications to Structure NM38 at South Port Road and Associated Channel Improvements
27	NMI-24	Stormwater Pump Station Downstream of International Boulevard
28	NMI-31	Stormwater Pump Station Upstream of Central Boulevard
28	RGI-8	Modifications to Structure RG12 at Paredes Line Road
29	NMI-25	Channel Lining and Widening and Structure Modifications from Downstream of International Boulevard to Old Port Isabel Road

being implemented and cost savings can be realized by constructing all the facilities at one time.

The increased numbers and sizes of pipes required to upgrade the overall storm drain system to the adopted design criteria, i.e., 5-year to 25-year capacities depending on drainage area, are listed in Table 6, Volume I. These improvements have been determined based on tailwater conditions for the existing major drainage subsystems, i.e., resacas and ditches, assuming that none of the projects listed in the improvements programs are in place.

The sizes of these facilities and their affected tailwater elevations should be determined at some future date when the major improvements which have been installed to that date can be assessed.

Although the expenditures for upgrading the storm drain system to the adopted design criteria represents a considerable investment that is probably not practicable for the City of Brownsville at this time, it should be recognized that they represent an approximate upper limit because they are based on the inherent assumption that no additional improvements to the major drainage subsystems will be implemented until large portions of improvements programs are completed. Certainly this should not be the case if the recommendations of this Master Drainage Plan are seriously considered and incorporated into the City's overall capital improvements program. At the point in time in the future when specific modifications to the storm drain system are contemplated, hydraulic design calculations should be made based on appropriate tailwater conditions that correspond to the level of major drainage subsystem improvements, i.e., components of the improvements programs, that are in place or that are actually planned for implementation. The pipe template spreadsheet computer program developed as part of this planning study and provided to the City's Engineering Department can be applied very easily and quickly for these analyses on a case-by-case basis.

B. Construction Priorities

The priorities for implementing various components of the overall Master Drainage Plan are listed in Tables 22 and 23. They range in priority from "one" to "twenty-nine". Generally, several individual improvement measures have been assigned the same priority number, indicating that either they are interrelated and need to be implemented as a unit or they are generally of equal importance with regard to their respective flood protection benefits and associated costs within the context of the overall Master Drainage Plan.

The Immediate Improvements Program includes specific projects that should be considered first in implementing the overall Master Drainage Plan. These improvements are essential for achieving adopted flood protection goals and for assuring the effectiveness of subsequent improvement measures in the major drainageways or in the storm sewer system.

The cutoff between the Immediate Improvements Program and the Long Range Improvements Program in terms of which individual components are included in the two programs is not rigid but flexible enough to be determined finally by the City's staff based on overall financing opportunities. Obviously, to be the most effective with respect to increased flood protection, as many of the individual improvement measures as possible need to be implemented as soon as possible.

C. Schedule of Proposed Improvements

The final schedule that ultimately is adopted by the City for implementing components of the Master Drainage Plan should weigh the relative importance of increased flood protection against the need for other expenditures within the framework of the City's overall capital improvements program. The total cost figure of the Immediate Improvements Program and its five-year implementation time frame generally have been considered to be practicable for the City of Brownsville, given the City's recent experience with the first $12,500,000 phase of the $48,000,000 street improvements bond package.

Certainly, the total cost of the Immediate Improvements Program can be tailored to fit the City's funding limitations, but the five-year schedule for implementing at least some major drainage system improvements should not be lengthened. The total costs and time-frames for the Long Range Improvement Program, of course, should be developed and modified as necessary during the course of implementing portions of the initial improvements over the next several years.

D. Funding of Proposed Improvements

The proper implementation of any public works project requires adequate funding. A portion of the revenue generated, perhaps 10%, should be set aside in a designated maintenance escrow fund and used to maintain each project built. This will protect the initial investment of capital and provide a continued high level of flood protection.

Funding of drainage improvements in outlying areas should be provided by developers or included with the fees charged to developers, or the design and zoning requirements should specifically stipulate how adequate drainage facilities are to be constructed. This is discussed in the latter parts of this section in more detail.

Several methods of funding the improvements proposed in the Master Drainage Plan are suggested in the following sections:

1. Bonds

   The funding of public works improvements is normally undertaken with the sale of municipal bonds (general obligation bonds supported by tax revenues). The revenue generated from these bonds is then used to finance the design and construction of the public works improvements.

   Bonds can also be issued to finance improvements by Flood Control and Improvement Districts. If a special area-wide district is created to deal with the problems, then bond sales can be used by this entity for financing these improvements.

2. Drainage Assessments

   The recipients of the benefits of drainage improvements usually own land or property within a defined drainage basin and can normally be assessed for their portion of the benefits on a per acre basis.

   However, the extreme flatness of the area and the complex interconnections of the major watershed systems could make benefit recipients and cost assessments difficult to allocate on the smaller improvements in the upper reaches of the watersheds. For major improvements at the downstream end of the watersheds, all upstream landowners will benefit by more rapid dispersal of flood waters. These major improvement costs for downstream channels could equitably be assessed to all landowners in the respective watershed.

3. Utility Fee

   A potential source of revenue is the utility fee applied to the water and sewer bills of the citizens of Brownsville. The utility of drainage is an important public benefit to be provided to the citizens. The basic provision of adequate storm drainage facilities protects property and life and provides for other community services, such as better access for police, fire, and ambulance services during a flood disaster.

   The use of a drainage utility fee could be an ongoing plan and a fund to provide for construction and maintenance of new drainage facilities for the City. It could also be set up to be utilized, when needed, for each phase of the plan and placed on hold when sufficient funds had accumulated to serve the purpose of construction, maintenance or repair of the particular phase of construction.

4. Government Aid

State and federal assistance can be sought to provide funding or a portion of the funding necessary to construct the drainage improvements.

The Texas Water Development Board should be contacted for available programs of assistance that could be utilized.

The U.S. Army Corps of Engineers should also be contacted for the potential of financial assistance.

The U.S. Water Resources Council is a good resource for finding sources that other cities have used to finance flood control projects.

5. Improvements in Outlying Areas

For outlying areas the need to provide adequate drainage facilities must be met. This need can be met initially by assessing a development fee or impact fee on a per developed acre basis on which is deposited to an interest bearing fund to pay for future improvements and the total system for the developing area on a regional basis.

On a local basis, the developer should install all drainage improvements in his subdivision as required by the design criteria and pass on this cost to the buyer of the developed and improved land. In this way, the cost of adequate drainage facilities will be borne by future citizens in the specific area benefitted rather than distribute the costs to citizens throughout the City.

CHAPTER X

X. MAINTENANCE PLAN

A. General

The maintenance plan for existing drainage courses and storm sewers should be one that occupies a high priority in the budgetary, political, and human resource allocations of the City of Brownsville. The detrimental effects of lack of maintenance are manifold. They include:

1. Flood damages to public and private structures during flood events;

2. Long-term damage or deterioration of roads due to poorly drained road sub-bases.

3. Loss of income to individuals, businesses and taxing authorities from cessation of business due to flooding of buildings and lack of passable routes for employees to their workplace; and,

4. Potential for lawsuits against the municipalities and agencies responsible for maintenance.

The maintenance of the storm drainage facilities on a routine basis cannot be overemphasized, as a maintenance plan is essential for the City to be able to provide a reliable storm drainage system.

B. Priorities for Maintenance

The ideal situation for maintenance plans is for sufficient money to be available to cover all the problem areas simultaneously. However, the reality of the situation is, often, only a fraction of the necessary funds are available to perform the many required tasks. The problem then becomes one of assigning priorities to what areas will be maintained first and how the distribution of effort shall be allocated.

To most effectively solve the problem, emphasis should always be placed on the downstream, outflow reaches of an area experiencing problems. This is justified because money spent to clean or improve conditions of existing drainage facilities in a local neighborhood or street intersection will not significantly help the problem if the channel or structure downstream will not allow the floodwaters to leave the problem area. Also, it is the most effective use of the City's maintenance dollars since it benefits everyone in the basin.

As a general rule, it is best to spend a majority of the available funds on maintenance of the outlet channels, ditches and resacas to allow them to pass floodwater. Specifically, the maintenance effort should be scheduled to clean, repair or improve conditions at the most downstream areas of the region that needs help and then work progressively upstream toward the smaller areas.

This would apply also to storm sewer pipes and related systems. Outlets of the storm sewer system should be cleaned first and opened; then trunks; then inlet laterals and inlets.

An ongoing program of maintenance and cleaning can incorporate both these activities so that inlets are being cleaned by some of the City personnel while the majority of the other cleanout and maintenance activities occur downstream at the same time.

A schedule of maintenance should be evaluated and set up based on the physical inventory provided in this report and the available resources and funding for the City. This should strive for a frequency of cleanout and repair that approaches at least an annual basis for streams, ditches and open channels.

C. Pump Stations

The importance of the storm water pump stations, particularly the Impala Pump Station, to the rapid dispersal of flood waters throughout the City is the same as the major outlet channels, resacas, and ditches. Since it is an active conveyor of water, and not a passive conveyance, it should be inspected and tested weekly to provide for assurance of its operation in the event of a flood. This pump maintenance schedule has already been implemented by the City Engineer.

Additional effort and emphasis should be placed on the maintenance of the inlet channels and sumps for each of the pumps so that floodwaters can effectively reach the intakes and be picked up by the pumps. This will provide the most effective use of the pumps that have been installed.

A maintenance checklist should be kept accessible for each pump setup that lists the pump supplier, how to obtain service and who in the City administration is authorized to order and obtain parts and service.

Each pump station should have a log listing maintenance procedures that have been performed, date, and by whom they were performed. Where diesel or gas standby generators are available, any special procedures necessary to start and operate these engines should be listed. There should be at least two persons that know how to operate each pump and associated equipment to provide continuity in operation in case one person is, for some reason, not available.

D. Ditch and Pipe Maintenance

The extremely flat terrain of the area produces two problems for the ditches (and pipes) in the study area. One problem is the large sizes of structures required to carry away the flood water run-off, due to the flat slopes of the channel or pipe.

The second problem posed by the flat slopes is the slow velocities produced in the channels and pipes, especially during periods of low flow. These slow velocities prevent the channels from carrying away sediment and silt loads that are washed into the drainageways. This sediment reduces the capacity of the channel or pipe and, in the case of open concrete-lined channels, provides a base for the start of vegetation growth. This vegetative growth further drastically reduces the flow conveyance capacity of the channel and, in time, will drastically increase flood problems upstream and locally.

The problem of flat channel slopes and the associated problems caused can not be solved directly, due to the topographic limitations of the region. However, steps can be taken to minimize the sedimentation problems in the system.

These steps include the following:

1. An ordinance should be adopted requiring sediment control measures on all new construction or whenever vegetative cover is removed. These preventive measures could include silt fences, hay bales, and mulching of disturbed areas.

2. Street sweeping and inlet cleaning will minimize the amount of dirt and debris that is transported into the system and directly aid in prevention of local flooding problems due to plugged inlets.

3. Excessive use of fertilizer on lawns and landscapes contributes to vegetation growth in the ditches and resacas. This can be minimized by a public education program that would encourage more frequent cutting of lawns and allowing the clippings to fall and provide an easier decomposition of the lawn clippings. This alleviates the need to fertilize as frequently. This plan also reduces the amount of material that trash collection trucks and personnel carry. This plan benefits the City in several ways and would help the drainageways of the City stay more clear of vegetation growth.

E. Access and Easement Considerations

To provide adequate drainage capacity in the existing or proposed facilities, maintenance must be performed on a regular basis in all areas of the system. All areas of the system must be accessible to the public agency charged with responsibility of maintenance. Maintenance easements, access ways and/or access agreements should be available for all areas and structures along the resacas and ditches that exist in the area. Where new drainage facilities are constructed, the provision of the access ways should be incorporated in the right-of-way purchased. For existing areas on resacas and ditches that do not have maintenance access, a strong effort should be made to obtain a maintenance easement of 20 feet on one side for ditches and 30 feet on each side for resacas.

There are areas in this Master Drainage Plan that show the need for immediate channel expansion or future channel construction. These areas should be protected, and sufficient rights-of-way should be provided with new development, especially in subdivisions and commercial development. The new development should provide the channel or drainageway capacity required by the City design criteria.

F. Channel Mowing and Cleaning

The capacity of the channels and ditches analyzed in this study and proposed in this plan are directly related to the maintenance performed. Allowing excessive vegetal growth and debris accumulation to occur can easily reduce the channel capacity to half and increase the frequency of flooding by manyfold. For this reason, maintenance of the channels and ditches is vital, particularly in the downstream areas.

The minimum recommended interval for ditch mowing and cleaning is once per year.

G. Resaca Maintenance

The resacas serve as stormwater storage during large storms. Their existing storage volumes should be protected or increased. This, however, cannot be accomplished by dredging the resacas below normal pool levels. The only storage capacity usable lies above the normal pools. Dredging will only have benefit if the resacas can be drained to the lowest possible level prior to the onset of a storm. This lowering of the water will undoubtedly produce protests from adjoining landowners but would be preferable to flood damage and subsequent legal problems to those same landowners.

The structures that control the levels of the resaca pools should be regulated by a public agency to provide maximum benefits to the public for flood, water supply and pool controls. Flood control devices and maintenance of pool levels should be placed in the hands of a public agency that is responsible for the good and benefit of the general public.

H. Pipe and Inlet Cleaning

The need for cleaning and maintenance of the storm sewer system is vital to maintain the ability of the system to convey water away from the streets and occupied areas of the City. Visual inspection should occur at manholes at least once every year. All structures should be flushed with water to remove debris on this frequency also.

I. Easement Enforcement

The drainage easements along drainageways should be enforced to prevent structures being built along the easement that would preclude access to channels. Since many drainageways carry flood flows along the channel banks, the construction of fences and other flow-obstructing structures should be prohibited in the easement.

The resaca systems and proposed maintenance easements should be maintained in a way that prevents encroachment into the resaca pools using up flood storage capacity. This would preclude filling of the resacas with earth structures for private use.

Capacity of the ditches and channels should be protected by enforcing, prosecuting and fining those that dump trash or other items in the ditches.

J. Funding of Maintenance

The importance of maintenance has been emphasized previously, but the problem becomes how to fund the work. The key to maintenance in a tight budget situation is to provide designated funds in an account that cannot be tapped for other uses.

Funds for maintenance can be taken from the new construction cost by designating a portion (5 to 10 percent) of the funds obtained to be placed in an escrow account to fund annual maintenance. Access to these funds should be restricted to use only for maintenance. This would be readily accountable by using contract services to provide this maintenance. This use of local contractors would also provide help to the local economy on a continuing basis.

CHAPTER XI

XI. GLOSSARY OF TERMS

<u>AMC</u>
Antecedent moisture condition; a measure of the soil moisture present before a storm.

<u>Boardweir</u>
A weir made with horizontal boards.

<u>Box culvert</u>
A culvert with one or more rectangular openings.

<u>c.f.s.</u>
Cubic feet per second. A measure of flow rate or volume of water per unit time.

<u>CMP</u>
Corrugated metal pipe.

<u>Conveyance</u>
The ability of a channel to carry water.

<u>Culvert</u>
A pipe or enclosed conduit that will carry flow.

<u>Curve Number</u>
An indicator of potential watershed run-off characteristics based on soil-type and land-use.

<u>D.A.</u>
Drainage area of the watershed in acres or square miles.

<u>D/S</u>
Abbreviation for downstream.

<u>Dike</u>
An embankment used to divert flow or protect sensitive areas from flood waters.

<u>Flow line</u>
The lowest point in a channel or pipe that will carry flow.

<u>Freeboard</u>
Distance between the water surface elevation and top of embankment or channel.

<u>Frequency</u>
The average return period of a rainstorm or other event (i.e., 100-year storm).

<u>ft.</u>
Feet

g.p.m.
Gallons Per Minute. A measure of flow rate or volume of water per unit time.

Hydrograph
A graph or representation of the increase and decrease of flow in a channel drainage system during rainfall.

Lag
The time from the beginning of a storm to the peak of the unit hydrograph.

Manning Equation
A steady flow prediction equation using standard hydraulic principles.

PMP
Probable Maximum Precipitation; the maximum rainfall depth that is likely to occur given the most extreme meterological conditions.

RCP
Reinforced Concrete Pipe

Resaca
Portions of old river bed that have been left behind when the river channel flow has shifted to another path.

Return Period
The average elapsed time between events having the same probability of exceedance.

SCS
Soil Conservation Service.

SCS Curve
See Curve Number definition.

Stationing
(i.e., 300+05) An engineering and construction notation for measuring distance along a project or survey line. Each station number represents 100 feet. The number to the right of the + sign is in feet. As an example, the station notation above would be 300 stations times 100 feet per station which equals 30,000 feet. The + 05 indicates it is 5 feet more. So the notation shown indicates the Station 300 + 05 is 30,005 feet from the beginning zero (0) point known as 0 + 00.

Subarea
Subdivisions of a larger area.

Time of Concentration
The time it takes for a particle of water to travel from the most distant part of the watershed to the point of consideration.

U/S
Abbreviation for upstream.

Unit Hydrograph
Watershed run-off simulation technique.

Weir
A simple type of overflow spillway with a generally horizontal surface.

CHAPTER XII

XII. BIBLIOGRAPHY

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APPENDIX

TABLE A1
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
TR0301	1	TR03	3.03	5.30	0.50
TR0302	1	TR03	3.02	2.85	0.38
TR0302	1	TR03	3.05	6.46	0.50
TR0302	1	TR03	3.01	7.63	0.40
TR0302	1	TR03	3.04	4.55	0.40
TR0401	1	TR04	4.03	10.09	0.50
TR0401	1	TR04	4.04	9.25	0.50
TR0401	1	TR04	4.05	5.72	0.50
TR0401	1	TR04	4.06	5.55	0.50
TR0402	1	TR04	4.01	11.16	0.50
TR0501	1	TR05	5.05	22.15	0.70
TR0501	1	TR05	5.02	5.44	0.65
TR0501	1	TR05	5.01	6.12	0.65
TR0501	1	TR05	5.03	6.69	0.65
TR0501	1	TR05	5.04	15.91	0.68
TR0601	1	TR06	6.08	7.09	0.90
TR0601	1	TR06	6.01	7.62	0.50
TR0601	1	TR06	6.09	5.10	0.90
TR0601	1	TR06	6.03	10.87	0.70
TR0601	1	TR06	6.02	6.19	0.70
TR0601	1	TR05	5.06	5.52	0.90
TR0601	1	TR06	6.07	6.46	0.90
TR0601	1	TR06	6.06	1.82	0.90
TR0601	1	TR06	6.05	3.75	0.90
TR0601	1	TR06	6.04	7.33	0.90
TR0601	1	TR06	6.10	2.73	0.90
TR0701	1	TR07	7.07	7.91	0.90
TR0701	1	TR07	7.08	3.38	0.90
TR0701	1	TR07	7.06	15.34	0.60
TR0701	1	TR07	7.09	4.95	0.50
TR0701	1	TR07	7.05	4.98	0.60
TR0701	1	TR07	7.04	12.78	0.60
TR0701	1	TR07	7.03	4.04	0.65
TR0701	1	TR07	7.02	15.43	0.45
TR0801	1	TR08	8.02	10.87	0.50
TR0801	1	TR08	8.04	7.32	0.50
TR0801	1	TR08	8.03	15.49	0.50
TR0801	1	TR08	8.05	2.04	0.50
TR0901	1	TR09	9.03	1.90	0.50
TR0901	1	TR09	9.04	2.20	0.50
TR0901	1	TR09	9.05	5.01	0.50
TR0901	1	TR09	9.06	7.34	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
TR0901	1	TR09	9.02	5.72	0.50
RRS0202	2	RS02	2.07	3.47	0.90
RRS0202	2	RS02	2.09	1.59	0.90
RRS0202	2	RS02	2.06	6.87	0.90
RRS0202	2	TR15	15.05	2.73	0.90
RRS0202	2	TR15	15.3	2.27	0.90
RRS0202	2	RS02	2.08	2.51	0.90
RRS0202	2	TR15	15.29	1.46	0.90
RRS0203	2	TR15	15.14	13.18	0.90
RRS0203	2	TR15	15.17	5.01	0.90
RRS0203	2	RS02	2.03	4.95	0.90
RRS0203	2	RS02	2.02	5.67	0.90
RRS0203	2	RS02	2.05	21.8	0.90
RRS0203	2	RS02	2.04	13.85	0.90
RRS0203	2	RS02	2.01	5.47	0.90
RRS0203	2	TR15	15.15	5.58	0.90
RRS0203	2	TR15	15.16	6.35	0.90
TR1501	2	TR15	15.20	19.24	0.50
TR1501	2	TR15	15.40	15.20	0.90
TR1501	2	TR15	15.03	8.74	0.90
TR1502	2	TR15	15.60	2.65	0.50
TR1502	2	TR15	15.01	11.96	0.50
TR2001A	2	TR15	15.01	19.24	0.90
TR2001A	2	TR15	15.02	31.1	0.90
TR2001A	2	TR15	15.26	11.57	0.90
TR2001A	2	TR15	15.04	15.2	0.90
TR2001A	2	TR15	15.08	11.96	0.90
TR2001A	2	TR15	15.25	15.83	0.90
TR2001A	2	TR15	15.03	8.74	0.90
TR2001A	2	TR15	15.27	14.78	0.90
TR2001A	2	TR15	15.24	7.69	0.90
TR2001A	2	TR15	15.28	15.2	0.90
TR2001A	2	TR20	2.13	7.69	0.90
TR2001B	2	TR15	15.1	2.73	0.90
TR2001B	2	TR15	15.11	2.76	0.90
TR2001B	2	TR15	15.07	4.26	0.90
TR2001B	2	TR15	15.12	2.59	0.90
TR2001B	2	TR15	15.06	2.65	0.90
TR2001D	2	RS02	2.12	1.99	0.90
TR2001D	2	RS02	2.11	3.74	0.90
TR2002	2	TR15	15.23	10.25	0.90
TR2002	2	TR15	15.19	8.11	0.90

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
TR2002	2	TR15	15.2	7.29	0.90
TR2002	2	TR15	15.22	12.74	0.90
TR2002	2	TR15	15.18	9.45	0.90
TR2002	2	TR15	15.21	6.89	0.90
TRS0201	2	RS02	2.1	6.57	0.90
NM0101	3	NM01	1.08	12.70	0.50
NM0101	3	NM01	1.10	13.14	0.50
NM0101	3	NM01	1.13	21.25	0.50
NM0101	3	NM01	1.12	22.85	0.50
NM0101	3	NM01	1.07	15.72	0.50
NM0101	3	NM01	1.12	23.34	0.50
NM0101	3	NM01	1.13	21.25	0.50
NM0101	3	NM01	1.07	15.60	0.50
NM0101	3	NM01	1.10	13.31	0.50
NM0101	3	NM01	1.08	11.61	0.50
NM0102	3	NM01	1.05	18.05	0.50
NM0102	3	NM01	1.03	3.76	0.50
NM0102	3	NM01	1.03	3.76	0.50
NM0102	3	NM01	1.04	6.96	0.50
NM0102	3	NM01	1.05	18.05	0.50
NM0102	3	NM01	1.02	4.41	0.50
NM0102	3	NM01	1.06	13.15	0.50
NM0102	3	NM01	1.06	13.15	0.50
NM0102	3	NM01	1.02	4.41	0.50
NM0102	3	NM01	1.04	6.96	0.50
NM0102	3	NM01	1.01	6.28	0.50
NM0102	3	NM01	1.01	6.28	0.50
NM0103	3	NM01	1.14	18.22	0.50
NM0103	3	NM01	1.11	12.64	0.50
NM0103	3	NM01	1.15	3.02	0.50
NM0103	3	NM01	1.09	12.42	0.50
RR0301	3	RR03	3.02	11.20	0.50
RR0301	3	RR03	3.03	13.07	0.50
RR0301	3	RR03	3.04	8.56	0.50
RR0301	3	RR03	3.01	6.02	0.50
RR0302	3	RR03	1.11	13.13	0.50
RR0302	3	RR03	1.09	12.42	0.50
RR0302	3	RR03	1.14	17.74	0.50
CC0441	4	CC04	4.48	3.45	0.55
CC0441	4	CC04	4.49	5.73	0.55
CC0441	4	CC04	4.46	3.67	0.55
CC0441	4	CC04	4.47	8.74	0.55

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
CC0442	4	CC04	4.50	2.31	0.55
CC0442	4	CC04	4.56	4.66	0.55
CC0442	4	CC04	4.53	3.34	0.55
CC0442	4	CC04	4.52	1.39	0.55
CC0442	4	CC04	4.51	1.80	0.55
CC0442	4	CC04	4.54	5.91	0.55
CC0442	4	CC04	4.57	4.89	0.55
CC0442	4	CC04	4.55	4.66	0.55
NM1401	5	NM14	14.07	2.48	0.50
NM1401	5	NM14	14.09	6.35	0.90
NM1401	5	NM14	14.06	2.26	0.50
NM1401	5	NM14	14.04	2.30	0.70
NM1401	5	NM14	14.11	11.83	0.50
NM1401	5	NM14	14.08	3.45	0.50
NM1401	5	NM14	14.05	1.74	0.50
NM1401	5	NM14	14.12	5.14	0.50
NM1401	5	NM14	14.03	2.12	0.70
NM1401	5	NM14	14.02	14.25	0.70
NM1401	5	NM14	14.10	13.86	0.50
NM1402	5	NM14	14.17	10.19	0.50
NM1402	5	TR37	37.01	3.58	0.50
NM1402	5	NM14	14.23	1.16	0.50
NM1402	5	NM14	14.14	4.04	0.50
NM1402	5	NM14	14.19	0.68	0.50
NM1402	5	NM14	14.18	2.85	0.50
NM1402	5	NM14	14.24	2.75	0.50
NM1402	5	NM14	14.21	5.44	0.50
NM1402	5	NM14	14.13	8.85	0.50
NM1402	5	NM14	14.22	0.92	0.50
NM1402	5	NM14	14.20	40.59	0.50
NM1403	5	NM14	14.15	10.27	0.50
NM1403	5	NM14	14.16	6.09	0.50
NM1404	5	NM12	12.00	9.99	0.50
NM1404	5	NM13	13.00	69.20	0.50
NM1405	5	NM11	11.01	3.43	0.90
NM1406	5	NM11	11.02	7.35	0.90
NM1407	5	NM08	8.03	7.90	0.90
NM1407	5	NM08	8.04	24.28	0.90
NM1407	5	NM08	8.02	6.68	0.90
NM1407	5	NM08	8.01	2.42	0.90
TR3601	5	TR36	36.01	10.45	0.50
TR3602	5	TR36	36.03	5.28	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
TR3602	5	TR36	36.04	1.20	0.50
TR3602	5	TR36	36.02	14.46	0.50
TR3602	5	TR36	36.05	1.42	0.50
TR3602	5	TR36	36.06	8.80	0.50
TR4101A	5	TR41	41.01	4.41	0.50
TR4101B	5	TR46	46.06	6.17	0.50
TR4601	5	TR46	46.04	7.71	0.50
TR4601	5	TR46	46.03	3.27	0.50
TR1601	6	TR16	16.03	5.01	0.35
TR1602	6	TR16	16.01	28.47	0.35
TR1701	6	TR17	17.03	6.58	0.50
TR1701A	6	TR17	17.01	7.11	0.50
TR1701A	6	TR17	17.02	8.65	0.50
TR1701B	6	TR17	17.05	6.15	0.50
TR1701B	6	TR17	17.04	2.08	0.50
TR1801	6	TR18	18.01	5.95	0.50
TR1801	6	TR18	18.02	1.22	0.50
TR1801	6	TR18	18.03	7.52	0.50
TR1801	6	TR18	18.04	11.90	0.50
TR1901	6	TR19	19.01	7.71	0.50
TR2004	6	TR20	20.03	4.95	0.75
TR2004	6	TR20	20.04	1.88	0.75
TR2005	6	TR20	20.02	2.73	0.75
TR2005	6	TR20	20.01	3.30	0.75
TR2006	6	TR20	20.05	3.13	0.75
TR2201	6	TR21	21.02	15.60	0.60
TR2201	6	TR21	21.01	4.53	0.50
TR2202	6	TR22	22.02	9.17	0.50
TR2202	6	TR22	22.03	12.86	0.50
TR2601	6	TR26	26.01	8.11	0.50
TR2602	6	TR26	26.02	5.64	0.50
TR2901	6	TR29	29.04	9.51	0.50
TR2901	6	TR29	29.03	4.27	0.50
TR2901A	6	TR29	29.05	8.37	0.50
TR2901A	6	TR28	28.02	11.61	0.50
TR2901E	6	TR28	28.01	3.33	0.50
TR2901E	6	TR28	28.05	4.07	0.50
TR2901E	6	TR28	28.03	2.31	0.50
TR2901E	6	TR28	28.06	6.04	0.50
TR2901E	6	TR28	28.04	1.57	0.50
TR2901F	6	TR28	28.08	14.89	0.35
TR2901F	6	TR28	28.07	8.03	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
TR2901H	6	TR29	29.02	30.80	0.60
TR2902	6	TR29	29.01	22.32	0.50
TR3801	6	TR38	38.01	24.59	0.50
TR4001	6	TR40	40.01	8.26	0.50
NM2101	7	NM21	21.02	20.92	0.55
NM2101	7	NM21	21.01	63.54	0.70
NM2102	7	NM21	21.03	21.61	0.60
NM2102	7	NM21	21.04	20.92	0.60
NM2301A	7	NM23	23.05	2.86	0.50
NM2301A	7	NM23	23.06	15.37	0.70
NM2301A	7	NM23	23.04	27.21	0.50
NM2301A	7	NM23	23.03	10.39	0.50
NM2301A	7	NM23	23.02	23.31	0.50
TR1101	7	TR11	11.03	5.40	0.80
TR1101	7	TR11	11.04	6.94	0.80
TR1101	7	TR11	11.02	5.11	0.80
TR1101	7	TR11	11.05	3.26	0.80
TR1101	7	TR11	11.01	5.00	0.80
TR1201	7	TR12	12.02	3.27	0.75
TR1201	7	TR12	12.05	6.69	0.75
TR1201	7	TR12	12.04	2.22	0.75
TR1201	7	TR12	12.07	4.21	0.50
TR1201	7	TR12	12.03	5.47	0.75
TR1201	7	TR12	12.08	23.88	0.50
TR1201	7	TR12	12.01	18.25	0.90
TR1201	7	TR12	12.06	7.46	0.75
TR1301	7	TR13	13.10	5.21	0.90
TR1301	7	TR13	13.09	4.66	0.90
TR1301	7	TR13	13.06	2.86	0.90
TR1301	7	TR13	13.07	2.19	0.90
TR1301	7	TR13	13.08	2.61	0.90
TR1302	7	TR13	13.05	3.07	0.55
TR1302	7	TR13	13.03	3.13	0.90
TR1302	7	TR13	13.01	5.80	0.90
TR1302	7	TR13	13.04	20.67	0.55
TR1302	7	TR13	13.02	11.24	0.55
TR1401	7	TR14	14.05	2.39	0.55
TR1401	7	TR14	14.04	7.63	0.55
TR1402	7	TR14	14.03	2.96	0.55
TR1402	7	TR14	14.02	6.83	0.90
TR2901A	8	TR28	28.10	20.55	0.50
TR2901A	8	TR28	28.26	12.35	0.90

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
TR2901A	8	TR28	28.13	7.77	0.80
TR2901A	8	TR28	28.25	12.55	0.75
TR2901A	8	TR28	28.18	4.40	0.80
TR2901A	8	TR28	28.27	4.19	0.80
TR2901B	8	TR28	28.28	5.18	0.90
TR2901B	8	TR28	28.11	3.93	0.50
TR2901B	8	TR28	28.12	7.71	0.54
TR2901C	8	TR28	28.15	2.33	0.50
TR2901C	8	TR28	28.16	4.33	0.50
TR2901C	8	TR28	28.17	3.22	0.90
TR2901C	8	TR28	28.14	4.38	0.40
TR2901D	8	TR28	28.23	1.19	0.50
TR2901D	8	TR28	28.20	2.82	0.60
TR2901D	8	TR28	28.22	2.39	0.50
TR2901D	8	TR28	28.24	1.19	0.50
TR2901D	8	TR28	28.21	3.99	0.50
TR3301A	8	TR30	30.09	5.98	0.90
TR3301A	8	TR30	30.07	5.72	0.80
TR3301A	8	TR31	31.03	11.05	0.50
TR3301A	8	TR30	30.08	14.12	0.55
TR3301A	8	TR30	30.03	26.27	0.70
TR3301A	8	TR30	30.04	18.67	0.75
TR3301A	8	TR30	30.02	10.76	0.90
TR3301A	8	TR31	31.02	81.85	0.50
TR3301A	8	TR30	30.06	37.12	0.50
TR3301A	8	TR31	31.01	11.50	0.50
TR3302	8	TR33	33.01	5.01	0.75
TR3303	8	TR35	35.01	8.40	0.40
TR3303	8	TR35	35.03	7.46	0.50
TR3304A	8	TR34	34.02	21.29	0.50
TR3304A	8	TR34	34.03	19.36	0.55
TR3304A	8	TR34	34.01	9.57	0.50
TR3304B	8	TR35	35.07	5.32	0.40
TR3304B	8	TR35	35.04	15.23	0.50
TR3304B	8	TR35	35.05	2.42	0.75
TR3304C	8	TR35	35.02	11.93	0.75
NM0603	9	TR47	47.01	7.49	0.50
NM0603	9	TR47	47.02	3.60	0.50
NM4401	9	NM44	35.10	3.93	0.50
NM501	9	NM05	5.02	16.28	0.50
NM601	9	NM05	5.01	14.29	0.50
NM602	9	NM05	5.03	4.04	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
TR4301	9	TR43		61.87	0.50
TR4401	9	TR44	44.04	3.73	0.50
TR4401	9	TR44	44.02	14.46	0.50
TR4401	9	TR44	44.03	1.34	0.50
TR4402	9	TR44	44.01	27.44	0.50
TR4501	9	TR45	45.02	8.89	0.50
CC1305	10	CC13	13.17	12.97	0.70
CC1305	10	CC13	13.18	18.84	0.70
CC1306	10	CC13	13.19	4.45	0.70
CC1306	10	CC13	13.20	8.71	0.70
CC1306	10	CC13	13.21	8.93	0.70
CC1307	10	CC13	13.22	60.28	0.70
CC1308	10	CC13	13.23	60.60	0.70
CC1310	10	CC13	13.25	17.08	0.70
CC1310	10	CC13	13.13	12.64	0.70
CC1311	10	CC13	13.24	148.31	0.35
CC1312	10	CC13	13.15	16.68	0.70
CC1313	10	CC13	13.16	32.76	0.50
CC1314	10	CC13	13.29	24.13	0.50
CC1314	10	CC13	13.28	6.60	0.70
CC1315	10	CC13	13.27	29.66	0.70
CC1316	10	CC13	13.14	29.35	0.70
CC1317	10	CC13	13.26	8.52	0.70
CC1318	10	CC13	13.09	5.44	0.75
CC1319	10	CC13	13.08	7.05	0.75
NM3302	10	NM33	33.22	29.89	0.70
NM3303	10	NM33	33.23	24.90	0.70
NM3304	10	NM33	33.25	3.12	0.70
NM3304	10	NM33	33.24	7.46	0.70
NM3305	10	NM33	33.19	9.55	0.70
NM3305	10	NM33	33.09	10.25	0.70
NM3305	10	NM33	33.18	15.87	0.70
NM3305	10	NM33	33.20	7.05	0.70
NM3305	10	NM33	33.08	6.28	0.70
NM3306	10	NM33	33.17	19.98	0.70
NM3306	10	NM33	33.10	6.61	0.70
NM3307	10	NM33	33.14	5.88	0.70
NM3307	10	NM33	33.16	25.16	0.70
NM3307	10	NM33	33.15	10.47	0.70
NM3308	10	NM33	33.13	48.45	0.70
NM3308	10	NM33	33.12	30.45	0.70
NM3309	10	NM33	33.06	16.57	0.70

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
NM3309	10	NM33	33.02	22.99	0.70
NM3309	10	NM33	33.07	46.76	0.70
NM3309	10	NM33	33.01	12.64	0.70
NM3310	10	NM33	33.05	13.15	0.70
NM3311	10	NM33	33.11	12.12	0.70
NM3311	10	NM33	33.03	11.97	0.70
NM3311	10	NM33	33.04	14.33	0.70
NM3313	10	NM33	33.26	133.41	0.70
NM1301A	11	NM13	13.02	4.88	0.90
NM1301A	11	NM13	13.03	18.88	0.90
NM1301B	11	NM13	13.01	17.67	0.90
NM1304A	11	NM13	13.04	43.82	0.90
NM1402	11	NM14	14.01	31.25	0.90
RG3101	11	RG31	31.02	2.91	0.50
RG3102	11	RG31	31.03	25.19	0.50
RG3103	11	RG31	31.05	7.71	0.90
CC0701	12	CC07	7.06	6.78	0.50
CC0702	12	CC07	7.07	3.47	0.50
CC0703	12	CC07	7.05	2.65	0.50
CC0703	12	CC07	7.04	9.96	0.50
CC0703	12	CC07	7.03	20.38	0.50
NM1601	12	NM16	16.01	14.29	0.50
NM1801A	12	NM19	19.11	6.78	0.50
NM1801A	12	NM19	19.15	3.32	0.50
NM1801A	12	NM19	19.13	4.38	0.50
NM1801A	12	NM19	19.12	5.40	0.50
NM1801A	12	NM18	18.01	4.96	0.50
NM1801B	12	NM19	19.20	2.97	0.50
NM1801B	12	NM19	19.16	3.21	0.50
NM1801B	12	NM19	19.19	3.42	0.50
NM1801B	12	NM17	17.01	9.34	0.50
NM1801B	12	NM19	19.16	7.90	0.50
NM1801B	12	NM19	19.14	2.35	0.50
NM1801B	12	NM17	17.02	17.43	0.50
NM1802	12	NM18	18.04	3.14	0.50
NM1802	12	NM19	19.18	3.59	0.50
NM1802	12	NM18	18.05	5.31	0.50
NM1901A	12	NM19	19.03	5.97	0.50
NM1901A	12	NM19	19.01	4.87	0.50
NM1901A	12	NM19	19.06	7.27	0.50
NM1901A	12	NM19	19.05	1.19	0.50
NM1901A	12	NM19	19.02	2.81	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
NM1901B	12	NM19	19.07	3.88	0.50
NM1902	12	NM19	19.08	3.36	0.50
RG2106	12	RG21	21.01	4.86	0.50
RG2601	12	RG26	26.03	5.32	0.50
RG2601	12	RG26	26.01	14.58	0.50
RG2601	12	RG26	26.02	9.54	0.50
RG2602	12	RG26	26.05	6.06	0.50
RG2602	12	RG26	26.04	14.72	0.50
RG2603	12	RG26	26.08	7.27	0.50
RG2604	12	RG26	26.06	21.34	0.50
RG2605	12	RG26	26.07	20.41	0.50
RG2901	12	RG29	29.01	86.91	0.50
RG2902	12	RG29	29.02	3.93	0.50
RG2903	12	RG29	29.03	5.80	0.50
RG3001	12	RG30	30.01	33.59	0.50
NM2401	13	NM24	24.14	11.79	0.50
NM2402	13	NM24	24.17	24.21	0.50
NM2403	13	NM24	24.18	25.49	0.50
NM2404	13	NM24	24.60	21.19	0.50
NM2404	13	NM24	24.50	8.67	0.50
NM2404	13	NM24	24.30	5.62	0.50
NM2404	13	NM24	24.40	3.86	0.50
NM2404	13	NM24	24.20	9.95	0.50
NM2405	13	NM24	24.21	5.07	0.50
NM2405	13	NM24	24.19	5.51	0.50
NM2405	13	NM24	24.10	12.42	0.50
NM2406	13	NM24	24.12	5.14	0.90
NM2406	13	NM24	24.90	9.55	0.90
NM2406	13	NM24	24.10	9.21	0.90
NM2406	13	NM24	24.11	3.56	0.90
NM2406	13	NM24	24.23	8.83	0.90
NM2406	13	NM24	24.13	1.76	0.90
NM2407	13	NM24	24.22	7.52	0.90
NM2409	13	NM24	24.70	11.68	0.50
NM2409	13	NM24	24.80	34.09	0.50
NM2410	13	NM24	24.16	13.99	0.50
NM2411	13	NM24	24.15	14.10	0.50
NM2501	13	NM24	24.20	4.78	0.50
NM2501	13	NM25	25.50	24.76	0.50
NM2501	13	NM25	25.60	33.61	0.50
NM2502	13	NM25	25.40	5.25	0.50
NM2601	13	NM26	26.70	10.14	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
NM2601	13	NM26	26.40	7.75	0.50
NM2601	13	NM26	26.60	7.90	0.50
NM2601	13	NM26	26.50	17.81	0.50
NM2601	13	NM26	26.80	5.87	0.50
NM2601	13	NM26	26.90	13.66	0.50
NM2601	13	NM26	26.10	8.98	0.50
TR0101	13	TR01	1.60	9.44	0.50
TR0101	13	TR01	1.80	6.50	0.50
TR0101	13	TR01	1.50	18.40	0.50
TR0101	13	TR01	1.90	2.17	0.50
TR0101	13	TR01	1.70	6.32	0.50
TR0102	13	TR01	1.30	14.29	0.75
TR0103	13	TR01	1.20	4.85	0.75
TR0104	13	TR01	1.10	6.35	0.75
TR0105	13	TR01	1.11	1.98	0.50
TR0107	13	TR01	1.12	26.59	0.50
TR0201	13	TR02	2.40	10.57	0.50
TR0201	13	TR02	2.10	18.28	0.50
TR0201	13	TR02	2.30	14.62	0.75
TR0201	13	TR02	2.10	8.82	0.55
TR0201	13	TR02	2.60	14.18	0.50
TR0201	13	TR02	2.20	6.60	0.75
TR0201	13	TR02	2.50	18.79	0.50
TR0201	13	TR02	2.70	11.75	0.50
TR0202	13	TR02	2.80	8.37	0.50
TR0203	13	TR02	2.90	4.26	0.50
TR1001	13	TR10	10.40	1.95	0.90
TR1002	13	TR10	10.30	2.98	0.90
TR1003	13	TR10	10.20	6.02	0.90
TR1004	13	TR10	10.10	19.14	0.90
TR4801	13	TR48	48.11	6.13	0.50
TR4801	13	TR48	48.10	8.37	0.50
TR4802	13	TR48	48.15	7.64	0.50
TR4802	13	TR48	48.14	13.44	0.50
TR4802	13	TR48	48.13	13.44	0.50
TR4803	13	TR48	48.12	6.65	0.50
TR4804	13	TR48	48.16	18.51	0.50
TR4804	13	TR48	48.21	10.06	0.50
TR4805	13	TR48	48.20	16.53	0.50
TR4805	13	TR48	48.19	11.06	0.50
TR4806	13	TR48	48.22	18.44	0.50
NM2501	14	NM25	25.10	4.39	0.50

TABLE 12

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
NM2502	14	NM25	25.20	4.50	0.50
NM32A01	14	NM32B	32B.1	22.20	0.50
NM32A02	14	NM32A	32A.2	3.42	0.50
NM32A03	14	NM32A	32A.1	5.18	0.50
NM32B01	14	NM32B	32B.2	9.77	0.50
NM32B02	14	NM32B	32B.3	3.27	0.50
CC0704A	15	CC07	7.10	17.45	0.50
CC0704B	15	CC07	7.20	22.90	0.50
NM2002A	15	NM20	20.40	6.86	0.50
NM2003	15	NM20	20.30	7.16	0.50
NM2004	15	NM20	20.20	16.08	0.50
NM2005	15	NM20	20.50	13.44	0.50
NM2005	15	NM20	20.80	40.54	0.50
NM2005	15	NM20	20.60	7.97	0.50
NM2005	15	NM20	20.10	5.40	0.50
NM2006	15	NM20	20.00	89.99	0.50
NM2007	15	NM20	20.70	20.93	0.50
RG2101	15	RG21	21.10	14.23	0.50
RG2102	15	RG23	23.10	12.21	0.50
RG2102	15	RG21	21.20	18.05	0.50
RG2104	15	RG21	21.40	5.51	0.50
RG2105A	15	RG21	21.30	12.20	0.50
RG2105B	15	RG21	21.80	6.10	0.50
RG2201	15	RG22	22.10	37.06	0.50
RG2401	15	RG24	24.10	198.38	0.50
CC0403	17	CC04	4.33	3.86	0.50
CC0404	17	CC04	4.34	4.78	0.50
CC0405	17	CC04	4.35	3.16	0.50
CC0406	17	CC04	4.36	2.83	0.50
CC0407	17	CC04	4.37	2.02	0.50
CC0408	17	CC04	4.38	13.83	0.50
CC0409	17	CC04	4.39	21.05	0.50
CC0410	17	CC04	4.41	19.50	0.50
CC0411	17	CC04	4.42	13.21	0.50
CC0412	17	CC04	4.43	5.98	0.50
CC0413	17	CC04	4.14	14.69	0.50
CC0414	17	CC04	4.13	5.41	0.50
CC0415	17	CC04	4.12	6.43	0.50
CC0416	17	CC04	4.11	4.08	0.50
CC0417	17	CC04	4.10	19.68	0.50
CC0418	17	CC04	4.90	4.26	0.50
CC0419	17	CC04	4.70	4.66	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
CC0420	17	CC04	4.40	15.53	0.50
CC0421	17	CC04	4.30	4.70	0.50
CC0422	17	CC04	4.50	23.91	0.50
CC0423	17	CC04	4.60	3.78	0.50
CC0424	17	CC04	4.17	25.42	0.50
CC0425	17	CC04	4.18	3.74	0.50
CC0426	17	CC04	4.19	19.17	0.50
CC0427	17	CC04	4.21	5.95	0.50
CC0428	17	CC04	4.20	7.05	0.50
CC0429	17	CC04	4.45	1.20	0.50
CC0430	17	CC04	4.23	23.32	0.50
CC0431	17	CC04	4.22	16.08	0.50
CC0432	17	CC04	4.24	69.60	0.50
CC0433	17	CC04	4.26	17.70	0.50
CC0434	17	CC04	4.27	29.75	0.50
CC0435	17	CC04	4.25	50.61	0.50
CC0436	17	CC04	4.30	5.33	0.50
CC0437	17	CC04	4.31	5.40	0.50
CC0438	17	CC04	4.32	1.69	0.50
CC0439	17	CC04	4.10	18.95	0.50
CC0440	17	CC04	4.20	18.21	0.50
RR0201	18	RR02	2.09	18.22	0.90
RR0201	18	RR02	2.08	14.40	0.90
RR0202	18	RR02	2.06	18.99	0.90
RR0202	18	RR02	2.05	9.29	0.90
RR0203	18	RR02	2.10	2.49	0.90
RR0203	18	RR02	2.04	5.33	0.90
RR0204	18	RR02	2.01	9.14	0.90
RR0204	18	RR02	2.03	6.54	0.90
RR0204	18	RR02	2.02	5.18	0.90
CC1301	20	CC13	13.60	7.53	0.50
CC1301	20	CC13	13.50	12.52	0.50
CC1302	20	CC13	13.40	6.14	0.50
CC1302	20	CC13	13.30	7.16	0.50
CC1303	20	CC13	13.20	4.66	0.50
CC1304	20	CC13	13.10	4.29	0.50
RG1501	20	RG15	15.30	12.67	0.50
RG1502	20	RG15	15.20	16.82	0.50
RG1901	20	RG15	15.10	3.64	0.50
RG1902	20	RG19	19.40	8.52	0.50
RG1903	20	RG19	19.60	7.19	0.50
RG1904	20	RG19	19.20	24.31	0.50

TABLE A1 (CONT'D)
SUB-AREA HYDROLOGIC
CHARACTERISTICS
FOR SUB-AREA DRAINAGE

TRUNK NO.	SHEET NO.	MAJOR WATERSHED ID	DRAINAGE ID NUMBER	DRAINAGE AREA (ACRES)	RUN-OFF FACTOR "C"
RG1905	20	RG19	19.90	9.14	0.50
RG1906	20	RG19	19.30	10.06	0.50
RG1907	20	RG19	19.80	17.70	0.50
CC0401A	21	CC04	4.45	23.97	0.75
CC0401B	21	CC04	4.44	36.73	0.75
NM2602	22	NM26	26.10	4.29	0.50
NM2605	22	NM26	26.20	6.65	0.50
NM2606	22	NM26	26.30	10.57	0.50
NM2701	22	NM27	27.20	2.31	0.50
NM2702	22	NM27	27.10	21.34	0.50
NM2703	22	NM27	27.30	4.11	0.50
NM2705	22	NM27	27.50	6.02	0.50
NM28A01	22	NM28A	28A.1	7.82	0.50
NM28A02	22	TR48	48.23	8.70	0.50
NM28B01	22	NM28B	28B.7	7.26	0.50
NM28B01	22	NM28B	28B.8	10.99	0.50
NM28B02	22	NM28B	28B.5	5.92	0.50
NM28B02	22	NM28B	28B.6	4.09	0.50
NM28B02	22	NM28B	28B.4	5.41	0.50
NM28B02	22	NM28B	28B.3	5.81	0.50
NM28B03	22	NM28B	28B.14	17.55	0.50
NM2901	22	NM29	29.20	9.56	0.50
NM2901	22	NM29	29.10	4.92	0.50
NM2901	22	NM29	29.30	11.44	0.50
TR4807	22	TR48	48.80	11.44	0.50
TR4807	22	TR48	48.50	6.72	0.50
TR4807	22	TR48	48.90	5.27	0.50
TR4807	22	TR48	48.70	14.69	0.50
TR4808	22	TR48	48.20	18.96	0.50
TR4808	22	TR48	48.60	8.71	0.50
TR4808	22	TR48	48.10	20.67	0.50
TR4809	22	TR48	48.40	3.41	0.50
RV2301	27	RV23	23.02	5.29	0.50
RV2302	27	RV23	23.03	4.70	0.50
RV2303	27	RV23	23.04	2.35	0.50
RV2304	27	RV23	23.05	2.37	0.50
RV2305	27	RV23	23.01	5.40	0.50
NM32A04	31	NM33	32A.5	14.18	0.50
NM32A05	31	NM33	32A.6	8.54	0.50